American
Fuel & Petrochemical
Manufacturers

1800 M Street, NW
Suite 900 North
Washington, DC
20036

202.457.0480 office
202.457.0486 fax
afpm.org

November 2, 2023

Environmental Improvement Board Administrator,
New Mexico Environment Department
Harold Runnels Building,
P.O. Box 5469, Santa Fe, NM 87502.

RE: EIB 23-56 (R) - In the Matter of Proposed Amendments to 20.2.91 NMAC – New Motor Vehicle Emission Standards.

Submitted via nmed.commentinput.com and email to: pamela.jones@env.nm.gov

I. Introduction and Summary.

A. AFPM and its interest in the New Mexico Department of Environmental Protection's proposed adoption of ACC II.

The American Fuel & Petrochemical Manufacturers (AFPM) appreciates the opportunity to comment on the New Mexico Environment Department (NMED) proposal to adopt California's Advanced Clean Car II (ACC II) standards, mandating the electrification of the New Mexico vehicle fleet. AFPM is a national trade association representing nearly all U.S. refining and petrochemical manufacturing capacity. AFPM members support more than three million quality jobs, contribute to our economic and national security, and enable the production of thousands of vital products used by families and businesses every day. AFPM members are also leaders in producing lower carbon fuels, such as renewable diesel and sustainable aviation fuel.

AFPM shares NMED's goal of reducing carbon emissions from transportation. Indeed, our members are investing heavily in technologies and processes that continue to reduce the carbon intensity of fuels while automakers are improving the fuel efficiency of internal combustion engines. Importantly, these investments can reduce carbon intensity of new and existing vehicles without relying on a lengthy automobile fleet turnover or trillions of dollars to massively expand the electrical transmission grid. Reducing carbon emissions from the transportation sector while meeting myriad consumer needs will require a diverse mix of technologies, including liquid transportation fuels and electric vehicles. Innovation and competition among technologies will achieve the State's carbon reduction goals while delivering better results for consumers. Putting aside its serious legal and analytical infirmities, NMED's proposal does exactly the opposite—it stifles innovation and reduces competition by ignoring the fundamental importance of liquid fuels in delivering affordable and reliable energy while reducing emissions. NMED should withdraw this proposal.

B. Summary of AFPM's reasons for opposing NMED's proposal.

NMED proposes to adopt the California Air Resources Board's (CARB) ACC II standards, but it is preempted from doing so. The measures called for in the California ACC II rules (and therefore NMED's proposal) are expressly preempted and in conflict with federal legislation including the Energy Policy and Conservation Act (EPCA) and the federal Clean Air Act (CAA) and is contrary to federal statutory objectives set forth in the Renewable Fuel Standard (RFS) and other federal programs promoting (renewable) liquid fuels.

Furthermore, NMED's analysis supporting its proposed adoption of ACC II is arbitrary and capricious. Where it does not simply adopt CARB's analysis wholesale without meaningfully adjusting for the differences between the two states, NMED's analysis contains unsupported, inaccurate assertions that misstate the actual costs and benefits of its proposal. For example, NMED fails to adequately investigate whether its electric grid can handle the significant increase in demand for electricity that its adoption of ACC II will create, the potential electricity costs to consumers, the lifecycle emissions impacts of expanding electricity generation and transmission as well as electric vehicle (EV) production, the rising price of critical minerals needed for batteries, and the prospect of "leakage" as NMED forces New Mexico residents to travel to surrounding states to buy internal combustion engine vehicles (ICEVs).[1]

NMED has not considered the broader geopolitical context against which it acts: the United States depends, and will necessarily continue to depend, on China and other foreign countries, for the minerals and metals (particularly copper) used to produce batteries and expand the electrical grid.[2] Adopting policies like ACC II only increases that dependence. A transition to so-called Zero Emission Vehicles (ZEVs)[3] exposes New Mexico residents to supply chain vulnerabilities largely beyond the control of regulators. This risk is exacerbated by long supply chains[4] and a reliance on geopolitical rivals who control those supply chains.[5]

Section II of these comments discusses federal preemption of ACC II and pending litigation, while Section III addresses the constitutional barriers to adopting ACC II. Section IV describes the administrative infirmities that render this rulemaking arbitrary and capricious and unlawful. Section V describes some of the unintended consequences of California's initial foray into EV mandates under ACC I.

II. ACC II is preempted by federal law.

Congress has not authorized federal agencies or states to force a transition to EVs through government mandates.[6] Indeed, this is a major policy question that is the subject of several lawsuits pending before the D.C. Circuit. When Congress has spoken on vehicle electrification,

---

[1] *See also* Ramboll, Multi-Technology Pathways To Achieve California's Greenhouse Gas Goals: Light-Duty Auto Case Study (May 31, 2022), Sec. 1.1 of AFPM's attached comments on California's ACC II proposal (*see* Attachment A): "CARB has not conducted a full life cycle GHG analysis for the vehicle/fuel system to assess GHG emission impacts of their proposal and alternatives. CARB did not consider the upstream fuel cycle GHG emissions from out-of-state fuel production and transportation activities for California reformulated gasoline (CaRFG) and hydrogen (H2), and vehicle cycle GHG emissions associated with the vehicle production. These life cycle emissions are significant, particularly for battery electric vehicles (BEVs) as compared to internal combustion engine vehicles (ICEVs), due to the energy-intensive nature of producing a BEV battery. Failure to consider these GHG emissions has the effect of overstating the emissions benefits of the proposed ACC II regulation."

[2] As such, New Mexico's adoption of ACC II conflicts with the dormant foreign affairs preemption doctrine under the Supremacy Clause, which preempts state laws that intrude on the exclusive federal power to conduct foreign affairs.

[3] On an LCA basis, of course, there is no such thing as a "zero-emission" vehicle since all vehicles have associated upstream and downstream emissions.

[4] *See* 2022 Global EV Outlook IEA (May 2022) at 6-7, 178-79, available at https://www.iea.org/reports/global-ev-outlook-2022 (accessed August 3, 2023).

[5] *Id.*

[6] *See West Virginia v. EPA*, 142 S. Ct. 2587 (2022).

it specifically prohibited EV mandates,[7] required studies,[8] and provided financial incentives with strict eligibility limits based on domestic production requirements and income levels.[9] Forcing a transition to EVs and banning the sale of ICEVs would constitute a major question of political and economic significance for which Congress must provide a clear statement; no such clear statement exists, particularly for giving *one state*—California—authority to address global climate change that is denied other similarly situated states. As detailed in AFPM's comments on EPA's Notice of Proposed Rulemaking: Multi-Pollutant Emissions Standards for Model Year 2027 and Later Light-Duty and Medium-Duty Vehicles (hereinafter referred to as "AFPM LDV Comments" and included as Attachment B), and AFPM's comments on NHTSA's Notice of Proposed Rulemaking: Corporate Average Fuel Economy Standards for Passenger Cars and Light Trucks for Model Years 2027–2032 and Fuel Efficiency Standards for Heavy-Duty Pickup Trucks and Vans for Model Years 2030–2035 (hereinafter referred to as "AFPM NHTSA Comments" and included as Attachment D) the question of whether to shift from ICEVs to EVs, and how to accomplish this shift, will reshape the U.S. automotive market and would have vast economic and political significance for New Mexico and throughout the country.[10]

A. ACC II is expressly preempted by the Energy Policy Conservation Act.

EPCA expressly preempts states from adopting or enforcing any regulation "related to" fuel-economy standards. This provision is extremely broad and self-executing, meaning no agency action is necessary for it to be effective. Moreover, Congress did not authorize NHTSA or EPA to waive this preemption provision, nor would EPA granting a waiver make ACC II a federal standard that is outside the scope of NHTSA's preemption provision.[11]

ACC II is clearly related to fuel-economy standards. Courts have found that state regulations "relate [ ] to" federal matters when they have a "connection with" or contain a "reference to" these matters.[12] NMED cannot avoid EPCA's preemptive effect by characterizing this rule as an environmental regulation despite its clear implications for fuel economy. Indeed, because carbon dioxide emissions are "essentially constant per gallon combusted of a given type of fuel," the fuel economy of a vehicle and its carbon-dioxide emissions are two sides of the same coin.[13] Accordingly, "any rule that limits tailpipe [greenhouse gas] emissions is effectively identical to a rule that limits fuel consumption."[14] Any proposed rule establishing ZEV mandates (and thus *de facto* average fuel economy standards) impedes NHTSA's ability to establish fuel economy standards that satisfy EPCA's requirements.[15]

An EV mandate thus has more than a mere "connection with" fuel economy—it has a direct connection, and courts have had little trouble finding federal preemption of state laws promoting

---

[7] *See* 49 U.S.C. § 32902(h) (prohibiting considering dedicated automobiles, which includes EVs).
[8] *See* EISA § 206.
[9] *See* generally Inflation Reduction Act.
[10] *See* AFPM LDV Comments (Attachment B) at 17-21.
[11] *See* Brief of Petitioners of the States of Ohio et al., *State of Ohio v. EPA*, Case No. 22-1081 (D.C. Cir.), Document #1969895 (Oct. 20, 2022), 39-41, incorporated by reference herein.
[12] *See e.g.*, *California Restaurant Association v. City of Berkeley* (9th Cir. April 17, 2023).
[13] Fed. Reg. at 25,324, 25327 (May 7, 2010).
[14] *Delta Constr. Co. v. EPA*, 783 F.3d 1291, 1294 (D.C. Cir. 2015).
[15] See AFPM LDV Comments (Attachment B) at 25-26.

hybrids or EVs.[16] New Mexico's adoption of ACC II "relate[s] to" fuel economy even more clearly than the New York taxi rules at issue in *Metropolitan Taxicab* and is thus expressly preempted by EPCA.

B. New Mexico may not adopt ACC II because it is expressly preempted by the Clean Air Act.

ACC II are also expressly preempted by the CAA, which provides that "No State or any political subdivision thereof shall adopt or attempt to enforce any standard relating to the control of emissions from new motor vehicles...."[17] Unlike EPCA, EPA may grant California a preemption waiver under the CAA under certain conditions.[18] Before a waiver can be granted, the CAA requires EPA to evaluate California's waiver request to ensure that California did not arbitrarily determine that it needs "ZEV mandates" to address compelling and extraordinary circumstances. Practically speaking, EPA should deny California's ACC II waiver request. As our attached comments on CARB's ACC II proposal (Attachment A)[19] demonstrate, ACC II and CARB's analysis supporting it are flawed by CARB's failure to conduct an accurate lifecycle assessment (LCA) demonstrating ACC II is needed to address compelling and extraordinary conditions or that its benefits exceed its costs. The lack of compelling and extraordinary conditions is highlighted by the fact that a recent EPA report on air quality trends shows continued improvement of ambient air quality.[20] Moreover, EPA has never established a National Ambient Air Quality Standard (NAAQS) to address ambient greenhouse gas (GHG) concentrations, nor any requirements for states to implement plans and rules to reduce in-state, upwind, or downwind GHG concentrations. For these reasons, CARB's adoption of ACC II cannot qualify for a CAA preemption waiver.[21]

The Principal Deputy Administrator for the Office of Air and Radiation Joe Goffman testified on June 21, 2023, that EPA has not determined whether it will grant a waiver for ACC II and no such waiver has been granted to date.[22] If EPA grants a waiver to California, other states may choose to opt-in to California's standards, In the absence of a preemption waiver, NMED lacks authority to adopt ACC II.[23]

---

[16] See, *e.g., Metropolitan Taxicab Bd. of Trade v. City of New York*, 615 F.3d 152, 157 (2d Cir. 2010) (holding EPCA preempts local taxi-fleet rules merely encouraging the adoption of hybrid taxis).
[17] 49 U.S.C. § 7543(a).
[18] *Id. at* § 7543(b).
[19] Available at https://www.arb.ca.gov/lists/com-attach/477-accii2022-AHcAdQBxBDZSeVc2.pdf (accessed August 3, 2023).
[20] U.S. EPA, Our Nation's Air: Trends Through 2022, available at https://gispub.epa.gov/air/trendsreport/2023/#home (accessed August 3, 2023).
[21] *See* AFPM LDV Comments Attachment B at p. 28. AFPM incorporates these comments by reference.
[22] Moreover, because California concedes ACC II will not meaningfully address the impacts of climate change in California and ACC II will slow fleet turnover and retard California's progress toward meeting the NAAQS, California and New Mexico are not eligible for a waiver.
[23] See *Am. Auto. Mf'rs Ass'n v. Comm'r, Mass. Dep't. of Envt'l Prot.*, 998 F. Supp. 10, 17-18 (D. Mass. 1997) ("A state regulation relating to control of emissions from new motor vehicles or engines can survive

New Mexico is additionally preempted because the NMED Proposal does not meet the conditions provided in CAA Sec. 177, specifically providing that states may only adopt California standards when "such standards are identical to the California standards for which a waiver has been granted for such model year…."[24]

Furthermore, CAA Section 209(b) violates the U.S. Constitution's equal sovereignty doctrine, since it grants authority to set motor vehicle standards only to California—it gives California a greater degree of sovereignty than other states. This is especially true as applied to standards aimed at global climate change. Because CAA Section 209(b) is unconstitutional, both it and CAA Section 177 are void and cannot authorize NMED's rules, which are therefore preempted by CAA Section 209(a).

C. NMED must not finalize the ACC II rule before ongoing litigation concludes.

NMED's proposed adoption of ACC II is premature and presumes California has authority to promulgate ACC II. There are multiple lawsuits before the D.C Circuit arguing that EV mandates are preempted by the CAA, by EPCA, or by the RFS.[25] As we explain elsewhere in these comments, ACC II is in fact preempted.[26] Moreover, the pending litigation challenges the constitutionality of the CAA preemption-waiver mechanism as well as its specific application in the case of California's motor vehicle GHG emission regulations.[27] NMED should wait until this litigation is resolved before adopting ACC II. To adopt ACC II now risks considerable disruption and whipsawing of regulated parties' and other stakeholders' expectations and investments, as well as wasted NMED resources.

D. ACC II conflicts with important federal statutory objectives.

Rather than independently analyze ACC II impact and feasibility for the State of New Mexico, NMED simply relies on CARB's analysis. In its haste to phase out the oil and gas production and refining industries, CARB did not consider the impact of ACC II on the remainder of our energy system. ACC II will sharply curtail, if not eliminate, the demand for renewable fuels, and will create demand that will overburden the electricity generation and transmission systems. Nor did CARB consider the impact on other essential products such as jet fuel, asphalt, sulfur, petrochemicals, and lubricants. This willful blindness and tunnel vision places ACC II on a

---

pre-emption if, in accordance with [Clean Air Act] § 177, it adopts and enforces standards which are 'identical to the California standards' for which the EPA has granted a waiver 'for such model year.' But a state may not either adopt or enforce a standard which does not meet these requirements. Put another way, under § 177, a state can pass regulations only if it accepts as the basis for its regulations a California "standard" which has been granted a waiver in accordance with § 209(b))." (citation omitted) (emphasis added)) (granting summary judgment for plaintiff and holding preempted Massachusetts state ZEV production, delivery, and reporting requirements).

[24] CAA § 177, 42 U.S.C. § 7507 (emphasis added).

[25] *Id. See also* Interv. For Pet'r Br*., NRDC v. NHTSA*, Doc. 1976944 (Dec. 8, 2022) (D.C. Cir. No. 22-1080) (arguing EV mandates are impliedly preempted by the Renewable Fuel Standard).

[26] *See generally Ohio v. EPA*, No. 22-1081 (D.C. Cir. filed May 5, 2022). See also *Texas v. EPA*, No. 22-1144 (D.C. Cir. filed June 30, 2022) (challenging Department of Transportation's Corporate Average Fuel Economy (CAFE) rulemaking, alleging violation of statutory prohibition on incorporating EV mandates into such regulations).

[27] *See Ohio v. EPA*, (D.C. Cir. No. 22-1081) *oral argument scheduled on* September 15 (The D.C. Circuit may not resolve the matter until 2024, with potential Supreme Court certiorari proceedings to follow).

collision course with multiple Congressionally mandated programs expressly designed to have the opposite impact: Congress wants to increase bio and renewable fuel production and ensure a reliable electricity supply.[28] Because ACC II undermines and conflicts with these Congressional objectives, ACC II—and NMED's adoption of it—are necessarily preempted.

It is a "well-established principle that the Supremacy Clause, U.S. Const., Art. VI, cl. 2, invalidates state laws," like ACC II, "that interfere with, or are contrary to federal law."[29] Even where Congress has not completely displaced state regulation in a specific area, state law is nullified to the extent that it conflicts with federal law. Such conflicts arise "when compliance with both state and federal law is impossible" or "when the state law 'stands as an obstacle to the accomplishment and execution of the full purposes and objectives of Congress.'"[30] The ACC II program fails on both counts and is, therefore, expressly and/or impliedly preempted by federal law.

First, Congress's intention to increase production, distribution, and use of bio and renewable fuels is expressed in no less than three statutes, which do everything from mandating bio and renewable fuel blending in conventional liquid fuel to incentivizing its production through loans and loan guarantees. EPCA includes provisions related to the integration of alternative fuels in the transportation sector and requires a "reasonable distribution" of the burden of any energy-use restrictions.[31] NMED's adoption of ACC II would eliminate any role for these alternative fuels for new vehicles in New Mexico by requiring 82% ZEV by 2032, removing a substantial portion of the demand for these fuels and depriving federal investments of significant value. This deprivation is made worse by the fact that Maine, New York, Delaware, Maryland, Connecticut, Rhode Island, Colorado and other Sec. 177 states may adopt or have unlawfully adopted California's engine and motor vehicle emission standards under CAA Section 177, 42 U.S.C. § 7507, and the potential that manufacturers are unlikely to produce two separate fleets to satisfy

---

[28] *See* 42 U.S.C. §§ 7545 et seq. (RFS) and the Energy Independence and Security Act (EISA), 42 U.S.C. ch. 152 § 17001 et seq.
[29] *Hillsborough Cty., Fla. v. Automated Med. Lab'ys, Inc.*, 471 U.S. 707, 712-13 (1985) (citations omitted).
[30] *Capital Cities Cable, Inc. v. Crisp*, 467 U.S. 691, 699 (1984) (quoting *Hines v. Davidowitz*, 312 U.S. 52, 67 (1941)) ("Under the Supremacy Clause of the United States Constitution, federal law preempts contrary state law. In general, the types of preemption recognized by federal courts can divided into three categories: express preemption, field preemption, and conflict preemption. Express preemption occurs when Congress preempts state law in express terms. Field and conflict preemption, by contrast, take a more contextual approach. Field preemption exists when it is clear, despite the absence of explicit preemptive language, that Congress has intended, by legislating comprehensively, to occupy an entire field of regulation and has thereby left no room for the States to supplement federal law. As for conflict preemption, even if Congress has not occupied the field, state law is naturally preempted to the extent of any conflict with a federal statute. Thus, conflict preemption exists when compliance with both state and federal law is impossible, or when state law stands as an obstacle to the accomplishment and execution of the full purposes and objective of Congress." (internal quotation marks and citations omitted)).
[31] *See* EPCA (42 U.S.C. § 6374, requiring alternative fuel use by light duty Federal vehicles), *id.* § 6391(b) (prohibiting "[u]nreasonably disproportionate share of burden" between segments of the business community and requiring that, "[t]o the maximum extent practicable, any restriction under authorities to which this section applies on the use of energy shall be designed to be carried out in such manner so as to be fair and to create a reasonable distribution of the burden of such restriction on all sectors of the economy").

177 states vs. the rest of the country. ACC II contradicts EPCA's requirement that any burdens stemming from energy-use restrictions be reasonably distributed across all industry sectors.

And the Energy Independence and Security Act (EISA) includes specific provisions to increase production of biofuels under the RFS program and requires blending of increasing volumes of bio and renewable fuels.[32] ACC II conflicts with these federal objectives and deprives federal funding programs of value by mandating complete electrification of the transportation sector. These programs set aside significant funding for the development and use of liquid fuels for transportation, with the expectation that these fuels will reduce carbon emissions from transportation and continue to play an important role in meeting transportation energy demand for many years.

Second, federal policy explicitly supports "the modernization of the Nation's electricity transmission and distribution system to maintain a reliable and secure electricity infrastructure that can meet future demand growth."[33] The ACC II program conflicts with this policy by introducing material security and reliability risks to California's electricity grid, and to the grid of New Mexico and other states who may adopt ACC II. AFPM discusses the significant national security and energy risks associated with *de facto* ZEV mandates in its comments to EPA's LDV proposal.[34] In short, ACC II increases reliance on imported critical minerals and metals for battery production and grid expansion that could have serious negative consequences for our energy and national security. The supply chain for key minerals needed to produce electric vehicle batteries is not assured and will require dramatic increases to meet expected demand.[35] The extraction and processing of battery critical minerals is concentrated in politically unstable or rival nations. Domestic copper and aluminum smelting capacity is insufficient to meet grid expansion needs, and new mines can take over a decade to increase domestic supply. The deployment timeline necessary to develop new resources for batteries and the grid is impracticable and presents unnecessary risks to our energy and economic security. In contrast, domestically consumed liquid fuels sourced from petroleum and bio feedstocks are largely sourced in North America, and the U.S. benefits from its position as a net exporter of petroleum and refined product exports.

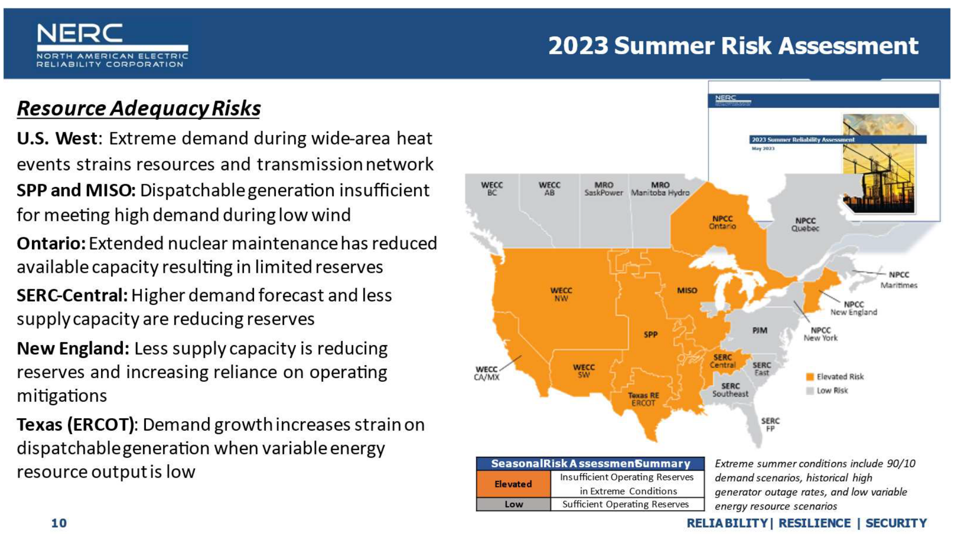
Rapidly electrifying the transportation sector will both substantially increase electricity demand in New Mexico and other states that may adopt ACC II and increase dependence on electricity services. Electrification of the transport sector will stress an already fragile grid and amplify the risk that the grid will be targeted for either physical or cyber-attacks. A 2023 Government

---

[32] EISA (Title 42, Chapter 152, Subchapter II: Programs for investment in biofuel research and infrastructure, centered around "increasing energy security," which is of special federal concern); 42 U.S.C. § 7545(o)(2)(B)(ii) (the RFS establishes requirements related to determining the applicable volume of cellulosic biofuel for the calendar years 2023 and later, based on considerations such as available infrastructure, consumer costs, and energy security). *See also* AFPM LDV Comments (Attachment B) at p. 21.
[33] 42 U.S.C. § 17381.
[34] AFPM LDV Comments (Attachment B) at 4-11.
[35] *See* International Energy Forum, Critical Minerals Outlook Comparison, August 2023 at 25 (although beyond the scope of the report comparing eleven studies on the demand for critical minerals, the authors noted geopolitics, high capital costs, ESG pressures and extended times to develop new mines "indicate a high risk for periods of demand exceeding supply," available at https://www.ief.org/focus/ief-reports/critical-minerals-outlooks-comparison

Accountability Office Report revealed that due to the increased connectivity from industrial control systems, the grid distribution systems grow more vulnerable to cybersecurity attacks.[36] According to the report, "threat actors can use multiple techniques to access those systems and potentially disrupt operations."[37] As demand increases due to accelerated electrification, grid reliability will pose a greater challenge due to additional resource buildout. As detailed in AFPM's LDV Comments, there is significant doubt that the U.S. electric grid can reliably support the proposal.[38] Demand for electric vehicle charging will place significant stress on generation, transmission, distribution, and consumer charging systems, that are unlikely to meet increased demand in such a short timeframe.[39] As recently reported by the North American Electric Reliability Corporation (NERC), while electricity supply has improved in 2023 versus 2022, several operating regions are still at-risk during periods of peak demand.[39] As shown in Figure 1, NERC's recent summer assessment shows roughly two-thirds of the U.S., including New Mexico and other Southwest states, face increased resource adequacy risk in the summer of 2023 before any additional increases in ZEV sales requirements under ACC I or ACC II.

Figure 1: NERC 2023 Summer Risk Assessment[40]



Further, the report found that increased use of networked consumer devices that are connected to the grid's distribution systems—including EVs and charging stations—also potentially introduce vulnerabilities because "distribution utilities have limited visibility and influence on the use and cybersecurity of these devices."[40]

---

[36] Gov't Accountability Office, Cybersecurity High-Risk Series: Challenges in Protecting Cyber Critical Infrastructure, GAO-23-106441 (Feb. 2023), available at https://www.gao.gov/assets/gao-23-106441.pdf (Accessed August 24, 2023)

[37] Id.

[38] AFPM LDV Comments (Attachment B) at 13.

[39] *See* discussion at AFPM LDV Comments at 11-17 and 34-36. NMED should better assess grid impacts from a regional basis before mandating a rapid shift to EVs.

[40] Gov't Accountability Office, Electricity Grid Cybersecurity: DOE Needs to Ensure Its Plans Fully Address Risks to Distribution Systems, GAO-21-81, at 18.

ACC II will increase New Mexico's electricity demand, undermining federal requirements targeting increased grid reliability. The increased demand for electricity under New Mexico's proposed adoption of ACC II will likely stress New Mexico's grid and the grids of states adopting ACC II, potentially compromising grid reliability in direct contravention of federal policy.

Because NMED's proposed adoption of ACC II conflicts with and presents an obstacle to clearly stated federal objectives, NMED lacks the authority to promulgate these regulations—and indeed is preempted from doing so.

III. NMED's adoption of ACC II constitutes a regulatory taking requiring just compensation.

NMED's plan to eventually phase out the sales of all ICEVs constitutes a regulatory taking. AFPM members invested substantial amounts of money in making their refineries, terminals, distribution networks, and renewable fuel facilities efficient and productive to supply our nation with cost-effective fuels. Therefore, our members and the broader industry have significant investment-backed expectations with respect to their properties, at least some of which may be forced to close because of NMED's proposed adoption of CARB's EV mandate. New Mexico landowners also would be harmed. Landowners in the state receive compensation from renting their land to companies. Policies that shut down facilities in the petroleum supply chain, such as refineries, pipelines, and distribution terminals, would prevent companies and New Mexico landowners from realizing these investment-backed expectations. Thus, adopting ACC II would constitute a regulatory taking based on its substantial interference with these expectations, and the state would be obligated to provide just compensation for companies' losses.

Therefore, as NMED considers the potential costs of policies that would shut down fuel infrastructure and other facilities, it should—at a minimum—account for the estimated costs of just compensation for the loss of property use and interference with investment-backed expectations that would inevitably result.

IV. The adoption of ACC II constitutes arbitrary and capricious rulemaking.

Even if EPCA and the CAA did not preempt New Mexico from adopting ACC II, the proposed regulations are substantively deficient and based on incomplete analysis.

There are numerous issues of central relevance that NMED failed to analyze or simply imported from California without adjustments needed to reflect conditions that are different between California and New Mexico. These include the true lifecycle emissions caused by this rule, critical mineral dependence and supply, grid composition, the costs of required grid upgrades, the state and reliability of the charging network, EV total cost of ownership, differences in temperature and topography and their impact on vehicle performance and use, and safety considerations.

A. NMED may not overlook New Mexico's administrative requirements for enacting new regulations.

Under the New Mexico Air Quality Control Act, the board can adopt regulations to "prevent or abate air pollution,"[41] and such regulations "shall be at least as stringent as federal law, if any,

[41] N.M.S.A. § 74-2-5(A), (B)(1).

relating to control of motor vehicle emissions."[42] They must consider "(1) character and degree of injury to or interference with health, welfare, visibility and property; (2) the public interest, including the social and economic value of the sources and subjects of air contaminants; and (3) technical practicability and economic reasonableness of reducing or eliminating air contaminants from the sources involved and previous experience with equipment and methods available to control the air contaminants involved."[43] For rules "more stringent than the federal act or federal regulations . . . the environmental improvement board or local board shall make a determination, based on substantial evidence and after notice and public hearing, that the proposed rule will be more protective of public health and the environment."[44]

NMED does not actually demonstrate that adopting ACC II will abate, *i.e.,* reduce carbon dioxide emissions in total, which in turn implicates NMED's analysis of economic reasonableness and the impacts on health, welfare, and the economic value of the petroleum and ethanol production and distribution chain. As we explain here and in Section IV.D of these comments, and in our attached comments on CARB's ACC II proposal (Attachment A), in the absence of a proper and thorough lifecycle GHG emissions analysis, neither CARB nor NMED can demonstrate the aggregate GHG impact of ACC II and thus that it is proposing effective and practical controls. Our attached comments on CARB's ACC II proposal include a study from Ramboll that evaluated whether alternative vehicle technology and fuel pathways could achieve lifecycle GHG emission reductions similar to or greater than the ACC II proposal. Unlike CARB's and NMED's partial analyses, Ramboll evaluated the full lifecycle impacts of EV technologies under the ACC II proposal to more completely and properly characterize the potential near-term and long-term GHG emissions performance. Ramboll considered other pathways that would not require a replacement of the entire transportation infrastructure system, and that would also not require the wholesale transformation of electric energy production and distribution infrastructure on an unprecedented short time scale. Instead, these other pathways would allow battery, hydrogen, and lower-carbon intensity gaseous and liquid fueled vehicles to compete to achieve GHG targets for light-duty transportation in the quickest and most cost-effective manner while addressing emissions from the existing fleet. Ramboll's conclusions showed that CARB's attributions of GHG reductions to its proposed ACC II regulation were incomplete and emphasized the need for CARB to conduct a full lifecycle GHG emission assessment to quantify the cradle-to-grave effects of the draft ACC II proposal. CARB did not remedy these inadequacies in its analysis before adopting ACC II, and NMED's reliance on CARB's assessment suffers from the same deficiencies.

Even if CARB's analysis included the carbon emissions associated with battery production and had been otherwise adequate (which, as our attached comments on its proposal demonstrated, it was not), NMED cannot simply rely on CARB. NMED must conduct an adequate LCA of the effects of adopting ACC II on statewide GHG emissions. An adequate LCA would consider factors such as the mix of the fuel base for electricity supplied to the grid on which New Mexico's EVs will charge, expected miles traveled by New Mexico drivers, New Mexico temperature trends throughout the year and their effect on charging needs and battery capabilities, and many other state-specific factors.

---

[42] N.M.S.A. § 74-2-5(E).
[43] N.M.S.A. §§ 74-2-5(F).
[44] N.M.S.A. § 74-2-5(G).

NMED's apparent dismissal of these administrative requirements, and adoption of analysis conducted by California for California underscores the arbitrary and capricious nature of the proposal.

B. NMED's analysis is based on unwarranted assumptions.

NMED provides no or inadequate support regarding cars, car components, and the costs of both. It mostly relies on CARB's analysis. Considering NMED's heavy reliance on CARB's analysis, we refer to and incorporate by reference our comments on CARB's ACC II proposal (Attachment A) and our comments to New York's proposed ACC II adoption (Attachment C).

Similar to other states "adopting" ACC II, NMED provides no analysis or support to demonstrate that there will be an adequate EV fleet to meet the requirements of its proposed adoption of ACC II. This is arbitrary in light of evidence in the public domain that NMED has ignored.[45] Moreover, NMED fails to consider whether the myriad direct and indirect federal and state subsidies required to bring current and future EVs into the marketplace are sufficient for EV sales and technology to be feasible, or whether these subsidies can even reasonably be expected to continue in their current state throughout the ramp-up required over the next decade and beyond under ACC II.[46]

Similarly, with respect to battery availability and costs, NMED provides no analysis of whether the likely future supply and demand trends for critical minerals and other battery components will allow for the necessarily massive supply ramp-up in conjunction with continued falling prices. A recent study comparing eleven reports evaluating critical mineral demand requirements for the energy transition concluded forecasting future critical mineral demand requirements is highly uncertain due to variations in energy markets, costs, and technological advancements.[47] Therefore, there is little basis for CARB's and NMED's conclusions that there will be ample critical minerals and battery components.

1. NMED failed to consider the feasibility of ACC II

The supply chain necessary to support new technologies contemplated by ACC II is not well established and is likely to increase dependence on critical minerals from foreign sources. Reliance on a limited number of technologies (e.g., ZEVs) on the timeline required by ACC II may result in a non-resilient transportation sector vulnerable to unexpected disruptions and cost increases. Unstable critical mineral supply chains could disrupt this future. ZEVs, as compared to ICEVs, have a much greater reliance on several critical minerals. NMED ignores the obvious benefits of a multi-technology approach that would reduce the risks associated with a ZEV-

---

[45] Analyst data suggests that automobile manufacturers are unlikely to produce as many EVs as they had hoped. *See e.g.,* Keith Naughton, Ford CEO Sticks to 'Crazy High' EV Goal, Bloomberg News (May 19, 2023), available at https://www.bloomberg.com/news/articles/2023-05-19/ford-ceo-pitches-50-billion-ev-plan-to-challenge-tesla#xj4y7vzkg (Accessed August 8, 2023).
[46] Because passenger vehicles have domestic manufacturing and sourcing requirements in the IRA to be eligible for the clean vehicle tax credit and many of the required critical minerals are imported, it will be challenging for all vehicles to be eligible for the full federal clean car tax credit. *See* IRA, Section 45W(c) (The IRA requires 50% of the value of battery components to be produced or assembled in North America to qualify for a $3,750 credit and 40% of the value of critical minerals sourced from the United States or a free trade partner also for a $3,750 credit).
[47] International Energy Forum, Critical Minerals Outlook Comparison, August 2023 at 25-26.

focused approach. For example, Toyota recently noted in a memo to its dealers that "the amount of raw materials in one long range battery electric vehicle could instead be used to make 6 plug-in hybrid electric vehicles or 90 hybrid electric vehicles . . . the overall carbon reduction of those 90 hybrids over their lifetimes is 37 times as much as a single battery electric vehicle."[48] There are six minerals critical to the production of ZEVs: cobalt, copper, graphite, lithium, manganese, and nickel.[49]

Critical mineral supply, especially those essential to the manufacturing of a lithium-ion (Li ion) battery, is dominated by China, Australia, and the Democratic Republic of Congo.[50] Of the foreign nations that produce cobalt, molybdenum, and other minerals needed to produce ZEVs, China has disproportionate influence. While 70 percent of global cobalt production comes from the Democratic Republic of Congo, most of those mines are owned/operated by China, and more than 60 percent of cobalt processing is in China. Moreover, 67 percent of the world's graphite is also produced in China.[51] The U.S. imports most of its manganese from Gabon, a less politically stable country that just experienced a military coup, providing 65 percent of the United States' supply.[52] NMED has ignored these real-world conditions that it should be analyzing before jumping into this extreme transformation of our transportation fleet.

Expected supply from existing mines and projects under construction is estimated to meet only half of projected world demand for lithium and cobalt.[53] Establishing new mines, particularly in the United States, is not a near-term solution. Permitting and authorizing new domestic mining and smelting capacity requires a substantial amount of time and government support. According to the National Mining Association, it can take up to 10 years to obtain a permit to commence mining operations in the U.S.[54] "[U]nless the permitting process can be improved, U.S. mining developments will continue to take longer to come online and carry more financial risks compared with the rest of the world, China's domination of battery manufacturing and critical minerals production will continue for a longer period, and the U.S. will find it increasingly difficult to acquire the metals and minerals it needs for its long-term clean-energy goals."[55]

---

[48] William Johnson, TESLARATI, "Toyota releases new defense of lagging EV strategy" (May 18, 2023). available at https://www.teslarati.com/toyota-defends-ev-strategy/.
[49] International Energy Administration, "The Role of Critical Minerals in Clean Energy Transitions," (revised March 2022) available at https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions. [hereinafter IEA Report 2022].
[50] Turner, Mason & Company. "Evaluation of EPA's Assumptions and Analyses Used in Their Proposed Rule for Multi-Pollutant Emissions Standards" (June 7, 2023) (Research funded by AFPM and available upon request) [hereinafter "Turner Mason Report"].
[51] G.R. Robinson, et al., U.S. GEOLOGICAL SURVEY, "Professional Paper 1802 Critical mineral resources of the United States—Economic and environmental geology and prospects for future supply" (Dec. 19, 2017) p. J1–J24, available at https://doi.org/10.3133/pp1802J.
[52] OEC, "Manganese Ore in the United States" (Mar. 2023) available at https://oec.world/en/profile/bilateral-product/manganese-ore/reporter/usa.
[53] Axios Generate, The supply crunch that could slow the climate fight, (May 5, 2021).
[54] National Mining Association, Delays in the U.S. Mine Permitting Process Impair and Discourage Mining at Home, May 31, 2021. Available at https://nma.org/2021/05/13/delays-in-the-u-s-mine-permitting-process-impair-and-discourage-mining-at-home/.
[55] Jason Lindquist, Don't Pass Me By - With Many Steps Required, Mining Projects Face Trickiest Path To Approval, RBN Energy Blog (June 30, 2023).

As demand for these commodities grows, the market concentration (and ability to exert power over pricing) swings toward producers in less politically stable countries. If producer countries have market power, they have the potential to impact not only price, but the ability for consumer countries to influence other issues, such as sanctity of commercial contracts, labor and/or human rights, and environmental standards in producing jurisdictions. The significance of this issue is compounded by the fact that multiple critical minerals are needed for ZEV production, so a disruption in the supply of a single mineral can disable the entire supply chain. The operation of ICEVs, to the contrary, relies on natural resources for which there are abundant domestic supplies.

The supply chain necessary to support new technologies under ACC II is uncertain and is likely to increase dependence on critical minerals from foreign sources.[56] In the event of supply disruption or pricing volatility related to geopolitical pressures, the U.S. is highly exposed as it heavily relies on imports to satisfy domestic demand in each of these critical minerals.[57] Except for copper, the U.S. does not produce significant quantities of these critical minerals. And, despite the U.S. having substantial domestic copper mining, it still relies on imports to meet 45 percent of U.S. demand.[58] China's dominance does not stop at critical mineral extraction and processing. "Two of China's largest battery companies control more than half of the global market resulting in up to 90% of the EV battery supply chain relying solely on China."[59] Conversely, the United States plays a small role in the global electric vehicle (EV) supply chain, with only 7 percent of battery production capacity.[60] "With a heavy dependence on China, the United States is at a disadvantage in its role in the global EV supply chain."[61]

"Between January 2022 and January 2023, the cost of lithium increased by almost 45%."[62] By May 2023, "battery costs were $110.7/kWh, which was driven by China's increased lithium carbonate price during its EV market recovery."[63] Indeed, battery costs rose 7 percent in 2022,

---

[56] *See e.g.*, Shelley Challis, POST REGISTER, "Jervois shuts down Idaho Cobalt mine" (Apr. 7, 2023), available at https://www.postregister.com/messenger/news/jervois-shuts-down-idaho-cobaltmine/article_efd97f32-d015-11ed-9424-bfb28220210c.html.

[57] China announced it will restrict the export of two metals (gallium and germanium) used in EV production. While these metals are not particularly rare, China could limit export of processed key EV battery minerals to maintain its supply chain dominance. See Archie Hunter & Alfred Cang, China Restricts Export of Chipmaking Metals in Clash with US, July 3, 2023. Bloomberg, available at https://www.bloomberg.com/news/articles/2023-07-03/china-to-restrict-exports-of-metals-critical-to-chip-production#xj4y7vzkg.

[58] *See* AFPM LDV Comments at 38-40 for additional discussion regarding the lack of critical minerals needed for battery production.

[59] Morgan Stanley, "Rewiring the Supply Chain for Electric Vehicle Batteries, (July 2023), https://www.morganstanley.com/ideas/ev-battery-lithium-supply.

[60] RMI, "The EV Battery Supply Chain Explained," (May 2023), https://rmi.org/the-ev-battery-supply-chain-explained/#:~:text=Today%2C%20the%20United%20States%20is,strengthen%20the%20US%20downstream%20sector.

[61] Morgan Stanley, "Rewiring the Supply Chain for Electric Vehicle Batteries, (July 2023), https://www.morganstanley.com/ideas/ev-battery-lithium-supply.

[62] International Energy Agency, "Trends In Batteries," (April 2023) https://www.iea.org/reports/global-ev-outlook-2023/trends-in-batteries.

[63] Mining.com, "EV battery prices rise for the first time in 2023," (June 2023), https://www.mining.com/ev-battery-prices-rise-for-first-time-in-2023/

and lithium-ion battery pack prices have recently begun to rise, even before the true impacts of ACC II are felt.[64] With EPA's and other developing nations' push to electrify transportation and the concomitant need to deploy utility-scale batteries, the demand for lithium (and other critical minerals) is expected to grow exponentially. While prices for key battery metals like lithium, nickel and cobalt have moderated slightly in recent months, Bloomberg New Energy Finance (BNEF) expects average battery pack prices to remain elevated in 2023 at $151/kWh.[65] Ample research and commentary warn that critical mineral and battery component supply issues will form a major obstacle to the type of EV ramp-up the proposal assumes will happen seamlessly.

To meet the mandates set by ACC II, the original equipment manufacturers (OEMs) must secure adequate amounts of raw materials in a short time. With the projected supply and demand gap that many analysts foresee, pricing of critical minerals will remain volatile as occurred through the early 2020s. Morgan Stanley estimates EV makers will need to increase prices by 25 percent to account for rising battery prices.[66] Battery raw materials are not commodities, they are classified as specialty chemicals, so pricing should not be analyzed according to traditional commodity pricing structures, especially given that these supplies are geographically concentrated in areas with geopolitical instabilities. Each OEM, cathode or anode producer, and battery manufacturer have their own specifications for the materials, and thus the raw materials must be refined and tested to meet their bespoke specification. Spot markets for battery materials are virtually non-existent and unlikely to develop in the near term.

Consumers are directly affected with higher EV costs, particularly when lower cost ICEVs are no longer available. Although there are various federal and state subsidies and incentives to partially offset higher vehicle and infrastructure costs associated with ACC II, NMED does not analyze whether this state of affairs is likely to last. The potential loss of EV subsidies and incentives affects the cost analysis and overall viability of the regulatory program. Setting aside whether California, New Mexico, or any state has authority to create ZEV credits, the costs of those subsidies, which are borne by gasoline vehicle buyers in other states (without their knowledge) must be evaluated by NMED.[67] The IRA has incentives to reduce battery prices, but this law simply extended the existing battery subsidy and even limited its applicability through domestic sourcing and income requirements. Thus, NMED and other states are relying on an existing program that has been curtailed for the proposition that it will lower battery prices in the

[64] BloombergNEF, Lithium-ion Battery Pack Prices Rise for First Time to an Average of $151/kWh (Dec. 6, 2022); Graham Evans, A reckoning for EV battery raw materials (S&P Global Mobility Oct. 31, 2022), available at https://www.spglobal.com/mobility/en/research-analysis/a-reckoning-for-ev-battery-raw-materials.html (Accessed August 8, 2023); Mark P. Mills, The "Energy Transition" Delusion: A Reality Reset (Manhattan Institute Aug. 2022), at 8, 10, available at https://media4.manhattan-institute.org/sites/default/files/the-energy-transition-delusion_a-reality-reset.pdf (accessed August 8, 2023). *See also* AFPM LDV Comments (Attachment B) at 49-51 for detailed discussion of battery costs.

[65] BLOOMBERGNEF "Lithium-ion Battery Pack Prices Rise for First Time to an average of $151/kWh" (Dec. 6, 2022) *available at* https://about.bnef.com/blog/lithium-ion-battery-pack-prices-rise-for-first-time-to-an-average-of-151-kwh/ (Accessed September 25, 2023).

[66] *See* James Thornhill, Morgan Stanley Flags EV Demand Destruction as Lithium Soars (Bloomberg Mar. 24, 2022), available at https://www.bloomberg.com/news/articles/2022-03-25/morgan-stanley-flags-ev-Demand-destruction-as-lithium-soars (last visited May 24, 2023).

[67] ACC II is largely funded on the backs of gasoline (and diesel) car buyers, through credit transfers and payments between automakers that hide the true costs of EVs. This scheme violates Federal (and State) laws that prohibit unfair or deceptive acts or practices in or affecting commerce.

future. However, those seeking to adopt ACC II simultaneously ignore that the increase in demand for batteries will raise their price. Moreover, NMED does not consider the market implications of an increasing percentage of vehicle sales depending on cross-subsidies from a shrinking number of gasoline vehicle buyers. As stated in a recent Wall Street Journal article, in 2023 car inventory increased yet there is a lack of buyers. High interest rates keep potential buyers at a distance while there are an increasing number of defaults on auto loans for current owners. Dealership owners grapple with getting cars off their lots with an optimal supply, but very minimal demand.[68] NMED must account for the costs and market impacts described in the following sections, which currently are ignored in its proposal.

2. NMED's cost analysis is woefully inadequate.

Rather than conduct its own analysis of the total cost of ownership for New Mexico consumers, NMED relies on CARB's analysis, which assesses costs for California, not New Mexico. This fact alone renders NMED's analysis deficient. Nonetheless, we offer the following comments on CARB's total cost of ownership analysis.

a. Purchase Price

While CARB and NMED acknowledge EVs have a higher purchase price than ICEVs, these states incorrectly assume that every ZEV will be eligible for the maximum federal purchase incentive. It is arbitrary and capricious for NMED to ignore the likelihood that battery raw materials will not be produced in the U.S. or available for import from credit-qualifying countries, given China's dominance in processing critical minerals needed for ZEV batteries and the manufacture of ZEV batteries. Consequently, it is unrealistic to assume ZEV purchases will be eligible for the full incentive which is tied to domestic manufacturing requirements (and household income limits).

NMED ignores that battery prices began to rise due to limited supply of minerals.[69] While there are a few affordable EVs, these EVs typically have a range below 200 miles on a full charge.[70] If consumers want longer range EVs, they will pay a considerable purchase price as seven of the top ten, range-rated EVs cost anywhere from $74,800 to $110,295.[71] In the first calendar quarter of 2022, the average price of the top-selling light-duty ZEV in the U.S. was about $20,000 more than the average price of top-selling ICEV.[72] The price disparity has not

---

[68] Ben Foldy, "Car Prices Might be Unsustainable for Car Buyers," The Wall Street Journal (Aug. 21, 2023), at https://www.wsj.com/personal-finance/car-prices-might-be-unsustainable-for-buyers-18d7b395.
[69] BLOOMBERGNEF "Lithium-ion Battery Pack Prices Rise for First Time to an average of $151/kWh" (Dec. 6, 2022) available at https://about.bnef.com/blog/lithium-ion-battery-pack-prices-rise-for-first-time-to-an-average-of-151-kwh/.
[70] *See* Sebastian Blanco, *List of EVs Sorted by Range* (Sept. 1, 2022), http://www.jdpower.com/cars/shopping-guides/list-of-evs-sorted-by-range.
[71] *See* Nicholas Wallace, Austin Irwin, & Nick Kurczewski, Longest Range Electric Cars for 2023, Ranked (Mar. 23, 2023), https://www.caranddriver.com/features/g32634624/ev-longest-driving-range/.
[72] Registration-weighted average retail price for the 20 top-selling ZEVs and ICEVs in the U.S. S&P Global, Tracking BEV prices – How competitively-priced are BEVs in the major global auto markets? May 2022.

improved, with the average price of light-duty EVs near $66,000 in August 2022 and continuing to rise.[73]

b. Cross-subsidies

Noticeably absent from CARB's and NMED's analysis is cross-subsidization. A ZEV typically costs tens of thousands of dollars more to produce than a comparable ICEV due primarily to the surging costs of critical minerals and resulting high costs of batteries.[74] ACC II will force manufacturers to sell an increasing percentage of ZEVs each year that goes far beyond the consumer demand for the product at its true cost. To ensure compliance with the ZEV mandate under ACC II, manufacturers will be forced to incentivize ZEV purchases through a practice called cross-subsidization.

Automobile cross-subsidization is a pricing strategy to spread the high cost of ZEVs across a manufacturer's other product offerings. Under this pricing convention, manufacturers set the prices of certain ICEVs higher than their production costs to generate additional profits that can then be used to offset losses incurred by selling ZEVs below their actual production costs. This practice operates as a hidden tax on ICEVs and results in the purchasers of ICEVs subsidizing the sale of ZEVs. Without cross-subsidies, ZEV mandates would fail.

While opaque, the magnitude of ZEV cross-subsidies is significant. Ford's decision to report EV financial information separately beginning in 2023 provides an additional glimpse into the magnitude of cross-subsidization. Ford lost approximately $58,000 for each ZEV car it sold during the quarter.[75] This reported per-vehicle loss is more than an order of magnitude greater than EPA's estimates of the price differential between the two technologies. Ignoring actual ZEV production costs, including credit trading costs, is arbitrary and capricious. These costs are ultimately borne by purchasers of ICEVs through cross subsidization.

c. Total cost of ownership[76]

The cost of ZEV ownership is higher than assumed by CARB and NMED. CARB's analysis presumes a consumer savings on ZEV maintenance, yet neglects to consider the differing ownership and use profiles, and the significant cost of battery replacement. One cannot assume

---

[73] Andrew J. Hawkins, EV prices are going in the wrong direction (The Verge Aug. 24, 2022), available at https://www.theverge.com/2022/8/24/23319794/ev-price-increase-used-cars-analysis-iseecars accessed May 24, 2023; see also Justin Banner, Latest Ford F-150 Lightning Price Hike Hands Chevy Silverado EV a $20K Advantage--The least-expensive electric F-150 Lightning now costs $4,000 more than it did late last year (Motortrend Mar. 30, 2023), available at https://www.motortrend.com/news/2023-ford-f-150-lightning-pro-price-increase-msrp/ accessed May 24, 2023.

[74] *See* PCMag, Profit vs. the Planet, (Sept. 26, 2022), Profit vs. the Planet: Here's Why US Automakers Are All-In on Electric Vehicles | PCMag https://www.pcmag.com/news/profit-vs-the-planet-heres-why-us-automakers-are-all-in-on-electric-vehicles accessed July 3, 2023 ("EVs are currently more expensive to manufacture than gas-powered vehicles because of spiking battery costs. The cost of lithium, the main ingredient, has skyrocketed since demand far exceeds the number of working mines that can supply it.").

[75] *See* Luc Olinga, TheStreet, Ford Loses Nearly $60,000 for Every Electric Vehicle Sold, (May 2, 2023) available at https://www.thestreet.com/technology/ford-loses-nearly-60000-for-every-electric-vehicle-sold accessed July 3, 2023.

[76] *See* AFPM LDV Comments (Attachment B) at 55-56 and AFPM CARB Comments (Attachment B) at B8-B13.

a new ICEV and a new ZEV will travel the same miles each year. EVs have less range, both technically and practically. As noted by J.D. Power, "the majority of EVs provide between 200 and 300 miles of range on a full charge."[77] One study shows that the average 3-year-old electric car is driven 9,059 miles per year, compared with 12,758 miles for ICEVs.[78] Other research suggests EVs travel only 5,300 miles per year.[79]

NMED also neglects to fully account for higher insurance costs of ZEVs. Insurance premiums for PHEVs are typically higher than comparable ICEVs because of higher repair costs. According to ValuePenguin, insurance on a PHEV, depending on the model, could be 19 percent to 32 percent higher than a comparable ICEV.[80] Another estimate from an October 2022 study from Self Financial concludes PHEVs' annual insurance is $1,674, $442 more compared to an ICEV annual insurance premium of $1,232.[81] NMED discussed routine maintenance savings from EV ownership, yet simultaneously ignores these repair costs differentials. This is another example of arbitrary rulemaking.

NMED and CARB assume lower retail fuel costs for ZEVs than liquid fuels. Real-world data squarely contradicts NMED's and CARB's cost assumptions on EV charging. For example, California's ZEV mandates have contributed to the inflationary impacts on energy prices. According to a 2021 California Public Advocates Office presentation to the California Public Utilities Commission, "it is already cheaper to fuel a conventional internal combustion engine (ICE) vehicle than it is to charge an EV" in the San Diego Gas & Electric Co. service area.[82] This is astonishing given that gasoline prices in California are the second highest in the nation, averaging approximately $4.01 per gallon of gasoline at that time in 2021. According to an Anderson Economic Group article, entry-priced, gas-powered cars were significantly more affordable to fuel at $9.78 per 100 "purposeful miles" compared to the $12.55 at-home charging costs for an entry-priced EV.[83] Future projections afford consumers no relief, as the California Energy Commission projects that both commercial and residential electricity prices will continue to rise, reaching nearly $7 per gasoline-gallon equivalent for the commercial sector. Similarly,

---

[77] *See* Sebastian Blanco, List of EVs Sorted by Range (Sept. 1, 2022), https://www.jdpower.com/cars/shopping-guides/list-of-evs-sorted-by-range accessed August 28, 2023.
[78] iSeeCars, *The Most and Least Driven Electric Cars* (May 22, 2023), https://www.iseecars.com/mostdriven-evs-study.
[79] Burlig, F., Bushnell, J., Rapson, D., Wolfram, C., "Low Energy: Estimating Electric Vehicle Electricity Use," National Bureau of Economic Research Working Paper 28451, http://www.nber.org/papers/w28451.
[80] ValuePenguin, How Much Does Electric Car Insurance Cost? https://www.valuepenguin.com/how-having-electric-car-affects-your-auto-insurance-rates accessed August 28, 2023.
[81] Self Financial, Electric Cars vs Gas Cars Cost in Each State https://www.self.inc/info/electric-cars-vs-gas-cars-cost/ accessed Augst 28, 2023.
[82] California Public Utilities Commission, "Utility Costs and Affordability of the Grid of the Future" (May 2021). Presentation from Mike Campbell, Public Advocates Office at 116-117 available at https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/office-of-governmental-affairs-division/reports/2021/senate-bill-695-report-2021-and-en-banc-whitepaper_final_04302021.pdf.
[83] Anderson Economic Group, "Some Cars Cheaper to Fuel with Gas Than Electric in 2023," August 1, 2023. Available at https://www.andersoneconomicgroup.com/many-gas-powered-cars-cheaper-to-fuel-than-electric-in-2023/.

many in the Boston-Cambridge-Newton area paid $0.34 per kWh in April 2023, which was nearly 107% higher than the national average.[84]

Charging pricing has been unpredictable, with some stations charging by the minute instead of charging for electricity consumed.[85] Other charging stations offer multiple subscription plans or charge different rates at various times of day, resulting in significant price increases over the past few months.[86] Boston charging companies raised charging fees in response to New England utilities increasing their rates to 39 cents per kilowatt-hour in February 2023, from 27 cents a year earlier.[87]

NMED must account for these real costs and assess these trends for New Mexico.

d. NMED fails to consider the cost of credits.

NMED fails to evaluate how government credits are embedded in vehicle pricing. For example, neither federal or state governments, nor auto manufacturers explain how state ZEV credits, EPA GHG multiplier credits, and NHTSA CAFE EV multiplier credits are accounted for in both ZEV and ICEV vehicle price.

i. State zero-emission vehicle credits.

"ZEV credits" are currency created by the State of California to provide supplemental subsidies to achieve their EV sales mandate. NMED, which adopts the same CARB program, must disclose the cost of this incremental subsidy that manufacturers of EVs require to entice buyers to meet state EV sales mandates. If buyers wanted EVs, the ZEV credit price would be $0, but California and other states explicitly decided to not collect this data from automakers, so the public has no information about the costs of this scheme. NMED must disclose who is paying the costs of the ZEV credits. Will New Mexico gasoline and diesel vehicle buyers cover the costs of ZEV credits for EV sales in the state through cross-subsidization, *i.e.*, will the MSRP of a gasoline pickup truck in New Mexico be higher than the MSRP of a gasoline pickup truck in a state without an EV sales mandate and ACC II? If so, by how much? Or will nationwide gasoline and diesel vehicle buyers cover these costs? If so, under what authority will New Mexico impose these costs on consumers nationwide? How much do these costs increase the price of gasoline and diesel vehicles? Also, if state EV sales mandates increase and battery minerals become scarcer, the value of ZEV credits are certain to increase significantly; however, NMED does not identify this risk or consider these costs. For example, one analyst (Joshua Linn) estimated the value of ZEV credits at $3,236 per credit.[88] Under California's rule, ZEV credits are awarded

---

84 U.S. Bureau of Labor Statistics, Northeast Information Office, Average Energy Prices, Boston-Cambridge-Newton — April 2023. Available at https://www.bls.gov/regions/northeast/news-release/averageenergyprices_boston.htm#:~:text=Source%3A%20U.S.%20Bureau%20of%20Labor,of%2016.5%20cents%20per%20kWh.

85 Aaron Pressman, "Inside the crazy, mixed-up world of electric-vehicle charger pricing," The Boston Globe, March 27, 2023. Available at https://www.boston.com/news/the-boston-globe/2023/03/27/electric-vehicle-charger-pricing/.

86 *Id.*

87 *Id.*

88 *See* Joshua Linn, Balancing Equity and Effectiveness for Electric Vehicle Subsidies (Resources for the Future Jan. 2022) available at https://media.rff.org/documents/WP_22-7_January_2022.pdf (accessed August 8, 2023).

based on the size of the battery (*i.e.*, the bigger the vehicle, the bigger the subsidy) and a typical EV receives 3 or more ZEV credits. Using Linn's estimate, every EV sale mandated by the State of New Mexico will impose a hidden cost of approximately $10,000 on ICEV buyers.[89]

ii. EPA GHG "multiplier" credits for EVs.

These credits give an extra manufacturing incentive to EV makers to meet EPA's GHG standards, despite EPA having no authority to do so, and are not based on any real-world avoided emissions. NMED does not estimate the costs of this subsidy to the extent that its proposal increases EV sales. Similarly, NMED does not consider that if EPA's GHG multiplier credits are determined to be unlawful and/or rescinded by regulation, the value of the aforementioned ZEV credits must necessarily increase to offset them. NMED should provide an estimate of the costs, which will be borne by purchasers of ICEVs.

iii. Corporate Average Fuel Economy (CAFE) "multiplier" credits.

Automakers and NHTSA are applying a long-expired incentive originally created by the Alternative Motor Fuels Act of 1988 to spur the commercial availability of alternative motor fuel vehicles (fueled with ethanol, methanol, or natural gas). This treatment allowed automakers to divide the gallon of gasoline equivalent for alternative fuel vehicles by 0.15, effectively producing a 6.67 multiplier of fuel economy credits. The Energy Policy Act of 1992 expanded the covered fuels to "alternative fuels," to also include LPG, hydrogen, coal-derived liquid fuels, other non-alcohol biofuels, and electricity. While this provision expired in either 1994 or 2004, depending upon one's interpretation, NHTSA continues to apply it to EVs.[90] In other words, EVs have been receiving credit for at least 667% of the real-world fuel economy they achieve on the road and EV manufacturers have been selling these credits to manufacturers of gasoline and diesel vehicles.[91] A NHTSA presentation suggests that its EV multiplier credits alone subsidize each

---

[89] This estimate is currently spread across roughly 19 gasoline car buyers for every 1 EV buyer (assuming BEVs are 5% market share of new sales); however, as EV mandates like New Mexico's increase and the gasoline and diesel vehicle buyer pool shrinks, these costs will compound at an increasing rate.
[90] *See* National Highway Traffic Safety Administration, "Alternative Fuels in CAFE Rulemaking," presentation to SAE International (2015), available at https://www.nhtsa.gov/sites/nhtsa.gov/files/2015sae-powell-altfuels_cafe.pdf (Accessed August 8, 2023).
[91] A 2015 NHTSA presentation to SAE, and a NHTSA CAFE Credit Model Documentation report, show how credits are being calculated for EVs despite not generating any real-world fuel savings or real-world fuel economy improvement. See also https://www.nhtsa.gov/sites/nhtsa.gov/files/2015sae-powell-altfuels_cafe.pdf; https://www.nhtsa.gov/sites/nhtsa.gov/files/2022-04/Model-Documentation_CAFE- MY-2024-2026_v1-tag.pdf; https://one.nhtsa.gov/cafe_pic/home/ldreports/manufacturerPerformance. Per the NHTSA information above, since MY2017 standards were ~35mpg and MY2017 Tesla FE performance (with multipliers) was 518.7 mpg, and since Tesla sold ~46,979 MY2017 vehicles in the U.S., then Tesla in MY2017 generated 227 million excess credits. If the market-value of these credits is ~$5.50 per 0.1 mpg shortfall per vehicle under the MY2017 CAFE standard of ~35 mpg, then these credits were worth approximately $1.25 billion, or $26,600 per EV that Tesla sold. [Calculation of estimated value: Credits = (518.7 – 35) x 46979 x 10 x CAFE Penalty of $5.50 per 0.1 mpg shortfall per vehicle]. Tesla may have banked, traded, or sold these credits. Tesla MY2022 sales in the U.S. were 484,351 and the CAFE civil penalty is now $15 per 0.1 mpg shortfall per vehicle.

EV by more than $25,000, increasing the true average cost of every EV sold to over $90,000.[92] Per the NHTSA information above, MY2017 standards were ~35mpg and MY2017 Tesla (with multipliers) was 518.7 mpg. Since Tesla sold ~46,979 MY2017 vehicles in the U.S., then Tesla in MY2017 generated 227 million excess credits. If the market-value of these credits is ~$5.50 per 0.1 mpg shortfall per vehicle under the MY2017 CAFE standard of ~35 mpg, then these credits were worth approximately $1.25 billion, or $26,600 per EV that Tesla sold.[93] We note that the U.S. Department of Energy (DOE) recently proposed to eliminate this multiplier when calculating the petroleum equivalence factor for EVs.[94] NMED should provide an estimate of the incremental costs of these subsidy payments and of the effect of a potential decision by DOE to remove the 667% multiplier.

While cross-subsidization, tax credits, emissions trading, and other EV subsidies may hide the true costs of a ZEV mandate from consumers, NMED has a duty to quantify and present those costs that are attributable to ACC II. NMED's failure to do so is in direct violation of New Mexico administrative requirements to examine the technical practicability and economic reasonableness detailed in section IV A above and renders this proposal legally deficient.

e. Tax Revenue Implications.

California and New Mexico are two very different states. NMED must deploy meaningful analysis, absent in its administrative record, as to how ACC II in New Mexico will shrink the pool of gasoline and diesel vehicles paying taxes and the corresponding shortfall in tax receipts. For example, California's geographical size is 28 percent larger than New Mexico, and the population of California is 18 times the population of New Mexico.[95] Moreover, what percentage of New Mexico's population lives in multi-unit dwellings, which makes EV charging more difficult? What are the median salaries and cost of living in New Mexico? What proportion of the population has a low income? How do these statistics compare to California? What are current and projected electricity rates and how do differences in temperature impact EV range and purchase decisions? What EV charging infrastructure is available and what is needed to expand

---

[92] *See* https://www.nhtsa.gov/sites/nhtsa.gov/files/2015sae-powellaltfuelscafe.pdf; https://www.nhtsa.gov/sites/nhtsa.gov/files/2022-04/Model-Documentation_CAFE-MY-2024-2026_v1-tag.pdf; https://one.nhtsa.gov/cafe_pic/home/ldreports/manufacturerPerformance.

[93] The calculation of estimated value: Credits = (518.7 – 35) x 46979 x 10 x CAFE Penalty of $5.50 per 0.1 mpg shortfall per vehicle]. Tesla may have banked, traded, or sold these credits. Tesla MY2022 sales in the U.S. were 484,351 and the CAFE civil penalty is now $15 per 0.1 mpg shortfall per vehicle.

[94] The Department of Energy has acknowledged that EV fuel economy is significantly overstated and has proposed certain modifications to the petroleum equivalency factor. See 88 Fed. Reg. 21,525 (April 11, 2023).

[95] Estimates as of July 1, 2022, U.S. Census Bureau, Quick Facts – New Mexico; California, available at https://www.census.gov/quickfacts/fact/table/NM,CA/LND110220 accessed October 27, 2023.

charging availability?[96] These factors affect EV adoption rate and, by extension, the impact on the state budget, which NMED ignored in adopting ACC II.[97]

EVs are heavier than comparable ICEVs, which means increased wear and tear on roadways. CARB and NMED fail to account for infrastructure impacts from increased operation of heavier ZEVs on the road including road and bridge deterioration and commensurate reduced funding for infrastructure from fuel tax collections. These excluded costs must be included in NMED's analysis—another example of the state's failure to address a major aspect of ACC II.

C. NMED's analysis of economic impacts is woefully inadequate.

NMED neglects to consider economic impacts to the public. We incorporate by reference our attached comments on CARB's ACC II proposal (Attachment A), AFPM's LDV comments (Attachment B), and AFPM's NHTSA comments (Attachment D). We further note that New Mexico's lack of analysis by itself makes NMED's proposal arbitrary and capricious. The state relies wholly on California's analysis. An evaluation of how adopting ACC II would harm or benefit the citizens of New Mexico cannot be properly conducted by a wholesale reliance on an analysis of impacts on another state, particularly states as different as New Mexico and California.

First and foremost, without a comparison of California's (CAISO) and New Mexico's (WECC) electrical grids and the relative reliability and status of repairs to these grids that are underway, NMED has not meaningfully assessed whether the assumptions underlying CARB's analysis of ACC II apply to its own proposed adoption of ACC II.[98] They do not, as the two states have very different electricity generation and distribution capabilities. Adopting an EV mandate will spike demand for electricity, placing further upward pressure on electric rates and threatening reliability.

Additionally, differences among New Mexico's climate and California's need to be considered. Colder weather negatively impacting charging efficiency and EV range, affecting both individual and systemic cost analyses.[99] EVs are less efficient in cold weather and extremely hot

---

[96] *See* AFPM LDV Comments at 36-38 (discussion of EV charging infrastructure). As the study on discontinuance cited by EPA states, "[R]ange isn't correlated with discontinuance in PHEVs or ZEVs but with and access to charging[is]." Hardman, S., and Tal, G., Discontinuance Among California's Electric Vehicle Buyers: Why are Some Consumers Abandoning Electric Vehicles, April 21, 2021, Report for National Center for Sustainable Transportation at 26.
[97] *See Id.* at 30-34 (discussion of EV adoption rate).
[98] *See* AFPM LDV Comments at 34-36 and 56-58 for detailed discussions of challenges and costs associated with upgrading the electricity transmission grid.
[99] *See, e.g.*, Sean Tucker, Study: All EVs Lose Range in the Cold, Some More Than Others (Kelley Blue Book Dec. 29, 2022), available at https://www.kbb.com/car-news/evs-lose-range-in-the-cold/ accessed August 8, 2023) ("Range loss is a significant concern for electric vehicle (EV) owners. Refueling an EV takes longer, and public charging stations can be hard to find in many parts of the country. That scarcity requires EV owners to plan longer trips around recharging points — and to know they'll need to stop more frequently when the mercury drops."); Paul Shepard, Quantifying the Negative Impact of Charging EVs in Cold Temperatures (EEPower Aug. 8, 2018), available at https://eepower.com/news/quantifying- the-

weather.[100] According to New York Department of Transportations' National Electric Vehicle Infrastructure (NEVI) Plan dated August 2022:

> [v]ery cold temperatures (below 30 degrees Fahrenheit) have a significant effect on electric battery and charging performance. Charging is much slower in cold temperatures, and direct-current fast-charging (DCFC) facilities may only charge at a fraction of their rated speed in cold temperatures. Further, all-wheel drive vehicles are more popular in snowy climates. These vehicles have lower range than identical vehicles with front or rear wheel drive, which could trigger the need for additional charging.[101]

CARB neglected to adequately evaluate how climate impacts EV efficiency and electrical demand. NMED cannot rely on any evaluation performed by CARB given the vastly different climates of New Mexico and California. NMED must do the hard work to evaluate ACC II's application to New Mexico's climate, electrical grid, and charging infrastructure.

There is increasing evidence that regulations like ACC II, which mandate EV sales—along with the cross-subsidies from gasoline and diesel vehicle buyers—are leading manufacturers to abandon sales of the least expensive and higher fuel economy gasoline and diesel vehicles that do not receive similar subsidization. Cox Automotive found that "in December 2017, automobile makers produced 36 models priced at $25,000 or less. Five years later, they built just 10," pushing low-income buyers out of the new-car market and into the used-car market. Conversely, in December 2017 automobile manufacturers offered 61 models for sale with sticker prices of

---

negative-impact-of-charging-evs-in-cold-temperatures/ accessed August 8, 2023, ("[A] new study on charging in cold temperatures suggests that industry and EV drivers still face charging challenges. The reason: cold temperatures impact the electrochemical reactions within the cell, and onboard battery management systems limit the charging rate to avoid damage to the battery. [R]esearchers at Idaho National Laboratory looked at data from a fleet of EV taxis in New York City and found that charging times increased as temperatures dropped.").

[100] AAA, Electric Vehicle Range Testing, AAA proprietary research into the effect of ambient temperature and HVAC use on driving range and MPGe (February 2019), https://www.aaa.com/AAA/common/AAR/files/AAA-Electric-Vehicle-Range-Testing-Report.pdf (ambient temperature and related HVAC use can result in moderate to significant reduction in EV range); Di Wu et al., Regional Heterogeneity in the Emissions Benefits of Electrified and Lightweighted Light-Duty Vehicles, Environ. Sci. Technol. 2019, 53, 18, 10560–10570 (July 23, 2019), https://pubs.acs.org/doi/full/10.1021/acs.est.9b00648 (model-based and empirical data-driven studies agree that ambient temperature impacts EV efficiency); Jon Witt, Winter & Cold Weather EV Range Loss in 7,000 Cars (Recurrent Dec. 12, 2022), available at https://www.recurrentauto.com/research/winter-ev-range-loss accessed August 8, 2023; see also 20 popular EVs tested in Norwegian winter conditions (Norwegian Automobile Fed'n Mar. 12, 2020, available at https://www.naf.no/elbil/aktuelt/elbiltest/ev-winter-range-test-2020/ Accessed August 8, 2023.

[101] New York Department of Transportation (NYDOT), New York State National Electric Vehicle Infrastructure Formula Program Plan, at 18 (Aug. 2022). Additionally, charging infrastructure reliability is an issue NMED must investigate. *See e.g.*, Julian Dnistran, InsideEvs (Feb. 2023) ("According to J.D. Power's Electric Vehicle Experience Public Charging Study, quoted by Automotive News, the number of failed charging attempts grew from 15 percent in the first quarter of 2021 to more than 21 percent by the third quarter of 2022. At worst, almost 2 in 5 visits to chargers – or 39% – were unsuccessful last year.").

$60,000 or higher and in December 2022, they offered 90.[102] Regulations like ACC I and ACC II are primary drivers of this trend toward eliminating affordable vehicles and NMED must account for these market impacts to lower-income car buyers.

Dramatic investments are required to expand the electrical grid and install adequate charging. Current office buildings, parking lots, apartment buildings, municipal buildings, and town centers will need to be retrofitted with adequate charging stations.

Finally, charging downtime and range limits will likely reduce vehicle operation time. Therefore, commercial enterprises, including small businesses, using light-duty vehicles will need to deploy more vehicles to provide the same level of service currently provided by ICEVs.

D. NMED fails to fully assess the environmental impacts of ACC II.

NMED claims ACC II will increase the number of ZEVs and reduce harmful emissions of pollutants and create health benefits.[103] NMED relies on California's analysis that calculates purported emissions benefits. NMED needs to perform a lifecycle assessment to compare the GHG emissions associated with manufacturing EVs and ICEVs. Mining critical minerals for batteries is an energy- and environmentally resource-intensive activity. Lithium, required for batteries, and copper, required to expand the electrical grid, are particularly vulnerable to water stress given their high-water usage.[104] And more than 50 percent of today's lithium and copper production is concentrated in areas with high water stress levels. Several major producing regions such as China, Africa, and Australia are also subject to extreme heat or flooding, which pose greater challenges in ensuring reliable and sustainable supplies. Strong focus on environmental best practices in this sector is needed to safeguard natural lands, biodiversity, and sustainable water use. Similarly, focus on ethical best practices is needed to protect Indigenous peoples' rights, and to provide better child labor protections. These challenges call for sustainable and socially responsible producers to lead the industry.

Absent a proper and thorough lifecycle assessment, NMED cannot assert that its proposal will result in reduced NOx, $PM_{2.5}$, and GHG emissions. This is because an all-EV mandate will significantly increase demand for electricity, requiring careful consideration of emissions resulting from generation of that electricity in order to determine the magnitude of overall changes in emissions. Moreover, the composition of the energy mix that will be used to generate additional electricity is unclear.

A full-scale transition to ZEVs will require continued careful coordination between state and federal leadership, utilities, energy regulators and the public to protect against increases in

---

[102] *See* Sean Tucker, Are we witnessing the demise of the affordable car? Automobile makers have all but abandoned the budget market (MarketWatch Feb. 28, 2023), available at https://www.marketwatch.com/story/are-we-witnessing-the-demise-of-the-affordable-car-automakers-have-all-but-abandoned-the-budget-market-a68862f0 Accessed August 8, 2023.
[103] State of New Mexico Environmental Improvement Board, In the Matter of Proposed Amendments to 20.2.91 NMAC – New Motor Vehicle Emission Standards, No. EIB 23-56(R). Statement of Reasons at 7.
[104] *See* EIA 2022 Report.

"upstream" emissions at power plants that threaten the health of other communities far from roadways.[105]

New Mexico is part of a regional power market, one which has a high concentration of coal and gas-fired power plants that supply most of the electricity to every customer in New Mexico.[106] Therefore, the in-state power mix is not necessarily representative of the GHG-related emissions associated with in- state power consumption. Without a true, robust LCA such as that conducted by Ramboll on CARB's ACC II proposal (and attached hereto), NMED cannot demonstrate that its proposal will achieve its stated objectives even directionally, let alone in terms of magnitude.

NMED did not fully consider the impact of the rule on fleet turnover. Higher purchase price of new ZEVs will keep older, higher-emitting, cars and trucks on the road longer and new ZEVs will increase particulate matter (PM) emissions through tire and road wear. NMED ignored the fleet turnover benefit that would result from replacing older ICEVs with new, more efficient ICEVs.

The average EV weighs more than the average ICEV, resulting in increased tire wear and road dust PM emissions. NMED and CARB ignored the National Emissions Inventory, which shows that roadway dust contributes more $PM_{2.5}$ emissions than tailpipe emissions.[107] There are also roadway weight restrictions, which could require a greater number of ZEVs to move the same tonnage of cargo, thus increasing the number of vehicles needed to haul the same amount of freight, vehicle miles traveled, and resulting PM emissions.

Finally, CARB and NMED's "environmental analysis" ignores the impacts of electric battery disposal related issues, including limited recycling. In fact, recycling ZEV batteries to recover high-value metals has not been proven to a commercial scale.[108] The majority of analysts are aligned that recycling will not become an integral supplier of raw materials until the 2030s, and at that point, recycling only will provide approximately 20 percent of demand.[109] In fact, unlike ICEVs, EPA recently stated that ZEV batteries may need to be handled as hazardous waste, further driving up the cost of such recycling efforts.[110] NMED and CARB must, therefore, conduct a full LCA to compare all environmental impacts to reasonably conclude that ACC II will decrease environmental impacts rather than merely shift them.

---

[105] *See* AFPM LDV Comments at 42-48 for a complete discussion of how *de facto* EV mandates overstate environmental benefits.
[106] U.S. Department of Energy, State of New Mexico Energy Sector Risk Profile. Available at https://www.energy.gov/sites/prod/files/2016/09/f33/NM_Energy%20Sector%20Risk%20Profile.pdf accessed October 16, 2023.
[107] EPA, "2020 National Emissions Inventory (NEI) Data," available at https://www.epa.gov/air-emissions-inventories/2020-national-emissions-inventory-nei-data. Roadway dust emissions, including particles from tire wear, are correlated with vehicle weight, so increases in fleet average vehicle weight would be expected to increase roadway dust $PM_{2.5}$ emissions.
[108] *See* AFPM LDV Comments at 47-48 for a detailed discussion of EV battery end-of-life challenges.
[109] Benchmark Minerals Intelligence, "Battery production scrap to be main source of recyclable material this decade" (Sept. 5, 2022) at n. 105, available at https://source.benchmarkminerals.com/article/battery-production-scrap-to-be-main-source-of-recyclable-material-this-decade.
[110] Letter from Carolyn Hoskinson, Director, EPA Office of Resource Conservation and Recovery, "Lithium Battery Recycling Regulatory Status and Frequently Asked Questions," (May 24, 2023).

V. California's struggles present a cautionary tale for New Mexico.

California policymaking is hardly an unqualified success story. Its policies—like the EV sales mandates—have had major inflationary impacts on gasoline and energy prices, as well as negative impacts on jobs in certain industries that are directly related to traditional fuels and vehicles.[111] While often lauded as a laboratory for GHG emission reduction policies, California's transportation fuel prices are now the highest in the nation, averaging approximately $5.33 per gallon of gasoline.[112] According to a 2021 Report from the California Public Utilities Commission, "it is already cheaper to fuel a conventional ICE vehicle than it is to charge an EV" in the San Diego Gas & Electric Co. service area.[113] The California Energy Commission projects that both commercial and residential electricity prices will continue to rise, reaching over $8/gasoline gallon equivalent (GGE) by 2026 for the residential sector and nearly $7/GGE for the commercial sector.[114] New Mexico should carefully consider the criticisms of California's policies, such as those leveled by The Two Hundred for Homeownership, which point out the disproportionate impacts to working and minority communities.[115]

As California has faced rolling blackouts and historic energy prices, Governor Newsom, in his May 2022 state budget proposal, pivoted to the use of traditional fuel infrastructure to ensure system reliability to protect against outages.[116]

Moreover, unworkable EV sales mandates put New Mexico at risk of missing the real carbon intensity reductions available through incentivizing low-carbon liquid fuels and by encouraging the development of emerging carbon removal technologies.

VI. Conclusion

Federal law preempts NMED from adopting ACC II in multiple respects. Separate and apart from this issue, even if NMED had the authority to adopt ACC II, NMED must conduct a meaningful public notice and comment process for its complex proposal before doing so. There are significant technical, economic, and legal facts and analysis that NMED has ignored or inadequately addressed in its process, rendering its proposal arbitrary and capricious. NMED should address these procedural and analytical deficiencies by conducting technical working groups to foster stakeholder participation in scenario development and assessment.

---

[111] California Legislative Analyst's Office, Assessing California's Climate Policies – An Overview (Dec. 21, 2018).
[112] AAA, California Average Gas Prices – Current Avg., available at https://gasprices.aaa.com/?state=CA (last visited October 27, 2023).
[113] CPUC, Utility Costs and Affordability of the Grid of the Future: An Evaluation of Electric Costs, Rates, and Equity issues Pursuant to P.U. Code § 913.1, at 116-117 (May 2021), available at https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/office-of-governmental-affairs-division/reports/2021/senate-bill-695-report-2021-and-en-banc-whitepaper_final_04302021.pdf accessed August 8, 2023.
[114] CEC, "Presentation - Transportation Energy Demand Forecast," 21-IEPR-03 (Dec. 14, 2021).
[115] *See* Plaintiffs' Complaint, The Two Hundred for Homeownership, et al. v. California Air Resources Board, et al., No. 1:22-CV-01474 (E.D. Cal. filed Nov. 14, 2022).
[116] *See* https://ebudget.ca.gov/2022-23/pdf/Revised/BudgetSummary/ClimateChange.pdf. Accessed August 28, 2023.

Multi-technology pathways can help the state achieve faster and more certain emission reductions while expanding ways to reduce greenhouse gas emissions. NMED should evaluate and propose performance standards as an alternative to its proposed adoption of ACC II and its EV mandate. If NMED did a proper life cycle analysis of the emissions of an EV compared to an ICEV, it would realize that the total emissions reductions from an EV are much lower than assumed. Similarly, if NMED did a proper cost analysis, it would realize that the costs of EV ownership are masked by credits and cross subsidization strategies. Correcting these two major deficiencies in NMED's analyses would reveal to policy makers that EVs are among the most expensive carbon reduction tools available. New Mexico families that depend upon affordable, reliable transportation, particularly lower-income households, are negatively impacted with higher costs, reduced energy security, and fewer vehicle choices to meet their needs.

Thank you for the consideration of these comments.

Patrick Kelly
Senior Director, Fuels & Vehicle Policy
American Fuels & Petrochemical Manufacturers

Attachments

Tanya DeRivi
Vice President, Climate Policy
Western States Petroleum Association

Don Thoren
Vice President, State & Local Outreach
American Fuel & Petroleum Manufacturers

Rock Zierman
Chief Executive Officer
California Independent Petroleum Association

May 31, 2022

(Submitted via the ISOR Comment Submittal Form and by email to cleancars@arb.ca.gov)

Advanced Clean Cars
California Air Resources Board
1001 I Street,
Sacramento, CA 95814

Re: Comments on Advanced Clean Cars II Regulation Initial Statement of Reasons (ISOR) Documents

The Western States Petroleum Association (WSPA), the American Fuel & Petrochemical Manufacturers (AFPM), and the California Independent Petroleum Association (CIPA) (collectively "the Associations") appreciate the opportunity to comment on the ISOR documents released by the California Air Resources Board (CARB) for the proposed Advanced Clean Cars II (ACC II) Regulation. WSPA is a non-profit trade association that represents companies that explore for, produce, refine, transport and market petroleum, petroleum products, natural gas, and other energy supplies in California and four other western states. It has been an active participant in air quality planning issues for over 30 years. AFPM is a national trade association representing nearly all U.S. refining and petrochemical manufacturing capacity. AFPM members support more than three million quality jobs, contribute to our economic and national security, and enable the production of thousands of vital products used by families and businesses throughout the U.S. AFPM members are also leaders in producing lower carbon fuels, such as renewable diesel and sustainable aviation fuel. The California Independent Petroleum Association (CIPA) represents 300 oil and gas producers, service and supply companies, and royalty owners who operate in California. CIPA's members proudly employ thousands of highly trained and well-paid California residents who safely and responsibly operate critical energy infrastructure under the world's most stringent public health and environmental standards. CIPA's natural gas producer-members deliver the energy necessary to power our homes and businesses, fuel our transportation, power our healthcare services and create thousands of products that shape our modern lives.

Our members form the backbone of California's economy, providing jobs, fueling air, road, and marine transport, and supplying necessary energy to the manufacturing and agriculture sectors. Our industry generates more than $152 billion in total economic output, and make significant fiscal contributions to California's state and local governments, including more than $21 billion in state and local tax revenues, $11 billion in sales taxes, $7 billion in property taxes, and $1 billion in income taxes.

While the economic impact numbers are compelling, our industry's greatest asset and contribution to the state's economy are the more than 360,000 hard-working women and men with careers providing affordable, reliable energy in California. We produce 42 million gallons of gasoline and 10 million gallons a day of diesel to support the State's 35 million registered vehicles. All these contributions to the state occur while our members continue to lower the carbon intensity of their fuels consistent with the low carbon fuel standard (LCFS) program and spur investment in emission reduction technologies and renewable fuels. In fact, 82 percent of recently announced investments in renewable diesel were made by AFPM members, including several projects in California.

The Associations believe that Californians should have the freedom to choose the type of vehicle technology that best fits their personal needs based on purpose, affordability, availability, and lifestyle choices. Battery electric vehicles (BEV) currently are and will likely continue to make up a growing portion of the Light Duty Vehicle (LDV) fleet in California. However, the Associations have significant concerns regarding the ISOR and the current ACC II proposal. The Executive Order N-79-20[1] set a goal for the State that 100 percent of in-state sales of new passenger cars and trucks will be zero-emission by 2035 **to the extent consistent with State and federal law**. The current proposal is not consistent with the Executive Order (See **Comment A.3** and **A.4** in **Attachment A)**. The Executive Order also acknowledged that without coordinated action by multiple other agencies to mitigate their impacts, implementing these targets will have profound negative consequences for low-income and working-class Californians. These impacts have not been fully identified, nor have they been mitigated. The proposed sales mandate conflicts with the purpose and scope of the statutes that authorize the mobile source regulations and govern the rulemaking process.

A summary of our key comments on the ACC II proposal is provided below with additional details in **Attachment A** (Legal Comments) and **Attachment B** (Technical Comments):

1. **CARB must set a technology neutral performance-based standard rather than the Zero Emission Vehicle (ZEV) mandate that is currently proposed in the ACC II regulation. This performance standard must consider the life cycle emissions of vehicles and fuels to ensure that sufficient greenhouse gas (GHG) emissions reductions are achieved by this sector.**

Under Government Code Section 11346.2(b)(4)(A), when CARB proposes a regulation that would mandate the use of specific technologies or equipment, or prescribe specific actions or procedures, it must consider performance standards as an alternative (See **Comment A.4 in Attachment A** for further details). The Proposed ACC II Regulation is presented as a performance standard by CARB. CARB argues in the ISOR at page 180 that no specific technology is mandated, contradicting the draft regulation that proposes a ZEV sales mandate

[1] Executive Order N-79-20. Available at: https://www.gov.ca.gov/wp-content/uploads/2020/09/9.23.20-EO-N-79-20-Climate.pdf. Accessed: May 2022.

for passenger cars and light-duty trucks beginning at 35% for 2026 model year and ramping up to 100% for the 2035 model year and beyond. This is not a performance standard; it is a technology mandate.

Despite multiple comments by many stakeholders, including the Associations, over the last two years, CARB has explicitly included ZEV technology mandates in its ACC II and Advanced Clean Fleets (ACF) proposals, without the necessary analyses to justify the choice of a sales mandate over a performance-based standard. CARB has even failed to analyze the full environmental effects of such a sales mandate under the proposed ACC II regulation.

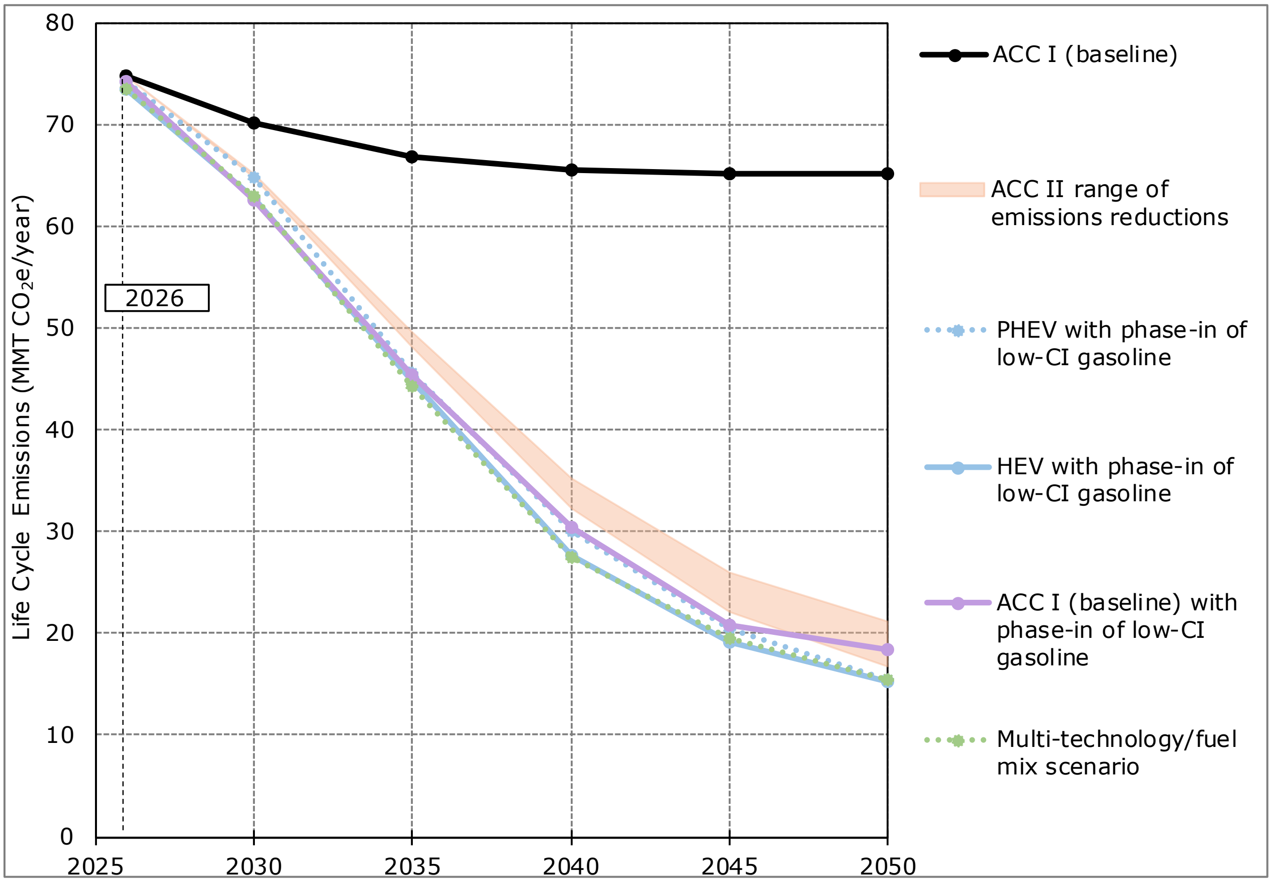
To provide some of this analysis, WSPA contracted with Ramboll to produce a technology neutral study of Light Duty Automobiles (LDA) to analyze the full life cycle GHG emissions of a broad range of alternative technologies and fuels ("Ramboll LDA Study"). This study attached as **Attachment C** conclusively shows that performance standards could be an alternative to a ZEV mandate (See **Comment B.2 in Attachment B** for further details).

The Ramboll LDA Study shows that a gradual transition to low carbon intensity (CI) gasoline with current vehicle technologies (represented by the purple line in **Figure 1**) could achieve similar life cycle GHG emissions as the current ACC II proposal (represented by the pink shaded region in **Figure 1**). Importantly, GHG emissions associated with zero emission vehicles are not zero. In fact, the GHG emissions from producing battery electric vehicles (BEVs) (the "vehicle cycle") is *significantly higher* than other vehicle technology types (see **Comment 3** for additional details). The failure to analyze these real world GHG emissions is significant and distorts the claimed benefits attributed to these vehicles.

Other technologies also achieve similar or lower emissions on a life cycle basis compared to the ACC II proposal. These include hybrid electric vehicles (HEVs) coupled with low-CI fuel (represented by the blue solid line), plug-in electric hybrid vehicles (PHEVs) coupled with low-CI fuels (represented by the blue dotted line), and a combination of HEVs, PHEVs, and BEVs with low-CI fuels (represented by the green dotted line).

Figure 1: Life Cycle Emissions for Key Scenarios in the Ramboll LDA Study

California Light Duty Automobile Fleet (2026 to 2050)



CARB is therefore required to conduct these studies and consider these performance standards as an alternative to the ACC II ZEV mandate, where the alternatives better meet the other Administrative Procedures Act (APA), Office of Administrative Law (OAL) regulations and Health & Safety Code (HSC) requirements. CARB should not move forward with the ACC II ZEV mandate as it is currently proposed but instead should draft a technology-neutral performance-based standard based on the life cycle emissions of LDVs.

2. The ACC II proposal is contrary to Executive Order N-79-20 because it is not consistent with State law. The proposal continues to have severe deficiencies and omissions in the analysis that are contrary to APA and the HSC Code requirements.

There are numerous deficiencies and/or omissions in the required analyses, including but not limited to those below, that must be addressed before CARB takes action on the proposed ACC II mandates.

- Inadequate Demonstration of Achievability: CARB must perform a complete and sufficient assessment of the technological feasibility of the ACC II ZEV mandates including but not limited to the assessment of mineral resource availability, impacts to the California electric grid, application of ZEVs to long-distance use cases. CARB must also consider consumer behavior and acceptance rates for ZEV, which is critical to evaluating achievability of the

ACC II proposal. See **Comment A.2** in **Attachment A** and **Comments B.4**, **B.5**, **B.10**, **B.11**, and **B.12** in **Attachment B**.

- Incomplete Cost Assessment: CARB must perform a complete and sufficient assessment of the economic impacts of the ACC II mandates to fully assess the impact on California's economy. This assessment should account for the costs associated with upgrades to the California grid infrastructure (new and upgraded generation, transmission, and distribution) and the costs associated with the installation of public and workplace EV chargers. It should also evaluate impacts on electricity, gasoline, and diesel rates. See **Comment A.1** in **Attachment A** and **Comments B.6** and **B.7** in **Attachment B** for further details.
- Inadequate Environmental Assessment: CARB has not fully or adequately assessed the impacts of the proposed ACC II regulation on GHG emissions, the California electric grid, liquid fuels supply chain, critical mineral supply chain, vehicle manufacturing facilities, public services, utilities, and service systems. See **Comment A.6** in **Attachment A,** and **Comments B.3**, **B.4**, **B.5**, **B.8**, **B.9**, **B.13**, **B.14**, and **B.15** in **Attachment B**.
- Inadequate Alternatives Analyses: CARB has not fully or adequately evaluated or analyzed a technology neutral performance-based standard that would all low-carbon fuel and engine technologies to compete with ZEVs in their alternative analyses presented in the Environmental Assessment (EA) and the Standardized Regulatory Impact Assessment (SRIA) for the proposed ACC II. See **Comment A.6** in **Attachment A** and **Comments B.1** and **B.2** in **Attachment B** for further details.

3. CARB must incorporate life cycle emissions from ZEV in evaluating the proposed ACC II regulation.

CARB has failed to analyze the full life cycle impacts of ZEVs, which precludes a true technology-neutral comparison and overestimates ACC II GHG reductions. **Figure 2** shows the limited scope of the ACC II GHG analysis (see **Comment B.3** in **Attachment B** for further details).

CARB has not quantified vehicle cycle emissions[2] in the ACC II ISOR. They must be included due to the large differences in these emissions between ZEVs and internal combustion engine vehicles (ICEVs). As shown in **Figure 3** below, the Ramboll LDA Study found that the vehicle cycle emissions for a model year 2026 BEV could be ~167% higher than an ICEV.

[2] Emissions associated with vehicle material recovery and production, vehicle component fabrication, vehicle assembly, and vehicle disposal/recycling.

Figure 2. CARB ACC II Emissions Assessment Scope[3]

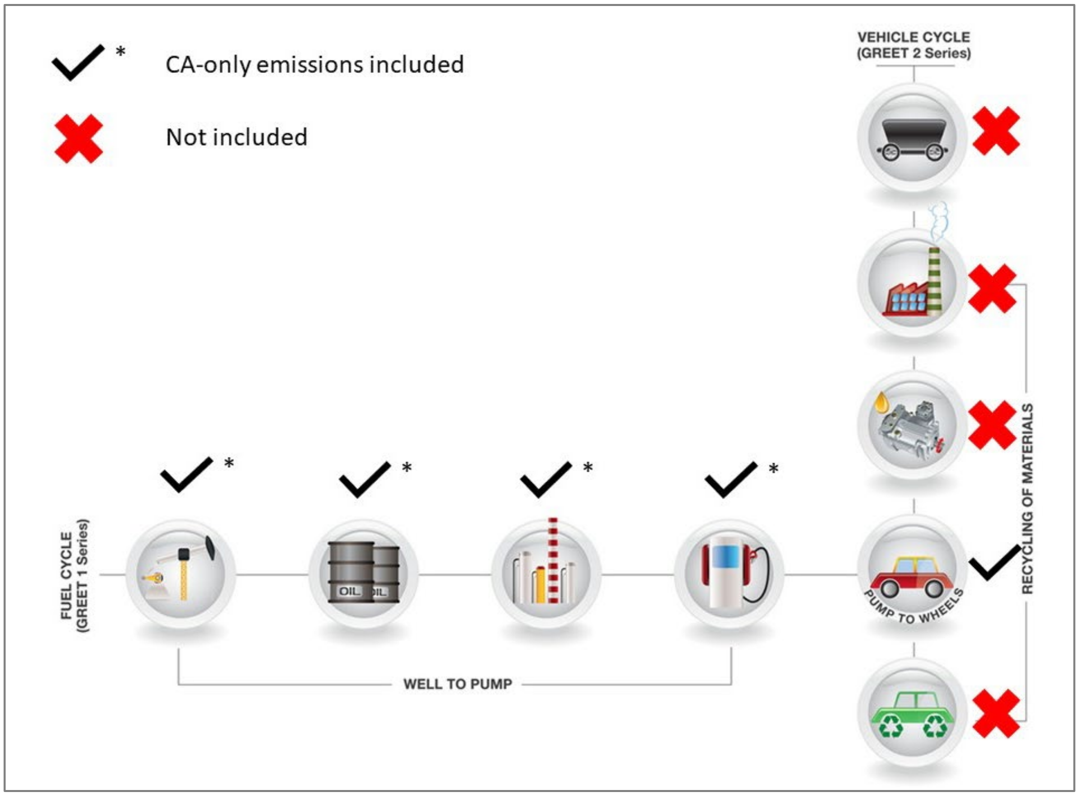
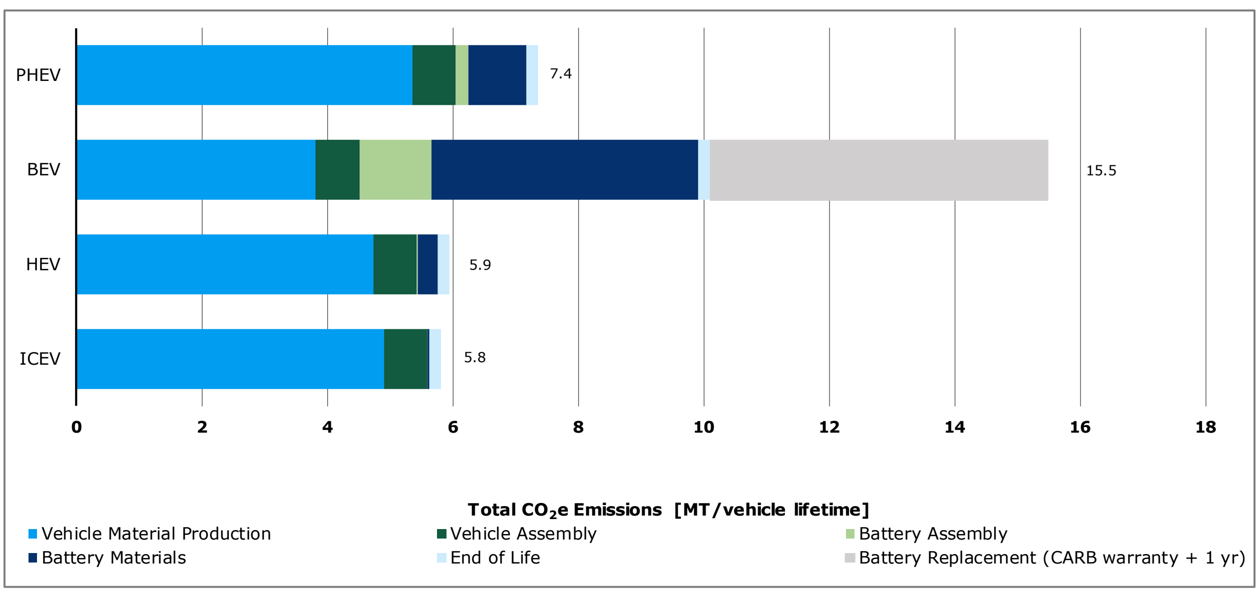


Figure 3: Vehicle Cycle GHG Emission Factors for Different Vehicle Technologies



CARB has performed no life cycle emissions analysis for ZEVs and thereby failed to adequately meet the requirements of HSC Sections 43018.5 and 57005 (see **Comment A.1.3 in**

3 GREET Model Home Page. Available at: https://greet.es.anl.gov/. Accessed: May 2022. Checkmark and X annotations by Ramboll on behalf of the Associations.

Attachment A for further details). Highly efficient low emission vehicles, which impose significantly fewer infrastructure expenses, will achieve substantial GHG emissions reductions on a faster timeline.

CARB must, therefore, update its emission analysis to include the full life cycle of the vehicle/fuel technologies included in the ACC II proposal, to understand and present the actual implications of the regulation for public review and comment, as required by law.

4. CARB must add provisions to the regulation, including periodic program reviews and program adjustments, to ensure cost containment.

CARB must also modify the ZEV mandate to include cost containment measures to protect California's economy. CARB includes cost containment measures in its other regulations, including its LCFS and GHG Cap-and-Trade programs. These measures should include:

- Annual CARB reviews and reports to the legislature of ZEV market conditions, barriers to ZEV deployment and cost to consumers, including
  - Manufacturing constraints resulting from limited critical mineral resources (see **Comment A.2 in Attachment A** and **Comment B.13 in Attachment B**)
  - Lack of affordability for purchase and use ZEVs (see **Comment A.1.2 in Attachment A** and **Comments B.9 and B.10 in Attachment B**)
  - Insufficient charging infrastructure, particularly in rural areas (see **Comment A.1.2 in Attachment A**)
  - Lower sales rates due to reluctant customer adoption (see **Comment B.12 in Attachment B**)
  - Cost of electricity (see **Comment A.1.2.** in **Attachment A**)
- Required adjustments to the program based on the review findings.

Conclusion

CARB must conduct a meaningful public notice and comment process for its complex ACC II ZEV mandate. There are significant technical, economic, and legal facts and analysis that CARB has ignored in its process, in violation of the law. CARB should address these process and analysis deficiencies by conducting technical working groups to foster stakeholder participation in scenario development and assessment. It should workshop revised ACC II language before submitting it to its Board for consideration.

Multi-technology pathways can help the state achieve faster and more certain emission reductions while expanding ways to reduce greenhouse gas emissions, to comply with the requirements of Government Code Section 11346.2(b)(4)(A). CARB should evaluate and propose performance standards as an alternative to the proposed ACC II ZEV mandate.

Thank you for the consideration of our comments. The Associations would welcome the opportunity to discuss these comments and recommendations in more detail with you. Please feel free to contact us at tderivi@wspa.org, jverburg@wspa.org, sellinghouse@wspa.org, DThoren@afpm.org, and rock@cipa.org with any questions or concerns.

Sincerely,

Tanya DeRivi
Vice President
Climate Policy
WSPA

Don Thoren
Vice President
State & Local Outreach
AFPM American Fuel & Petrochemical Manufacturers

Rock Zierman
Chief Executive Officer
CIPA California Independent Petroleum Association

cc: Joshua Cunningham – Branch Chief, Transportation Systems Regulations and Technology Branch – California Air Resources Board

Jim Verburg – Director, Fuels – Western States Petroleum Association

Sofie Ellinghouse – Vice President, General Counsel and Corporate Secretary – Western States Petroleum Association

Attachment A: Legal Comments

Attachment B: Technical Comments

Attachment C: List of Previous WSPA Comments on the Proposed ACC II Regulation

Attachment D: “Multi-Technology Pathways To Achieve California’s Greenhouse Gas Goals: Light-Duty Auto Case Study” by Ramboll dated May 31, 2022

Attachment E: “Impact of Advanced Clean Cars II (Internal Combustion Engine Ban) Regulation on California Businesses” by Capitol Matrix Consulting dated May 17, 2022

Attachment F: “Distributional Impacts of the Advanced Clean Cars II (Internal Combustion Engine Ban) Regulatory Proposal” by Capitol Matrix Consulting dated May 26, 2022

ATTACHMENT A
Legal Comments

Comments

CARB's ACC II ZEV mandate centers around achieving 100% zero emission vehicle (ZEV) or plug-in hybrid electric vehicle (PHEV) sales in California by model year 2035. This unprecedented mandate is not supported by a demonstration of its technological and economic feasibility. Yet, these unsupported mandates necessitate the complete electrification of the transportation sector, forcing the phase-out of oil and gas production and refinery industries. CARB lacks authority to promulgate sweeping regulations that would exchange our existing transportation system for another, with unintended and far-reaching consequences across a broad range of environmental, economic, and social issues. First and foremost, the ACC II Program is preempted by federal law and is impermissible under the California Constitution. Even if allowed, legislative delegation has its limits— if CARB wishes to push past these limits, it must return to the legislature for additional authorizations. Further, even if the legislature delegated transformative regulatory authority to CARB (which it did not), CARB has failed to meet the express statutory requirements for exercising such authority. Indeed, if CARB evaluated all the economic, technical, and environmental impacts required by statute, CARB could not reasonably finalize the ACC II Program.

A.1 CARB must perform a complete and sufficient assessment of economic impacts resulting from its ZEV targets.

CARB must perform a complete and sufficient assessment of economic impacts resulting from rapid electrification of the transportation sector. The provisions of the California Administrative Procedures Act (APA) and the California Health & Safety Code (HSC), and their implementing regulations, that govern CARB's regulatory authority require CARB to consider the economic impacts associated with any rulemaking proposal. These also require CARB to consider potential impacts to California's workers, businesses, and greater economy.[4] CARB claims these provisions as authorizing ACC II,[5] yet fails to comply with the provisions' mandates to conduct a robust economic analysis.

Specifically, the APA and HSC, and implementing regulations require CARB to assess:

- HSC §§ 43101, 43018.5 and APA § 11346.3 – Impacts to the state's economy, including specific evaluation of the following:
  - The creation of jobs within the state;
  - The creation of new businesses or the elimination of existing businesses within the state;
  - The expansion of businesses currently doing business within the state;
  - The ability of businesses in the state to compete with businesses in other states;
  - The ability of the state to maintain and attract businesses in communities with the most significant exposure to air contaminants, localized air contaminants, or both, including,

[4] *See John R. Lawson Rock & Oil, Inc. v. State Air Res. Bd.*, 20 Cal. App. 5th 77, 114 (2018) (supporting a "broad reading of the required analysis").

[5] *See* ISOR at 11-12, 70, 73, 77, 134, 183.

but not limited to, communities with minority populations or low-income populations, or both;

- The automobile workers and affiliated businesses in the state; and
- The benefits of the regulation to the health and welfare of California residents, worker safety, and the state's environment;

- HSC § 57005 – Less costly but equally effective alternatives to ACC II;
- APA § 11346.5(a)(7) – Adverse economic impacts on California business enterprises and individuals, including the ability of California businesses to compete with businesses in other states;
- APA § 11346.5(a)(7)(A) – The specific types of businesses that would be affected by the proposal; and
- HSC § 38562(b)(8) – The potential for leakage.

While the ISOR is a preliminary assessment, it still must take into account fact-based analyses based on information and impacts currently known to CARB.[6] Importantly, CARB's analysis cannot "ignore evidence of impacts to specific segments of businesses already doing business in California."[7] As a recent decision emphasized, "[i]f the Board's proposed regulatory amendments place[s] the state's thumb on the scale for one group of in-state businesses over another, it need[s] to consider that impact."[8] CARB notes in its ISOR that "[t]he Executive Officer has made an initial determination that the proposed regulatory action would not have a significant statewide adverse economic impact directly affecting businesses, including the ability of California businesses to compete with businesses in other state[s], or on representative private persons."[9] This conclusion is not supported by CARB's Standardized Regulatory Impact Analysis (SRIA) which overlooks key facts, including significant costs and other key impacts stemming from the forced electrification of the transportation sector.

CARB's economic analysis is deficient in several respects. First, CARB does not consider any competitive impacts to oil and gas production and refinery businesses in the state, nor to any of the numerous other businesses related to the petroleum industry (e.g., storage terminals, asphalt production, lubricants, and others). In assessing competitive advantage or disadvantage in its SRIA, CARB considers only the potential advantage to certain vehicle manufacturers as a result of already producing ZEVs.[10] This analysis completely overlooks the blatant "thumb on the scale" that ACC II will place in favor of the electricity sector as compared to oil and gas producers and refineries by forcing electrification of the transportation sector.

---

6 *See California Ass'n of Med. Prods. Suppliers v. Maxwell-Jolly*, 199 Cal. App. 4th 286, 304–05 (2011); W. States Petroleum Ass'n v. Bd. of Equalization, 57 Cal. 4th 401, 428 (2013).
7 *John R. Lawson Rock & Oil, Inc. v. State Air Res. Bd.*, 20 Cal. App. 5th 77, 115 (2018).
8 *Id.*
9 ISOR at 172.
10 CARB, *Standardized Regulatory Impact Assessment (SRIA)*, at 129 (Jan. 26, 2022). Available at: https://dof.ca.gov/wp-content/uploads/Forecasting/Economics/Documents/ACCII-SRIA.pdf. Accessed: May 2022.

This analysis also overlooks potential competitive disadvantages to California businesses as compared to businesses in other states.[11]

Second, CARB fails to consider the leakage potential of its ZEV proposal, based on an accurate life cycle analysis of the greenhouse gas (GHG) emissions associated with electric vehicles and associated infrastructure, as well as residual demand for liquid fuels for internal combustion engine vehicles (ICEV) remaining in 2035 and beyond. CARB has a responsibility to minimize the "leakage" potential of any regulatory activities.[12] As part of this responsibility, CARB must analyze the potential for emissions reduction activities in the state to be offset by an equivalent or greater increase in GHG emissions outside the state. This analysis necessarily requires estimating emissions impacts outside the state, including how higher in-state power sector costs would drive greater economic investment outside of California, potentially resulting in increased emissions outside of the state, which CARB has failed to do. CARB acknowledges in its ISOR that "ICEVs will remain in use on California's roads well beyond 2035,"[13] but fails to account for the possibility that competitive disadvantages to California oil and gas production and refinery businesses will either drive these businesses out of state or force these businesses to shut down, requiring California to import petroleum or refined petroleum products to meet remaining demand.[14] Moreover, the loss of public funds by way of gas taxes is not factored into the economic analysis and should be.

Finally, despite CARB's access to ample information related to the economic impacts of electrification and existing strains on California's grid, CARB failed to address these impacts, and instead constrained its analysis to a narrow consideration of direct costs centered around vehicle manufacturing and ownership.[15] CARB's SRIA concludes that only vehicle manufacturers are directly affected by the proposed ACC II program,[16] which fails to account for extensive economic impacts stemming from the electrification of the transportation sector, discussed in detail below. This assessment is therefore insufficient to fulfill CARB's legal duty to broadly consider economic impacts.

---

11 For example, businesses would face higher capital investment in vehicles, reduced fleet utilization from recharging, and higher utility rates, among other challenges. Certain businesses, particularly small businesses in rural areas, would bear disproportionate impacts, as detailed in Capitol Matrix Consulting's analysis at Appendix F.

12 HSC § 38562(b)(8).

13 ISOR at 12.

14 Importantly, refineries are long-cycle investments that require advanced planning—owners and operators will make capital decisions in the coming years about investments to serve markets 10 years from now. Under CARB's proposed program, refineries operating in California may consider this trend toward phase-out and determine that a long-term capital investment is not warranted. If the ZEV market does not materialize as anticipated, ACC II may shutter refinery operations needed to serve continued demand for liquid fuels based on incompatibility with long-term planning needs for these businesses.

15 *See* SRIA at 98.

16 *See Major Regulations Standardized Regulatory Impact Assessment Summary*, State of California Department of Finance (Jan. 21. 2022). Available at: https://dof.ca.gov/wp-content/uploads/Forecasting/Economics/Documents/Summary-ACCII-SRIA.pdf. Accessed: May 2022.

A.1.1 CARB must consider grid reliability impacts from the electrification of the transportation sector.

As part of its evaluation of potential economic impacts to the welfare of California residents and in-state businesses, CARB must assess grid reliability impacts stemming from ACC II's forced electrification of the transportation sector.[17]

California already faces unresolved grid reliability issues that will be exacerbated by ACC II's ZEV targets and the resulting increases in electricity demand. During a heatwave in August 2020, nearly half a million Californians lost power. The California Independent System Operator's (CAISO) root cause analysis of these rotating outages identified three major causal factors, including:

- "The climate change-induced extreme heat wave across the western United States resulted in demand for electricity exceeding existing electricity resource adequacy (RA) and planning targets";
- "In transitioning to a reliable, clean, and affordable resource mix, resource planning targets have not kept pace to ensure sufficient resources that can be relied upon to meet demand in the early evening hours. This made balancing demand and supply more challenging during the extreme heat wave;"
- "Some practices in the day-ahead energy market exacerbated the supply challenges under highly stressed conditions."[18]

Recent studies reflect that factors affecting grid reliability are predicted to increase in future years. For example, a recent report by the California Legislative Analyst's Office indicates that California is expected to experience higher average temperatures; more frequent, intense, and prolonged heatwaves; and a greater number of extreme heat days due to climate change.[19] As these increasingly frequent extreme weather events increase demand for electricity, existing supply shortages will also worsen.[20] According to CAISO's 2021 Summer Loads & Resources Assessment,[21] 2021 faced "potential challenges in meeting demand during extreme heat waves … [which] affect a substantial portion of the Western Interconnection and cause simultaneously high loads across the West … reduc[ing] the availability of imports into the ISO balancing authority area." As recently as July 30, 2021, Governor Gavin Newsom issued an emergency

---

17 These impacts also have implications for cybersecurity, as discussed at Section A.7.

18 *See* CPUC, *2020 Resource Adequacy Report* (Apr. 2022). Available at: https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/resource-adequacy-homepage/2020_ra_report-revised.pdf. Accessed: May 2022.

19 Legislative Analyst's Office, *Climate Change Impacts Across California* (Apr. 5, 2022). Available at: https://lao.ca.gov/Publications/Report/4575. Accessed: May 2022.

20 Governor Newsom recently requested federal funding assistance to facilitate continued operations at the Diablo Canyon nuclear power plant in order to help meet existing supply challenges. *See* Doug Alexander, *California, Long Leery of Nuclear Power, Joins Bid to Save It*, Bloomberg Law (May 25, 2021). Available at: https://news.bloomberglaw.com/environment-and-energy/california-long-leery-of-nuclear-power-joins-bid-to-save-it?context=search&index=1. Accessed: May 2022.

21 CAISO, *2021 Summer Loads and Resources Assessment* (May 12, 2021). Available at: http://www.caiso.com/Documents/2021-Summer-Loads-and-Resources-Assessment.pdf. Accessed: May 2022.

proclamation highlighting that California currently faces an energy supply shortage of up to 3,500 megawatts during the afternoon-evening net-peak period of high-power demand on days when there are extreme weather conditions.[22],[23]

ACC II and other CARB rulemakings will exacerbate supply challenges by significantly increasing demand for electricity in California. According to discussions during a Staff Workshop regarding the California Energy Commission's (CEC) 2022 Integrated Energy Policy Report Update, existing regulations are "very modest compared to what is on the near horizon and in the future"—increases in state electricity demand are already apparent, and the electrification of the transportation sector will increase demand by around 300,000 gigawatt-hours (GWh) statewide.[24] In addition, CARB's SRIA predicts a 20.23% increase in output for electric power generation, transmission, and distribution by 2040.[25]

While securing additional generation capacity will mitigate some of these supply challenges, overreliance on renewable generation may exacerbate existing shortages, particularly during early evening hours. The California Public Utility Commission's (CPUC) recently adopted Integrated Resource Plan for 2018-2020 demonstrates that substantial new resource capacity will be required to support accelerated electrification.[26] The CPUC's preferred portfolio for electricity generation heavily relies on substantial scale-up of renewable resources that already face reliability challenges.

---

22 Governor Gavin Newsom, *Proclamation of a State of Emergency* (July 30, 2021), available at: https://www.gov.ca.gov/wp-content/uploads/2021/07/Energy-Emergency-Proc-7-30-21.pdf, accessed: May 2022. The order noted that "sufficient resources were not available" through CAISO's Capacity Procurement Mechanism to combat this shortfall, and that the summer of 2022 will also likely see a shortfall of up to 5,000 megawatts. To combat these shortfalls, the order called for the California Energy Commission to accelerate reviews of proposed natural gas generator projects that are 10 megawatts or larger, authorized incentive payments of up to $2 per kilowatt-hour reduced for large energy users, and eliminated permitting restrictions and air regulations on the use of existing backup fossil fuel fired generators. On August 17, 2021, the California Energy Commission approved five temporary gas-fueled generators, each with a generation capacity of 30 megawatts, to help address continued electricity shortages. Darrell Proctor, *California Will Add Gas-Fired Units to Increase Power Supply*, PowerMag (Aug. 20, 2021), available at: https://www.powermag.com/california-will-add-gas-fired-units-to-increase-power-supply/, accessed: May 2022.

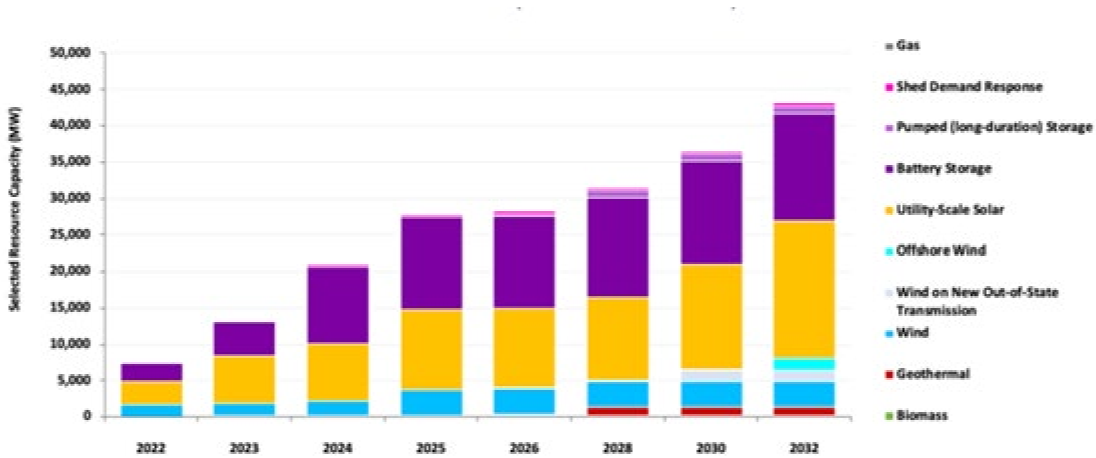
23 Further, the North American Electric Reliability Corporation's (NERC) draft 2022 Summer Reliability Assessment determined that extreme weather creates an elevated reliability risk in the western United States. NERC, *2022 Summer Reliability Assessment* (May 2022). Available at: https://www.nerc.com/pa/RAPA/ra/Reliability%20Assessments%20DL/NERC_SRA_2022.pdf. Accessed: May 2022.

24 CEC, *Transcript - IEPR Staff Workshop on Demand Scenarios*, Electricity Forecast, 22-IEPR-03, TN# 243031 at 64, 79 (May 12, 2022). Available at: https://efiling.energy.ca.gov/Lists/DocketLog.aspx?docketnumber=22-IEPR-03. Accessed: May 2022.

25 SRIA at 125.

26 CPUC, Order Instituting Rulemaking to Continue Electric Integrated Resource Planning and Related Procurement Processes, Decision No. 22-02-004 (Feb. 10, 2022). Available at: https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M451/K412/451412947.PDF. Accessed: May 2022.

Figure A-1. New Resource Buildout Based on CPUC's Preferred Portfolio[27]



By 2026, when ACC II goes into effect, the CPUC must plan for a new resource buildout of 28,154 MW, climbing to 43,131 MW by 2032.[28] Nearly half of this capacity depends on battery storage, for which feasibility has not been demonstrated, and the majority of the remaining capacity is supplied by utility-scale solar, which also involves significant feasibility and reliability concerns.[29] Battery storage at this scale would result in significant additional demand for critical minerals, increasing consumer costs for both electricity and electric vehicles. CARB has failed to adequately assess these reliability challenges, despite its clear legal duty to do so.

A.1.2 CARB must consider economic impacts and burdens to communities, including low-income and disadvantaged communities.

CARB is required to assess any adverse economic impacts on California business enterprises and individuals resulting from its proposal.[30] Further, under Executive Order N-79-20, CARB must ensure that its ZEV regulations "serve all communities and in particular low-income and disadvantaged communities."[31] These requirements are written broadly to ensure that CARB considers a wide range of both direct and indirect impacts to individuals—this consideration must include electricity rate increases.

First, CARB must consider the impact of electricity rates. CARB acknowledges that by increasing the amount of electricity used, this will increase the amount of Utility User Tax

---

27 *Id.* at 87.
28 *Id*.
29 *See id*.
30 *See* APA § 11346.5(a)(7); HSC § 43018.5(c)(2)(E), (CARB must consider "[t]he ability of the state to maintain and attract businesses in communities with the most significant exposure to air contaminants, localized air contaminants, or both, including, but not limited to, communities with minority populations or low-income populations, or both.").
31 Governor Gavin Newsom, Executive Order N-79-20 (Sep. 23, 2020). Available at: https://www.gov.ca.gov/wp-content/uploads/2020/09/9.23.20-EO-N-79-20-Climate.pdf. Accessed: May 2022.

levied.[32] However, CARB fails to address the fact that low-income and disadvantaged communities spend a disproportionate amount of their income on essential utilities, such as electricity.[33] In order to facilitate the ACC II targets, significant infrastructure buildout is necessary to support the increased electricity demand. Electrification of transportation sector will require an estimated $49 billion dollars.[34] Low-income households will bear a disproportionate share of these costs.[35]

Second, the lack of sufficient charging equipment is significant both as it relates to public and home charging. Both CARB and the CEC acknowledge that sufficient charging infrastructure is needed to accommodate the ACC II ZEV targets.[36] But CARB fails to consider that residents of low-income communities are more dependent on public charging infrastructure, which is more expensive and less convenient than home charging. A recent study indicates that home charging is often not an option for people living in multi-family housing, who are disproportionately low-income,[37] because "[p]ublic charging can be 2-4 times more expensive than home charging."[38]

While CARB does acknowledge the need to expand public charging infrastructure into ESJ communities, it does not take into consideration the interim consequences of uneven access before improvements are made. For example, CARB states that "already, in disadvantaged communities in California, used electric vehicles are purchased at higher rates than new electric vehicles."[39] As a result, the proposed solution is to increase warranty, durability and

---

32 *See* SRIA at 112.

33 *See* CPUC, 2019 Annual Affordability Report at 10-11 (Apr. 2021). Available at: https://www.cpuc.ca.gov/-/media/cpuc-website/industries-and-topics/reports/2019-annual-affordability-report.pdf. Accessed: May 2022.

34 *See* CPUC, Order Instituting Rulemaking to Continue Electric Integrated Resource Planning and Related Procurement Processes, Decision No. 22-02-004 (Feb. 10, 2022), available at: https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M451/K412/451412947.PDF, accessed: May 2022. Further, as discussed in additional detail in the Technical Comments at Appendix B, cumulative costs associated with electricity grid infrastructure upgrades could reach $1.55 trillion for 2026-2050. *See* Section B.6. *See also* CEC, Presentation - Transportation Energy Demand Forecast, 21-IEPR-03, TN# 240934 (Dec. 14, 2021). Available at: https://www.energy.ca.gov/event/workshop/2020-12/session-1-transportation-energy-demand-forecast-update-commissioner-workshop. Accessed: May 2022.

35 CPUC, Draft Environmental & Social Justice Action Plan Version 2.0, at 21 (Mar. 25, 2022). Available at: https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M465/K846/465846599.pdf. Accessed: May 2022.

36 CEC, Assembly Bill 2127 Electric Vehicle Charging Infrastructure Assessment Analyzing Charging Needs to Support ZEVs in 2030, 19-AB-2127 at ii (Jul. 14, 2021), available at: https://www.energy.ca.gov/programs-and-topics/programs/electric-vehicle-charging-infrastructure-assessment-ab-2127, accessed: May 2022 . As discussed in further detail in the Technical Comments at Appendix B, the total cost associated with purchasing and installing these chargers is estimated to be between $13 and $24 billion. *See* Section B.6.

37 *See* Scott Hardman, et al., *A perspective on equity in the transition to electric vehicle*, 2 MIT Sci. & Pol. Rev. 46, 49 (Aug. 30, 2021). Available at: https://sciencepolicyreview.org/wp-content/uploads/securepdfs/2021/08/A_perspective_on_equity_in_the_transition_to_electric_vehicles.pdf. Accessed: May 2022.

38 *Id*.

39 *See* ISOR at 21.

affordability of new ZEVs beginning in model year 2026.[40] However, CARB does not address the economic impacts to ESJ communities between now and when model year 2026 ZEVs are viable as "used."

Finally, CARB has not factored the subsidization of electric vehicles into its economic analysis. The electric vehicle market is buoyed by state and federal subsidies. From California this includes grants for the purchase of zero-emission buses, grants for the replacement or repower of heavy-duty vehicles, and various rebate programs such as the Clean Vehicle Rebate Project and the Clean Fuel Reward program,[41] and from the federal government this includes a tax credit of up to $7,500 for the purchase of a new electric vehicle.[42] Similarly, CARB must consider the impact of electric vehicle mandates on *all* motor vehicles, not just electric vehicles, as manufacturers spread unrecouped and compliance costs across their business.[43] CARB cannot claim to have reasonably considered cost impacts to consumers or accurately evaluated electric vehicle purchase prices without adjusting for these subsidies and cross-subsidization.

Without considering the aforementioned effects, CARB has failed to fully account for substantial economic impacts from forced electrification to individuals in general and to vulnerable communities in particular.

A.1.3 **CARB must consider life cycle emissions from Zero Emission Vehicles in evaluating the ACC II program.**

Along with impacts to the state's economy from proposed regulations, CARB is required to consider any less costly but equally effective alternatives.[44] The ISOR and associated rulemaking document do not satisfy this obligation because nowhere does CARB compare the life cycle emissions analysis of ZEVs and highly efficient low emission vehicles, which impose significantly fewer infrastructure expenses while achieving equivalent or greater GHG emissions reductions on a faster timeline.

As noted by the National Bureau of Economic Research, "…despite being treated by regulators as 'zero emission vehicles', electric vehicles are not necessarily emissions free."[45] Battery

---

40 *Id.* at 153.

41 *See* U.S. Dept. Energy, *California Laws and Incentives*. Available at: https://afdc.energy.gov/laws/all?state=CA#State%20Incentives. Accessed: May 2022.

42 *See* U.S. Dept. Energy, *Federal Tax Credits for New All-Electric and Plug-in Hybrid Vehicles.* Available at: https://www.fueleconomy.gov/feg/taxevb.shtml. Accessed: May 2022.

43 The Associations are concerned that ACCII will harm consumers and small businesses that depend on affordable comprable internal combustion vehicles—which cost significantly less and are more accessible— by driving up the cost of these vehicles. This cross-subsidization of electric vehicles at the expense of non-electric vehicles occurs in two ways. First, driven by the need to sell electric vehicles to meet California requirements, motor vehicle manufacturers will attempt to bolster sales by decreasing the sales price of electric vehicles and increasing the sales price of internal combustion engine vehicles. Second, manufacturers that do not meet sales mandates likely will spread the cost of buying compliance credits across all vehicle models, rather than only increasing the cost of their electric vehicles. CARB must consider the impact of ACC II on all new motor vehicles.

44 *See* HSC § 57005.

45 Stephen P. Holland, et al., *Environmental Benefits from Driving Electric Vehicles?*, Working Paper 21291, National Bureau of Economic Research. Available at: http://www.nber.org/papers/w21291. Accessed: May 2022.

production, transport, and disposal or recycling present emissions and waste impacts[46] as well as national security concerns.[47] Furthermore, as the Ramboll LDA Study observes, "it is likely that the vast majority of batteries produced in the future would require virgin material given the significant increase in demand under a mass vehicle electrification scenario."[48]

Low-carbon fuels like renewable diesel, ethanol and renewable gasoline should be evaluated as an alternative because they are compatible with existing vehicle infrastructure, from light- to heavy-duty long-haul vehicles *right now*. By contrast, electric vehicles require transformation of energy production and distribution infrastructure—which will take significant time even in the most optimistic scenarios. This makes low-carbon fuels a commonsense solution to reduce transportation GHG emissions near-term, allowing battery, hydrogen, and low-carbon intensity gaseous and liquid fueled vehicles to compete to achieve the State's GHG targets in the quickest and most cost-effective manner. For example, a scenario that phases in low-carbon intensity gasoline as a drop-in fuel for ICEVs over a two-decade period could reduce GHG emissions the same or more than the proposed ZEV-only mandate, when viewed on a life cycle basis. Other scenarios involving hybrid electric vehicles and PHEVs could be equally effective in providing GHG reductions when coupled with a phase in of low-carbon intensity gasoline.

Additionally, unlike with electric vehicles, vehicle owners that use drop-in fuels such as renewable diesel achieve emission reductions but do not have to face the high up-front cost to replace their current vehicles or the costs associated with locating and installing electric vehicle charging infrastructure.[49]

Accounting for life cycle emissions and short-term emissions reductions is necessary for CARB to fulfill its legal duty to conduct a reasonable assessment of the effectiveness of alternatives and the significant impacts to the state's economy of all scenarios. From this perspective, including highly efficient low emission vehicles in the ACC II program is both less costly and equally effective in meeting CARB's regulatory goals, and CARB's failure to consider this alternative violates HSC § 57005.

A.2 CARB must perform a complete and sufficient assessment of the technological feasibility of the ACC II ZEV mandates.

Similar to economic impacts, the APA and HSC mandate that CARB consider the technological feasibility of proposed motor vehicle standards. CARB's interpretation of this requirement is overly narrow because it focuses only on whether a manufacturer has the technology to provide an electric vehicle. It fails to consider whether manufacturers have the resources (including

46 Perry Gottesfeld, *Electric cars have a dirty little recycling problem—batteries*, National Observer (Jan. 22, 2021). Available at: https://www.nationalobserver.com/2021/01/21/opinion/electric-cars-have-dirty-little-recycling-problem-their-batteries. Accessed: May 2022.

47 Eric Onstad, *China frictions steer electric automakers away from rare earth magnets*, Reuters (Jul. 19, 2021). Available at: https://www.reuters.com/business/autos-transportation/china-frictions-steer-electric-automakers-away-rare-earth-magnets-2021-07-19. Accessed: May 2022.

48 *See* Attachment D, Ramboll LDA Study, at 29.

49 *See* Attachment D, "Multi-Technology Pathways To Achieve California's Greenhouse Gas Goals: Light-Duty Auto Case Study" by Ramboll dated May 31, 2022 for further details.

critical and rare earth minerals) to shift to rapidly producing electric vehicles and whether there is a reliable supply of electricity to fuel them.[50]

Specifically, CARB is required to consider:

- HSC § 39602.5 – ambient air quality standards ("state board shall adopt these measures if they are necessary, technologically feasible, and cost effective…");
- HSC § 38562 – GHG emissions ("[T]he state board shall adopt greenhouse gas emissions limits… to achieve the maximum technologically feasible and cost-effective reductions…");
- HSC § 43013 – motor vehicle emission standards ("…which the state board has found to be necessary, cost effective, and technologically feasible, to carry out the purposes of this division");
- HSC § 43101 – new motor vehicle emission standards ("…that the state board finds to be necessary and technologically feasible to carry out the purposes of this division. Before adopting these standards, the state board shall consider the impact of these standards on the economy of the state, including, but not limited to, their effect on motor vehicle fuel efficiency.");
- HSC § 43018.5 – GHG vehicle emissions ("maximum feasible and cost-effective reduction of greenhouse gas emissions from motor vehicles");
- HSC § 43018 – NOx emissions ("the state board shall take whatever actions are necessary, cost-effective, and technologically feasible in order to achieve… a reduction in the actual emissions of reactive organic gases… [and] a reduction in emissions of oxides of nitrogen… from motor vehicles"); and
- HSC § 38560 – GHG emissions ("The state board shall adopt rules and regulations… to achieve the maximum technologically feasible and cost-effective greenhouse gas emission reductions from sources or categories of sources").

As CARB considers the technological feasibility of its proposal, it should further explore whether vehicle manufacturers are likely to possess adequate resources to adapt to these stringent requirements, especially in light of increasing global supply chain issues and commodity price increases associated with battery demand. Currently, CARB plans to set interim requirements for the percentage of electric vehicle sales starting in 2026, with this requirement increasing by 8 percentage points per year for the first 5 years, and then 6 percentage points per year for the latter 5 years. This is an unprecedented rate of vehicle technology change that the nation and vehicle manufacturers have never experienced before.

Importantly, the question here is not *only* whether a vehicle manufacturer has the technology (and, inherent in this question, the resources) to produce a single electric vehicle. Rather, examining the technological feasibility of electric vehicle mandates must include asking whether vehicle manufacturers have the technology and resources to rapidly shift to producing electric vehicles—a relatively new technology category that requires different resources than traditional vehicles—by the millions, as well as whether there is a reliable supply of electricity to fuel them.

[50] Further, as noted above, the significant existing state and federal subsidies for electric vehicles call into question whether this technology is mature enough to be considered feasible.

First, both the federal government and the private sector have recognized that critical minerals are essential to the future of electric vehicles, and likewise, that unstable critical mineral supply chains could disrupt this future. According to Rystad Energy, by 2024, global demand for nickel (one of the most widely used critical minerals for EV batteries) will have increased from 2.5 million tons to 3.4 million tons, thereby surpassing supplies.[51] Likewise, the International Energy Agency has estimated that lithium demand could increase by over 40 times by 2030, and cobalt could face similar demand issues.[52,53]

The U.S. is disproportionately reliant on international supplies of critical minerals necessary for electric vehicle and electric battery production. Ninety-one percent of the lithium that the United States imports is sourced from Chile and Argentina.[54] Relatedly, China has disproportionate influence compared to other foreign nations that produce cobalt, molybdenum, and other minerals needed to produce electric vehicles. For instance, the U.S. Geological Service (USGS) reported that domestic primary aluminum production in 2021 (880,000 metric tons) was less than half of domestic production in 2013 (1,946,000 metric tons).[55] China, however, possesses over half of the entire world's aluminum smelting capacity.[56] Seventy percent of the world's supply of cobalt comes from the Democratic Republic of Congo,[57] where eight of the largest 14 mines are Chinese-owned.[58] Similarly, U.S. domestic mining production of cobalt has declined (760,000 tons in 2015 compared to 700,000 tons in 2021).[59] Secondary cobalt production has also declined between 2017 and 2021 (2,750,000 tons to 1,600,000 tons).[60] The United States imports all its graphite and manganese, having no domestic production of these minerals. China produces 82 percent of the world's graphite,[61] while Gabon, a less stable country, provides 67 percent of the United States' manganese.[62] For any one of these minerals, ACC II's 100% electrification mandate could put the United States into a situation resembling the oil embargoes of the 1970s, where foreign actors control majorities of the critical raw

---

51 David Iaconangelo, *Nickel shortage spells trouble for EVs – report*, E&E News (Oct. 13, 2021). Available at: https://www.eenews.net/articles/nickel-shortage-spells-trouble-for-evs-report/. Accessed: May 2022.

52 Neil Winton, *Lithium Shortage May Stall Electric Car Revolution And Embed China's Lead: Report*, Forbes (Nov. 14, 2021). Available at: https://www.forbes.com/sites/neilwinton/2021/11/14/lithium-shortage-may-stall-electric-car-revolution-and-embed-chinas-lead-report/?sh=70d7fed046ef. Accessed: May 2022.

53 U.S. Geological Survey, *Mineral Commodity Summaries 2022,* at 100 (Jan. 31, 2022), available at: https://pubs.usgs.gov/periodicals/mcs2022/mcs2022.pdf, accessed: May 2022, ("2022 Mineral Commodities Summaries").

54 *Id.* In addition, 8% of imported lithium is from China and Russia. *Id.*

55 *Id.* at 22; U.S. Geological Survey, *Mineral Commodity Summaries 2018,* at 20 (Jan. 31, 2018), available at: https://minerals.usgs.gov/minerals/pubs/mcs/2018/mcs2018.pdf, accessed: May 2022, ("2018 Mineral Commodities Summaries").

56 2022 Mineral Commodieis Summaries at 23.

57 *Id.* at 53.

58 *See China Has a Secret Weapon in the Race to Dominate Electric Cars*, Bloomberg (Dec. 2, 2018). Available at: https://www.bloomberg.com/graphics/2018-china-cobalt/. Accessed: May 2022.

59 2018 Mineral Commodities Summaries at 50; 2022 Mineral Commodities Summaries at 53.

60 2022 Mineral Commodities Summary at 52.

61 *Id.* at 75.

62 *Id.* at 106.

material supplies used in the manufacture of fuels, battery, and motor components designed to provide transportation mobility services for the U.S. consumer.[63]

California's ACC II mandates risk arbitrarily exacerbating supply chain strains, and CARB does not adequately account for how the increasing adoption of electric vehicles will further affect the technological feasibility of its proposed mandates. In the Draft Environmental Assessment (EA), CARB identifies this problem but does not offer a solution: "In summary, while substantial research has been done and there is a clear commitment to increasing domestic supply of lithium, exact actions that will be taken in response to this goal of increasing domestic supply of lithium are yet to be identified with certainty."[64]

Second, as described in detail above, California already faces unresolved grid reliability issues that will be exacerbated by ACC II's ZEV targets.[65] Increases in state electricity demand are already apparent, and electrification of the transportation sector will increase demand by around 300,000 GWh statewide.[66] By 2026, when ACC II would go into effect, California will need an additional 28,154 MW, climbing to 43,131 MW by 2032.[67] Nearly half of this capacity depends on battery storage that has not been demonstrated, and the majority of the remaining capacity is supplied by utility-scale solar, which also presents significant feasibility concerns.[68] It is entirely unreasonable to determine that a vehicle is technologically feasible solely because it can be *built* when it simultaneously cannot reliably *operate* because it does not have the power to do so. Creating a rapid increase in electricity demand before more renewable energy infrastructure is built could increase emissions from traditional energy generating sources and offset GHG reductions achieved by ZEVs, an unintended consequence CARB did not consider.

By failing to account for these issues, CARB not only offers an arbitrary and capricious assessment of technological feasibility, but also violates its statutory obligations as set forth in the APA and HSC.

---

63 *See* Securing America's Future Energy, *The Commanding Heights of Global Transportation*, https://secureenergy.org/wp-content/uploads/2020/09/The-Commanding-Heights-of-Global-Transportation.pdf.

64 *See* CARB, *Appendix E – Draft Environmental Analysis for the Proposed Advanced Cleans Cars II Program*, 121 (Apr. 12, 2022). Available at: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/accii/appe1.pdf. Accessed: May 2022.

65 These reliability challenges are discussed in more detail in the Technical Comments at Appendix B, Section B-5.

66 CEC, *Transcript - IEPR Staff Workshop on Demand Scenarios*, Electricity Forecast, 22-IEPR-03 at 79 (May 12, 2022). Available at: https://efiling.energy.ca.gov/Lists/DocketLog.aspx?docketnumber=22-IEPR-03. Accessed: May 2022.

67 CPUC, *Order Instituting Rulemaking to Continue Electric Integrated Resource Planning and Related Procurement Processes*, Decision No. 22-02-004, at 87 (Feb. 10, 2022). Available at: https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M451/K412/451412947.PDF. Accessed: May 2022.

68 *See id.*

A.3 CARB lacks the legal authority to unilaterally ban entire industries.

CARB's ACC II Program centers around achieving 100% ZEV or PHEV sales in California by model year 2035. This target necessitates the complete electrification of the transportation sector, forcing the phase-out of oil and gas production and refinery industries. CARB's attempt to unilaterally ban entire industries exceeds its delegated authority under California's Constitution.

The California Supreme Court has held that "[t]he constitutional guaranties of liberty include the privilege of every citizen to freely select those tradesmen [he desires to patronize]."[69] ACC II will intrude on this liberty interest by stripping Californians' current right to choose ICEVs when it bans new ICEV sales and effectively banning infrastructure to support these vehicles by forcing the phase-out of related industries in California. Under the California Constitution, legislation that impacts a protected liberty interest must not "be 'unreasonable, arbitrary or capricious' but... have 'a real and substantial relation to the object sought to be attained.'"[70]

ACC II's exclusive selection of ZEVs is neither reasonable nor rationally related to California's goal to limit GHG emissions from vehicles. Low-carbon fuels and highly efficient ICEVs can achieve the same GHG emissions reductions as ZEVs and on a shorter timeline. Low-carbon fuels like renewable diesel, ethanol, and renewable gasoline are compatible with existing vehicle infrastructure, from light- to heavy-duty long-haul vehicles. These fuels can *immediately* reduce transportation GHG emissions and are not dependent on an electric vehicle infrastructure. Further, when viewed from a life cycle perspective, these fuels achieve similar or greater emissions reductions and do not impair liberty interests because Californians will retain their current options to choose between ICEVs and electric vehicles. As noted above, GHG emissions from a light-duty vehicle that runs on soybean-based renewable diesel has 25% fewer life cycle GHG emissions when compared to an EV, and this percentage is even greater for a vehicle that runs on waste-oil-based renewable diesel.

Because eliminating an entire sector of industry is not rationally related to California's interest in limiting GHG emissions, ACC II impermissibly interferes with liberty interests protected under the California Constitution.

A.4 ACC II fails to comply with the APA because it effectively mandates the use of specific technologies.

APA § 11346.2(b)(4)(A) requires CARB to consider performance standards as an alternative whenever CARB proposes a regulation that would mandate the use of specific technologies or equipment, or prescribe specific actions or procedures.

ACC II will establish interim requirements for the percentage of EV sales starting in 2026— the requirement increases by 8 percentage points per year for the first 5 years, and then 6 percentage points per year for the latter 5 years, achieving 100% ZEV sales by 2035.[71] In its

69 *New Method Laundry Co. v. MacCann*, 174 Cal. 26, 32 (1916).
70 *Coleman v. Department of Personnel Administration*, 52 Cal. 3d 1102, 1125 (1991) (internal citations omitted).
71 See ISOR at 9.

ISOR, CARB indicates that its proposed ACC II program is a performance standard because "manufacturers can meet this proposed regulation requirements using BEV, PHEV or [fuel cell electric vehicle (FCEV)] technologies and with several options for securing ZEV values."[72] However, CARB also notes that, even if ACC II is considered a prescriptive standard, "[a]nything less prescriptive than ACC II in terms of emission limits and requirements for ZEVs erodes the proposal's ability to secure the emissions reductions needed for meeting California's public health and climate goals and State and federal air quality standards."[73]

CARB's conclusion that ACC II is not a prescriptive standard entirely ignores the prescriptive effect of mandating one specific avenue for compliance— ACC II requires a transition to ZEV technologies rather than setting minimum emission standards that can be achieved through a variety of technologies such as highly efficient ICEVs and low-carbon liquid fuels. Providing flexibility to choose among various ZEV technologies does not change CARB's clear selection of one compliance pathway, because this "choice" is itself prescriptive.

Similarly, CARB's cursory conclusion that ACC II "would still be preferred over other performance-based alternatives" overlooks important near-term emissions reductions achievable through low carbon fuels and other technologies.[74] CARB asserts that "[l]ess prescriptive measures would allow, by omission, additional flexibilities on technology, valuation, fleet mixing, and assurance measures that would likely not achieve the same magnitude of emissions reductions or support for the ZEV market."[75] However, CARB has not adequately analyzed the achievable emissions reductions stemming from such performance standards.

CARB completely overlooks the significant current and projected reductions in GHG emissions associated with the liquid transportation fuel pool that are occurring in response to the LCFS,[76] the federal Renewable Fuel Standard (RFS),[77] and interest from shareholders to reduce GHG emissions associated with the production of fuels. Production of fuels with lower carbon intensity has already resulted in significant reductions in GHG emissions attributable to the domestic transportation fuel pool and, due to the continued success of the LCFS and RFS, there is significant and increasing private investment in low-carbon fuel technologies that will further expand GHG reductions in the transportation economy.[78] Further, numerous companies

72 *Id*. at 181.

73 *Id*.

74 *Id.*

75 *Id*.

76 *See* California Air Resources Board, *LCFS Workshop CARB Presentation,* at 5 (Oct. 14, 2020), available at: https://ww2.arb.ca.gov/sites/default/files/2020-10/101420presentation_carb.pdf, accessed: May 2022. ("Over 15 million metric tons of GHG reductions in 2019.")

77 A study performed by Life Cycle Associates found that "The RFS2 has resulted in significant GHG reductions, with cumulative CO_2 savings of 980 million metric tonnes over the period of implementation to date." Stefan Unnasch and Debasish Parida, *GHG Emissions Reductions due to the RFS2 – A 2020 Update* (Feb. 11, 2021). Available at: https://ethanolrfa.org/wp-content/uploads/2021/02/LCA_-_RFS2-GHG-Update_2020.pdf. Accessed: May 2022.

78 By prescribing specific zero-emission technologies, CARB ignores and frustrates the vast emission reductions that could be achieved via continued operation of the LCFS. Market signals benefitting electric vehicle automakers and electric generators only will drive away private investment and innovation into alternative zero emission technologies.

involved in both exploration and production of crude oil as well as production of both renewable and nonrenewable liquid fuels have begun projects to sequester, capture, or displace carbon, further reducing the GHG emissions associated with liquid fuels in the transportation sector.

Without adequately considering the emissions reductions available from a performance-based vehicle emissions standard, CARB has exceeded its regulatory authority under APA § 11346.2(b)(4)(A).

A.5 ACC II thwarts legislative priorities by undermining wildfire resilience and exacerbating impacts to low-income communities.

The California legislature has made clear that wildfire resilience is a priority for the state. Despite this clear legislative priority, CARB's proposed ACC II program will undermine wildfire resilience by forcing electrification of the transportation sector through its ZEV sales mandate, which will necessarily require significant build-out of electricity infrastructure, exacerbating existing wildfire risks and worsening wildfire impacts. These impacts will disproportionately affect low-income and disadvantaged communities.

In September 2021, Governor Newsom signed SB-456 into law, requiring the Wildfire and Forest Resilience Task Force to "develop a comprehensive implementation strategy to track and ensure the achievement of the goals and key actions identified in the state's 'Wildfire and Forest Resilience Action Plan' issued by the task force in January 2021."[79] The state has also dedicated substantial funding to Wildfire and Forest Resilience Early Action,[80] as well as fire prevention programs and projects targeted towards reducing GHG emissions caused by uncontrolled wildfires.[81]

Electric utility infrastructure poses a significant wildfire ignition risk that CARB has failed to assess, and that ACC II will exacerbate. The December 2020 *Utility Wildfire Mitigation Strategy and Roadmap* emphasized that climate change will amplify utility wildfire risks by increasing vegetation contact through invasive species and tree mortality[82] and increasing the size, scope, and frequency of wildfires, meaning that utilities will "operate in more high-risk areas going forward."[83] Utilities are already operating in areas facing extreme or elevated wildfire risk in both Northern and Southern California, and these risks "will almost certainly increase" in the future.[84]

Apart from ignition risks, overreliance on electrification, as required by ACC II, can amplify wildfire risks to electrical transmission and distribution assets throughout the state. Wildfire damages are generally very costly to repair—a 2018 CEC Report indicated that "[o]ver the 2000-2016 period, wildfire damages to the transmission and distribution system in selected

79 Senate Bill No. 456.
80 Senate Bill No. 85 (Apr. 13, 2021) (amending the *2020-21 Budget Act* to provide $536 million in funding for various wildfire and forest resilience activities).
81 Senate Bill No. 155(5) (Sep. 23, 2021) (appropriating $200,000,000 annually from the Greenhouse Gas Reduction Fund beginning in the 2022–23 fiscal year through 2028–29 fiscal year).
82 CUPC, *Utility Wildfire Mitigation Strategy and Roadmap for the Wildfire Safety Division*, at 18 (Dec. 2020). Available at: https://energysafety.ca.gov/wp-content/uploads/docs/strategic-roadmap/final_report_wildfiremitigationstrategy_wsd.pdf. Accessed: May 2022.
83 *Id.* at 14.
84 *Id*.

areas exceeded $700 million," although "[t]otal wildfire damages to all sectors of the economy were much larger."[85] These damages can also increase generation costs and disrupt customer service.[86] Future wildfire risk is expected to significantly increase, exacerbating these existing challenges.[87] The CEC Report estimated that cost impacts of fires in a high-capacity utilization scenario would reach $92.6 million in the midcentury period.[88] Again, CARB must account for these increased costs in assessing the projected impacts of its proposed program.

CARB itself notes the increasing wildfire risks faced by the state in its ISOR: "California's annual wildfire extent has increased fivefold since the 1970s, and California's 2020 fire season alone shattered records, not only in the total amount of acres burned (at just over 4 million) but also in wildfire size, with 5 of the 6 largest wildfires in California history occurring in 2020."[89] However, CARB fails to account for any wildfire risks stemming from the electrification of the transportation sector, concluding that short-term construction-related and long-term operation related effects to wildfire would be "less than significant."[90] Instead, CARB considers only perceived *benefits* to wildfire resilience based on the unproven ability to use ZEVs "to provide grid services and decentralized backup power for California residents" to mitigate disruptions.[91] Moreover, CARB overlooks the potential hazards faced by communities with an urgent need to evacuate from fires who may be stranded if they cannot charge their electric vehicles. CARB's analysis is entirely one-sided, assessing highly attenuated benefits while ignoring demonstrable costs based on extensive analyses by other California agencies.

Low-income communities are disproportionately burdened by wildfire impacts. According to a recent study analyzing wildfire impacts from 2010 to 2020, rural communities "sustained three times more wildfire on average"-- these communities exhibited significant environmental justice indicators, including "higher rates of poverty, unemployment, and vacant housing, as well as higher proportions of low-income residents and residents without college degrees."[92]

Likewise, environmental justice communities are most impacted by de-energization events—according to the CPUC's report, "[t]hese events have had massive implications for [environmental and social justice (ESJ)] communities, particularly low-income people in rural,

---

85 Larry Dale, et. al, *Assessing the Impact of Wildfires on the California Electricity Grid*, CCCA4-CEC-2018-002, at iv (Aug. 2018). Available at: https://www.energy.ca.gov/sites/default/files/2019-11/Energy_CCCA4-CEC-2018-002_ADA.pdf. Accessed: May 2022.

86 *See id.* at 11. The CEC Report indicated that "In one Northern California subregion, over 100 wildfires occurred between 2000 and 2016, covering 15-20% of the land area. Of those, 19 fires approached within a quarter mile of Paths 25 and 66. Wildfires near transmission paths may force the California Independent System Operator (CAISO) to cut power to those paths (line outages)." *Id.*

87 In addition, increased dependency on electricity may impact emergency response, increasing vulnerability to wildfires and other natural disasters by limiting the availability of fungible fuel sources and decreasing variability of energy supply.

88 *Id.* at 28.

89 ISOR at 7 (internal citations omitted).

90 ISOR at 150.

91 ISOR at 171.

92 Shahir Masri, et al., *Disproportionate Impacts of Wildfires among Elderly and Low-Income Communities in California from 2000-2020*, at 16 (Apr. 8, 2021). Available at: https://pubmed.ncbi.nlm.nih.gov/33917945/. Accessed: May 2022.

high fire threat areas including people with access and functional needs."[93] The CPUC's 2022 *Environmental and Social Justice Action Plan* indicates that "electric utilities have used de-energization strategies more frequently to prevent ignition of wildfires by electric utility infrastructure."[94] Among the three largest utilities in California, data shows an average of 14 outages per year, impacting more than a million customers.[95] CARB must account for the impact of rapid electrification on wildfire risk *and* consider the communities that will bear them.

CARB does not have the authority to contravene express statutory mandates by omission. It must consider the potential for ACC II to increase wildfire risk and change course accordingly.

A.6 CARB does not adequately consider feasible alternatives or the full range of environmental impacts.

CARB's Draft Environmental Analysis (EA) does not meet requirements under the California Environmental Quality Act (CEQA) because it (1) fails to consider low-carbon fuel and engine technologies as feasible alternatives and (2) ignores a number of potentially significant environmental impacts.

A.6.1 **The EA must consider low-carbon fuel and engine technologies as alternatives.**

As mentioned, in its Draft EA, CARB has failed to consider further supporting the production of low-carbon fuel and engine technologies that can immediately reduce GHG emissions today as an alternative alongside, rather than in lieu of, mandating a certain amount of electric vehicles.[96] The Associations urge CARB to recognize the proven value of using a diversified mix of other low-carbon technologies to achieve its GHG reduction goals. At the least, CARB should present a robust and scientifically credible alternatives analysis in its Final EA that compares the costs and benefits of using all feasible technologies to the costs and benefits of mandating 100% electric vehicles.

According to the Draft EA, the "primary objectives" of the ACC II Program include goals to "[m]aintain and continue reductions in emissions of GHGs beyond 2020" and "[c]omplement existing programs and plans to ensure, to the extent feasible, that activities undertaken pursuant to the measures complement, and do not interfere with, existing planning efforts to reduce GHG emissions, criteria pollutants, petroleum-based transportation fuels, and TAC

93 CPUC, *DRAFT Environmental & Social Justice Action Plan Version 2.0*, at 20 (Mar. 25, 2022). Available at: https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M465/K846/465846599.pdf. Accessed: May 2022.

94 CPUC, *DRAFT Environmental & Social Justice Action Plan Version 2.0*, at 20 (Mar. 25, 2022). Available at: https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M465/K846/465846599.pdf.

95 PSE Blog, *Preventing Wildfires with Power Outages: The Growing Impacts of California's Public Safety Power Shutoffs* (Mar. 19, 2021). Available at: https://www.psehealthyenergy.org/news/blog/preventing-wildfires-with-power-outages-2/#ref. Accessed: May 2022.

96 *See* CARB, *Appendix E – Draft Environmental Analysis for the Proposed Advanced Cleans Cars II Program*, 182-83 (Apr. 12, 2022). Available at: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/accii/appe1.pdf. Accessed: May 2022.

emissions."[97] Low-carbon alternative fuel and engine technologies align with these primary objectives, and thus, CARB should consider how these technologies can achieve more immediate environmental benefits while mitigating any cost burdens the ACC II Program may impose, especially with regard to low-income communities. Indeed, not doing so would conflict and "interfere with[] existing planning efforts to reduce GHG emissions [and] criterial pollutants" under the LCFS and RFS.[98]

In the ACC II rulemaking, CARB is required to consider a reasonable range of alternatives, including "alternatives that are proposed as less burdensome and equally effective in achieving the purposes of the regulation in a manner that ensures full compliance with the authorizing statute or other law being implemented or made specific by the proposed regulation."[99] This aligns with the CEQA Guidelines, which also specify that CARB must consider a reasonable range of alternatives that "shall include those that could feasibly accomplish most of the basic objectives of the project and could avoid or substantially lessen one or more of the significant effects."[100] The CEQA Guidelines define "feasible" as "capable of being accomplished in a successful manner within a reasonable period of time, taking into account economic, environmental, legal, social, and technological factors."[101] Specifically, when considering the feasibility of alternatives, the CEQA Guidelines provide the following factors to consider: "economic viability, availability of infrastructure, general plan consistency, other plans or regulatory limitations, [and] jurisdictional boundaries."[102]

Importantly, CARB is prohibited from predetermining a particular method to narrow the alternatives it considers for achieving the agency's ultimate policy goals. When examining whether or not alternatives or particular features have been foreclosed by the agency, courts look "to the surrounding circumstances to determine whether, as a practical matter, the agency has committed itself to the project as a whole or to any particular features, so as to effectively preclude any alternatives or mitigation measures that CEQA would otherwise require to be considered."[103] By deeming ZEVs as the only acceptable technologies and hardly considering in this rulemaking how other low-carbon technologies could provide important near-term reductions in GHG emissions, CARB is effectively predetermining the outcome of this proceeding. This predetermined outcome is not only arbitrary and capricious, but is also a violation of CARB's statutory obligations.

97 *Id.* at 7–8. While CARB is responsible for regulating emissions from transportation fuels, CARB has provided no authority for its premise that reducing petroleum-based transportation fuels is a legitimate objective for the agency. As noted throughout these comments, carbon capture and other innovative technologies offer opportunities for petroleum-derived fuels to achieve carbon reductions equivalent to or superior to those offered by ZEVs on a lifecycle basis. It is arbitrary to seek to reduce the use of these fuels categorically without regard to their lifecycle emissions.

98 *Id.* at 8.

99 California Government Code § 11346.2(b)(4)(A) (emphasis).

100 Cal. Code Regs. tit. 14, § 15126.6(c).

101 Cal. Code Regs. Tit. 14 § 15364; *Bay Area Citizens v. Ass'n of Bay Area Governments*, 248 Cal. App. 4th 966, 1018 (2016).

102 Cal. Code Regs. tit. 14, § 15126.6(f)(1).

103 *Save Tara v. City of W. Hollywood*, 45 Cal. 4th 116, 139 (2008), *as modified* (Dec. 10, 2008).

While increased electric vehicle adoption will be part of the energy mix to achieve California's GHG goals, it is impossible for this strategy alone to solve the issue of transportation emissions, especially in the short-term. Electric vehicles are simply too expensive for the majority of American families, and significant portions of California's population will rely on vehicles utilizing gasoline and diesel fuel for decades to come. A recent report by the Rhodium Group projects that, nationwide, where more than half of light-duty sales are electric by 2030 and nearly 90% are electric by 2035, 34% of transportation sector GHG emissions will still remain in 2050.[104] The report concludes that "low-GHG liquid fuels are needed to fill the remaining gap and achieve net-zero emissions in the transportation sector by mid-century."[105]

Low-carbon fuels like renewable diesel, ethanol and renewable gasoline are compatible with existing vehicle infrastructure. Such fuels are a commonsense solution to *immediately* reduce transportation GHG emissions without waiting for the time and expenses it will take to build out EV infrastructure. Additionally, unlike with electric vehicles, vehicle owners that use drop-in fuels such as renewable diesel or low carbon intensity gasoline do not have to face the high up-front cost to replace their current vehicles or the costs associated with locating and installing electric vehicle charging infrastructure.[106]

A.6.2 **The EA fails to consider potentially significant environmental impacts.**

CEQA requires that the Draft EA and Final EA contain "[a] discussion and consideration of environmental impacts, adverse or beneficial, and feasible mitigation measures which could minimize significant adverse impacts identified," as well as "[a] discussion of cumulative and growth-inducing impacts."[107] The Draft EA for the Proposed Regulation fails to consider the following potentially significant environmental impacts:

- Regarding aesthetics, the Draft EA does not consider the unpleasing aesthetic of businesses that will close as a result of the Proposed Regulation. Because millions of businesses depend upon transportation as a factor, the ZEV mandate will likely result in the closure of not only gas stations, but many other kinds of businesses as well. This could cause many gas stations and buildings within the state to become unoccupied and fall into a state of disrepair.
- CARB does not consider how the Proposed Regulation could cause businesses to relocate to other states based on the proposal's harmful competitive impacts to California industries. The act of relocating to another state involves greenhouse gas emissions and other harmful pollutants from transportation, as well as the potential construction of new business sites. Such transportation and construction could also injure wildlife and impact overburdened communities.
- CARB does not consider how California residents will likely drive to other states to purchase more affordable, traditional vehicles, significantly increasing the number of out-of-state

104 Rhodium Group, *Closing the Transportation Emissions Gap with Clean Fuels*, at 3 (Jan. 15, 2021). Available at: https://rhg.com/wp-content/uploads/2021/01/Closing-the-Transportation-Emissions-Gap-with-Clean-Fuels-1.pdf. Accessed: May 2022.
105 *Id.* at 2.
106 *See* Attachment D, "Multi-Technology Pathways To Achieve California's Greenhouse Gas Goals: Light-Duty Auto Case Study" by Ramboll dated May 31, 2022 for further details.
107 Cal. Code Regs. tit.17, § 60004.2(a).

vehicle purchases. This will result in additional greenhouse gas emissions and other harmful pollutants, which also pose a threat to wildlife and overburdened communities.

- CARB does not consider how, because the Proposed Regulation will likely increase vehicle costs. As a result, many Californians may choose to keep their cars for longer than they otherwise would have, thereby forgoing opportunities to replace their aging vehicles with more efficient models. This would also result in additional greenhouse gas emissions and criteria pollutants, compared to existing regulatory requirements.
- CARB does not adequately consider how increased demand on the electric grid due to significantly increased ZEV use will require additional increases in electric utility construction, which will likely include gas units to make up for the intermittency of renewable resources such as wind and solar. The construction of these facilities, as well as the use of additional gas facilities to meet demand, will have environmental impacts, including impacts on biological resources and increased greenhouse gas emissions and criteria pollutants.
- CARB does not consider how the negative economic impact of this Proposed Regulation on the petroleum industry could result in the abandonment of carbon capture, utilization, and storage technology already being developed, thereby increasing greenhouse gas emissions by eliminating opportunities to mitigate these emissions.
- CARB does not consider how requiring ZEVs will necessitate accessible residential charging stations, which will drive up the costs of housing in the state and could result in housing displacement.
- CARB does not consider the cumulative effects of the factors mentioned above that could result in greenhouse gas emission and other criteria pollutant increases.

WSPA and AFPM ask that CARB fully consider and provide mitigation measures for these factors, as it must do under CEQA. Notably, supporting low-carbon fuels and engine technologies could be a potential mitigation measure, as demonstrated by the previous subsection.[108]

A.7 The ACC II program is preempted by Federal law.

A.7.1 ACC II is expressly preempted by the Energy Policy Conservation Act.

CARB lacks authority to adopt or enforce any regulation "related to" fuel-economy standards under the Energy and Policy Conservation Act (EPCA). While the Clean Air Act grants California certain leeway to address localized pollution, EPCA's broad preemption provision prevents CARB from adopting such regulations when they are "related to" fuel economy,

[108] The Draft EA demonstrates that the Proposed Regulation will have significant environmental impacts that will be important to mitigate. For example, the document notes that increased lithium mining would require expanding existing facilities or constructing new ones in the Salton Sea Area, which "is an important feeding grounds for more than 400 species of birds including waterfowl and shorebirds during annual migration[,] and several bird species also use the area for breeding (USFWS 2021)." Draft EA, at 86. The Draft EA characterizes the impacts of such mining activities to these hundreds of bird species as "potentially significant." *Id.* Additionally, CARB indicates throughout the Draft EA that making electric vehicles will require industrial-scale mining and manufacturing of batteries, which may not occur in California and will generate significant emissions. Likewise, the disposal of spent batteries will have concerning environmental impacts, and California's plan to handle significant increases in the disposal of toxic batteries is unclear.

regardless of any accompanying localized pollution benefits. This provision is self-executing, meaning that no agency action is necessary for it to be effective—the lack of a National Highway Traffic Safety Administration (NHTSA) regulation expressly preempting CARB's program does not affect EPCA's preemptive effect. This provision also contains no waiver.

ACC II is clearly related to fuel-economy standards. Courts have found that state regulations "relate to" federal matters when they have a "connection with" or contain a "reference to" these matters. CARB's SRIA specifically discusses the fuel savings that would result from this rulemaking. CARB cannot avoid EPCA's preemptive effect by characterizing this rule as an environmental regulation despite its clear implications for fuel economy.

A.7.2 ACC II conflicts with important federal statutory objectives.

A critical failing of ACC II is that in its haste to phase-out oil and gas production and refinery industries it does not consider the impact to the remainder of our energy system, including on biofuels (which will be sharply curtailed) and electricity supply (which will be overburdened). A critical failing of ACC II is that in its haste to phase-out oil and gas production and refinery industries, CARB did not consider the impact to the remainder of our energy system, as well as other essential products such as jet fuel, asphalt, petrochemicals, and lubricants. This willful blindness places ACC II on a collision course with multiple Congressionally mandated programs expressly designed to have the *opposite* impact— biofuels (increased and increasing) and electric supply (reliable). Because ACC II undermines and conflicts with the fulfillment of these Congressional objectives, it is necessarily preempted.

It is a "well-established principle that the Supremacy Clause, U.S. Const., Art. VI, cl. 2, invalidates state laws," like ACC II, "that interfere with, or are contrary to federal law."[109] Even where Congress has not completely displaced state regulation in a specific area, state law is nullified to the extent that it actually conflicts with federal law. Such conflicts arise "when compliance with both state and federal law is impossible" and "when the state law 'stands as an obstacle to the accomplishment and execution of the full purposes and objectives of Congress.'"[110] The ACC II program fails on both accounts.

First, Congress' intention to increase production, distribution, and use of biofuels is expressed in no less than three statutes, which do everything from mandating biofuel blending in liquid fuel to incentivizing its production through loans and loan guarantees. Specifically, the ACC II Program conflicts with these federal objectives and deprives federal funding programs of value by mandating complete electrification of the transportation sector. These programs set aside significant funding for the development and use of liquid fuels for transportation, with the expectation that these fuels will continue to play an important role in meeting transportation energy demand for many years.

---

109 *Hillsborough Cty., Fla. v. Automated Med. Lab'ys, Inc.*, 471 U.S. 707, 712–13 (1985) (citations omitted).

110 *Capital Cities Cable, Inc. v. Crisp*, 467 U.S. 691, 699 (1984) (quoting *Hines v. Davidowitz*, 312 U.S. 52, 67 (1941)); see also *Dowhal v. SmithKline Beecham Consumer Healthcare*, 32 Cal. 4th 910, 923, 929 (2004) (adopting federal construction of preemption issues and finding that "the use of a Proposition 65 warning would conflict with [federal] policy" on a theory of conflict preemption).

The Energy Policy Conservation Act (EPCA)	The Federal Power Act	The Energy Independence and Security Act of 2007 (EISA)
Includes provisions related to the integration of alternative fuels[111] in the transportation sector and requires a "reasonable distribution" of the burden of any energy-use restrictions: • 42 U.S.C. § 6374: Requires alternative fuel use by light duty Federal vehicles • 42 U.S.C. § 6391(b): Prohibition on "[u]nreasonably disproportionate share of burden" between segments of the business community and requires that, "[t]o the maximum extent practicable, any restriction under authorities to which this section applies on the use of energy shall be designed to be carried out in such manner so as to be fair and to create a reasonable distribution of the burden of such restriction on all sectors of the economy"	Provides for investment in alternative fuels through grant programs and loan guarantees: • 42 U.S.C. § 16501: Commercial byproducts from municipal solid waste and cellulosic biomass loan guarantee program – loans by private institutions for the construction of facilities for the processing and conversion of municipal solid waste and cellulosic biomass into fuel ethanol • 42 U.S.C. § 16503: Sugar ethanol loan guarantee program • 42 U.S.C. § 16071: Grant program for the acquisition of alternative fueled vehicles or fuel cell vehicles and the installation of related infrastructure	Includes specific provisions to increase energy security through increased production of biofuels: • Title 42, Chapter 152, Subchapter II: Programs for investment in biofuel research and infrastructure, centered around "increasing energy security," which is of special federal concern Requires blending of increasing volumes of biofuel and other renewable fuels: • 42 U.S.C. § 7545(o)(2)(B)(ii): Establishes requirements related to determining the applicable volume of cellulosic biofuel for the calendar years 2023 and later, based on considerations such as available infrastructure, consumer costs, and energy security

By contrast, ACC II would eliminate any role for these alternative fuels in California by requiring 100% ZEVs and PHEVs by 2035, removing a substantial portion of the demand for these fuels and depriving federal investments of significant value. This deprivation is made worse by the

[111] While EPCA recognizes electricity within its definition of alternative fuels, it is one of a multitude of alternatives in the Act that provide for a diverse energy base preserving flexibility and security. Overreliance on electricity does not reasonably distribute the burden of energy-use restrictions as required by the Act.

potential—indeed California's expectation[112]—that other states may adopt California's engine and motor vehicle emission standards under Section 177 of the Clean Air Act, 42 U.S.C. § 7507 and the potential that manufacturers are unlikely to produce two separate fleets (177 states vs. the rest of the country).[113]

Further, ACC II expressly contradicts EPCA's requirement that any burdens stemming from energy-use restrictions be reasonably distributed across all industry sectors, instead placing the entirety of the burden of these restrictions on the oil and gas production and refinery sector of California's economy.

Second, federal policy explicitly supports "the modernization of the Nation's electricity transmission and distribution system to maintain a reliable and secure electricity infrastructure that can meet future demand growth." 42 U.S.C. § 17381. The ACC II program conflicts with this policy by introducing material security and reliability risks to California's electricity grid.

The rapid electrification of the transportation sector will both substantially increase electricity demand in California and increase dependence on electricity services, amplifying the risk that the grid will be targeted for either physical or cyber-attacks. A 2021 Government Accountability Office Report found that "[t]he grid's distribution systems face significant cybersecurity risks—that is, threats, vulnerabilities, and impacts—and are increasingly vulnerable to cyberattacks."[114] According to the report, these risks "are compounded for distribution systems because the sheer size and dispersed nature of the systems present a large attack surface."[115] As demand increases due to accelerated electrification, grid security will pose a greater challenge due to additional resource buildout. Further, the report found that increased use of networked consumer devices that are connected to the grid's distribution systems—including electric vehicles and charging stations—also potentially introduce vulnerabilities because "distribution utilities have limited visibility and influence on the use and cybersecurity of these devices."[116] ACC II's proposed ZEV regulation will therefore introduce new vulnerabilities to the nation's distribution system by significantly increasing the use of consumer devices.

In addition, the increased demand for electricity under CARB's proposed ACC II program will worsen existing instabilities in California's grid, compromising grid reliability in direct contravention of federal policy. During a heatwave in August 2020, nearly half a million Californians lost power. As recently as July 30, 2021, Governor Gavin Newsom issued an emergency proclamation highlighting that California currently faces an energy supply shortage of up to 3,500 megawatts during the afternoon-evening net-peak period of high-power demand

---

[114] Gov't Accountability Office, *Electricity Grid Cybersecurity: DOE Needs to Ensure Its Plans Fully Address Risks to Distribution Systems*, GAO-21-81, at 11 (Mar. 2021). Available at: https://www.gao.gov/assets/gao-21-81.pdf. Accessed: May 2022.

[114] Gov't Accountability Office, *Electricity Grid Cybersecurity: DOE Needs to Ensure Its Plans Fully Address Risks to Distribution Systems*, GAO-21-81, at 11 (Mar. 2021). Available at: https://www.gao.gov/assets/gao-21-81.pdf. Accessed: May 2022.

[114] Gov't Accountability Office, *Electricity Grid Cybersecurity: DOE Needs to Ensure Its Plans Fully Address Risks to Distribution Systems*, GAO-21-81, at 11 (Mar. 2021). Available at: https://www.gao.gov/assets/gao-21-81.pdf. Accessed: May 2022.

[115] *Id*.

[116] *Id.* at 18.

on days when there are extreme weather conditions.[117] ACC II will increase demand despite existing shortfalls, undermining federal requirements targeting increased grid reliability.

Because CARB's proposed ACC II program conflicts with and presents an obstacle to clearly-stated federal objectives, CARB lacks the authority to promulgate these regulations—and indeed is preempted from doing so.

A.8 CARB ban on ICEVs constitutes a regulatory taking.

CARB's plan to eventually phase out the sales of all ICEVs constitutes a regulatory taking.[118] A regulatory taking occurs when a policy "substantially interferes with the ability of a property owner to make economically viable use of, derive income from, or satisfy reasonable, investment-backed profit expectations with respect to the property." *Jefferson St. Ventures, LLC v. City of Indio*, 236 Cal. App. 4th 1175, 1193–94.

The Associations' members have invested substantial amounts of money in making their oil facilities safe and productive, and therefore, have significant investment-backed expectations with respect to their properties, at least some of which may be forced to close as a result of CARB's electric vehicle mandate. California landowners also would be harmed. Landowners across the state receive royalties from renting their land to companies. Policies that shut down oil facilities would prevent companies and California landowners from realizing these investment-backed expectations. Thus, such policies would constitute a regulatory taking based on their substantial interference with these expectations, and the state would be obligated to provide just compensation for companies' and landowners' losses.

Therefore, as CARB considers the potential costs of policies that would shut down oil facilities, it should—at a minimum—account for the estimated costs of just compensation for the loss of property use and investment-backed expectations that would inevitably result

[117] Governor Gavin Newsom, *Proclamation of a State of Emergency* (July 30, 2021). Available at: https://www.gov.ca.gov/wp-content/uploads/2021/07/Energy-Emergency-Proc-7-30-21.pdf. Accessed: May 2022.

[118] *See* Cal. Const. art. I, § 19; U.S. Const. 5th Amend.

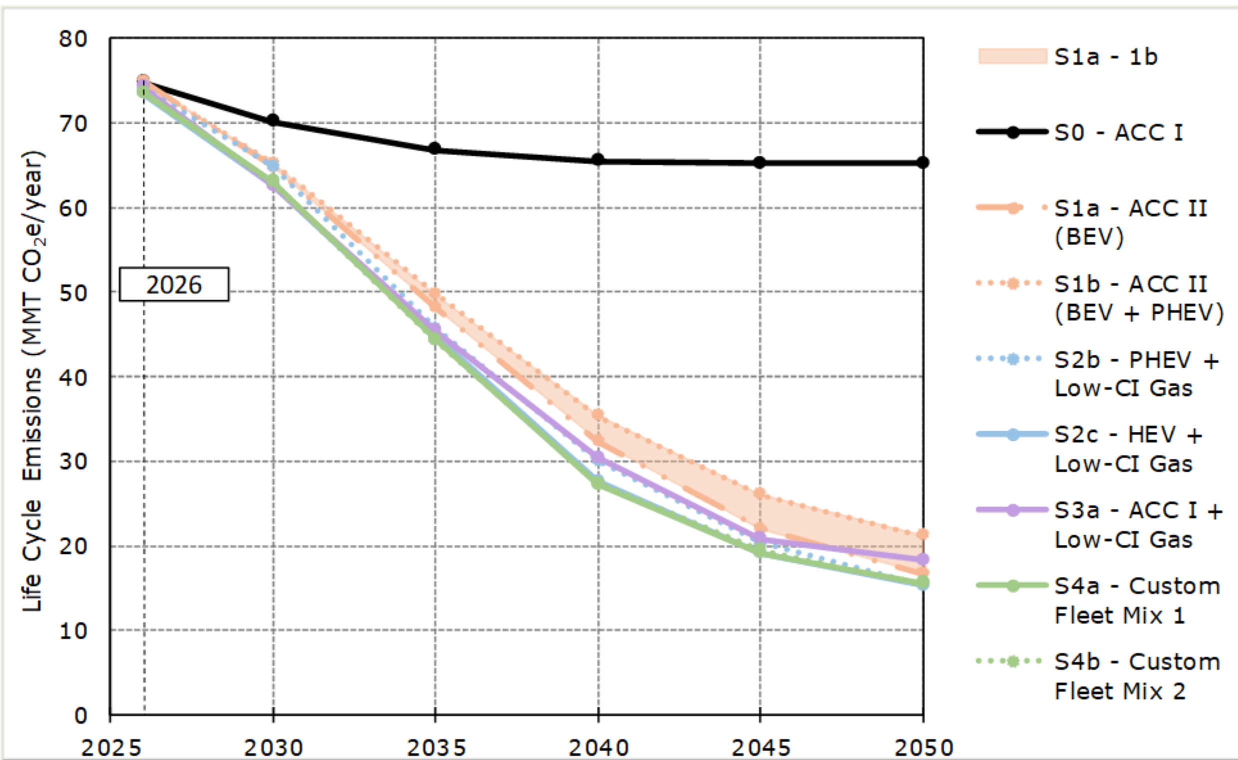
ATTACHMENT B
Technical Comments

B.1 CARB must set a technology neutral performance-based standard rather than the ZEV mandate that is currently proposed under the ACC II regulation.

Despite multiple comments by WSPA and other stakeholders over the last two years, CARB has explicitly insisted on the ZEV technology mandate in its ACC II proposal. It has failed to justify this mandate or make an argument that only the mandate can achieve the State's GHG or criteria pollutant goals. It also failed to analyze the full life cycle impacts of ZEVs, which precludes a true technology neutral comparison and overestimated ACC II GHG reductions (refer to **Comment B.3** below for further details).

WSPA contracted with Ramboll to produce the type of technology neutral study of LDVs that analyzes the full life cycle[119] GHG emissions of each technology/fuel ("Ramboll LDA Study") for the statewide light duty automobile fleet. This study (included in **Attachment D**) conclusively shows that performance standards could be an alternative to a ZEV mandate.

Figure B-1: Life Cycle Emissions for Key Scenarios



The Ramboll LDA Study shows that a gradual transition to low-CI gasoline (represented by the purple line in **Figure B-1**) with current vehicle technologies could achieve similar life cycle GHG emissions as the current ACC II proposal (represented by the pink shaded region in **Figure B-1**). The reason for this is that GHG emissions associated with zero emission vehicles are not

[119] Emissions associated with vehicle material recovery and production, vehicle component fabrication, vehicle assembly, and vehicle disposal/recycling.

zero. The GHG emissions for the "vehicle cycle" for BEVs is significantly higher than other vehicle technology types (see **Comment B.3** for additional details).

CARB must consider alternatives such as low-CI fuels because there is not a one-size-fits-all solution to reducing transportation sector GHG emissions, and it allows for more flexibility in the transition towards lowering transportation GHG emissions in the short and long-term. Other technologies also realize similar or lower emissions on a life cycle basis compared to the ACC II proposal. These include hybrid electric vehicles (HEVs) coupled with low-CI fuel (represented by blue solid line in **Figure B-1**), plug-in electric hybrid vehicles (PHEVs) coupled with low-CI fuels (represented by the blue dotted line in **Figure B-1**), and a combination of HEVs, PHEVs, and BEVs with low-CI fuels (represented by the green solid and dotted lines). These alternative pathways would also not require the wholesale transformation of electric energy production and distribution infrastructure on an unprecedented short time scale, but they would allow battery, hydrogen, and low-carbon intensity gaseous and liquid fuelled vehicles to compete to achieve the State's GHG targets for light-duty transportation in the quickest and most cost-effective manner.

CARB could craft a regulation based on a GHG-reducing performance standard such as the LCFS instead of a ZEV sales mandate, which would be more consistent with traditional regulations that rely upon innovation within existing marketplaces. The Ramboll LDA Study shows that such an approach could dramatically reduce GHG emissions without the systemic cost and delay risks associated with the current ZEV-centric strategy that include, but are not limited to, electric generation/infrastructure development, zero emission technology readiness/feasibility, and cost.

B.2 The justification for not including an alternative analysis for "Low-Carbon Fuel Technology in lieu of ZEV Requirements" due to the inability to enforce low-carbon fueling is contradicted by the mechanisms included in the current Low Carbon Fuel Standard (LCFS).

While CARB states that they considered a low-carbon fuel technology alternative to the proposed ACC II, they rejected this alternative without analysis by claiming that this type of performance-based regulation would not be "verifiable or enforceable".[120] The conclusion appears without foundation given that CARB presently administers the LCFS program, which contains established mechanisms for verification and enforcement for such a performance-based alternative. CARB acknowledges that a low-carbon fuel technology alternative may reduce GHG emissions in the near to mid-term but fails to perform an environmental or benefit-cost analyses as required by the California Environmental Quality Act (CEQA), to assist with the process of identifying the environmentally superior alternative.

California has led the nation in the use of lower-CI fuels through its LCFS regulation, which relies on market-based mechanisms that deliver sustainable GHG emission reductions without a technology-based mandate. Further, the LCFS is poised to drive further reductions in carbon

---

[120] Draft Environmental Analysis (EA) for the Proposed ACC II Program. Available at: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/accii/appe1.pdf. Accessed: May 2022.

intensity through market incentives that will produce opportunities for carbon capture and sequestration and numerous novel low-carbon fuel pathways. CARB Executive Officer Richard W. Corey described the LCFS program as "catalyzing investments in these cleaner alternative fuels, providing consumers with more choices, and reducing emissions of toxic pollutants and greenhouse gases."[121] The assertion that there is an inability to enforce low-carbon fueling discredits all the progress that the LCFS program has made over the past 10 years and is simply incorrect. CARB has claimed leadership in this space, encouraging billions of dollars of investments in developing low-carbon fuel solutions for the California market. Before arbitrarily declaring that the program is unenforceable, CARB must give serious and robust consideration to the LCFS as an alternative approach.

By employing market-based approaches instead of instituting zero emission technology mandates, CARB would allow for innovation within existing marketplaces to dramatically reduce GHG emissions without the systemic risks associated with the ZEV-centric approach concerning electric/hydrogen infrastructure development, zero emission technology readiness, and cost.

B.3 CARB did not conduct a full life cycle greenhouse gas (GHG) emissions analysis for the vehicle/fuel system to assess GHG emission impacts of their proposal and alternatives, and thus have under-represented the full emissions impact of the regulation.

The current ACC II proposal does not consider the life cycle emissions for "zero emission" vehicles, assess GHG emissions leakage outside of the state of California that would be caused by the ACC II proposal, or include a technology-neutral analysis of alternatives that could meet the GHG reduction goals. Simply put, the ACC II proposal focuses on a complete transition to zero-emission vehicle (ZEV) without consideration of other vehicle technologies or a future role for renewable fuels.[122] In the ISOR analysis, there were several stages of the emissions assessment that were excluded. The pieces of life cycle GHG emissions that were excluded from the analysis include:

- Upstream fuel cycle GHG emissions from out-of-state fuel production and transportation activities for California reformulated gasoline (CaRFG) and hydrogen (H_2), and
- GHG emissions associated with vehicle production changes required by the proposed regulation; this could be significant particularly for minerals extraction and processing and battery production, transportation, and disposal impacts for battery electric vehicles (BEVs) that are not part of the baseline for internal combustion engine vehicles (ICEVs).

Figure B-2 below outlines the scope of the CARB ACC II emissions assessment and shows what components were included/considered and what was noticeably missing from the ISOR

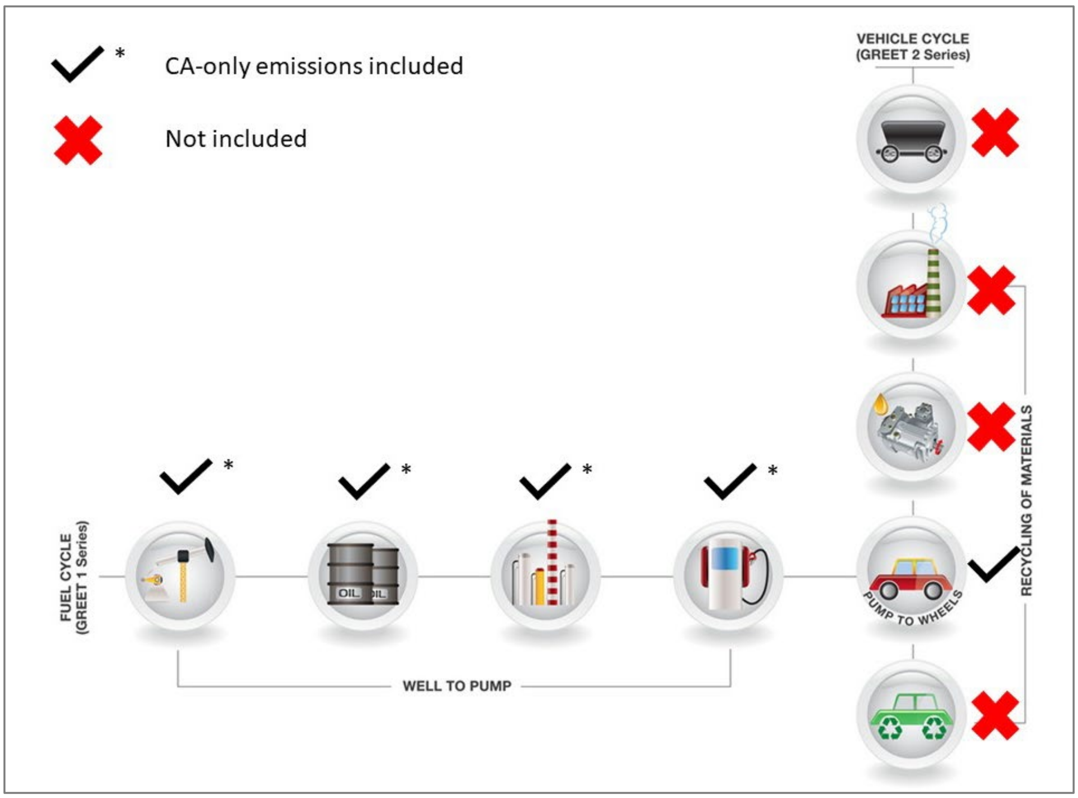
[121] Cleaner fuels have now replaced more than 3 billion gallons of diesel fuel under the LCFS. Available at: https://ww2.arb.ca.gov/news/cleaner-fuels-have-now-replaced-more-3-billion-gallons-diesel-fuel-under-low-carbon-fuel. Accessed: May 2022.

[122] Note that this is inconsistent with Federal mandates under the Renewable Fuel Standard to promote domestic production and consumption of renewable fuels in domestic transportation. 42 U.S.C. 7545.

analysis. This figure was adapted from the GREET website and shows the components that make up a comprehensive vehicle life cycle assessment.

CARB has claimed that only in-state emissions for fuels were included due to an AB 32 emission boundary at state lines. However, this boundary is a regulatory-based line that is not representative of the actual behaviour of GHG emissions. GHG emissions are global pollutants that enter the atmospheric carbon stock and cause global consequences, no matter the point of origin. CARB must assess the full life cycle emissions associated with this regulation, regardless of location of the emission. Any assessment that does not recognize these impacts misrepresents the actual environmental effects of the proposed regulation and would lead to factually incorrect conclusions that undermine any rationale for adoption of the proposed rule.

Figure B-2. CARB ACC II Emissions Assessment Scope[123]

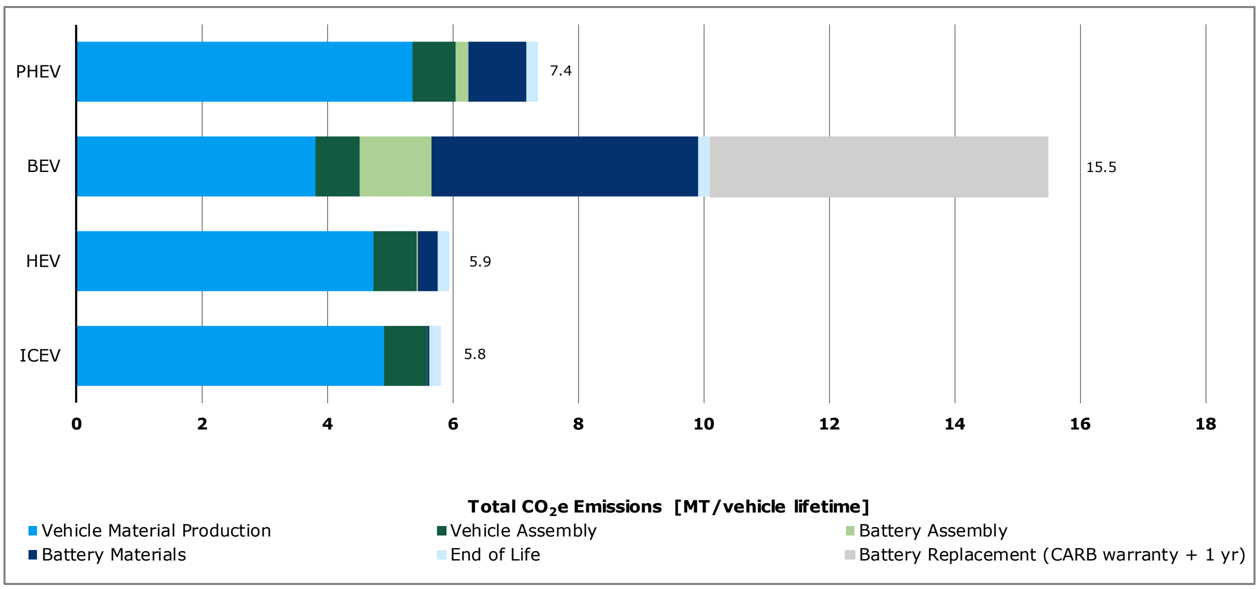


Ramboll conducted an analysis of California's light-duty auto (LDA) fleet to evaluate whether alternative vehicle technology and fuel pathways could achieve life cycle GHG emission reductions similar or greater than the ACC II proposal ("Ramboll LDA Study", included in **Attachment D**). Unlike the ISOR analysis, Ramboll has evaluated the full life cycle impacts of ZEV technologies under the ACC II proposal to more completely characterize the potential near-term and long-term GHG emissions performance and consider other pathways that would not require a replacement of the entire transportation infrastructure system.

123 GREET Model Home Page. Available at: https://greet.es.anl.gov/. Accessed: May 2022.

Vehicle cycle emissions[124] were not considered in the ISOR analysis but should be included due to the large differences in these emissions between ZEVs and ICEVs. The Ramboll LDA Study found that the vehicle cycle emissions for a model year 2026 BEVs (10.1 metric tons (MT) CO_2e per vehicle) was about 74% higher than those for a MY 2026 ICEV (5.8 MT CO_2e per vehicle) (see **Figure B-3**). If the BEV undergoes a battery replacement during its lifetime, its vehicle cycle emissions increase to 15.5 MT CO_2e per vehicle, which is ~167% higher than those of an ICEV. The significant emission increases associated with the production of a BEV, as compared to an ICEV, must be included in the ISOR emission analysis to fully understand the impacts of the proposed ACC II regulation.

Figure B-3: Vehicle Cycle GHG Emission Factors for Different Vehicle Technologies



B.4 CARB does not discuss the potential impact to the California electric grid from this regulation including requirements for new and upgraded generation, transmission, and distribution.

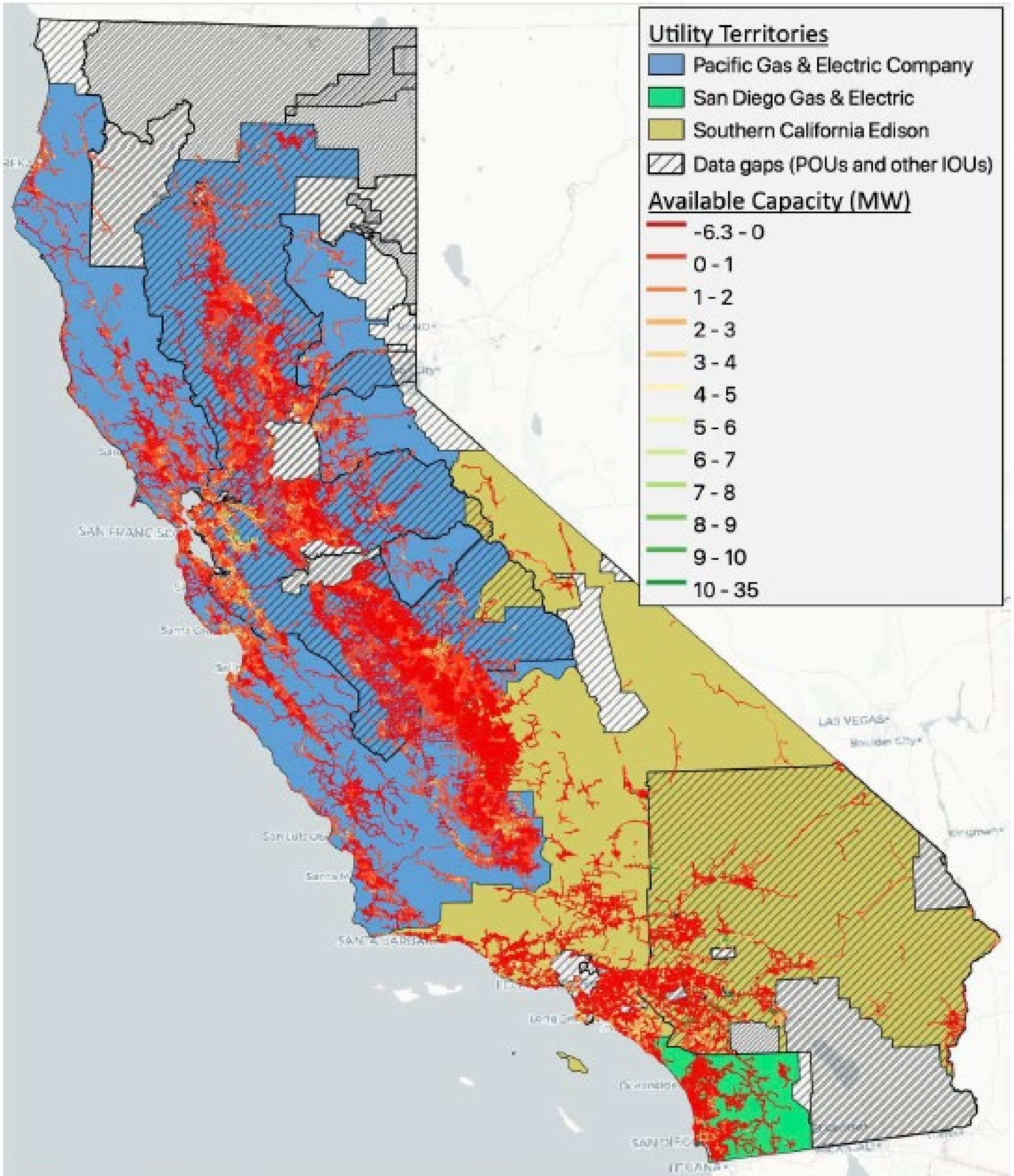
CARB has not provided any analysis of the feasibility of the proposed regulation given the significant increase of charging infrastructure, electrical generation and transmission and distribution infrastructure that would be required to support a ZEV fleet. The Capacity Analysis from CEC's EDGE Model (**Figure B-4** below, obtained from Page 48 in the Draft EA[125]) shows the grid has no additional capacity to add electrical load for charging for most of these circuits. You can see this in numerical terms in **Figure B-5** (obtained from Virtual Medium and

---

124 Emissions associated with vehicle material recovery and production, vehicle component fabrication, vehicle assembly, and vehicle disposal/recycling.

125 Draft Environmental Analysis (EA) for the Proposed ACC II Program. Available at: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/accii/appe1.pdf. Accessed: May 2022.

Figure B-4: Capacity Analysis from CEC's EDGE Model[126] (dark red indicates no available additional capacity)

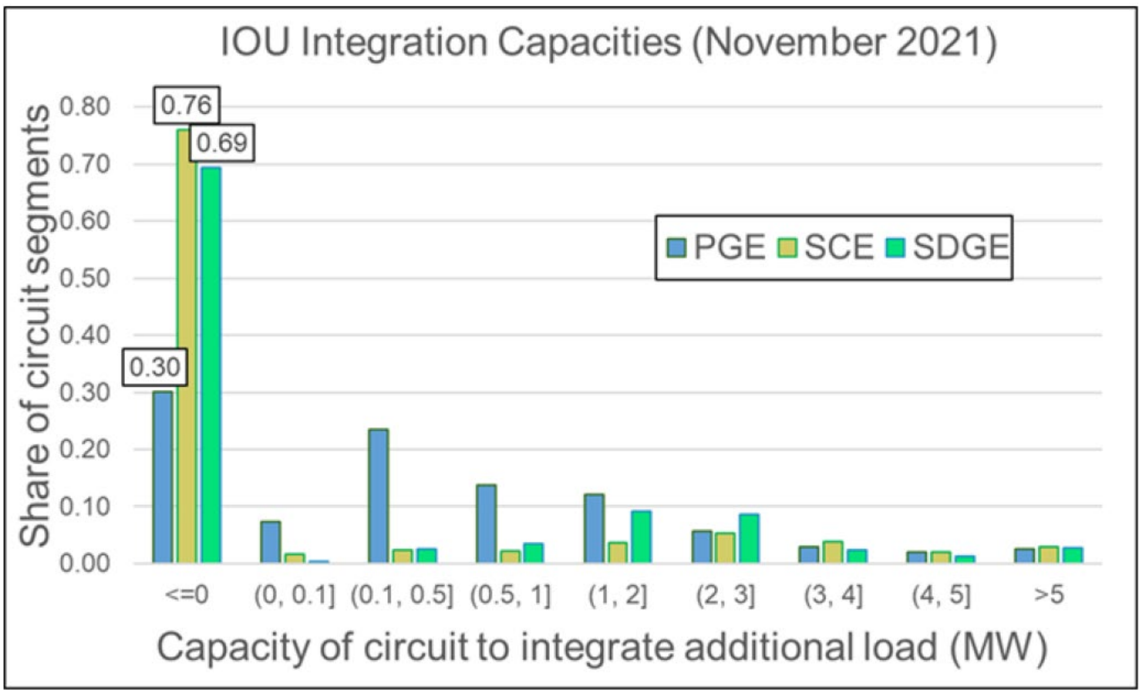


[126] Draft Environmental Analysis (EA) for the Proposed ACC II Program. Available at: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/accii/appe1.pdf. Accessed: May 2022.

Heavy-Duty Infrastructure Workgroup Meeting - Electricity and the Grid on January 12, 2022[127]), which details the capacity of circuits to integrate additional load. This figure illustrates that 30% to 76% of circuit segments have no capacity to integrate additional load. Thus, no appreciable charging capacity can be added to most of these circuits without the expenditure and time for additional construction of needed transmission and distribution infrastructure.

CARB has cited growth in the electric utilities sector and noted that new infrastructure will be needed to support this transition, however, they have failed to account for the costs of the infrastructure needed for this regulation in the SRIA,[128] and have instead ascribed benefits to the electric utilities sector for job growth. This is misleading, and CARB must evaluate the full economic impact to electric utilities as a result of this regulation rather than just account for the benefits while ignoring the required costs associated with this transition.

Figure B-5: Capacity of circuits to integrate additional loads[129]



[127] Virtual Medium and Heavy-Duty Infrastructure Workgroup Meeting - 01/12/22. Available at: https://www.youtube.com/watch?v=_mr0TmwxGZQ. Accessed: May 2022.

[128] Standardized Regulatory Impact Assessment (SRIA) for the for the Proposed ACC II Program. Available at: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/accii/appc1.pdf. Accessed: May 2022.

[129] Virtual Medium and Heavy-Duty Infrastructure Workgroup Meeting - 01/12/22. Available at: https://www.youtube.com/watch?v=_mr0TmwxGZQ. Accessed: May 2022.

B.5 The proposed ACC II strategy will place further stress on California's strained electric infrastructure and does not address measures to ensure stability and reliability of the grid during public safety power shut-off (PSPS) events.

There have been increasing number of PSPS events in California over the last five years, due in large part to an aging electrical transmission and distribution infrastructure that utility companies in California have neglected to maintain in order to reduce their costs and increase profits.[130] In 2019, PG&E explained to the California Public Utilities Commission (CPUC) that it would take 10 years to decrease PSPS event severity significantly,[131] and this does not include all the additional upgrades that will now be needed as a result of the requirements in the proposed ACC II regulation. The proposed ZEV strategy may leave California particularly vulnerable to PSPS events, which would eliminate the ability to recharge ZEVs. CARB claims that vehicle-to-grid (V2G) technology would help solve PSPS event issues, but this is assuming that a consumer would consent to feeding their electricity back into their house without knowledge of when the power would be restored. Electrical grid upgrades are needed to prevent PSPS events and increase the stability and reliability of the electric vehicle charging infrastructure. This is an issue unique to electricity as a fuel and must be analyzed. Meanwhile, the Renewable Portfolio Standard (RPS) mandates increased reliance on renewable power sources such as solar and wind, which has already posed challenges to the reliability of the California electrical grid. CARB must consider the impacts of rolling blackouts, higher utility costs, destabilization of industrial operations, and other foreseeable consequences of shifting significant additional power demand onto the grid.

B.6 CARB has failed to account for the full costs associated with the charging infrastructure and grid infrastructure upgrades in their benefit-cost analysis of the proposed ACC II regulation.

CARB estimated a benefit-cost ratio of 1.17 for the proposed ACC II regulation in the recently released SRIA[132]. This value was calculated as a ratio of the benefits associated with the rulemaking to the total costs for vehicle ownership. The list of benefits considered for this benefit-cost ratio calculation include: cost of ownership savings (gasoline fuel costs, maintenance and repair costs, electricity cost savings from V2G integration), health benefits associated with avoided health outcomes of fine particulate matter ($PM_{2.5}$) emissions, and changes in tax/fee revenues for state and local governments. The total costs for vehicle ownership include vehicle price, charger price for single family homes, sales tax, fuel (electricity and hydrogen) cost, insurance, and registration.

While the costs considered in the calculation include charger costs for single family homes (detached, attached, duplex, triplex, and quad), CARB has not accounted for the costs

---

130 Preventing Wildfires with Power Outages. Available at: https://www.psehealthyenergy.org/news/blog/preventing-wildfires-with-power-outages-2/. Accessed: May 2022.

131 Ibid.

132 ACC II Standardized Regulatory Impact Assessment (SRIA). Available at: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/accii/appc1.pdf. Accessed: May 2022.

associated with multi-family residential, public, and workplace chargers which would include direct current (DC) fast charging stations. CARB claims that the "*capital cost of public charging infrastructure is assumed to be passed through to the consumer via refueling rates*".[133] Upon further review, it appears that the commercial/residential fueling (electricity) rates used in the SRIA were developed based on the fuel forecasts in the California Energy Commission's (CEC's) 2021 Integrated Energy Policy Report (IEPR).[134] While the 2021 IEPR notes that the key driver of electricity rates is the cost of investment in the grid infrastructure (including chargers) to meet state policy goals, it also states the that the demand forecasts "*do not incorporate currently nonexistent policies, such as [the proposed] Advanced Clean Cars II*". Hence, the electricity rates do not account for the costs associated with these (multi-family residential, public, and workplace) chargers. We estimated a total cost of **$13 - 24 billion** for these chargers using the charger purchase and installation costs (**Table B-1**) from South Coast Air Quality Management District's (SCAQMD's) Final Staff Report for the Warehouse Indirect Source Rule[135] and projected number of chargers (**Table B-2**) required for the implementation of the ACC II from the Draft 2022 State Strategy for the State Implementation Plan.[136] If just the costs associated with multi-family residential/public/workplace chargers were accounted for in the ACC II SRIA benefit-cost analysis, the benefit-cost ratio would fall to 1.08-1.12.

133 See Page 169 in the SRIA.

134 Available at: https://efiling.energy.ca.gov/GetDocument.aspx?tn=241581. Accessed March 2022.

135 Available at: http://www.aqmd.gov/docs/default-source/Agendas/Governing-Board/2021/2021-May7-027.pdf?sfvrsn=10. Accessed: May 2022.

136 Available at: https://ww2.arb.ca.gov/sites/default/files/2022-01/Draft_2022_State_SIP_Strategy.pdf. Accessed: May 2022.

Table B-1. Electric Vehicle Charger Purchase and Installation Costs

EV Charger Cost Item	EV Charger Type[1]	EV Charger Level[2] (kW)	Cost Range[2] ($/charger)	
			Low Estimate	High Estimate
Purchase	LDV DC Fast Charger	19.2-50	$10,000	$30,000
	LDV Level 1 and 2 Chargers	up to 19.2	$3,000	$5,000
Installation	LDV DC Fast Charger[3]	19.2-50	$10,000	$16,518
	LDV Level 1 and 2 Chargers	Level 2	$5,000	$10,000

Notes:

[1] EV charger types based on charger levels presented in SCAQMD Warehouse ISR Staff Report.

[2] Data obtained from Table 18 in Appendix B of the Final Draft Staff Report Proposed Rule 2305 – Warehouse Indirect Source Rule. Available at: http://www.aqmd.gov/docs/default-source/Agendas/Governing-Board/2021/2021-May7-027.pdf?sfvrsn=10. Accessed March 2022.

Abbreviations:

$ - dollars, DC – direct current, EV – electric vehicle, LDV – light duty vehicle, SCAQMD – South Coast Air Quality Management District

Table B-2. Charger Costs Not Accounted for in the ACC II SRIA			
Charger Type	**Additional Chargers Needed (2026-2037)[1]**	**Low Estimate[2] (millions of $)**	**High Estimate[2] (millions of $)**
MUD (Level 1/2) Charger	420,073	3,361	6,301
Public Level 2 Charger	585,490	4,684	8,782
Work Level 2 Charger	470,133	3,761	7,052
Public DC Fast Charger	43,531	870	2,025
	Total Cost	12,676	24,160

Notes:

[1] Data obtained from Draft 2022 State Strategy for the State Implementation Plan, Figure 25. Available at: https://ww2.arb.ca.gov/sites/default/files/2022-01/Draft_2022_State_SIP_Strategy.pdf. Accessed: March 2022.

[2] Charger costs estimated as a product of the additional chargers needed (shown in this table) and the sum of the purchase and installation costs for a charger (obtained from Table A-1).

Abbreviations:

MUD - Multi-unit dwellings, DC – Direct Current

Additionally, CARB has failed to account for the electricity grid infrastructure (generation, distribution, and transmission) upgrade costs that would be necessary to support the additional load demand generated from the ACC II proposal. While the SRIA acknowledges that there would be tremendous growth in the electricity grid infrastructure and estimates the benefits of job growth in this sector, it remains silent on the costs associated with this grid infrastructure upgrades and development. As noted in the 2018 E3 Deep Decarbonization in a High Renewables Future Report (2018 E3 Report), these costs could be significant. For example, the cumulative cost for electric grid infrastructure development and maintenance for a high electrification scenario that includes the deployment of 35 million ZEVs is of $1.55 trillion from 2026-2050.[137] This value is $378 billion higher than the current policy reference case that was evaluated in that 2018 E3 Report. (Refer to Table A-3 for further details on the current policy scenario and the high electrification scenario). Hence, CARB must include the costs associated with the electricity grid infrastructure updates needed for the implementation of the proposed ACC II in their benefit-cost analysis.

[137] The grid infrastructure costs accounted for in the 2018 E3 Report include: capital, operations and maintenance (O&M), administrative, and taxes.

Table B-3. 2018 E3 Report Scenario Descriptions

Scenario Parameters	E3 CEC Study[1]	
	Reference Scenario (CEC 2018 Policy)	**High Electrification Scenario**
Meets California's 2050 GHG Emission Reduction Target?	No	Yes
Meets California's 2030 LD ZEV Targets?	No, 4M LD ZEVs	Yes, 6M LD ZEVs
2050 ZEV Population (percentages as fraction of EMFAC[2] in-state fleet in 2050)	24M LD ZEVs (68%) 303k MD/HD ZEVs (4%)	35M LD ZEVs (100%) 1.3M MD/HD ZEVs (18%)
2050 Electric Grid Mix	50% Renewable (2030 through 2050)	95% Zero Carbon 70% Renewable
2050 Building Electrification	None (2030)	91% Building Energy is Electric
2050 Total Electricity Demand (TWh)	378 TWh	456 TWh
Cumulative Cost for Electric Grid Infrastructure 2026-2050 (Trillions of $)[3]	$1.17	$1.55

Notes:

1 E3 2018 Deep Decarbonization PATHWAYS Report. Available at: https://www.ethree.com/projects/deep-decarbonization-california-cec/. Accessed April 2022.
2 EMFAC2017. Available at: https://arb.ca.gov/emfac/emissions-inventory. Accessed April 2022.
3 The grid infrastructure costs accounted for in the 2018 E3 Report include: capital, operations and maintenance (O&M), administrative, and taxes.

Abbreviations:

AEO – Annual Energy Outlook, BEV – battery electric vehicle, CEC – California Energy Commission, EIA – Energy Information Agency, HD – heavy duty, LD – light duty, M – Million, NZA – Net Zero America, TWh – terawatt hour, ZEV – zero emission vehicle

B.7 The ISOR overestimates the potential benefits associated with the vehicle-to-grid (V2G) technology.

CARB has assumed there would be savings associated with V2G technology as seen in total cost of ownership calculations. These savings begin in 2027 at $2 million, increasing over time to $5.3 billion by 2040. The cumulative savings for V2G technology are nearly 40% of the total net savings as a result of the ACC II proposal and are therefore a significant driver in the benefit-cost ratio calculation. CARB has described these purported benefits, without accounting for the costs of V2G technology on the lifetime and warranties for battery electric vehicles (BEVs). If the batteries in BEVs are used as a source of power for homes, this would increase the number of vehicle battery charging cycles without adding miles which will negatively impact the battery state of health and the lifetime. Further, BEVs currently available in the market are not intended to be used in this fashion. Hence, there is potential for the battery warranty to be voided with such use. There is no mention of V2G technology in the draft regulatory language for BEVs in the proposed ACC II.[138] Hence, warranty requirements for future BEVs manufactured to meet the sales requirements of ACC II may preclude V2G technology from being used on these vehicles. Assuming benefits for V2G technology without considering the potential cost impacts to the vehicle battery lifetime and warranty results in a one-sided benefit-cost evaluation. Additionally, CARB has assumed that up to 25% of BEV owners in single-family homes will partake in this use case, without any factual basis or hard references for these assumptions. Because of this, the savings calculated as a result of these numbers must be re-evaluated and considered carefully in the benefit-cost analysis. CARB should update the SRIA to present a more complete analysis.

B.8 CARB erroneously claims that because the proposed program will divert energy from fossil fuel-powered systems to an increasingly renewable electrical system, the regulation will not result in a significant cumulative impact related to energy, grossly oversimplifies the efforts that will be required to achieve this transition.

CARB appears to be arguing that a unit of energy is fungible regardless of its source (i.e., from the electrical grid or from liquid fuels) and that because the net consumption of energy for fueling will decrease as a result of this transition, the overall impacts to the energy sector will be less than significant. This assumption is fundamentally flawed because these two energy systems (the electrical grid and liquid fuels) are wholly independent.

The challenges associated with increasing the supply in the electrical grid will include complications of mismatched renewable energy supply and demand (i.e., duck curve), upgrading the grid infrastructure (generation, storage, transmission, and distribution) to accommodate increased electric vehicle charging.

The renewable energy supply versus demand curve (i.e., duck curve) is one example of a barrier that is unique to renewable energy that will need to be considered during the transition to electric vehicles alongside the transition to 100% renewable grid electricity. California has abundant solar energy generated during the day when demand is low and lower supply of renewable energy at night paired with higher demand when residents will want to charge their electric vehicles and power other appliances once they get home from work. This imbalance calls for advanced efforts to plan EV charging events and make improvements to the grid infrastructure to accommodate the increased demand at off-peak hours. Based on the ACC II

138 Available at: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/accii/appa9.pdf. Accessed: May 2022.

SRIA, residential charging is projected to be the second cheapest form of charging an electric vehicle battery for the foreseeable future.[139] Electric utilities will have to work with EV users to implement smart charging measures that do not exacerbate the duck curve. This planning may include increasing investment in energy storage devices that can be used to supply power at off-peak periods (I.e., night-time) when BEV users will charge their cars.

This proposed regulation will require an increase in electrical consumption on the scale of terawatt-hours (TWh's) on an annual basis. The impacts of this increased demand to the State's electrical generation, distribution, and transmission systems must be analyzed. CARB cannot assert without evidence that renewable energy would be available for the increased demand for electrical generation without impacts to the existing grid infrastructure.

The ISOR assumption that the regulation will not have a significant cumulative impact related to energy does not consider the factors described above that will generate additional stress on the electric grid. The challenges that renewable electricity presents must be analyzed, and there is no credible basis to assume that there will be no cumulative impact to energy as a result of this transition to ZEVs.

Additionally, CARB has not considered any alternatives that minimize the number of stranded liquid fuel infrastructure assets or addressed the economic impact of these stranded assets that will result by the adoption of the ACC II proposal. If this regulation were to consider a technology-neutral approach, there could be potential for existing liquid fuels infrastructure to be converted from carrying fossil fuels to renewable fuels. This has already been demonstrated by the conversion of some refineries to renewable fuel facilities.[140] There are over 14 refineries currently located in California and the total input capacity is more than 1.7 million barrels per day.[141] The liquid fuel network in California is already extensive and fully built out to scale. Hence using this existing network for the production and distribution of renewable fuels presents a lower risk scenario compared to an unprecedented rate of electrical grid infrastructure development on which the implementation of the current ACC II proposal would require.

B.9 CARB has not fully assessed the economic impact the proposed regulation would have on the liquid fuels supply chain.

CARB assumes that gasoline prices will follow the current CEC IEPR fuel price projection but has not assessed the impacts a technology mandate could have on these prices and how this will affect the domestic and foreign supply-chains. As discussed in the Stillwater Study[142] if the proposed regulation goes into effect as currently written, there will be a 66% decrease in gasoline sales by 2035 and a 90% decrease by 2050. Gasoline and petroleum-based diesel

---

139 ACC II Standardized Regulatory Impact Assessment (SRIA). Available at: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/accii/appc1.pdf. Accessed: May 2022.

140 Possible Market Implications of California's Efforts to Ban Internal Combustion Engines. Available at: https://stillwaterassociates.com/possible-market-implications-of-californias-efforts-to-ban-internal-combustion-engines/. Accessed: May 2022.

141 Ibid.

142 Ibid.

demand will be reduced to 1 billion gallons per year, which is less than half of what is produced by a moderate California facility today. As a result of this, it is likely California will consolidate or eliminate the entire petroleum refining industry in the State and shift to imported finished product (See the Stillwater Study[143] and **Attachment E**). This will lengthen the supply chain and threaten the security of supply. Capitol Matrix Consulting predicts that per-gallon petroleum prices will increase as a result of this increased importation of finished product as the supply-chain is lengthened and the fixed costs for distribution and sale of gasoline are spread over a decreasing number of customers (**Attachment E**). CARB has addressed the job and income-related impacts of declining oil and gasoline production, refining and distribution in California, but has not addressed the long-term impacts to the gasoline and diesel prices in the state and the impact this would have on consumers and the economy.

B.10 The ISOR assessment of the prices of ZEVs is unfounded and leads to a skewed cost assessment that does not fully capture the cost of ZEVs to consumers.

The ISOR estimates of the future ZEV price declines do not consider the supply-chain constraints that could have an impact on the cost of the ZEVs. Capitol Matrix Consulting (CMC) completed a review of the impact of ACC II on California Businesses (**Attachment E**) and notes that CARB has assumed a continued decrease in battery costs of ~7% per year from 2020-2030 and ~5% annually from 2030-2035. CMC found that this does not take into account key factors that drive battery prices up such as supply constraints and worldwide demand for battery-powered vehicles. CMC cites that battery prices are rising in 2022 due to increases in prices of battery-related metals. These prices could potentially continue to increase as there is a continued growing uptake of battery-powered vehicles, and this would be further exacerbated by the additional demand generated by the implementation of the ACC II proposal.

CMC estimated the resulting incremental purchase price of a EV pickup would be $16,000 in 2026 and nearly $10,000 in 2035, if the recent uptick in battery prices was taken into account and the future price decline assumptions in the SRIA were cut in half. CARB should re-evaluate they assumptions for BEV vehicles update their cost-effectiveness and benefit-cost ratio analysis to reflect the recent market trends noted in CMC's analysis (**Attachment E**).

The ISOR analysis does not address distributional impacts of the Proposed ACC II regulation. CMC also conducted a review of the distributional impacts of the ACC II proposal (**Attachment F**) and found that the incremental cost for a BEV compared to an ICE vehicle with similar features, capabilities, and range is $12,000 or more for small passenger vehicles, and well over $20,000 for high-end sedans, SUVs, and pickup trucks. The increased expenditures required to purchase and maintain a ZEV will be disproportionally felt by lower- and middle-income households. CARB must consider these cost implications when evaluating the proposed rule.

---

143 Ibid.

B.11 CARB has not demonstrated that ZEVs will meet the long-distance use cases of customers, and therefore has not demonstrated that this regulation will achieve the claimed GHG emission reductions.

The ISOR analysis has not definitively shown that BEVs will be used as a one-to-one replacement for ICEVs, which may lead to a use case that has not been addressed in the environmental assessment as currently written. The Stillwater Study[144] on Possible Market Implications of California's Efforts to Ban ICEs states that ZEVs are expected to provide only 65-95 percent of the vehicle miles travelled by their gasoline counterpart. The Study also notes that ICEVs would be typically used for infrequent long-distance trips which contribute to a majority of the GHG emissions, because today's long-range ZEVs with supercharger recharging add significantly more travel time on long trips.

While BEV ranges have continued to improve, the charging times have still lagged, and consumers may continue to use ICEVs for long-range range trips even past 2035 while they still own these vehicles if battery and charging technology do not improve significantly. CARB must consider a technology-neutral alternative, which could allow liquid fuel alternatives that would meet a performance-based standard. This could allow a phase-in of low-carbon drop-in replacement fuels that could be used in an ICEV, PHEV or HEV, thus generating near- and long-term GHG reductions for long-range applications.

B.12 CARB has not proven that consumers will be able to buy ZEVs on the schedule outlined in the rule.

While the ISOR analyses indicates that the total cost of ownership of ZEVs are less than their ICEVs counterparts, they have not evaluated if consumers will have the capital necessary to invest in ZEVs which have a higher purchase price than ICEVs. Capitol Matrix Consulting (CMC) completed a review of the impact of ACC II on California Businesses (**Attachment E**) and found that the ACC II regulation could lead to a "loss of customer discretionary income tied to higher ZEV purchase prices". As a result, customers who do not want to give up their extra discretionary income may postpone the purchase of a ZEV, resulting in lower ZEV sales rates than those assumed under the current ACC II proposal.

While CARB claims that the purchase price of ZEVs will drop rapidly in the future (~7% annually from 2026-2030 and ~5% annually from 2030-2035), current market trends indicate otherwise (refer to **Comment B.10** for further details). Affordability of ZEVs has not been guaranteed by the proposed ACC II regulation, leaving consumers with very few choices for affordable ZEVs. CARB must consider customer-related impacts of the proposed ACC II as described in the CMC analysis (**Attachment E**) while evaluating the feasibility and cost-effectiveness of their proposal.

---

[144] Ibid.

B.13 CARB has provided no foundation for the conclusion that the Proposed Program "would not result in a cumulatively considerable contribution to a significant cumulant impact related to mineral resources."

CARB has not assessed the amount of mineral resources that would be required for this regulation, and therefore has no factual basis to conclude that the impact "would be generally small when viewed in the context of global lithium markets."[145] Nor has CARB developed the factual record needed to conclude that other mineral resources needed to meet ACC II are adequate.

The findings of the 2021 International Energy Agency's report titled *The Role of Critical World Energy Outlook Special Report Minerals in Clean Energy Transitions*,[146] indicate that a typical electric car would require six times the amount of mineral inputs compared to a conventional vehicle. This report also stated that the rapid deployment of clean energy technologies (including EVs) would result in a significant impact on mineral resources, and that there are currently not enough of these resources available to meet this demand.

CARB must provide a basis for their significance argument, including but not limited to an estimate of the minerals required to manufacture the ZEVs mandated by this proposed regulation, the potential strain on global mineral resources, and impacts to the global supply chains for lithium, cobalt, nickel, and other critical minerals. The assessment should include sensitivity analysis to determine how costs and availability may be affected by mineral scarcity and global supply chain disruptions.

While CARB did not provide mineral resource estimates for the proposed regulation, CARB does provide an estimate for the projected annual increase in battery production in Table 4 of the Draft EA.[147] These projections show an annual increase in battery production, ranging from 43.2 gigawatt-hours (GWh) in 2026 to 150.8 GWh in 2035. The recently released Assembly Bill (AB) 2832 Lithium-ion Car Battery Recycling Advisory Group Final Report cites that over 60 GWh of Li-ion battery capacity has been deployed in the US EV market from 2010-2020.[148] In the current proposal, CARB expects that two-thirds of this capacity that was deployed over the last decade, would be made available during the first year of the rule implementation. CARB also projects that the annual battery production capacity would continue to increase into the future reaching levels that are two and a half times the production capacity deployed in the last decade. This unprecedented ramp-up in battery production capacity which in turn would lead to

[145] CARB. Draft Environmental Assessment. Available at: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/accii/appe1.pdf. Accessed: May 2022.

[146] International Energy Agency (IEA). 2021. The Role of Critical World Energy Outlook Special Report Minerals in Clean Energy Transitions. Available at: https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions. Accessed: May 2022.

[147] CARB. Draft Environmental Assessment. Available at: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/accii/appe1.pdf. Accessed: May 2022.

[148] Available at: https://calepa.ca.gov/wp-content/uploads/sites/6/2022/05/2022_AB-2832_Lithium-Ion-Car-Battery-Recycling-Advisory-Goup-Final-Report.pdf. Accessed: May 2022.

a similar ramp up of mineral extraction cannot be ignored. CARB must first analyze and evaluate these impacts before rushing to conclude that they are "not significant".

B.14 The ISOR assertion that no new facilities will be required to manufacture ZEVs is likely not representative of reality. The manufacturing process of ZEVs greatly differs from that of ICEVs and will require dedicated facilities outside of the existing ICEV manufacturing facilities.

CARB has failed to fully address the additional resources and facilities that will be needed to ramp up electric vehicle production to meet the proposed state zero-emission vehicle mandate. CARB has stated that they assume that existing vehicle manufacturing facilities will be able to meet the growing demand for ZEVs, but this assumption fails to account for the differences in the manufacturing processes between ICEVs and ZEVs.

As CARB describes in the Draft EA, Lithium-ion (Li-ion) batteries can pose a potential risk if damaged, exposed to a fire or a heat source, or poorly packaged.[149] This risk will need to be mitigated through additional measures, which could include additional training of facility operators, emergency responders, and manufacturing personnel and additional design measures added to vehicle manufacturing facilities. The assumptions that no new facilities will be required assumes that all these upgrades can take place at existing ICEV manufacturing facilities. This assumption is made without any factual basis. CARB must consult with existing ICEV and ZEV manufacturers to understand the differences in the manufacturing processes and use this information to assess and evaluate the environmental and economic impacts associated with the conversion of ICEV manufacturing facilities to ZEV manufacturing facilities.

B.15 The ISOR misrepresents potential impacts to public services, utilities, and service systems.

CARB must comprehensively address the full potential of impacts to public services, utilities, and service systems to understand the potential environmental and economic impacts this regulation will have, including the potential impact on the State's GHG reduction goals as well as its criteria pollutant emissions goals. Increased use of high-capacity battery storage and high-voltage upgrades to the grid's electrical distribution and transmission infrastructure may lead to increased risk of wildfires, which would have an impact on fire response and other emergency services. CARB recognized that the increased reliance on the electrical grid and increase in infrastructure needed could lead to increased risk of wildfire ignition, but they have failed to fully account for the environmental effects of this impact and impacts on public services such as CAL FIRE. According to a letter by the California State Auditor, 19% of CAL FIRE-reported acres burned from 2019-2020 were caused by electrical power. [150] A scale-up of the grid in response to the ZEV mandate could have detrimental effects on public services that support fire-suppression and wildfire response.   These impacts may be significant. A January

---

[149] Available at: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/accii/appe1.pdf. Accessed: May 2022.

[150] California State Auditor. Electrical System Safety: California's Oversight of the Efforts by Investor-Owned Utilities to Mitigate the Risk of Wildfires Needs Improvement. Available at: https://www.bsa.ca.gov/reports/2021-117/. Accessed: May 2022.

2021 study by Stanford researchers modelling the effects of wildfires on ambient air quality indicated that the contribution of wildfire smoke to $PM_{2.5}$ concentrations currently accounts for up to half of the overall $PM_{2.5}$ exposures in western regions of the United States.[151] CARB must perform a full economic and emissions analysis of the potential impacts of increased wildfire risk as a result of the proposed ACC II regulation.

B.16 CARB must provide justification as to why rescinding the SAFE rule would result in an increase in BEVs in the State's baseline fleet from ~11% to ~19% in 2026.

The Emissions Inventory Methods for the ACC II analysis (ISOR Appendix D) appear to update the baseline BEV and PHEV sales following the rescinding of the Safer Affordable Fuel-Efficient Vehicles (SAFE) rule. However, in the newest version of EMFAC released (v1.0.2), the light-duty auto (LDA) population in 2026-2050 does not appear to change relative to the population from the previous version of EMFAC (v1.0.1), which included the SAFE rule. It is not clear how CARB has derived these new ZEV vehicle baseline population values presented in the ISOR Appendix D, and their basis for increasing the BEV population baseline based on the rescinding of the SAFE rule is similarly unclear. The SAFE rule sets a standard for GHG emission reductions, not a mandate of increased BEV and PHEV sales. CARB must provide justification as to why this would result in an increase in BEVs in the State's fleet from ~11% to ~19% in 2026 given the SAFE rule does not require the sale of ZEVs and provide EMFAC runs to show where how this new population baseline was derived to ensure transparency in their emissions inventory development through this rulemaking process.

151 Available at: https://www.pnas.org/doi/10.1073/pnas.2011048118. Accessed: May 2022.

ATTACHMENT C
List of Previous WSPA Comments on the Proposed ACC II Regulation

October 27, 2021 Comments[152]

1. CARB's credit pooling concept requires further discussion.
2. CARB must include lower-carbon alternative fuel and engine technologies.

September 1, 2021 Comments[153]

1. CARB must evaluate lower-CI vehicle/fuel systems, similar to the evaluation for the BEV/electrical grid system. Such an evaluation would show that there are additional cost-effective options, which build on the Low Carbon Fuel Standard (LCFS) and other successful programs, for reducing GHG emissions.
2. CARB must determine if additional ZEV requirements could increase consumer costs and potentially delay ZEV deployment, assess if new PHEV and LEV standards are appropriate, and evaluate how these factors may impact the emission benefits sought in ACC II.
3. It is CARB's responsibility to provide analyses on alternatives to the draft regulatory proposal that include emissions and cost benefits analyses, whether or not stakeholders provide analyzed alternatives.
4. CARB must clarify and expand the scope of the Environmental Analysis (EA) to ensure that all indirect and unintentional impacts from this rule are being considered, as required under CEQA.
    a. Note: CARB claims that the upstream emissions of electricity generation will be accounted for in the analysis, but has not yet published the analysis
5. CARB's assumptions in the ZEV Cost Modeling workbook released prior to the May 6th ACC II workshop are optimistic and do not reflect the true cost increase that consumers would likely experience while purchasing a ZEV.
    a. Note: CARB has updated some of these parameters but has not released an updated cost analysis workbook.
6. We respectfully request that CARB respond to our prior June 11th comment letter (Attachment A) and this letter.

June 11, 2021 Comments[154]

1. Evaluate multiple vehicle/fuel technology scenarios instead of focusing on an electric vehicle (EV) centric approach to reducing NOx and Greenhouse Gas (GHG) emissions from light-duty and medium-duty vehicles (LD/MDVs)

---

152 WSPA Comments on the October 13, 2021, Public Workshop on the ACC II Regulation. Available at: https://www.arb.ca.gov/lists/com-attach/27-accii-comments-w3-ws-UwxTMwFpAz5XMAhk.pdf. Accessed: April 2022.

153 WSPA Comments on the August 11, 2021 Public Workshop on the ACC II Regulation. Available at: https://www.arb.ca.gov/lists/com-attach/19-accii-comments-w3-ws-BXJVIF0sBDZWDwVm.pdf. Accessed: April 2022.

154 WSPA Comments on the May 6, 2021 Public Workshop on the ACC II Regulation. These comments are not posted online.

2. Justify that a bifurcated criteria air pollutant emission standard for ZEVs and non-ZEVs will be a cost-effective pathway to achieve emission reductions
3. Evaluate the impact of the proposed ZEV penetration on the state-wide particulate matter (PM) inventory (notably, due to heavier battery electric vehicles (BEVs)), especially in PM2.5 nonattainment areas
4. Consider the costs of additional road maintenance and loss of revenue from fuel sales into a techno-economic feasibility and cost-effectiveness assessment
5. Assess how future electric grid reliability and infrastructure needs will affect the feasibility of CARB's proposed ZEV purchase mandate
6. Evaluate potential electric vehicle battery supply chain requirements, especially demand for critical mineral resources which would be necessary to support the proposed ZEV sales mandate
7. Evaluate the feasibility of achieving CARB's anticipated near-term ZEV sales targets given current low adoption rates and consumer concerns
8. Address shortfalls in BEV performance that fail to satisfy end-uses currently met by internal combustion engines (ICEs)
9. Incorporate the cost implications of the proposed Durability and Minimum Warranty Requirements on the future sales prices of ZEVs
10. Account for increased financial burden on non-dealer Independent Repair Shops resulting from ZEV transition
11. Provide data regarding the expected emission impacts of medium duty vehicle travel that is in towing mode
    a. Note: CARB presented some verbal comments about the emissions impact of this regulation but has not provided emission calculations

ATTACHMENT D

"Multi-Technology Pathways To Achieve California's Greenhouse Gas Goals: Light-Duty Auto Case Study" by Ramboll dated May 31, 2022

Prepared for
Western States Petroleum Association
Sacramento, California

Prepared by
Ramboll US Consulting, Inc.
Irvine, California

Project Number
1690024977

Date
May, 2022

MULTI-TECHNOLOGY PATHWAYS TO ACHIEVE CALIFORNIA'S GREENHOUSE GAS GOALS:

LIGHT-DUTY AUTO CASE STUDY

Ramboll US Consulting, Inc.
5 Park Plaza
Suite 500
Irvine, California 92614
(949) 261-5151
(949) 261-6202

CONTENTS

		Page
EXECUTIVE SUMMARY		**1**
1.	**INTRODUCTION**	**1**
1.1	Proposed ACC II Regulation Summary	1
1.2	Purpose of this Study	2
2.	**MULTI-TECHNOLOGY SCENARIOS: LIGHT-DUTY VEHICLE FLEET EXAMPLE**	**3**
3.	**SCENARIO ANALYSIS METHODOLOGY**	**15**
3.1	Vehicle Technologies	16
3.1.1	Internal Combustion Engine Vehicles	16
3.1.2	Battery Electric Vehicles	17
3.1.3	Plug-In Hybrid Electric Vehicles	17
3.1.4	Hybrid Electric Vehicles (HEVs)	18
3.2	Fuel Cycle Emissions	19
3.2.1	Upstream (Well-to-Tank) Emissions	19
3.2.2	Tailpipe (Tank-to-Wheel) Emissions	27
3.3	Vehicle Cycle Emissions	29
3.3.1	Vehicle Cycle Emission Factors	30
3.3.2	Vehicle Cycle GHG Emissions in Scenario Analysis	32
3.3.3	GHG Emissions from Lithium Battery Replacement	34
4.	**SCENARIO ANALYSIS EMISSIONS RESULTS**	**36**
4.2	Life Cycle Emissions	40
4.3	Life Cycle Emissions with BEV Battery Replacement	44
5.	**CONCLUSIONS**	**47**
5.1	Summary of Analysis Conclusions	47
5.2	Next Steps – Technical	47

TABLES

Table 2-1. ZEV Sales Requirements in the Proposed ACC II Regulation	3
Table 3-1. Low-CI Fuel Carbon Intensity Summary	23
Table 3-2. Tailpipe Emission Assumptions	27

FIGURES

Figure ES-1: Life Cycle Emissions for Key Scenarios 2
Figure 2-1. LDA New Vehicle Sales Fractions for Scenarios 0, 1a, 1b, 1c, 1d, and 2a 8
Figure 2-2. LDA New Vehicle Sales Fractions for Scenarios 2b, 2c, 3a, 4a, 4b, and 4c 9
Figure 2-3. LDA Fleet Mixes for Scenarios 0, 1a, 1b, 1c, 1d, and 2a 10
Figure 2-4. LDA Fleet Mixes for Scenarios 2b, 2c, 3a, 3b, 4a, 4b, and 4c 11
Figure 2-5. Fuel Usage Fractions for Scenarios 0, 1a, 1b, 1c, 1d, and 1d-1 12
Figure 2-6. Fuel Usage Fractions for Scenarios 2a, 2b, 2c, 3a, 3b, and 4a 13
Figure 2-7. Fuel Usage Fractions for Scenarios 4b and 4c 14
Figure 3-1. Fuel Cycle and Vehicle Cycle Emissions Representation in the GREET Model 15
Figure 3-2. Upstream (EER-unadjusted) GHG Emission Factors by Fuel Type 20
Figure 3-3. Upstream (EER-adjusted) GHG Emission Factors by Fuel Type 21
Figure 3-4: Feedstock Breakdown for CARB SRIA H_2 25
Figure 3-5: Vehicle Cycle and Battery Replacement GHG Emission Factors 31
Figure 3-6: LDA Vehicle Population in EMFAC2021 34
Figure 4-1: Fuel Cycle Emissions for Baseline Scenarios 37
Figure 4-2: Fuel Cycle Emissions for Alternative Scenarios Part 1 38
Figure 4-3: Fuel Cycle Emissions for Alternative Scenarios Part 2 39
Figure 4-4: Fuel Cycle Emissions for Alternative Scenarios Part 3 40
Figure 4-5: Life Cycle Emissions for Baseline Scenarios 41
Figure 4-6: Life Cycle Emissions for Alternative Scenarios Part 1 42
Figure 4-7: Life Cycle Emissions for Alternative Scenarios Part 2 43
Figure 4-8: Life Cycle Emissions for Alternative Scenarios Part 3 43
Figure 4-9: Life Cycle Emissions with BEV Battery Replacement for Baseline Scenarios 45
Figure 4-10: Life Cycle Emissions with BEV Battery Replacement for Alternative Scenarios Part 1 45
Figure 4-11: Life Cycle Emissions with BEV Battery Replacement for Alternative Scenarios Part 2 46
Figure 4-12: Life Cycle Emissions with BEV Battery Replacement for Alternative Scenarios Part 3 46

APPENDICES

Appendix A: Scenario Analysis Assumptions and Detailed Methodology

ACRONYMS AND ABBREVIATIONS

AB:	Assembly Bill
ACC:	Advanced Clean Cars
ANL:	Argonne National Laboratory
BEV:	battery electric vehicle
CA-GREET:	California's Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation Model
CAP:	criteria air pollutant
CARB:	California Air Resources Board
CARBOB:	California reformulated gasoline blendstock for oxygenate blending
CaRFG:	California reformulated gasoline
CEC:	California Energy Commission
CEQA:	California Environmental Quality Act
CH_4	methane
CI:	carbon intensity
CO_2:	carbon dioxide
CO_2e:	carbon dioxide equivalent
cVMT:	combustion vehicle mile traveled
CY:	calendar year
DSL:	diesel
E3:	Energy + Environmental Economics
EA:	environmental assessment
EER:	energy economy ratio
eGRID:	Emissions & Generation Resource Integrated Database
EMFAC:	EMission FACtors Model
EPA:	Environmental Protection Agency
EV:	electric vehicle
eVMT:	electric vehicle mile traveled
FCEV:	fuel cell electric vehicle
g:	gram
GHG:	greenhouse gas
GREET:	Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation Model
GWP:	global warming potential

H_2:	hydrogen
HEV:	hybrid electric vehicle
ICE:	internal combustion engine
ICEV:	internal combustion engine vehicle
IPCC:	International Panel on Climate Change
ISOR:	Initial Statement of Reasons
kWh:	kilowatt-hour
LCFS:	Low Carbon Fuel Standard
LDA:	light-duty auto
LDT1:	light-duty truck 1
LDT2:	light-duty truck 2
LDV:	light-duty vehicle
Li-ion:	lithium ion
mi:	mile
MJ:	megajoule
MMT:	million metric tons
MPG:	miles per gallon
MPGe:	miles per gallon equivalent
MT:	metric ton
MSS	Mobile Source Strategy
MY:	model year
N_2O	nitrous oxide
NG:	natural gas
NMC:	nickel manganese cobalt
PHEV:	plug-in hybrid electric vehicle
SMR:	steam methane reforming
SOC:	state of charge
SRIA:	Standardized Regulatory Impact Assessment
US:	United States
VMT:	vehicle mile traveled
ZEV:	zero emission vehicle

EXECUTIVE SUMMARY

The California Air Resources Board (CARB or Board) Advanced Clean Cars program aims to reduce criteria air pollutants (CAP) and greenhouse gas (GHG) emissions throughout the state by setting regulations and standards aimed at light-duty vehicles (LDVs). The newest generation of rulemaking that has been drafted is the Advanced Clean Cars II (ACC II) proposal and is expected to be presented to the Board in summer 2022. This proposal introduced by CARB includes setting zero emission vehicle (ZEV) sales mandates for model year 2026 and later passenger cars and light-duty trucks (i.e., light-duty vehicles, LDVs). This proposed sales mandate would begin at 35% in 2026 and ramp up to 100% for the 2035 model year and beyond.[1] The stated aim of the ACC II proposal is to reduce CAP and GHG emissions through a ZEV sales mandate. This technology mandate is different from traditional CARB motor vehicle regulations that set engine emission standards or emission-based performance standards that allowed multiple lower-emitting technologies to compete. Although a stated goal is to reduce GHG emissions, the current ACC II proposal does not consider or analyze the full life cycle emissions for "zero emission" vehicles, account for greenhouse gas emissions leakage that would be caused outside of the state of California by the ACC II proposal, or include a technology-neutral analysis of alternatives that could help meet the greenhouse gas reduction goals. Simply put, CARB's ACC II proposal focuses on a complete transition to ZEVs without a full accounting of GHG emissions impacts, and without consideration of other vehicle technologies or a future role for renewable and other low carbon fuels.

Ramboll has conducted an analysis of California's light-duty auto (LDA) fleet to evaluate whether alternative vehicle technology and fuel pathways could achieve life cycle GHG emission reductions similar or greater than the ACC II proposal. Unlike CARB's analysis, Ramboll has evaluated the full life cycle impacts of ZEV technologies under the ACC II proposal to more completely characterize the potential near-term and long-term GHG emissions performance and considers other pathways that would not require a replacement of the entire transportation infrastructure system. These alternative pathways would also not require the wholesale transformation of electric energy production and distribution infrastructure on an unprecedented short time scale, but they would allow battery, hydrogen, and low-carbon intensity gaseous and liquid fueled vehicles to compete to achieve the State's GHG targets for light-duty transportation in the quickest and most cost-effective manner.

> Ramboll's **multi-technology pathways analysis** demonstrates that there are multiple light duty vehicle technology and fuel pathways that can meet California's GHG emission reduction targets.

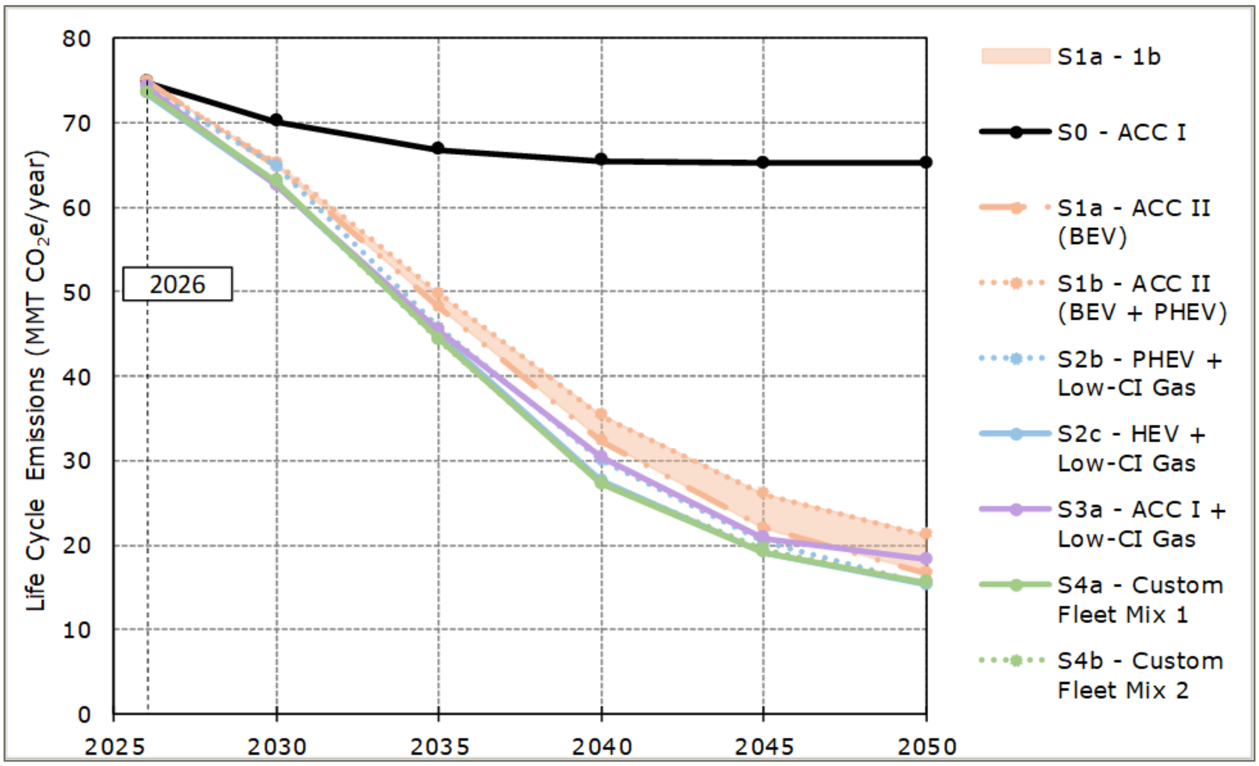
The main conclusions of our analysis are:

- Zero emission vehicle technology is only one of many different technology/fuel scenarios that could be utilized to meet California's GHG emission reduction targets;
- A full life cycle emission assessment is necessary if GHG reductions are a goal of the regulation, in order to understand the cradle-to-grave effects of a given vehicle/fuel technology pathway;

[1] California Air Resources Board (CARB). 2022. Appendix A-5: Proposed Regulation Order for Section 1962.4 Zero-Emission Vehicle Standards for 2026 and Subsequent Model Year Passenger Cars and Light-Duty Trucks. April 12. Available at: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/accii/appa5.pdf. Accessed: May 2022.

- BEV technology of the scope and schedule proposed under ACC II would require technology and electrical generation/infrastructure developments that CARB has not analyzed and cannot mandate, control, or incentivize;
- There is a growing potential for renewable and low carbon fuels, including some with negative carbon intensity (CI), to meet long-term GHG reduction targets for light-duty transportation;
- Low-CI gasoline (included in scenarios represented by the blue, purple, and green lines in **Figure ES-1**) could decarbonize the transportation sector at a rate comparable to a ZEV-only regulation (represented by the pink shaded region in **Figure ES-1**); and
- Allowing the market flexibility to meet emission reduction targets could lead to a more diverse deployment of fuel and vehicle technologies to meet State targets.

Figure ES-1: Life Cycle Emissions for Key Scenarios



These conclusions show that GHG reductions attributed by CARB to the proposed ACC II regulation are incomplete and emphasize the need for CARB to conduct a full life cycle GHG emission assessment to quantify the cradle-to-grave effects of the draft ACC II proposal. As demonstrated in this study, a full life cycle analysis demonstrates that there are multiple GHG-reducing vehicle/fuel technologies that, individually or in combination, have equivalent GHG reductions as ZEV-mandated ACC II proposal. CARB should revise the environmental analysis to consider all feasible vehicle/fuel pathways that could achieve the State's emission reduction goals. This must be done in the alternative analyses presented in the Standardized Regulatory Impact Assessment (SRIA)[2] and the Environmental Assessment (EA)[3] for the proposed ACC II, including evaluations of the environmental, cost, and socioeconomic impacts of the different technology pathways. Consistent with rule development precedent, the results of this broader alternative analyses should inform the appropriate revisions to the draft ACC II rule language.

[2] CARB. 2022. Appendix C-1: Standardized Regulatory Impact Assessment (SRIA). April 12. Available at: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/accii/appc1.pdf. Accessed: May 2022.

[3] CARB. 2022. Appendix E-1: Draft Environmental Analysis for the Proposed Advanced Clean Cars II Program. April 12. Available at: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/accii/appe1.pdf. Accessed: May 2022.

1. INTRODUCTION

1.1 Proposed ACC II Regulation Summary

The California Air Resources Board (CARB) Advanced Clean Cars program aims to reduce criteria air pollutants (CAP) and greenhouse gas (GHG) emissions throughout the state by setting regulations and standards aimed at LDVs. The newest generation of rulemaking that has been drafted is the Advanced Clean Cars II (ACC II) proposal and is expected to be presented to the Board in summer 2022. This proposal introduced by CARB includes setting zero emission vehicle (ZEV) sales mandates for model year 2026 and later passenger cars and light-duty trucks (i.e., light-duty vehicles, LDVs). This proposed sales mandate begins at 35% in 2026 and would ramp up to 100% for the 2035 model year and beyond.[4] The stated aim of the ACC II regulation is to reduce CAP and GHG emissions through a ZEV sales mandate. This technology mandate is different from traditional CARB motor vehicle regulations that set engine emission standards or emission-based performance standards that allowed multiple lower-emitting technologies to compete. Although a stated goal is to reduce GHG emissions, the current ACC II proposal does not consider or analyze the full life cycle emissions for "zero emission" vehicles, account for greenhouse gas emissions leakage that would be caused outside of the state of California by the ACC II proposal, or include a technology-neutral analysis of alternatives that could help meet the greenhouse gas reduction goals. Simply put, CARB's ACC II proposal focuses on a complete transition to ZEVs without a full accounting of GHG emissions impacts, and without consideration of other vehicle technologies or a future role for renewable and other low carbon fuels.

The current ACC II proposal takes a narrow approach to achieving the State's GHG emission goals by setting a ZEV mandate, rather than setting performance-based emission targets. The alternatives analyzed in the Standardized Regulatory Impact Assessment (SRIA)[5] and the Environmental Assessment (EA)[6] for the proposed ACC II represent varying penetration rates for ZEV sales mandates for the 2026 through 2035 model years, and do not include a performance-based analysis of technology/fuel alternatives.

Additionally, CARB has not conducted a full life cycle GHG analysis for the vehicle/fuel system to assess GHG emission impacts of their proposal and alternatives. CARB did not consider the upstream fuel cycle GHG emissions from out-of-state fuel production and transportation activities for California reformulated gasoline (CaRFG) and hydrogen (H_2), and vehicle cycle GHG emissions associated with the vehicle production. These life cycle emissions are significant, particularly for battery electric vehicles (BEVs) as compared to internal combustion engine vehicles (ICEVs), due to the energy-intensive nature of producing a BEV battery. Failure to consider these GHG emissions has the effect of overstating the emissions benefits of the proposed ACC II regulation.

---

4 California Air Resources Board (CARB). 2022. Appendix A-5: Proposed Regulation Order for Section 1962.4 Zero-Emission Vehicle Standards for 2026 and Subsequent Model Year Passenger Cars and Light-Duty Trucks. April 12. Available at: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/accii/appa5.pdf. Accessed: May 2022.

5 CARB. 2022. Appendix C-1: Standardized Regulatory Impact Assessment (SRIA). April 12. Available at: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/accii/appc1.pdf. Accessed: May 2022.

6 CARB. 2022. Appendix E-1: Draft Environmental Analysis for the Proposed Advanced Clean Cars II Program. April 12. Available at: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/accii/appe1.pdf. Accessed: May 2022.

1.2 Purpose of this Study

The proposed ACC II regulation would prescribe a ZEV-centric pathway to achieve the State's long-term climate goals through sales mandates. Ramboll conducted an analysis of California's light-duty auto (LDA) fleet to evaluate alternative vehicle technology and fuel pathways that could achieve life cycle GHG emission reductions similar or greater than the ACC II proposal. Ramboll's analysis approaches the State's climate goals from an emission reduction or environmental performance perspective, rather than a technology mandate and a potential means to allow increased market flexibility. This analysis evaluates the life cycle impacts of ACC II to more fully characterize the potential near-term and long-term GHG emissions reductions of that proposal and considers alternative technology/fuel pathways that would not require an overhaul of the entire transportation infrastructure system. These alternative pathways would not require the wholesale transformation of energy production and distribution infrastructure on an unprecedented short time scale, but they would allow battery, hydrogen, and low carbon intensity gaseous and liquid fueled vehicles to potentially co-exist in a market to achieve the State's GHG targets in the quickest and most cost-effective manner.

This white paper provides a summary of the methodology, results, and conclusions of Ramboll's analysis.

2. MULTI-TECHNOLOGY SCENARIOS: LIGHT-DUTY VEHICLE FLEET EXAMPLE

The CARB ACC II proposal would prescribe a sales mandate for ZEVs in the LDV fleet in order to meet California's long-term climate goals. **Table 2-1** below presents the proposed ZEV sales requirements for the statewide LDV fleet as contained in the draft ACC II regulation released on April 12, 2022. As shown in the table, the draft ACC II regulation requires manufacturers that produce and deliver LDVs for sale in California to meet increasing ZEV sales fractions from 35% in the 2026 model year, 68% in 2030, and 100% by the 2035 model year and beyond. In the proposed ACC II regulation, CARB does not consider or assess other scenarios that could use a mix of alternative vehicle and fuel technologies to achieve the California's long-term climate goals.

Table 2-1. ZEV Sales Requirements in the Proposed ACC II Regulation[7]

Model Year	Percentage Requirement
2026	35%
2027	43%
2028	51%
2029	59%
2030	68%
2031	76%
2032	82%
2033	88%
2034	94%
2035 and subsequent	100%

Ramboll's analysis presented in this report evaluates the potential GHG emission benefits for a series of technology and fuel scenarios for a subset of the statewide LDV fleet consisting of light-duty autos (LDAs)[8] from calendar year 2026 through 2050. Specifically, Ramboll's scenario analysis considers gasoline-fueled ICEVs, BEVs, plug-in hybrid electric vehicles (PHEVs), hybrid electric vehicles (HEVs), and fuel cell electric vehicles (FCEVs).[9] Additional information on each of the vehicle technologies considered in this analysis is presented in **Section 3.1**. The purpose of this analysis is to evaluate if there are alternative vehicle/fuel

[7] CARB. 2022. Appendix A-5: Proposed Regulation Order for Section 1962.4 Zero-Emission Vehicle Standards for 2026 and Subsequent Model Year Passenger Cars and Light-Duty Trucks. April 12. Available at: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/accii/appa5.pdf. Accessed: May 2022.

[8] LDVs subject to ACC II ZEV sales requirements include the LDA, LDT1, and LDT2 vehicle classes in EMFAC2021. Only the LDA vehicle class is considered in Ramboll's analysis.

[9] Natural gas vehicles are excluded as they are not included in the default EMFAC2021 LDA fleet. Diesel vehicles are not included in this analysis because they comprise less than 0.3% of the total LDA population in EMFAC2021.

technology pathways besides CARB's ACC II proposal that could achieve life cycle GHG emission reductions similar or greater than the ACC II proposal and meet the State's long-term climate goals. Because CARB does not provide a breakdown between the classes of LDVs included in the ACC II proposal, Ramboll's analysis of the proposed ACC II scenarios assumes the sales mandates and other requirements (e.g., range requirements, battery warranty, etc.) for LDVs in the ACC II proposal apply to LDAs. Additionally, because the ZEV sales mandates in the ACC II proposal can be met with a combination of PHEVs, BEVs and FCEVs, Ramboll's analysis considers several scenarios to outline the range of potential fleet mixes allowable under the proposed ACC II regulation.

A brief description of the analyzed scenarios is presented below. **Figure 2-1** and **Figure 2-2** present new vehicle sales fractions by model year while **Figure 2-3** and **Figure 2-4** show the resulting fleet mix. **Figure 2-5** through **Figure 2-7** presents the resulting fuel usage for these scenarios. A detailed matrix of all scenarios can be found in **Appendix A**.

- **S0 – ACC I**: This scenario serves as the baseline and is based on EMFAC2021 fleet mix defaults, which represents ACC I PHEV and BEV sales requirements. As shown in **Figure 2-2**, the fleet is comprised primarily of ICEVs, with a small but increasing percentage of PHEVs and BEVs. PHEVs and BEVs represent approximately 4% and 12% of new vehicle sales, respectively, for model years 2026-2050 (**Figure 2-1**). Note, in all scenarios, the existing sales fraction and population of PHEVs and BEVs in EMFAC2021 defaults served as the minimum penetration of these vehicle technologies. Thus, while additional BEVs and/or PHEVs were added in some scenarios, only ICEVs in the EMFAC2021 default fleet were replaced with other vehicle types as applicable in each scenario.
- **S1 – Baseline ACC II Scenarios**: In this set of scenarios, Ramboll evaluated multiple possible outcomes allowable under the proposed ACC II regulation to understand the range of potential emission reductions.
  - **S1a – ACC II (BEV)**: This scenario assumes that any additional ZEVs sales beyond those (BEVs and PHEVs) in the S0-ACC I Scenario that are needed to meet the ZEV sales requirements in the draft ACC II proposal are met with BEVs.
  - **S1b – ACC II (BEV + PHEV)**: This scenario assumes that the ZEV sales needed to meet the ZEV sales requirements in the draft ACC II proposal are met with the maximum allowable fraction of PHEVs (20% of ZEV sales requirement) and BEVs (80% of ZEV sales requirement).
  - **S1c – ACC II (CARB SRIA)**: This scenario assumes that the ZEV sales needed to meet the draft ACC II proposal are met with combination of PHEVs, BEVs, and FCEVs as noted in the CARB's SRIA for the ACC II proposal.
  - **S1d – ACC II (FCEV)**: This scenario assumes that any additional ZEVs sales beyond those (BEVs and PHEVs) in the S0-ACC I Scenario that are needed to meet the ZEV sales requirements in the draft ACC II proposal are met with FCEVs. The carbon intensity (CI) of hydrogen fuel used to power FCEVs in this scenario was developed based on the feedstock projections in CARB's SRIA for the ACC II proposal. Refer to **Section 3.2.4** for further discussion of hydrogen pathways.
    - **S1d-1 – ACC II (FCEV) + AB32 H_2**: This sensitivity scenario is identical to scenario S1d – ACC II (FCEV) with the following exception: the CI for hydrogen

fuel used to power FCEVs was developed based on the assumptions in the Assembly Bill (AB) 32 Source Emissions Initial Modeling Results[10] ("AB 32 Initial Modeling") for the draft 2022 Scoping Plan Update.

- **S2 – Alternative Scenarios Part 1**: In this set of scenarios, Ramboll evaluated alternatives to the draft ACC II proposal where the ZEV sales requirements are met with PHEVs or HEVs instead of BEVs and FCEVs. Some of these scenarios also include the phase-in of a lower CI renewable drop-in fuel ("low-CI gasoline") used as a replacement for CaRFG that is used to fuel internal combustion engines (ICEs) in ICEVs, PHEVs, and HEVs. The carbon intensity of low-CI gasoline analyzed in these scenarios is 19g CO_2e/MJ (see **Section 3.2.2** for further discussion of low-CI gasoline).
  - **S2a – PHEV**: This scenario assumes that any additional ZEVs sales beyond those (BEVs and PHEVs) in the S0-ACC I Scenario that are needed to meet the ZEV sales requirements in the draft ACC II proposal are met with PHEVs.
  - **S2b – PHEV + Low-CI Gas**: This vehicle fleet mix for this scenario is identical to scenario S2a – PHEV. However, it also includes the gradual phase-in of low-CI gasoline (see orange area in **Figure 2-6**) beginning as a replacement of 1% of CaRFG in 2026 and increasing to a replacement of 30% and 100% of CaRFG by 2035 and 2050 respectively.
  - **S2c – HEV + Low-CI Gas**: This scenario assumes that any additional ZEVs sales beyond those (BEVs and PHEVs) in the S0-ACC I Scenario that are needed to meet the ZEV sales requirements in the draft ACC II proposal are met with all HEVs. It also includes a phase-in of low-CI gasoline (see orange area in **Figure 2-6**) beginning as a replacement of 2% of CaRFG in 2026 and increasing to a replacement of 35% and 100% of CaRFG by 2035 and 2050 respectively.
- **S3 – Alternative Scenarios Part 2**: In this set of scenarios, Ramboll utilized the same vehicle fleet mix as scenario S0 – ACC I along with a phase-in of low-CI gasoline as a replacement for CaRFG that is used to power internal combustion engines in the analyzed LDAs. The scenarios considered under S3 evaluate a range carbon intensities and phase in timetables for low-CI gasoline.
  - **S3a – Low-CI Gas**: This scenario analyzes the same vehicle fleet mix as S0 – ACC I with a gradual phase-in of low-CI gasoline (see orange area in **Figure 2-6**) beginning as a replacement of 1% of CaRFG in 2026 and increasing to a replacement of 45% and 100% of CaRFG by 2035 and 2050 respectively. The CI of the low-CI gasoline used in this scenario is 19 g CO_2e/MJ (see **Section 3.2.2** for further discussion of low-CI gasoline).
    - **S3a-1 – Low-CI Gas (Upper Range)**: This sensitivity scenario is identical to scenario S3a – Low CI Gas with the following exception: the carbon intensity of the low-CI gasoline is increased by 10 g CO_2e/MJ to 29 g CO_2e/MJ.

[10] Energy + Environmental Economics (E3). 2022. AB 32 Initial Model Results. March 15. Available at: https://ww2.arb.ca.gov/sites/default/files/2022-03/SP22-Model-Results-E3-ppt.pdf. Accessed: May 2022.

      - **S3a-2 – Low-CI Gas (Lower Range)**: This sensitivity scenario is identical to scenario S3a – Low-CI Gas with the following exception: the carbon intensity of the low-CI gasoline is reduced by 10 g CO_2e/MJ to 9 g CO_2e/MJ.

  - **S3b – Low-CI Gas (Delayed)**: This scenario is identical to scenario 3a with the following exception: the phase in of low-CI gasoline is delayed and occurs more slowly from 2026-2035 (replacement of 1% to 20% of CaRFG from 2026-2035) but increases rapidly from 2035-2040 (replacement of 97% and 100% of CaRFG by 2045 and 2050 respectively), as compared with scenario 3a (see orange area in **Figure 2-6**).

- **S4 – Alternative Scenarios Part 3**: In this set of scenarios, Ramboll evaluated various vehicle fleet mixes that utilize a combination of HEVs, PHEVs, BEVs, and/or FCEVs along with a gradual phase-in of low-CI gasoline as a replacement for CaRFG that is used to power ICEs in the analyzed LDA fleet.

  - **S4a – Custom Fleet Mix 1**: This scenario evaluates a custom fleet mix (see **Figure 2-4**) that assumes early implementation of HEVs from 2026-2035, with HEV sales declining after 2035 (see green area in **Figure 2-2**). PHEV sales increase by 1% per year from 2026-2040 and 2% per year thereafter (see gold area in **Figure 2-2**). BEV sales increase by 1% per year from 2030-2044 and 2% per year thereafter (see blue area in **Figure 2-2**). This scenario also includes a phase-in of low-CI gasoline (CI of 19 g CO_2e/MJ) beginning as a replacement of 2% of CaRFG in 2026 and increasing to a replacement of 100% of CaRFG by 2050 (see orange area in **Figure 2-6**).

  - **S4b – Custom Fleet Mix 2**: This scenario evaluates a custom fleet mix (see **Figure 2-4**) similar to S4a – Custom Fleet Mix 1, but with aggressive early implementation of HEVs from 2026-2035 and HEV sales declining after 2035 (see green area in **Figure 2-2**). PHEV sales increase by 1% per year from 2028-2031, stay constant from 2031-2035, increase by 2% per year from 2036-2039, increase by 4% per year in 2040 and 2041, and then stay constant at 39% from 2042 and thereafter (see gold area in **Figure 2-2**). Phase-in of additional BEVs is delayed until 2036, beginning at 7% in 2036 and increasing by 1% per year from 2036-2041. Additional BEV sales then increase by 3.5% per year until 2046 and remain constant thereafter at 42% (see blue area in **Figure 2-2**). This scenario also includes a phase-in of low-CI gasoline (CI of 19 g CO_2e/MJ) beginning as a replacement of 2% of CaRFG in 2026 and increasing to a replacement of 100% of CaRFG by 2050 (see orange area in **Figure 2-7**).

  - **S4c – Custom Fleet Mix 3**: This scenario evaluates a custom fleet mix (see **Figure 2-4**) similar to scenario S4a - Custom Fleet Mix 1, but with more FCEVs and less BEVs. Specifically, HEV and PHEV implementation is the same as scenario 4a (see green and gold areas in **Figure 2-2**), while BEV sales increase by only 0.5% per year from 2031-2044 and 1.5% per year thereafter (see blue area in **Figure 2-2**). FCEV sales start at 1% in 2030 and increase by 0.5% per year thereafter (see purple area in **Figure 2-2**). This scenario also includes a phase-in of low-CI gasoline (CI of 19 g CO_2e/MJ) beginning as a replacement of 2% of CaRFG in 2026 and increasing to a replacement of 100% of CaRFG by 2050 (see orange area in **Figure 2-7**). Similar to scenario S1d – ACC II (FCEV), the carbon intensity (CI) of hydrogen fuel used to power FCEVs in this scenario was developed based on the feedstock projections in CARB's SRIA for the ACC II proposal. Refer to **Section 3.2.4** for further discussion of hydrogen pathways.

Figure 2-1. LDA New Vehicle Sales Fractions for Scenarios 0, 1a, 1b, 1c, 1d, and 2a

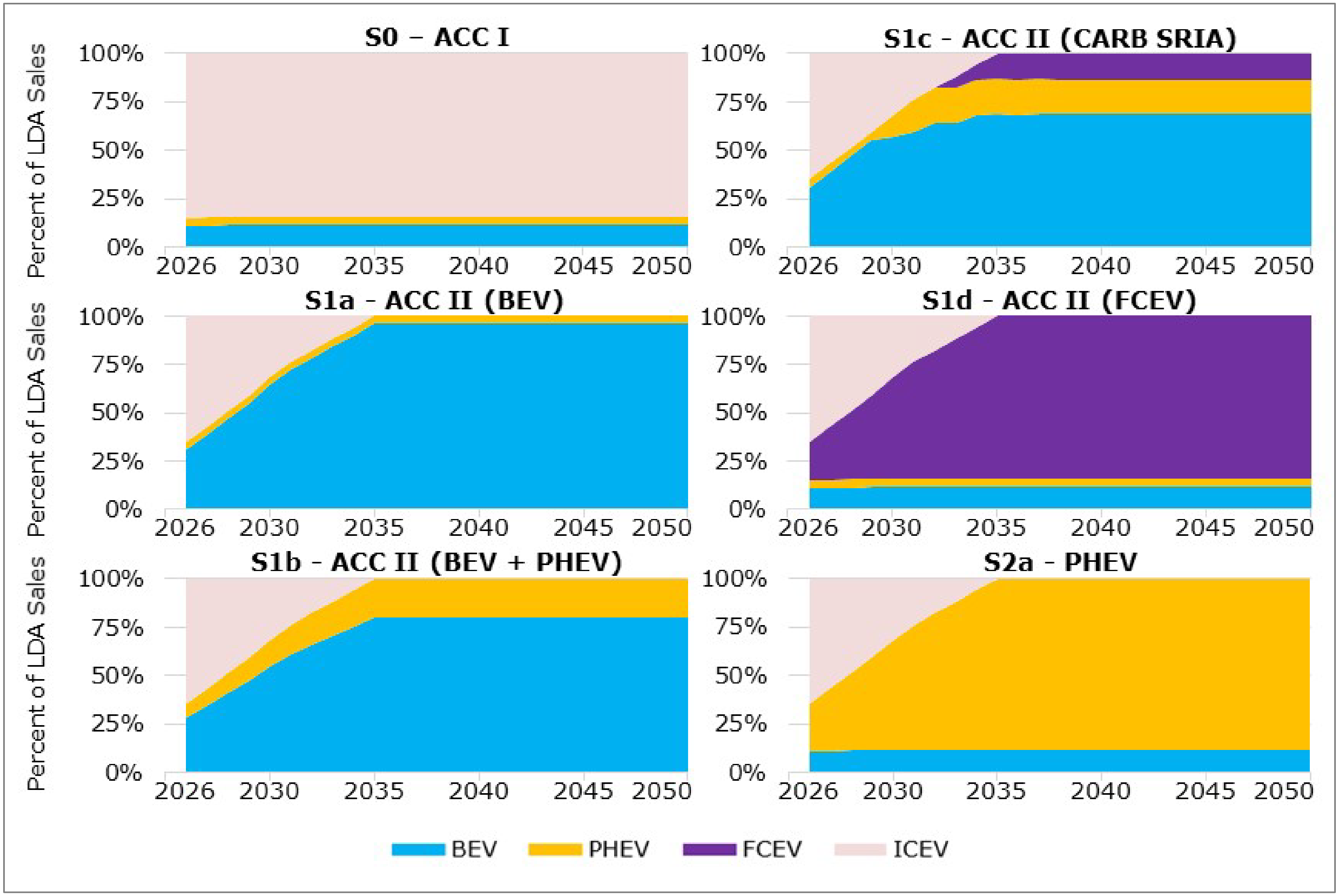


Figure 2-2. LDA New Vehicle Sales Fractions for Scenarios 2b, 2c, 3a, 4a, 4b, and 4c

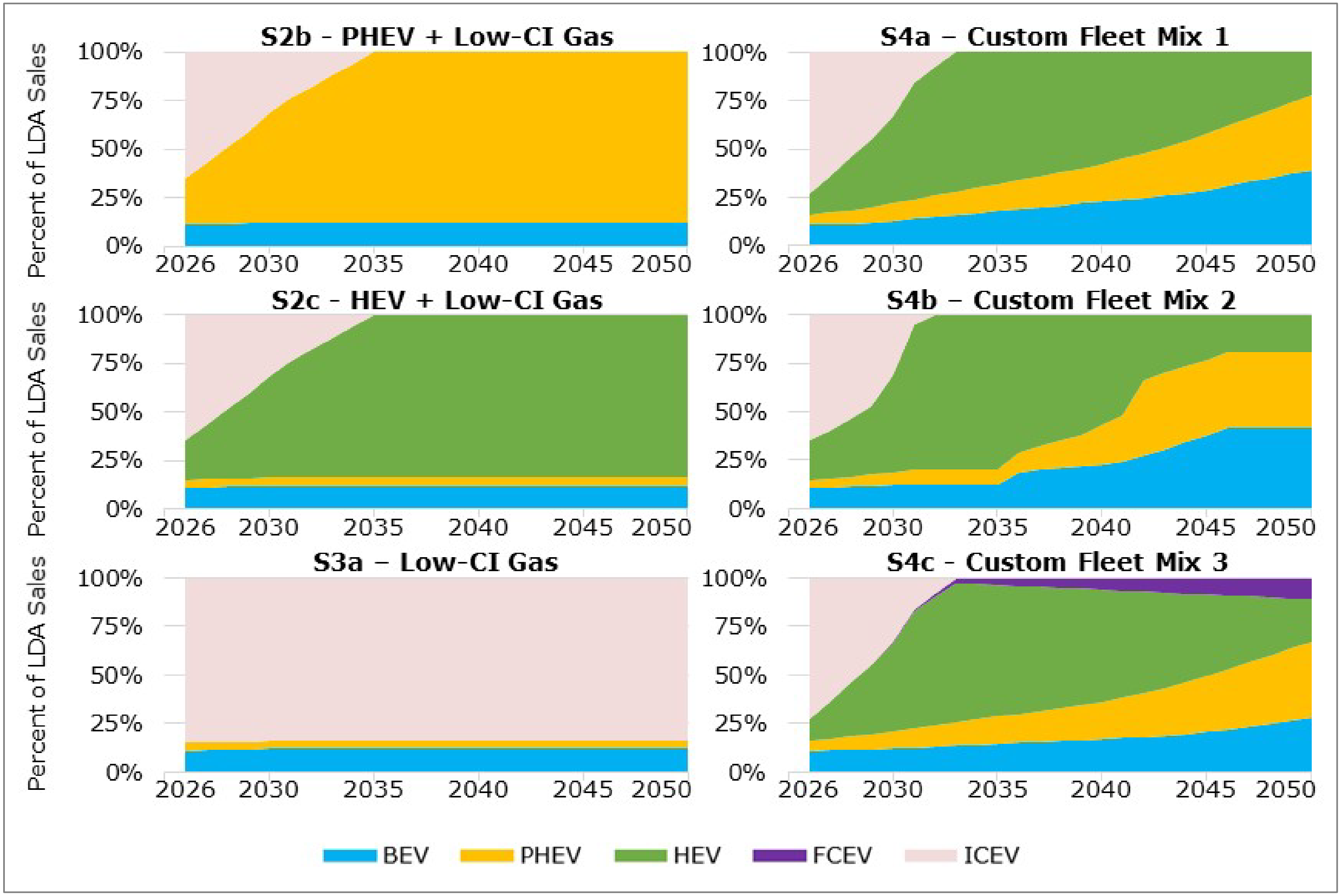


Figure 2-3. LDA Fleet Mixes for Scenarios 0, 1a, 1b, 1c, 1d, and 2a

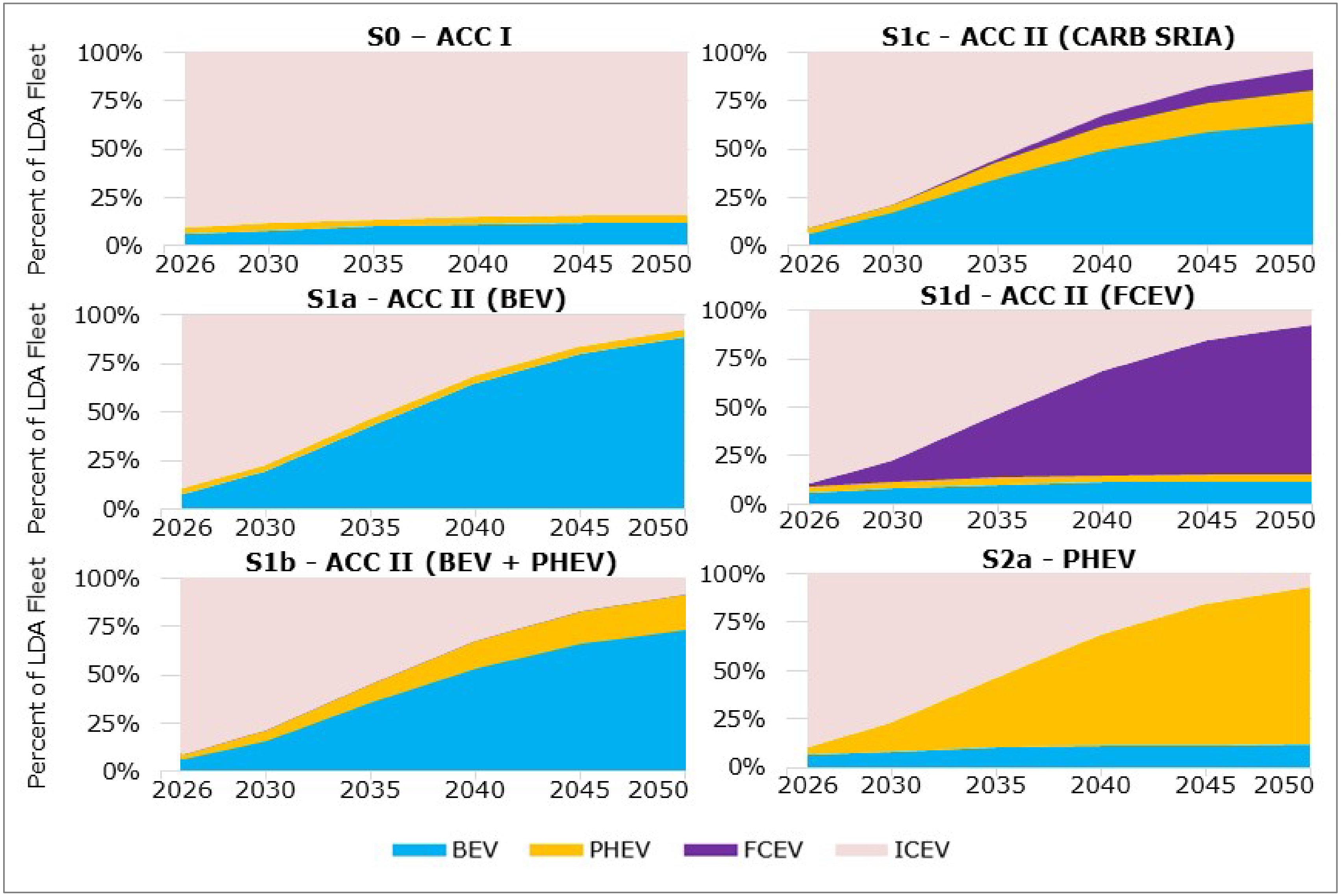


Figure 2-4. LDA Fleet Mixes for Scenarios 2b, 2c, 3a, 3b, 4a, 4b, and 4c

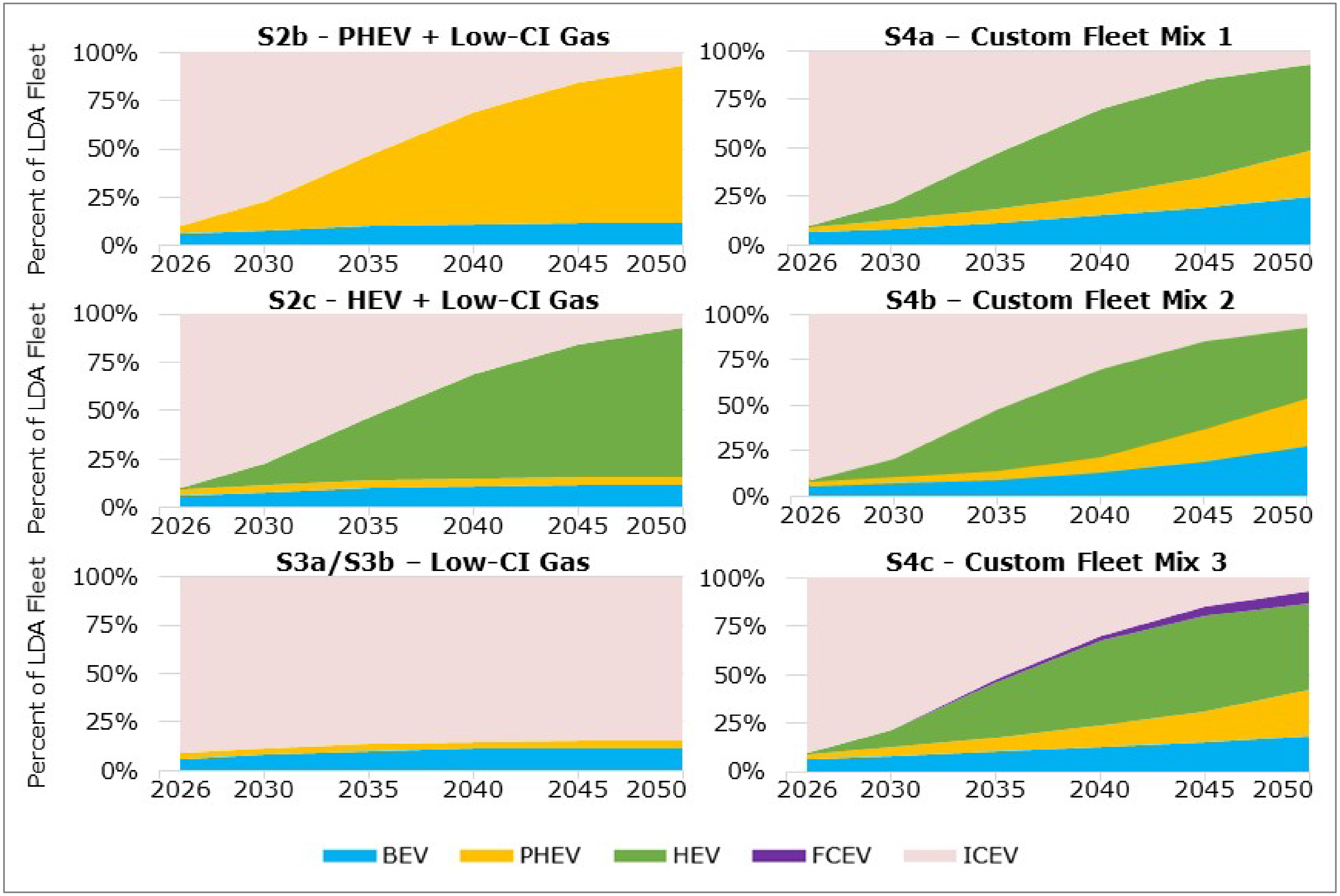


Figure 2-5. Fuel Usage Fractions for Scenarios 0, 1a, 1b, 1c, 1d, and 1d-1

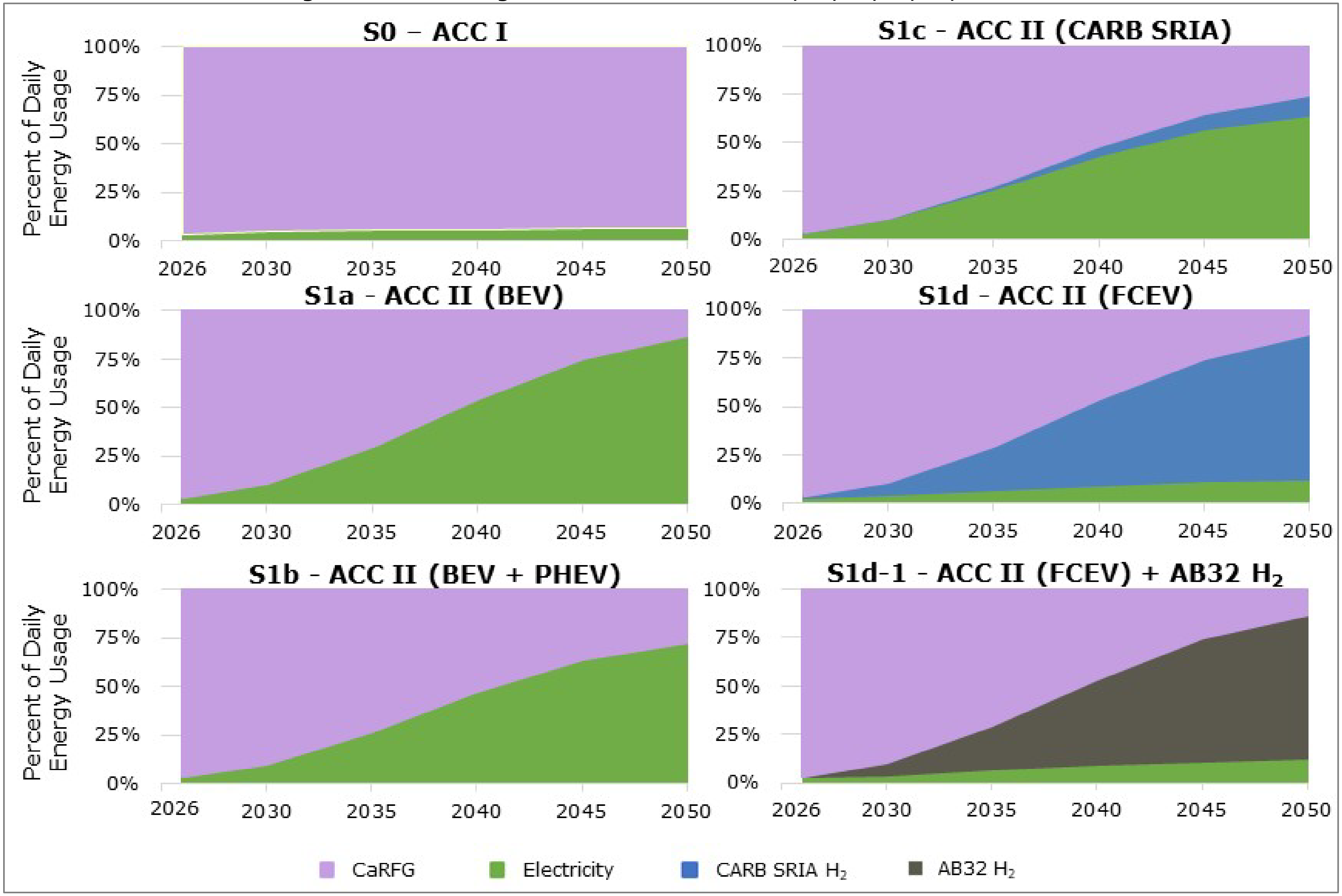


Figure 2-6. Fuel Usage Fractions for Scenarios 2a, 2b, 2c, 3a, 3b, and 4a

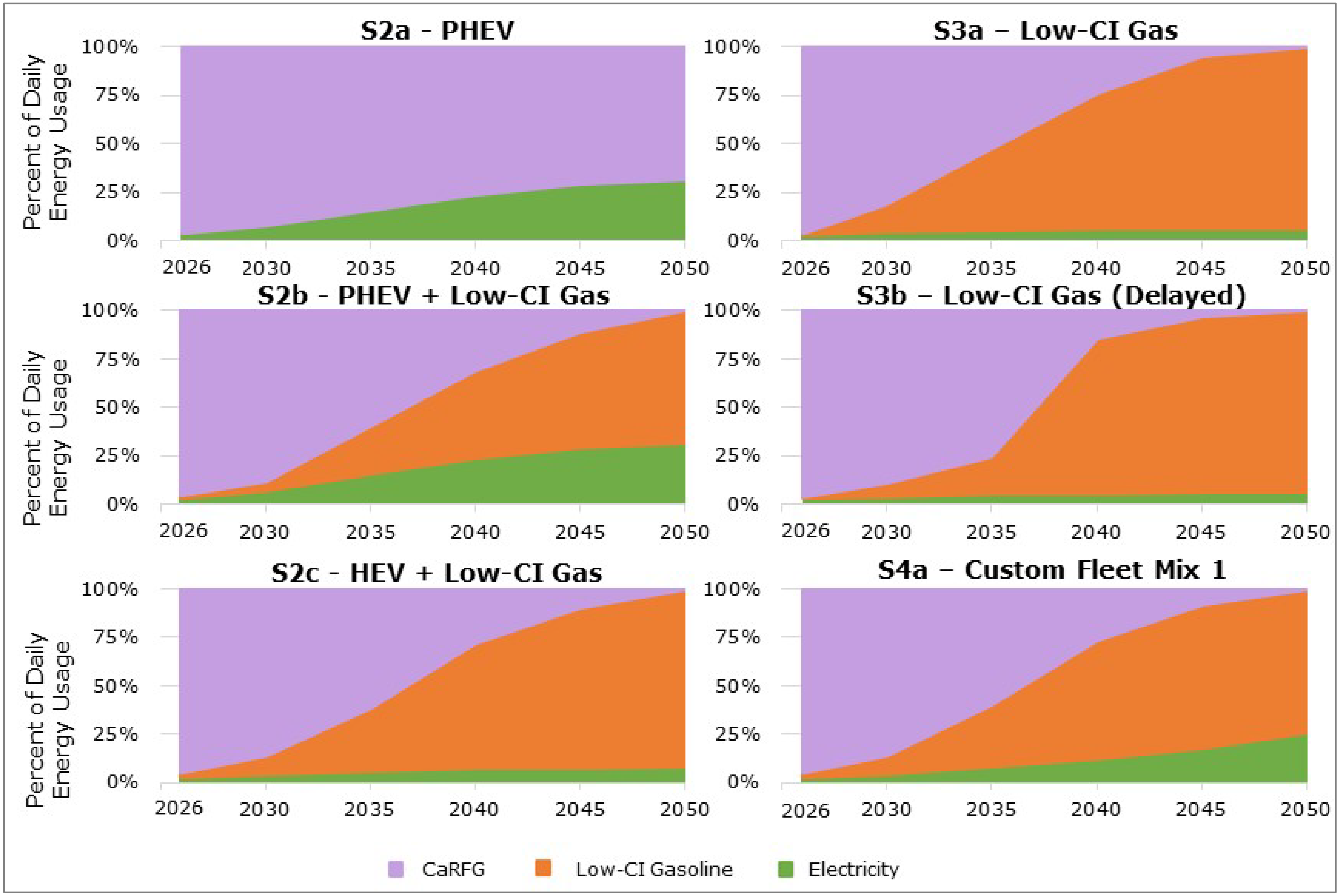
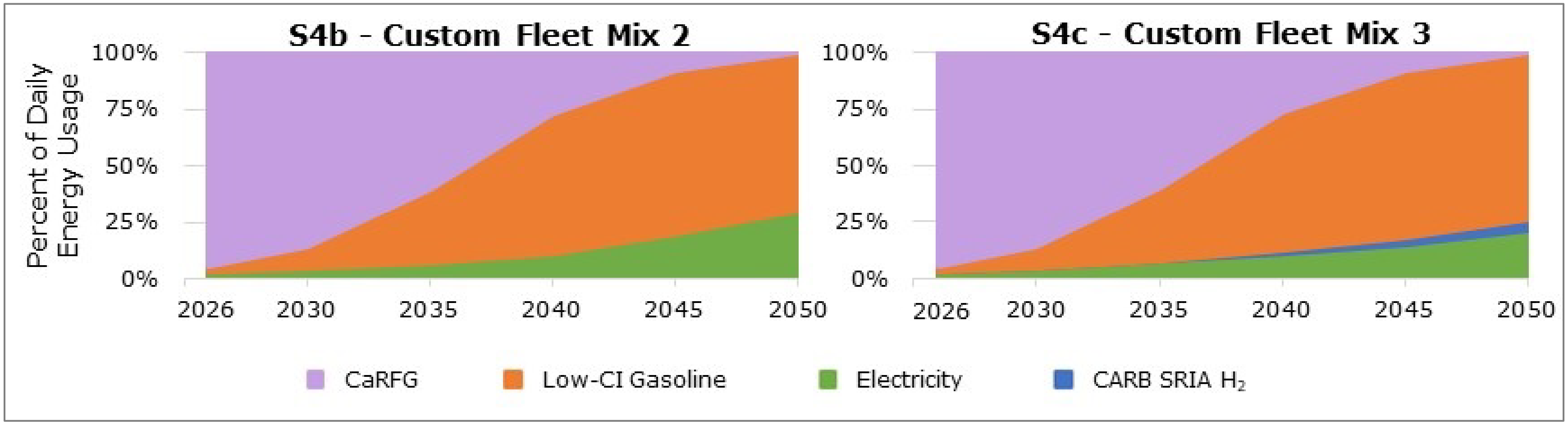


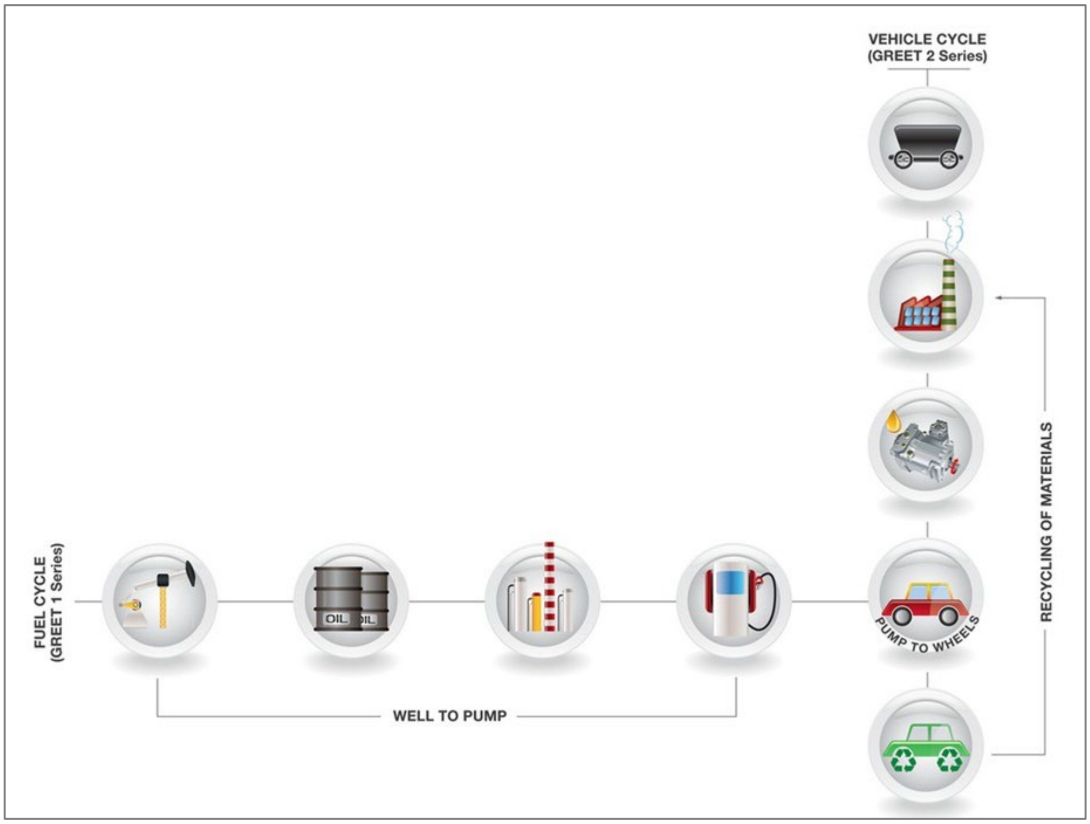
Figure 2-7. Fuel Usage Fractions for Scenarios 4b and 4c



3. SCENARIO ANALYSIS METHODOLOGY

An accurate assessment of future vehicle/fuel technology pathways requires full life cycle emissions analysis, including fuel cycle emissions and vehicle cycle emissions. The vehicle cycle analysis includes emissions associated with vehicle material recovery and production, vehicle component fabrication, vehicle assembly, and vehicle disposal and recycling, while the fuel cycle analysis considers energy use and emissions associated with fuel production and distribution activities as well as energy use and emissions associated with vehicle operation.[11,12] The various processes included in the fuel cycle and vehicle cycle are represented in **Figure 3-1** below.

Figure 3-1. Fuel Cycle and Vehicle Cycle Emissions Representation in the GREET Model[13]



[11] P. Moon, A. Burnham, M. Wang. 2006. "Vehicle-Cycle Energy and Emission Effects of Conventional and Advanced Vehicles (abstract)". April 3. Available here: https://greet.es.anl.gov/publication-hkjun004. Accessed: May 2022.

[12] USEPA. Lifecycle Analysis of Greenhouse Gas Emissions under the Renewable Fuel Standard. Available at: https://www.epa.gov/renewable-fuel-standard-program/lifecycle-analysis-greenhouse-gas-emissions-under-renewable-fuel. Accessed: May 2022.

[13] ANL. 2021. Greenhouse gases, Regulated Emissions, and Energy use in Technologies model. Available at: https://greet.es.anl.gov/. Accessed: May 2022.

The following sections provide a high-level description of the methodology used for Ramboll's scenario analysis. Detailed modeling inputs, outputs, and methodology are provided in **Appendix A**.

3.1 Vehicle Technologies

Several LDA vehicle technologies are considered in Ramboll's analysis, as described in the following sections. Of these vehicle technologies, ICEVs, PHEVs, and BEVs are present in the EMFAC2021 default fleet mix for LDAs while FCEVs and HEVs are not. As described previously, LDAs fueled by diesel and natural gas are not included in this analysis.[14]

3.1.1 Internal Combustion Engine Vehicles

ICEVs are vehicles that use only an internal combustion engine to attain propulsion power. As described previously, only gasoline-fueled ICEVs are considered in this analysis. ICEVs comprise the majority of the LDA fleet in the EMFAC2021 default fleet mix and are replaced to varying degrees with other vehicle technologies in the scenarios described in **Section 2**. Key data for ICEVs used to perform the analysis were derived from EMFAC2021.[15] Specifically, Ramboll used EMFAC2021 data to derive fuel economy, daily vehicle miles travelled (VMT) per vehicle, and tailpipe emission factors for ICEVs by model year for each calendar year. Fuel economy for ICEVs was determined using fuel consumption and VMT data from EMFAC2021 and vary by model year and calendar year, ranging from about 18 miles per gallon (MPG) for the oldest vehicles to 35 MPG for the newest vehicles. Similarly, daily VMT per vehicle was calculated using VMT and population data from EMFAC2021 and ranges from 5 miles per vehicle per day for the oldest vehicles to 55 miles per vehicle per day for the newest vehicles. The methodology used to calculate tailpipe emissions is discussed in **Section 3.3**. See **Appendix A** (**Tables A-8** through **A-25**) for ICEV fuel economy, tailpipe emission factors, and daily VMT per vehicle by model year for each calendar year considered in this analysis.

Daily VMT per vehicle for ICEVs serves as the basis for calculating VMT for other vehicle technologies as ICEVs are replaced with PHEVs, BEVs, HEVs, or FCEVs in each scenario. Specifically, this analysis assumes that any vehicle technology replacing an ICEV travels the same number of miles per vehicle per day as the ICEV it is replacing, as determined from EMFAC2021. Thus, in each scenario, as ICEVs are replaced with other vehicle technologies, the population and corresponding VMT of ICEVs is reduced and allocated to the replacement vehicles in a one-to-one ratio.[16] Similarly, Ramboll's analysis assumes that the vehicle lifetime (i.e., retirement rate) for ICEVs obtained from EMFAC2021 remains the same for any replacement vehicle technology. Therefore, Ramboll's analysis does not alter the total vehicle

[14] Natural gas vehicles are excluded as they are not included in the default EMFAC2021 LDA fleet. Diesel vehicles are not included in this analysis because they comprise less than 0.3% of the total LDA population in EMFAC2021.

[15] This analysis uses EMFAC2021 v1.0.1. A newer version of EMFAC2021 v1.0.2 was released on May 2, 2022 (after completion of this analysis) that reflects the revocation of the Safe Affordable Fuel-Efficient or SAFE vehicles rule. While this update increases the fuel economy, methane (CH_4), and nitrous oxide (N_2O) tailpipe emission factors by <5% and <0.5% for 2025+ model year ICEVs and PHEVs, respectively, it does not change the overall conclusions of the analysis.

[16] For PHEVs replacing ICEVs, total VMT from the ICEV is allocated to eVMT and cVMT for the replacement PHEV according to the EMFAC2021 default split between eVMT and cVMT for the replacement vehicle. Additional details are provided in **Section 3.1.3** and **Appendix A.**

population and VMT projections in EMFAC2021, even as vehicle technologies change in each scenario.

3.1.2 Battery Electric Vehicles

BEVs are vehicles that use energy from batteries to attain propulsion power. BEVs have larger batteries than PHEVs and HEVs and are plugged in and charged using electricity from the grid. BEVs have no ICE, do not use gasoline fuel, and have zero tailpipe emissions. BEVs comprise a small but increasing percentage of the EMFAC2021 default fleet mix and are the primary vehicle technology assumed to replace ICEVs under the proposed ACC II regulation. Fuel economy for BEVs was calculated using energy consumption and VMT data from EMFAC2021. Unlike fuel economy for ICEVs, which varies by model year and calendar year, fuel economy for all model year BEVs in EMFAC2021 is fixed at 0.386 kilowatt-hour per mile (kWh/mi) (~86 miles per gallon equivalent (MPGe))[17] irrespective of the calendar year in which they operate. Although VMT per vehicle for BEVs is not used in this analysis because any BEV replacing a ICEV is assumed to travel the same number of miles as the ICEV it is replacing, EMFAC2021 assumes that BEVs generally travel a similar number of miles per vehicle per day as ICEVs.

3.1.3 Plug-In Hybrid Electric Vehicles

PHEVs are vehicles that use energy from a battery, an ICE fueled by gasoline, or a combination of the two to attain propulsion power. PHEVs have smaller batteries than BEVs but can operate solely on energy from the battery and can be plugged in and charged using electricity from the grid. PHEVs comprise a small but increasing percentage of the EMFAC2021 default fleet mix and are the only vehicle technology considered in this analysis that is capable of both electric-only trips and trips using an ICE.

In order to account for the two potential operational modes of a PHEV (i.e., propulsion using only energy from the battery or propulsion with use of the ICE), total VMT in EMFAC2021 is resolved by combustion VMT (cVMT), for miles traveled by vehicles powered by an ICE, and electric VMT (eVMT), for miles traveled by vehicles powered by energy from a battery.[18] Similarly, EMFAC2021 accounts for electric energy consumption separate from gasoline fuel consumption. In EMFAC2021, eVMT is defined as miles traveled during a pure electricity powered trip, and energy consumption is determined based on only pure electric trips during which an ICE does not turn on.[19] Thus, only PHEVs have both cVMT and eVMT and both energy consumption and fuel consumption in EMFAC2021. The remaining vehicle technologies in EMFAC2021 have either cVMT and fuel consumption (e.g., ICEVs), or eVMT and energy consumption (e.g., BEVs). Throughout this analysis, we utilize the term "fuel

[17] Non-liquid fuels, like electricity and hydrogen, are not measured in gallons, so using conversion factors allows them to be displayed on an energy-equivalent basis using the familiar MPG measurement. MPGe, or miles per gallon of gasoline equivalent, is calculated based on the energy content of gasoline, 119.53 MJ/gal for CARBOB, which is then converted to kWh to derive a conversion factor of 33.203 kilowatt-hours/gallon of gasoline equivalent. Available at: https://ww2.arb.ca.gov/sites/default/files/2022-05/quarterlysummary_043022.xlsx. Accessed: May 2022.

[18] CARB. 2021. EMFAC2021 Volume I – User's Guide. January 15. Available at: https://ww2.arb.ca.gov/sites/default/files/2021-01/EMFAC202x_Users_Guide_01112021_final.pdf. Accessed: May 2022.

[19] CARB. 2021. EMFAC2021 Volume III Technical Document - Version 1.0.0. March 31. Available at: https://ww2.arb.ca.gov/sites/default/files/2021-03/emfac2021_volume_3_technical_document.pdf. Accessed: May 2022.

economy" as a fuel-neutral description of miles traveled per unit of fuel or energy consumed, whether the fuel is gasoline, hydrogen, or electricity. For example, fuel economies for all vehicles considered in this analysis are shown in **Appendix A, Tables A-8, A-11, A-14, A-17, A-20, and A-23.**

Based on these distinctions, Ramboll used EMFAC2021 data to derive electric and gasoline fuel economy, and the split between eVMT and cVMT for PHEVs. Gasoline fuel economy was determined based on fuel consumption and cVMT while electric fuel economy was determined based on energy consumption and eVMT. Gasoline fuel economy values for PHEVs in EMFAC2021 vary by model year and calendar year, ranging from 23 MPG to 29 MPG. In contrast, electric fuel economy values for PHEVs are constant in EMFAC2021 at 0.302 kWh/mi (~110 MPGe) for all model years in all calendar years. For PHEVs, the split between eVMT and cVMT varies by model year and calendar year. The eVMT fraction of total VMT increases from 46% in the earlier model years to 59% in the later model years, while the cVMT fraction decreases from 54% to 41%. These percentages are used to allocate total VMT to eVMT and cVMT when a PHEV replaces a ICEV in the scenario analysis. Although total VMT per vehicle for PHEVs is not used in this analysis because any PHEV replacing a ICEV is assumed to travel the same number of miles as the ICEV it is replacing, EMFAC2021 data shows that PHEVs generally travel a similar number of miles per vehicle per day as ICEVs. The methodology used to estimate tailpipe emissions for PHEVs is discussed in **Section 3.3**. See **Tables A-8** through **A-25** in **Appendix A** for PHEV fuel economy, tailpipe emission factors, and eVMT and cVMT percentages.

3.1.4 Hybrid Electric Vehicles (HEVs)

HEVs operate similar to ICEVs and obtain propulsion power primarily from an ICE, but incorporate a small battery and electric motor to improve overall fuel economy. Unlike BEVs and PHEVs, HEVs are not able to be plugged in and charged using electricity from the grid, nor are they capable of electric-only trips. Because of these operational characteristics, HEVs were analyzed similar to ICEVs in this analysis. HEVs are not included in the EMFAC2021 default fleet mix but were considered as replacements for ICEVs in some of the scenarios described in **Section 2**.

Fuel economy for HEVs was calculated based on the fuel economy of ICEVs obtained from EMFAC2021 and the relative fuel economies of the average model year 2020 HEV and ICEV as obtained from the United States Environmental Protection Agency's (USEPA's) 2020 EPA Automotive Trends Report ("EPA Report").[20] The EPA Report shows that, as a production-weighted average, hybrid cars had a fuel economy about 41% higher than the average non-hybrid car in model year (MY) 2020. This factor was assumed to remain constant in future years and was used to estimate fuel economies for MY 2026 to 2050 HEVs. Using this factor, HEVs are estimated to have gasoline fuel economies ranging from about 43 MPG to 50 MPG. The methodology used to calculate tailpipe emissions for HEVs is discussed in **Section 3.3** and HEV fuel economies are shown in **Appendix A**.

[20] United States Environmental Protection Agency (USEPA). 2021. The 2020 EPA Automotive Trends Report. EPA-420-R-21-003. January. Available at: https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1010U68.pdf. Accessed: May 2022.

3.1.5 Fuel Cell Electric Vehicles

FCEVs use an electric propulsion system similar to that of BEVs but use an on-board fuel cell to convert energy stored as hydrogen to electricity rather than utilizing energy only from a battery. Thus, FCEVs are fueled with hydrogen stored in a tank on the vehicle. Similar to BEVs, FCEVs produce zero tailpipe emissions. FCEVs are not included in the EMFAC2021 default fleet mix but were considered as replacements for ICEVs in some of the scenarios described in **Section 2**. Fuel economy for FCEVs was calculated based on the fuel economy of ICEVs and the Energy Economy Ratio (EER) of a FCEV relative to an ICEV. EERs are dimensionless values that represent the efficiency of a fuel as used in a powertrain as compared to a reference fuel used in the same powertrain. Ramboll used an EER of 2.5 based on the value for a FCEV used as a replacement for a gasoline-fueled ICEV in light/medium-duty applications as reported in CARB's LCFS Regulation.[21] This EER was applied to ICEV fuel economies as described in **Section 3.1.1** to determine FCEV fuel economies by model year and calendar year for MY 2026-2050 FCEVs. Using this methodology, FCEV energy economies range from about 0.366 to 0.374 kWh/mi (89 to 91 MPGe) as shown in **Appendix A**.

3.2 Fuel Cycle Emissions

An accurate assessment of future vehicle/fuel technology pathways requires a complete fuel-cycle analysis, commonly called a well-to-wheels analysis. A well-to-wheels analysis considers energy use and emissions associated with fuel production and distribution activities ("well-to-tank" or "upstream") as well as energy use and emissions associated with vehicle operation ("tank-to-wheels" or "tailpipe") activities.[22] The following sub-sections describes the methodology used to estimate upstream and tailpipe emissions for the vehicle/fuel technologies that are considered in this analysis.

3.2.1 Upstream (Well-to-Tank) Emissions

Upstream emissions are generated from feedstock-related processes (recovery, processing, storage, and transportation of feedstocks) and fuel-related processes (production, transportation, storage, and distribution of fuels).[23]

Ramboll estimated well-to-tank GHG emission factors for each analyzed fuel type (CaRFG, low-CI gasoline, electricity, and hydrogen) using carbon intensities obtained from the CA-GREET3.0 model,[24] LCFS Lookup Pathways Tables,[25] LCFS Quarterly Summary data,[26]

---

[21] CARB. 2020. Unofficial Electronic Version of the Low Carbon Fuel Standard. May 27. Available at: https://ww2.arb.ca.gov/sites/default/files/2020-07/2020_lcfs_fro_oal-approved_unofficial_06302020.pdf. Accessed: May 2022.

[22] Brinkman, Norman, Michael Wang, Trudy Weber, and Thomas Darlington. 2005. Well-to-Wheels Analysis of Advanced Fuel/Vehicle Systems – A North American Study of Energy Use, Greenhouse Gas Emissions, and Criteria Pollutant Emissions. May. Available at: https://greet.es.anl.gov/files/4mz3q5dw. Accessed: May 2022.

[23] Ibid.

[24] CA-GREET 3.0 Model. Available at: https://www.arb.ca.gov/fuels/lcfs/ca-greet/ca-greet30-corrected.xlsm. Accessed: January 2021.

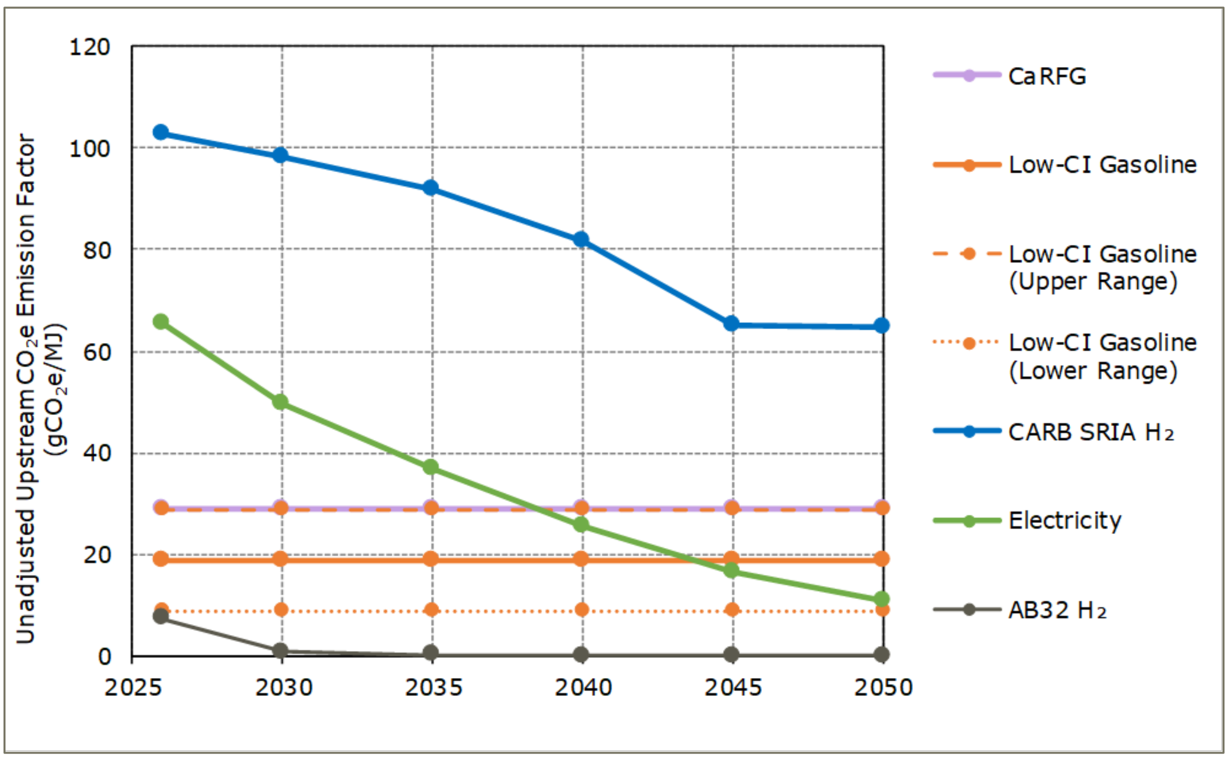
[25] CARB. 2018. CA-GREET3.0 Lookup Table Pathways Technical Support Documentation. August 13. Available at: https://ww2.arb.ca.gov/sites/default/files/classic/fuels/lcfs/ca-greet/lut-doc.pdf. Accessed: May 2022.

[26] CARB. LCFS Quarterly Summaries. Available at: https://ww2.arb.ca.gov/resources/documents/low-carbon-fuel-standard-reporting-tool-quarterly-summaries. Accessed: May 2022.

and assumptions used in CARB's ACC II SRIA,[27] and AB 32 Initial Modeling.[28] Upstream GHG emission factors are typically represented as carbon intensities, i.e., the mass of GHG emissions in carbon dioxide equivalent (CO_2e) per unit of energy consumed in mega joules (MJ) for each fuel type. Carbon intensities for all fuel pathways considered in this analysis with and without EER adjustment are shown in **Figure 3-2** and **Figure 3-3** respectively. Additional details on the methodology used to estimate upstream GHG emission factors or CIs are provided in **Sections 3.2.1.1** through **3.2.1.4**.

Ramboll estimated the total upstream GHG emissions for each analysis year in each modeled scenario as a sum-product the upstream CI for each fuel type (**Figure 3-2**) and the total amount of each fuel consumed for each fuel type across all vehicle technologies (**Tables A-26** through **A-91** in **Appendix A**). The total amount of each fuel consumed was calculated using the VMT and fuel economy of the vehicle technologies included in each scenario. Fuel economies and VMT are determined as described in **Section 3.1**. This methodology accounts for the differences in EER between vehicle technologies because the conventional gasoline fuel energy derived from EMFAC2021 for the proportion of ICEVs replaced by other vehicle technologies was adjusted by the relative fuel economy of the replacement vehicles.

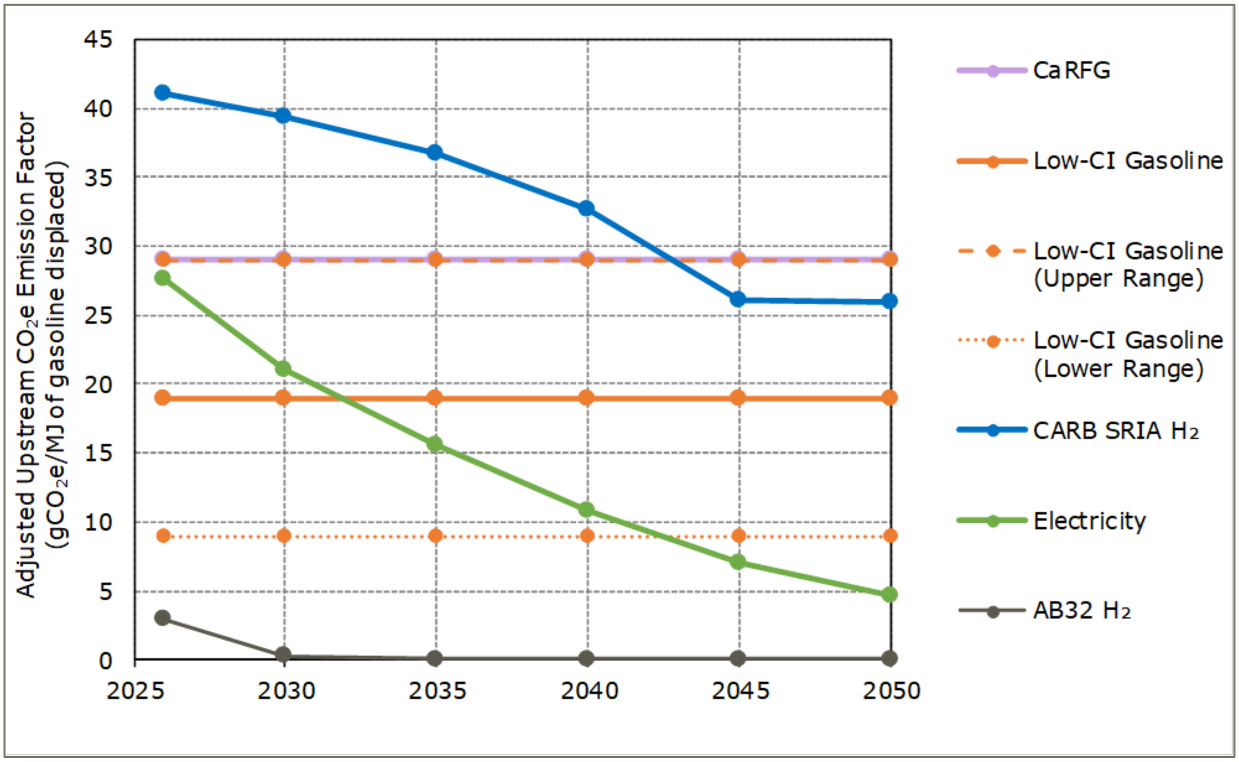
Figure 3-2. Upstream (EER-unadjusted) GHG Emission Factors by Fuel Type



[27] CARB. 2022. Appendix C-1: Standardized Regulatory Impact Assessment (SRIA). April 12. Available at: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/accii/appc1.pdf. Accessed: May 2022.

[28] E3. 2022. AB 32 Initial Model Results. March 15. Available at: https://ww2.arb.ca.gov/sites/default/files/2022-03/SP22-Model-Results-E3-ppt.pdf. Accessed: May 2022.

Figure 3-3. Upstream (EER-adjusted) GHG Emission Factors by Fuel Type



3.2.1.1 California Reformulated Gasoline

Ramboll estimated the upstream CI of CaRFG as an energy-weighted average value of the upstream CIs of the two components that make up CaRFG: California reformulated gasoline blendstock for oxygenate blending (CARBOB), and ethanol.

The upstream CI values used in this calculation include:

- 26.9 g CO_2e/MJ for CARBOB obtained from the CA-GREET3.0 Lookup Table Pathways,[29] and
- 59.8 g CO_2e/MJ for ethanol calculated as an average of the ethanol CIs available in the LCFS Quarterly Reports[30] for the most recent period (2020 Q1 to 2021 Q3) at the time of this analysis.

The blend ratio applied to these CI values to obtain a CI of 29.1 g CO_2e/MJ for CaRFG is 6.61% ethanol and 93.39% CARBOB on an energy basis, which is consistent with the 9.5% ethanol blend by volume assumed in the GREET model.[31]

---

[29] CARB. 2018. CA-GREET3.0 Lookup Table Pathways Technical Support Documentation. August 13. Available at: https://ww2.arb.ca.gov/sites/default/files/classic/fuels/lcfs/ca-greet/lut-doc.pdf. Accessed: May 2022.

[30] CARB. LCFS Quarterly Summaries. Available at: https://ww2.arb.ca.gov/resources/documents/low-carbon-fuel-standard-reporting-tool-quarterly-summaries. Accessed: May 2022.

[31] CA-GREET3.0 Model. Available here: https://www.arb.ca.gov/fuels/lcfs/ca-greet/ca-greet30-corrected.xlsm?_ga=2.255823756.582239942.1645477627-990540269.1603987774. Accessed: May 2022. Available under the tab 'Petroleum' under 'Energy % Ethanol in CaRFG'.

Finally, Ramboll estimated the upstream GHG emissions for CaRFG consumed by LDVs in each scenario using this CI value and the total consumption of CaRFG across all vehicle technologies in each analysis year.

3.2.1.2 Low-CI Gasoline

To estimate a carbon intensity for the low-CI gasoline considered in this analysis, a review of currently available and documented carbon intensities for low-CI renewable gasoline drop-in fuels was performed, as documented in **Table 3-1**. Sources for low-CI drop-in renewable gasoline fuels included the USEPA lifecycle GHG results, LCFS fuel pathways, Argonne National Laboratory (ANL) state-of-technology research, CARB-driven research, and a research paper published by the University of Chicago ANL. While the research yielded multiple pathways that spanned both renewable gasoline (e.g., bio-based feedstocks) as well as lower-CI gasoline alternatives, we chose to represent them as a single category due to their similar function as a drop-in replacement fuel. The average of these values was taken in order to find a representative carbon intensity for the low-CI gasoline fuel considered in this analysis, resulting in a CI of 19.0 g CO_2e/MJ, which is about 35% lower than the upstream CI for CaRFG.

Upstream GHG emissions associated with the use of low-CI gasoline in LDAs with ICEs for Scenarios S2b - PHEV + Low -CI Gas, S2c – HEV + Low-CI Gas, S3a – Low-CI Gas, S3b – Low-CI Gas (Delayed) and Custom Fleet Mix scenarios (S4a, S4b, and S4c) were calculated using this CI value of 19 g CO_2e/MJ and the total consumption of low-CI gasoline across all vehicle technologies in each analysis year.

In order to understand the impact of this carbon intensity on upstream and life cycle emissions, we also considered two sensitivity scenarios:

- Scenario 3a-1 – Low-CI Gas (Upper Range): For this scenario the low-CI gasoline CI was increased by 10 g CO_2e/MJ to 29 g CO_2e/MJ. This value is similar to the upstream CI for CaRFG.
- Scenario 3a-2 – Low CI-Gas (Lower Range): For this scenario the low-CI gasoline CI was reduced by 10 g CO_2e/MJ to 9 g CO_2e/MJ. This value is about 69% lower than the upstream CI for CaRFG.

Table 3-1. Low-CI Fuel Carbon Intensity Summary

Reference	Process	Feedstock	Upstream CI ($g\ CO_2e/MJ$)
USEPA Lifecycle GHG Results[1]	Direct biochemical fermentation	Cellulose from corn stover	-29.0
USEPA Lifecycle GHG Results[1]	Catalytic pyrolysis and upgrading	Cellulose from corn stover	28.7
USEPA Lifecycle GHG Results[1]	Biochemical fermentation and upgrading	Cellulose from corn stover	30.6
LCFS Fuel Pathways[2]	Pyrolysis	Forest residue [transport by rail]	21.2
LCFS Fuel Pathways[2]	Pyrolysis	Forest residue [transport by truck]	26.1
ANL state-of-technology research[3]	Ex Situ Catalytic Fast Pyrolysis	Woody biomass	20.7
Biofuel Supply Module[4]	Pyrolysis	Cellulosic	8.1
Biofuel Supply Module[4]	Pyrolysis	Wood	24.7
University of Chicago ANL Research Paper[5]	Fischer-Tropsch Fuel Synthesis	Solar/Nuclear/Wind Energy for Hydrogen and Corn Ethanol Production for CO_2	37.1
		Average Carbon Intensity	**19.0**

References:

[1] EPA. 2016. Lifecycle Greenhouse Gas Results. Available here: https://www.epa.gov/fuels-registration-reporting-and-compliance-help/lifecycle-greenhouse-gas-results. Accessed: May 2022.

[2] CARB. 2022. LCFS Current Pathways. Available here: https://ww2.arb.ca.gov/sites/default/files/classic/fuels/lcfs/fuelpathways/currentpathways_all.xlsx. Accessed: May 2022.

[3] Argonne National Laboratory. 2021. Supply chain sustainability analysis of renewable hydrocarbon fuels- update of the 2020 state-of-technology cases. Available here: https://greet.es.anl.gov/publication-2020_update_renewable_hc_fuel. Accessed: May 2022.

[4] CARB. 2016. Biofuels Supply Module. Available here: https://www.arb.ca.gov/cc/scopingplan/meetings/090716/bfsmv83b.zip. Accessed: May 2022.

[5] University of Chicago. 2021. Life Cycle Analysis of Electrofuels: Fischer–Tropsch Fuel Production from Hydrogen and Corn Ethanol Byproduct CO_2. Available here: https://pubs.acs.org/doi/10.1021/acs.est.0c05893. Accessed: May 2022.

3.2.1.3 Electricity

Ramboll estimated upstream GHG emissions associated with the production and distribution of electricity consumed by PHEVs and BEVs in each modeled scenario using emission factors obtained from the CA-GREET 3.0 model.[32] Developed from Argonne National Laboratory's GREET 2016 model,[33] the CA-GREET 3.0 model is used by CARB to calculate well-to-wheel emissions from transportation fuels under the California LCFS Program. Hence, use of this model to estimate upstream emissions is consistent with the CARB methodologies.

For purposes of this analysis, Ramboll adjusted the electricity grid mix inputs to the CA-GREET 3.0 model based on California Energy Commission (CEC) projections for each of the modeled calendar years 2026, 2030, 2035, 2040, 2045, and 2050.[34] Further details regarding CA-GREET 3.0 model inputs and outputs can be found in **Appendix A**.

As shown in **Figure 3-2**, the electricity CI values estimated using CA-GREET 3.0 decrease from 65.3 g CO_2e/MJ in 2026 to 11.1 g CO_2e/MJ in 2050. Once adjusted for the differences in the efficiency of electricity in BEVs as compared to gasoline-fueled ICEVs, the electricity CI values range from 27.6 g CO_2e/MJ of gasoline displaced (5.1% lower than that for CaRFG) in 2026 to 4.7 g CO_2e/MJ of gasoline displaced (83.9% lower than that for CaRFG) in 2050 (**Figure 3-3**).

3.2.1.4 Hydrogen

The methodology used to derive the carbon intensity for the hydrogen fuel pathways modeled in this analysis are described in the following sub-sections.

CARB SRIA Hydrogen

Ramboll assumed that 40% of the hydrogen for the CARB SRIA H_2 fuel pathway would come from renewable feedstocks and the remaining 60% from fossil feedstocks based on the methodology used in the SRIA for the proposed ACC II[35] and discussions with CARB ACC II staff.[36] The fossil feedstock for hydrogen is assumed to be fossil natural gas which is processed via a steam methane reformation (SMR) process to produce Fossil Hydrogen per

---

[32] CARB. 2019. CA-GREET3.0 Model - Current Version: Effective January 4, 2019 (released August 13, 2018). Available at: https://www.arb.ca.gov/fuels/lcfs/ca-greet/ca-greet30-corrected.xlsm?_ga=2.203396115.367263062.1651770761-1504446328.1547148412. Accessed: May 2022.

[33] Available at: https://greet.es.anl.gov/publication-greet-model. Accessed: January 2021.

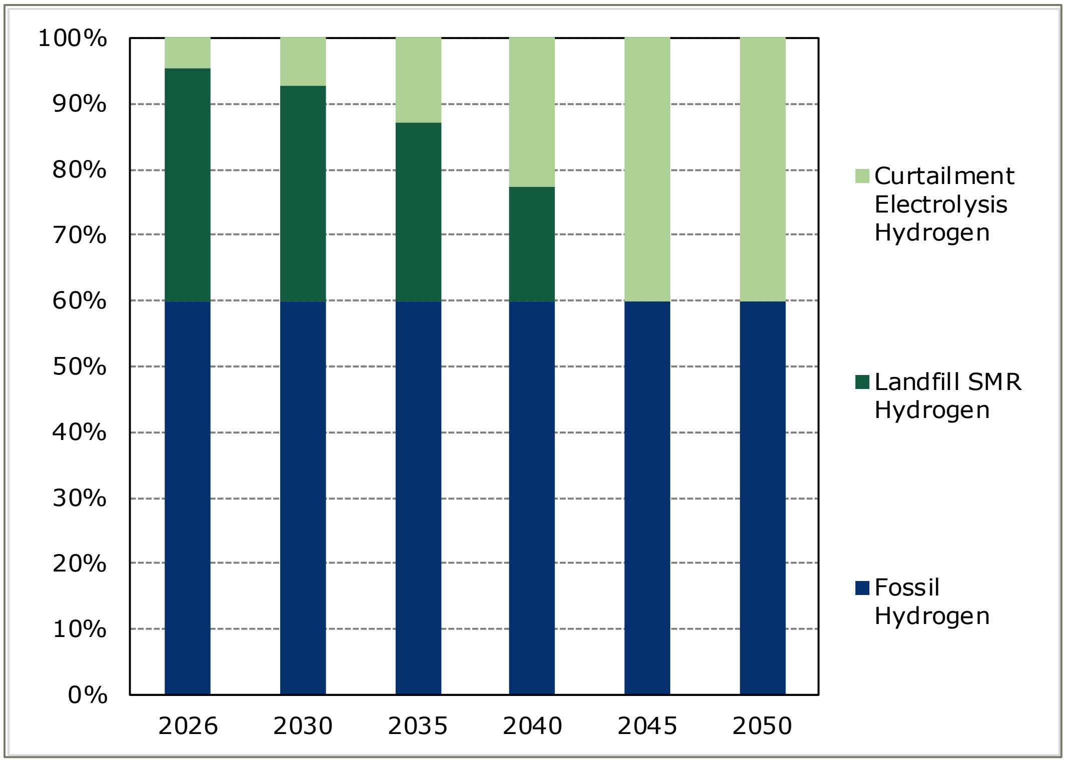
[34] CEC 2018. Deep Decarbonization in a High Renewables Future - Implications for Renewable Integration and Electric System Flexibility, Docket 18-IEPR-06 - 223869, Slide 10. Available at: https://efiling.energy.ca.gov/GetDocument.aspx?tn=223869&DocumentContentId=54081. Accessed: January 2021.

[35] CARB. 2022. Appendix C-1: Standardized Regulatory Impact Assessment (SRIA). April 12. Available at: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/accii/appc1.pdf. Accessed: May 2022.

[36] Based on e-mail communication between S. Moca, Ramboll US Consulting and CARB ACC II Staff on February 15, 2022. CARB staff indicated in their email that hydrogen fuel in the SRIA for the proposed ACC II consisted of 3 major blends of fuel types: fossil natural gas (NG) hydrogen, renewable hydrogen from renewable NG, renewable hydrogen from curtailments. CARB assumed that renewable hydrogen levels off at 40% of the total hydrogen used, and that renewable hydrogen gradually transitions from renewable NG hydrogen to renewable hydrogen from curtailments. CARB shared that this transition was modeled with a log function assuming a market share (%) of renewable hydrogen at specific time points which are 6% at 2020, 10% at 2025, and 100% at 2045. Additionally, they shared that the renewable natural gas feedstock was assumed to be 100% from landfill biogas. Lastly, for renewable hydrogen from curtailments, CARB staff assumed zero GHG emissions given transmission/distribution and refilling phases using renewable energy.

the 2020 Mobile Source Strategy[37] and as cited in the SRIA. The renewable feedstock is assumed to be Landfill Biogas with hydrogen production via SMR (Landfill SMR Hydrogen) and electrolysis using curtailment electricity (Curtailment Electrolysis Hydrogen). [38] Based on correspondence with CARB ACC II staff, the transition of hydrogen production from landfill biogas to curtailment electricity was modeled with a log function assuming specific feedstock shares at three points in time: 6% at 2020, 10% at 2025, and 100% at 2045.[39] The feedstock breakdown shown in **Figure 3-4** below illustrates this transition.

Figure 3-4: Feedstock Breakdown for CARB SRIA H_2[40]



The upstream carbon intensity values for each feedstock were estimated as follows:

- Fossil Hydrogen: A CI of 117.67 g CO_2e/MJ for Fossil Hydrogen was obtained from the LCFS certified pathway for hydrogen production from SMR using fossil natural gas.[41]

[37] CARB. 2021. 2020 Mobile Source Strategy. October 28. Available here: https://ww2.arb.ca.gov/sites/default/files/2021-12/2020_Mobile_Source_Strategy.pdf. Accessed: May 2022.

[38] Curtailment is the reduction of output of a renewable resource below what it could have otherwise produced due to oversupply or other factors. Thus, the energy source for curtailment electrolysis hydrogen is envisioned to be electricity produced by an oversupply of a renewable resource. Reference: CAISO. 2017. Impacts of renewable energy on grid operations. Available here: https://www.caiso.com/documents/curtailmentfastfacts.pdf. Accessed: May 2022.

[39] Based on e-mail communications between S. Moca, Ramboll US Consulting and CARB ACC II Staff on February 15, 2022.

[40] Ibid.

[41] CARB. 2018. CA-GREET3.0 Lookup Table Pathways Technical Support Documentation. August 13. Available at: https://ww2.arb.ca.gov/sites/default/files/classic/fuels/lcfs/ca-greet/lut-doc.pdf. Accessed: May 2022.

Since the gaseous hydrogen compression and precooling processes in this pathway use California grid electricity, the CIs for Fossil Hydrogen SMR were adjusted over time to account for the increased renewables in the grid. Refer to **Table A-6** in **Appendix A** for further details.

- Landfill SMR Hydrogen: A CI of 99.48 g CO_2e/MJ for Landfill SMR Hydrogen was obtained from the LCFS certified pathway for hydrogen production from SMR using landfill biogas.[42] Since the gaseous hydrogen compression and precooling processes in this pathway use California grid electricity, the CIs for Landfill SMR were adjusted over time to account for the increased renewables in the grid. Refer to **Table A-6** in **Appendix A** for further details.
- Curtailment Electrolysis Hydrogen: It was assumed that Curtailment Electrolysis Hydrogen would have a CI of zero, as the hydrogen is produced by electrolysis using curtailment electricity.[43]

The resulting CIs for the CARB SRIA Hydrogen are estimated as a feedstock weighted average of the CIs for the individual feedstocks (Fossil Hydrogen, Landfill SMR, and Curtailment Electrolysis) based on the feedstock breakdown shown in **Figure 3-4** for each analysis year. As shown in **Figure 3-2**, these CIs reduce from 102.6 g CO_2e/MJ in 2026 to 64.8 g CO_2e/MJ in 2050. Once adjusted for the for differences in the efficiency of electricity in FCEVs as compared to gasoline-fueled ICEVs, the CARB SRIA Hydrogen CI values range from 41.0 g CO_2e/MJ of gasoline displaced (41% greater than that for CaRFG) in 2026 to 25.9 g CO_2e/MJ of gasoline displaced (11% lower than that for CaRFG) in 2050 (**Figure 3-3**).

AB32 Hydrogen

The AB 32 Initial Modeling[44] for the draft 2022 Scoping Plan Update assumes that 100% of hydrogen production in the future would come from renewable sources, with the primary hydrogen production pathway being electrolysis using electricity generated by solar photovoltaic systems (Solar Electrolysis Hydrogen). To evaluate how hydrogen from a 100% renewable feedstock (AB32 Hydrogen) would impact the GHG inventory for the draft ACC II proposal, Ramboll modeled sensitivity scenario S1d-1 – ACC II (FCEV) + AB32 H_2 with this lower CI hydrogen. The following assumptions were used to develop the CI for AB32 Hydrogen:

- We assumed that AB32 Hydrogen would be a combination of hydrogen produced using the following pathways: Landfill SMR Hydrogen and Solar Electrolysis Hydrogen.
- The methodology used to estimate the CI for Landfill SMR Hydrogen is described in **Section 3.2.4.1**. As noted in that section, this CI reduces over time to account for the increased renewables in the California grid electricity that is used in the hydrogen compression and precooling processes. Refer to **Tables A-6** and **A-7** for further details.

[42] Ibid.

[43] Based on e-mail communications between S. Moca, Ramboll US Consulting and CARB ACC II Staff on February 15, 2022

[44] E3. 2022. CARB Draft Scoping Plan: AB32 Source Emissions Initial Modeling Results. March 15. Available at: https://ww2.arb.ca.gov/sites/default/files/2022-03/SP22-Model-Results-E3-ppt.pdf. Accessed: May 2022.

- The upstream CI for Solar Electrolysis Hydrogen was assumed to be zero, as hydrogen is produced using electrolysis with zero CI electricity that is generated by solar photovoltaic systems.
- The volumes of Landfill SMR Hydrogen for the analysis years was assumed to not exceed the total renewable hydrogen volume (2,700,000 kg/year or 324,000,000 MJ/year) produced in 2021 per Annual Hydrogen Evaluation.[45] The remaining hydrogen demand in each analysis year was assumed to be met by Solar Electrolysis Hydrogen. Refer to **Table A-7** for further details.

The resulting CIs for the AB32 Hydrogen were estimated as a feedstock weighted average of the CIs for the individual feedstocks (Landfill SMR and Solar Electrolysis) are shown in **Figure 3-2** for each analysis year. These CIs reduce from 7.45 g CO_2e/MJ in 2026 to less than 1 g CO_2e/MJ in 2030 and beyond. Once adjusted for the for differences in the efficiency of electricity in FCEVs as compared to gasoline-fueled ICEVs, the AB32 Hydrogen CIs values are even lower, ranging from 2.98 g CO_2e/MJ of gasoline displaced in 2026 to less than 0.5 g CO_2e/MJ of gasoline displaced in 2030 and beyond (**Figure 3-3**).

3.2.2 Tailpipe (Tank-to-Wheel) Emissions

Tailpipe emissions (tank-to-wheel) are generated from fuel consumption during vehicle operation.[46] **Table 3-2** summarizes the assumptions used to estimate the tailpipe GHG emissions from various vehicle/fuel technologies that are included in this analysis.

Table 3-2. Tailpipe Emission Assumptions

Vehicle/Fuel Technology	Tailpipe GHG
ICEVs fueled by CaRFG	Default EMFAC emission factors adjusted for the ethanol content of CaRFG
ICEVs fueled by Low-CI Gasoline	Zero tailpipe CO_2 emissions, default EMFAC emission factors for CH_4 and N_2O emissions
PHEVs fueled by CaRFG and Electricity	cVMT: Default EMFAC emission factors adjusted for the ethanol content of CaRFG eVMT: Zero GHG tailpipe emissions
PHEVs fueled by Low-CI Gasoline and Electricity	cVMT: Zero tailpipe CO_2 emissions, default EMFAC emission factors for CH_4 and N_2O emissions eVMT: Zero GHG tailpipe emissions
HEVs fueled by CaRFG	Default EMFAC emission factors for ICEVs adjusted for the fuel economy of HEVs and the ethanol content of CaRFG
HEVs fueled by Low-CI Gasoline	Zero tailpipe CO_2 emissions, default EMFAC emission factors for CH_4 and N_2O emissions

[45] CARB. 2021 Annual Evaluation of Fuel Cell Electric Vehicle Deployment and Hydrogen Fuel Station Network Development. September. Available at: https://ww2.arb.ca.gov/sites/default/files/2021-09/2021_AB-8_FINAL.pdf. Accessed: May 2022.

[46] Brinkman, Norman, Michael Wang, Trudy Weber, and Thomas Darlington. 2005. Well-to-Wheels Analysis of Advanced Fuel/Vehicle Systems – A North American Study of Energy Use, Greenhouse Gas Emissions, and Criteria Pollutant Emissions. May. Available at: https://greet.es.anl.gov/files/4mz3q5dw. Accessed: May 2022.

Table 3-2. Tailpipe Emission Assumptions	
Vehicle/Fuel Technology	**Tailpipe GHG**
BEVs fueled by Electricity	Zero GHG tailpipe emissions
FCEVs fueled by Hydrogen	Zero GHG tailpipe emissions

Combustion of gasoline (CaRFG and Low-CI gasoline) in ICEs in ICEVs, PHEVs, and HEVs generate the following greenhouse gas emissions: carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). Ramboll estimated tailpipe GHG emissions from gasoline fueled vehicle operation for each Scenario using data from EMFAC2021, as follows:

- EMFAC2021[47,48] was queried at the statewide level for analysis years 2026, 2030, 2035, 2040, 2045 and 2050 to obtain daily total GHG exhaust emissions and gasoline fuel consumption data for ICEV and PHEV LDAs by model year.
- Tailpipe emission factors for CO_2, CH_4, and N_2O in mass of emissions per unit of gasoline fuel consumed (e.g., tons/gal and tons/MJ) were calculated for ICEVs and PHEVs as a ratio of the total exhaust emissions to gasoline fuel consumption obtained from EMFAC2021[49] for each model year vehicle in each analysis year. Refer to **Tables A-10**, **A-13**, **A-16**, **A-19**, **A-22**, and **A-25** in **Appendix A** for further details.
- Tailpipe GHG emission factors in mass of emissions per unit of gasoline fuel consumed (e.g., tons/gal and tons/MJ) for HEVs are assumed to be the same as ICEVs because of their operating characteristics, as described in **Section 3.1.4**.
- Tailpipe GHG emissions for ICEVs, PHEVs, and HEVs were then estimated using tailpipe GHG emission factors and the cVMT and gasoline fuel economies for these vehicle technologies in each Scenario (determined as described in **Section 3.1**). Specifically, gasoline fuel economies were used to calculate the average daily gasoline consumption for each vehicle type based on daily cVMT, and then the tailpipe emission factors for each vehicle type, were applied to the gasoline fuel consumption to estimate average daily tailpipe emissions of CO_2, CH_4, and N_2O for ICEVs, PHEVs, and HEVs.
- Total average daily tailpipe GHG emissions reported in units of carbon dioxide equivalent (CO_2e) were calculated by applying the global warming potentials (GWPs) from the International Panel on Climate Change (IPCC) Fourth Assessment Report[50] to the average daily emissions of CO_2, CH_4, and N_2O.

[47] CARB. 2021. EMFAC2021 Database v1.0.1. Available at: https://arb.ca.gov/emfac/emissions-inventory. Accessed: January 2022.

[48] This analysis uses EMFAC2021 v1.0.1. A newer version of EMFAC2021 v1.0.2 was released on May 2, 2022 (after completion of this analysis) that reflects the revocation of the Safe Affordable Fuel-Efficient or SAFE vehicles rule. While this update increases the fuel economy, methane (CH_4), and nitrous oxide (N_2O) tailpipe emission factors by <5% and <0.5% for 2025+ model year ICEVs and PHEVs, respectively, it does not change the overall conclusions of the analysis.

[49] Note, tailpipe emission factors for PHEVs are based only on *fuel* consumption, as *energy* consumption associated with pure electric trips has zero tailpipe emissions.

[50] Greenhouse Gas Protocol. Available at: https://www.ghgprotocol.org/sites/default/files/ghgp/Global-Warming-Potential-Values%20%28Feb%2016%202016%29_1.pdf. Accessed January 2021.

- These average daily GHG emissions are scaled up to annual GHG emissions based on 347 days of operation per year for LDAs reported in EMFAC technical documentation.[51]
- Finally, since the CO_2 emissions generated by the combustion of the renewable ethanol content in CaRFG and Low-CI gasoline are considered biogenic, they are excluded from this analysis,[52] using the following adjustments.
  - <u>Adjustments for Tailpipe GHG Emissions Associated with CaRFG</u>: EMFAC2021 calculates tailpipe emissions assuming gasoline vehicles are fueled by CaRFG. However, while tailpipe CO_2 emissions in EMFAC2021 account for the reduction in carbon content of CaRFG relative to CARBOB due to the 9.5 percent blend of ethanol by volume, CO_2 emissions from the renewable ethanol fraction in CaRFG are still included in EMFAC2021 default outputs. Thus, in order to account for the elimination of CO_2 emissions from the renewable ethanol content of CaRFG, Ramboll applied an emission reduction factor of 6.3 percent to all tailpipe CO_2 emissions resulting from the use of CaRFG. The emission reduction factor was derived based the 9.5 percent volume fraction of ethanol in CaRFG and the carbon content of ethanol, CARBOB, and CaRFG, assuming renewable ethanol has zero CO_2 tailpipe emissions. No adjustments were made to the tailpipe CH_4 and N_2O.
  - <u>Adjustments for Tailpipe GHG Emissions Associated with Low-CI Gasoline:</u> The low-CI gasoline included in this analysis is produced from renewable feedstocks (See **Section 3.2.1.2)** and tailpipe CO_2 emissions associated with the combustion of this fuel are biogenic and set to zero. No adjustments were made to tailpipe CH_4 and N_2O emissions for Low-CI Gasoline use.

Electricity consumption from batteries in PHEVs and BEVs does not produce tailpipe emissions. Hence, tailpipe GHG emissions for eVMT associated with PHEVs and BEVs was assumed to be zero. Similarly, hydrogen consumption in FCEVs does not generate GHG emissions, so tailpipe GHG emissions for FCEVs are assumed to be zero. Further details regarding tailpipe emission estimation methodology, including EMFAC2021 inputs and outputs, can be found in **Appendix A**.

3.3 Vehicle Cycle Emissions

Ramboll estimated vehicle cycle emissions using the Argonne National Laboratory (ANL) 2021 Greenhouse gases, Regulated Emissions, and Energy use in Technologies (GREET) Model.[53] GREET is a life cycle model developed by Argonne National Laboratory that evaluates the energy and environmental impacts of a range of vehicle technologies and transportation fuels, allowing users to model the effects of various vehicle-fuel type

[51] CARB. 2018. EMFAC 2017 Volume III – Technical Documentation. July 20. Available at: https://ww3.arb.ca.gov/msei/downloads/emfac2017-volume-iii-technical-documentation.pdf. Accessed: May 2022.

[52] This aligns CARB's methodology for estimating the statewide GHG emission inventory, as noted in the 2021 CARB Report on the *California Greenhouse Gas Emissions for 2000 to 2019*, which states that "carbon dioxide (CO_2) emissions from biofuels (the biofuel components of fuel blends) are classified as "biogenic CO_2". They are tracked separately from the rest of the emissions in the inventory and are not included in the total emissions when comparing to California's 2020 and 2030 GHG Limits." Available at: https://ww3.arb.ca.gov/cc/inventory/pubs/reports/2000_2019/ghg_inventory_trends_00-19.pdf?msclkid=9f56cab9d01611ec878dcdb49cca2c91. Accessed: May 2022.

[53] ANL. 2021. Greenhouse gases, Regulated Emissions, and Energy use in Technologies model. Available at: https://greet.es.anl.gov/. Accessed: May 2022.

combinations. GREET 1 focuses on fuel life cycle impacts and estimates the energy consumption and emissions associated with fuel production ("well-to-tank") and vehicle operation ("tank-to-wheel"). GREET 2 is the vehicle life cycle model and evaluates the energy and emission impacts associated with vehicle material recovery and production, vehicle component fabrication, vehicle assembly, and vehicle disposal/recycling.[54]

3.3.1 Vehicle Cycle Emission Factors

For this analysis, Ramboll used GREET 2 (and GREET 1 inputs as needed) to estimate vehicle life cycle emission factors for ICEV, HEV, BEV, and PHEV technologies. FCEVs were not included in the scope of Ramboll's vehicle cycle emissions analysis.[55] The vehicles are evaluated as model year 2026 passenger vehicles; while vehicle cycle emissions may decrease over time with the increase in the renewable content of the electricity used for vehicle production, we do not expect the reduction to significantly alter the results or conclusions of the study.

Battery recycling for BEVs and PHEVs is not included in this assessment. This assumption is informed by current end-of-life recycling rate of <1% globally for lithium and rare earth minerals noted in the 2021 International Energy Association (IEA) Study on the *Role of Critical Minerals in Clean Energy Transition.*[56] Furthermore, it is likely that the vast majority of batteries produced in the future would require virgin material given the significant increase in demand under a mass vehicle electrification scenario.

The vehicle emission and electric grid mix data input to the model is based on the most current information available at the time of this study as the scope of this analysis does not include forecasting or projecting future energy demands from vehicle and battery manufacturing.

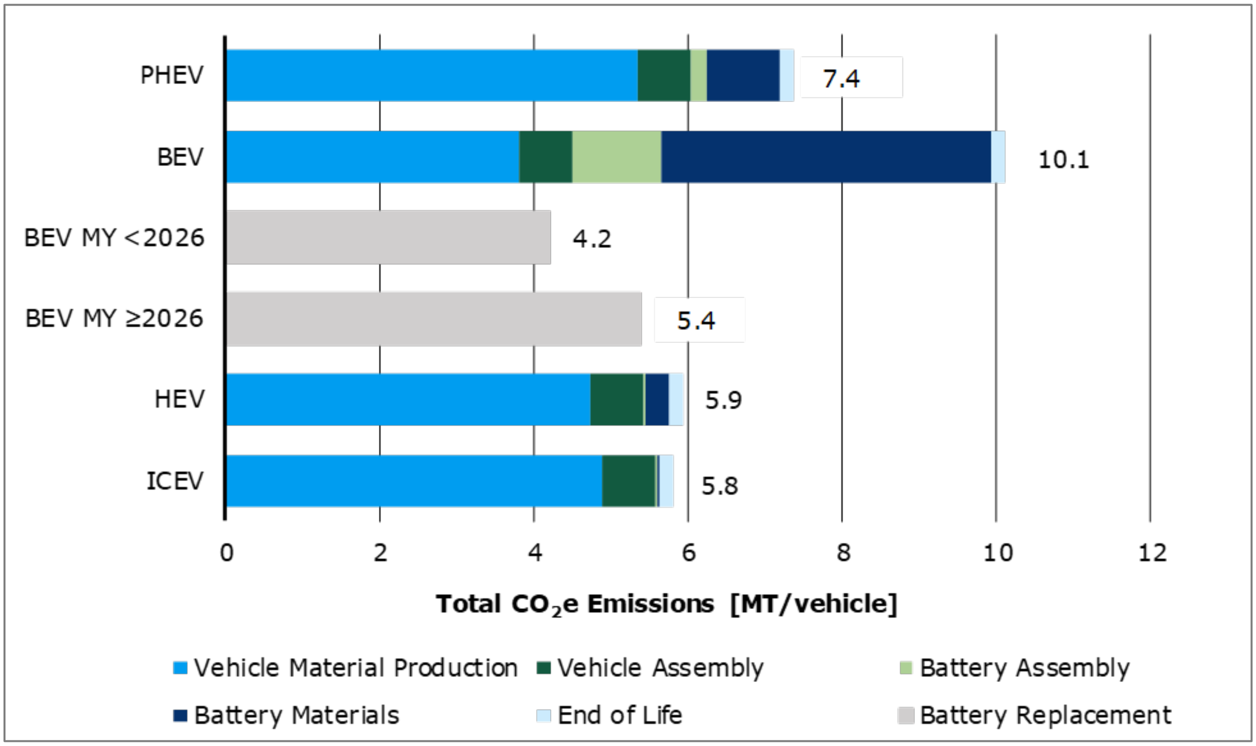
The resulting vehicle cycle emission factors in metric tons of CO_2e per vehicle for PHEVs, BEVs, HEVs, and ICEVs are shown in **Figure 3-5**. Additional details on the GREET model inputs used to estimate these emissions are described in the following sub-sections.

[54] ANL. 2021. GREET Model Platforms. Available at: https://greet.es.anl.gov/greet.models. Accessed: May 2022.

[55] FCEVs represented only a small fraction (<0.8%) of total 2020 ZEV sales and an even smaller fraction (<0.06%) of the total 2020 LDV sales in California. The vehicle material recovery and production, vehicle component fabrication, vehicle assembly, and vehicle disposal/recycling processes are still in the developmental stage, and it would be too speculative to estimate vehicle cycle emissions until the market for these vehicles mature. Sales data obtained from CEC data dashboard 'New ZEV Sales in California'. Available here: https://www.energy.ca.gov/data-reports/energy-almanac/zero-emission-vehicle-and-infrastructure-statistics/new-zev-sales. Accessed: May 2022.

[56] International Energy Agency (IEA). 2021. The Role of Critical Minerals in Clean Energy Transitions. May. Available at: https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions?msclkid=fa519918d01f11ecbcf188dc9fbbf9f2. Accessed: May 2022.

Figure 3-5: Vehicle Cycle and Battery Replacement GHG Emission Factors



3.3.1.1 GREET Inputs for ICEVs and HEVs

To model ICEVs and HEVs, Ramboll used default values in the GREET model for all vehicle production and assembly parameters except for the electricity mix used for material and fuel production. The US electric mix for stationary use in GREET 1 was updated with the 2020 national electricity mix published by the EPA's Emissions & Generation Resource Integrated Database (eGRID).[57] Ramboll also updated the GREET 1 electric grid mixes for fuel production for non-US countries where vehicle and battery components are produced or assembled. These grid mixes were updated using most recent available data from the IEA.[58] A full matrix of all non-default GREET inputs can be found in **Appendix A**.

3.3.1.2 GREET Inputs for BEVs and PHEVs

For BEVs, Ramboll modeled a lithium-ion (Li-ion) battery with a nickel manganese cobalt (NMC 622) cathode material, which per a 2021 study from the International Council on Clean Transportation (ICCT) is the most common cathode material used in BEVs globally.[59] The Li-ion peak battery energy for BEVs is modeled as 81 kWh. This value was calculated as a product of BEV fuel economy, range, and charge utilization. The fuel economy is 2.59-mi/kWh based on EMFAC2021 data (described in **Section 3.1.2**), the range is

---

[57] EPA. 2022. eGRID Summary Tables 2020. January 27. Available here: https://www.epa.gov/egrid/summary-data. Accessed: May 2022.

[58] IEA. 2022. Countries and regions. Available at: https://www.iea.org/countries. Accessed: May 2022.

[59] ICCT. 2021. A Global Comparison of The Life-Cycle Greenhouse Gas Emissions Of Combustion Engine And Electric Passenger Cars. Available here: https://theicct.org/publication/a-global-comparison-of-the-life-cycle-greenhouse-gas-emissions-of-combustion-engine-and-electric-passenger-cars/. Accessed: May 2022.

200 miles based on the minimum certified all-electric range in the draft ACC II regulation,[60] and the state of charge (SOC) utilization is 95% based on CARB's ZEV cost modeling worksheets.[61,62] Battery production and assembly share by country is derived from the number of battery cells supplied to the US BEV market by production location, reported in an Argonne National Laboratory publication on the 2010-2020 Lithium-Ion Battery Supply Chain for E-Drive Vehicles in the United States.[63] Production shares for 2020 were used in order to reflect the most current information available.

To model PHEVs, Ramboll assumed the NMC 111 cathode material (which is the GREET default) since NMC 622 is not an option provided in GREET 2 for PHEVs. The Li-ion peak battery energy for PHEVs is modeled as 14 kWh. This value was calculated as a product of PHEV fuel economy, range, and charge utilization. The fuel economy is 3.31 mi/kWh based on EMFAC2021 data (described in **Section 3.1.3**), the range is 40 miles based on the US-06 minimum certified all-electric range in the draft ACC II regulation,[64] and the SOC utilization is 85% based on CARB's ZEV cost modeling worksheets.[65,66] Battery production and assembly shares by country are assumed to be equivalent to those used in the BEV model.

All other vehicle and battery parameters for BEVs and PHEVs were left unchanged from GREET default values, and a full matrix of all non-default inputs for these vehicles can be found in **Appendix A**.

3.3.2 Vehicle Cycle GHG Emissions in Scenario Analysis

Ramboll incorporated vehicle cycle GHG emissions for all ICEVs, PHEVs, BEVs, and HEVs in the scenario analysis by calculating GHG emissions for all vehicles of a given model year, and attributing those emissions to the corresponding calendar year (assumed to be the same as the model year) in which they were produced. The following steps were used to develop the vehicle cycle emissions and incorporate it into the scenario analysis:

---

[60] CARB. 2022. Appendix A-5: Proposed Regulation Order for Section 1962.4 Zero-Emission Vehicle Standards for 2026 and Subsequent Model Year Passenger Cars and Light-Duty Trucks. April 12. Available at: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/accii/appa5.pdf. Accessed: May 2022.

[61] CARB. 2021. ZEV Cost Modeling Workbook October 2021. Available at: https://ww2.arb.ca.gov/sites/default/files/2021-11/ZEV_Cost_Modeling_Workbook_Update_October2021.xlsx. Accessed: January 2022.

[62] The October 2021 version of CARB's ZEV Cost Modeling Workbook was referenced for this analysis. A newer version of this workbook was released in late April 2022 (after completion of this analysis), which assumed a lower SOC utilization for BEV batteries of 92.5%. However, this does not change the overall conclusions of the analysis.

[63] ANL. 2021. Lithium-Ion Battery Supply Chain for E-Drive Vehicles in the United States: 2010-2020. March. Available at: https://publications.anl.gov/anlpubs/2021/04/167369.pdf. Accessed: May 2022.

[64] CARB. 2022. Appendix A-5: Proposed Regulation Order for Section 1962.4 Zero-Emission Vehicle Standards for 2026 and Subsequent Model Year Passenger Cars and Light-Duty Trucks. April 12. Available at: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/accii/appa5.pdf. Accessed: May 2022.

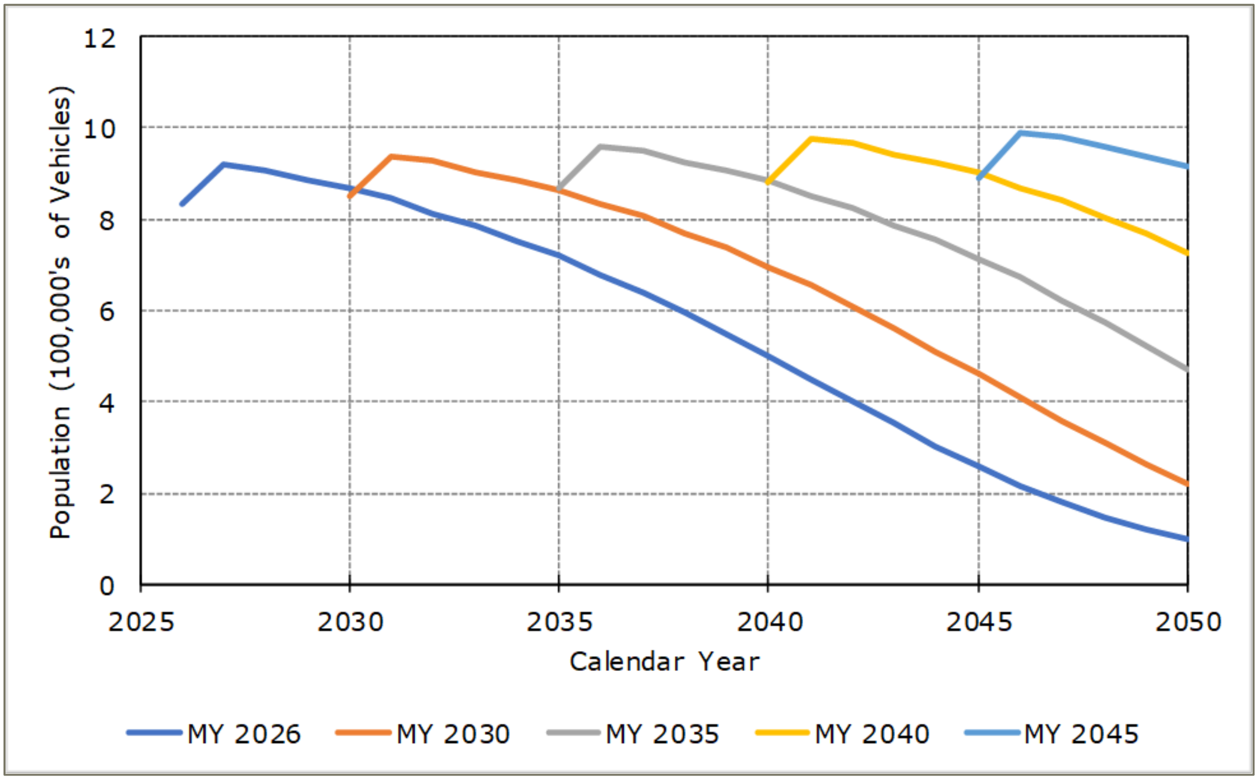
[65] CARB. 2021. ZEV Cost Modeling Workbook October 2021. Available at: https://ww2.arb.ca.gov/sites/default/files/2021-11/ZEV_Cost_Modeling_Workbook_Update_October2021.xlsx. Accessed: January 2022.

[66] The October 2021 version of CARB's ZEV Cost Modeling Workbook was referenced for this analysis. A newer version of this workbook was released in late April 2022 (after completion of this analysis), which assumed a lower SOC utilization for PHEV batteries of 80%. However, this does not change the overall conclusions of the analysis.

- Ramboll assumed that the total number of vehicles produced for a given model year is equal to the peak population of that model year in EMFAC2021. **Figure 3-6** shows that the peak vehicle population for any given model year in EMFAC2021 occurs one year after the corresponding calendar year (CY) in which they were first introduced to the fleet.[67]
- GHG emissions from production of vehicles of a certain MY are assumed to occur in the calendar year the vehicles are produced (for example, MY 2026 vehicle population peaks in CY 2027, but vehicle cycle emission from vehicle production occur in CY 2026).
- Since EMFAC2021 does not output fleet data for CY 2051, Ramboll estimated the peak population of MY 2050 vehicles (which would occur in CY 2051) by applying the percentage increase in MY 2049 vehicles from CY 2049 to CY 2050 to the MY 2050 vehicle population in CY 2050.
- It is assumed that production patterns for different vehicle technologies would be similar to the pattern modeled in EMFAC2021. Therefore, the total number of vehicles produced for each vehicle technology in each model year is calculated based on the fleet mix percentage for that vehicle technology and the total peak population in the following calendar year. Fleet mixes for each scenario are shown in **Figure 2-3** and **Figure 2-4** and detailed tables showing fleet mix percentages and population data for each vehicle technology by model year in each calendar year are included in **Appendix A**.
- Finally, the total annual life cycle GHG emissions for each modeled scenario in the analysis years (2026, 2030, 2035, 2045, and 2050) were estimated as follows: The total number of vehicles produced for each vehicle technology in an analysis year was multiplied by the corresponding GREET vehicle life cycle emission factor (on a per-vehicle basis, see **Figure 3-5** for vehicle cycle emission factors) in order to generate vehicle life cycle GHG emissions. These emissions were then added to the upstream and tailpipe emissions for each analysis year in order to estimate total annual life cycle GHG emissions.

[67] Total LDA vehicle population reported in **Figure 3-6** is based on the EMFAC2021 queries performed for this analysis, as described in detail in Appendix A. Diesel vehicles are not included.

Figure 3-6: LDA Vehicle Population in EMFAC2021



3.3.3 GHG Emissions from Lithium Battery Replacement

In addition to GHG emissions from vehicle and battery production, Ramboll analyzed the GHG emissions associated with battery replacement for BEVs. Battery replacement for BEVs lithium-ion batteries is assumed to occur in the ninth year of use based on the 8-year warranty requirement proposed in the CARB ACC II Initial Statement of Reasons (ISOR) Staff Report.[68] Ramboll's scenario analysis assumes that one battery replacement occurs over the vehicle lifetime for all BEVs remaining in the vehicle fleet in the ninth year of operation (e.g., battery replacement emissions in CY 2026 are calculated based on the population of MY 2017 BEVs in CY 2026). This methodology accounts for the default retirement rate of vehicles in EMFAC2021, as illustrated in **Figure 3-6** above.

The emissions per vehicle associated with this battery replacement were estimated from the results of the GREET modelling described in **Section 3.4.1**. In particular, the emissions for battery production and assembly were combined to estimate battery replacement emissions on a per vehicle basis. For MY 2026-2050 BEVs, BEV battery replacement is assumed to occur for an 81-kWh battery as described in **Section 3.4.1**. However, for pre-2026 BEVs, a peak battery energy of 62.5 kWh was assumed a weighted average of the battery sizes and cumulative sales of various BEV models from 2010-2020 in the United States.[69] Thus,

---

[68] CARB. 2022. Staff Report: Initial Statement of Reasons. April 12. Available at: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/accii/isor.pdf. Accessed: May 2021.

[69] Lithium-Ion Battery Supply Chain for E-Drive Vehicles in the United States: 2010-2020. March. Available at: https://publications.anl.gov/anlpubs/2021/04/167369.pdf. Accessed: May 2022.

battery replacement emission factors for BEVs MY <2026 and BEVs MY ≥2026 were estimated separately, as represented by the gray bars in **Figure 3-5**.

Battery replacement emissions were calculated by multiplying the remaining population of BEVs in the vehicle fleet in the ninth year of operation by the emission factors per vehicle shown in **Figure 3-5**. The resulting emissions associated with BEV mid-life battery replacements were incorporated into the multi-technology scenario analysis by adding battery replacement emissions to life cycle emissions.

While batteries in PHEVs and HEVs deteriorate over time, for purposes of this analysis Ramboll has assumed that vehicle owners/operators would not replace the battery in these vehicle technologies. Instead, they would continue to operate these vehicles using the ICE and the underperforming battery till the end of the vehicle lifetime.

4. SCENARIO ANALYSIS EMISSIONS RESULTS

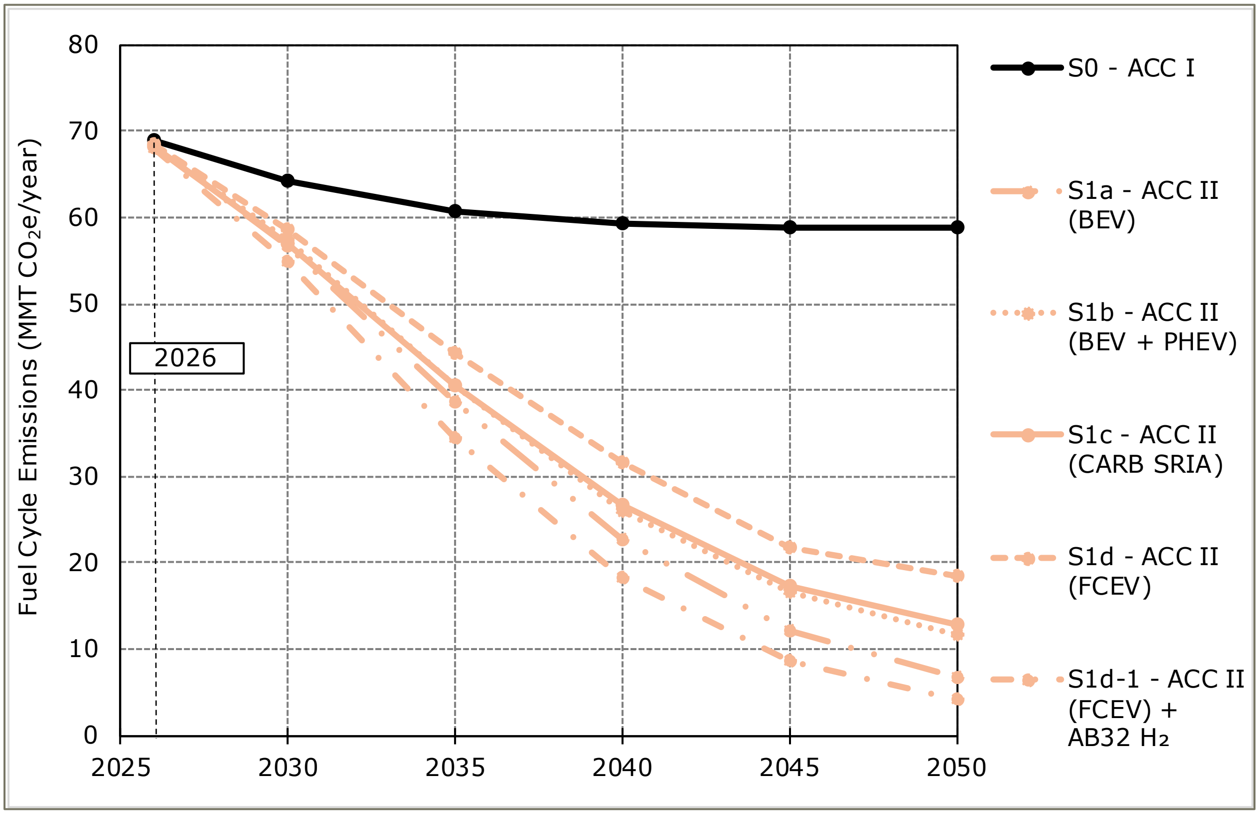
4.1 Fuel Cycle (Well-to-Wheel) Emissions

Fuel cycle emissions, also known as "well-to-wheel" emissions, include both upstream (well-to-tank) emissions and tailpipe (tank-to-wheel) emissions and represent overall emissions impacts of the fuel, including extraction of the raw materials for the fuel, fuel production and distribution, and use of the finished fuel during operation of the vehicle.[70] **Figure 4-1** through **Figure 4-4** below present the estimated total GHG fuel cycle emissions for calendar years 2026 to 2050 for each modeled scenario: S0 – ACC I (represented by black line), S1 – Baseline ACC II Scenarios (represented by the pink lines and shaded pink region), S2 – Alternative Scenarios Part 1 (represented by blue lines), S3 – Alternative Scenarios Part 2 (represented by purple lines), S4 – Alternative Scenarios Part 3 (represented by green lines).

The results presented in **Figure 4-1** show that scenario S1d – ACC II (FCEV) achieves the fewest GHG emissions reductions of the S1 - Baseline ACC II Scenarios as compared to the S0 – ACC I Scenario. This result is driven by the relatively high CI of the CARB SRIA Hydrogen as compared to electricity and the AB32 Hydrogen that displace CaRFG used in scenario S0 – ACC I. On the other hand, scenario S1d-1 – ACC II (FCEV) + AB32 H_2 provides the greatest potential GHG emission reductions of the S1 - Baseline ACC II Scenarios, due to the significant reduction in upstream emissions for AB32 Hydrogen as compared to CaRFG.

[70] https://www.epa.gov/renewable-fuel-standard-program/lifecycle-analysis-greenhouse-gas-emissions-under-renewable-fuel

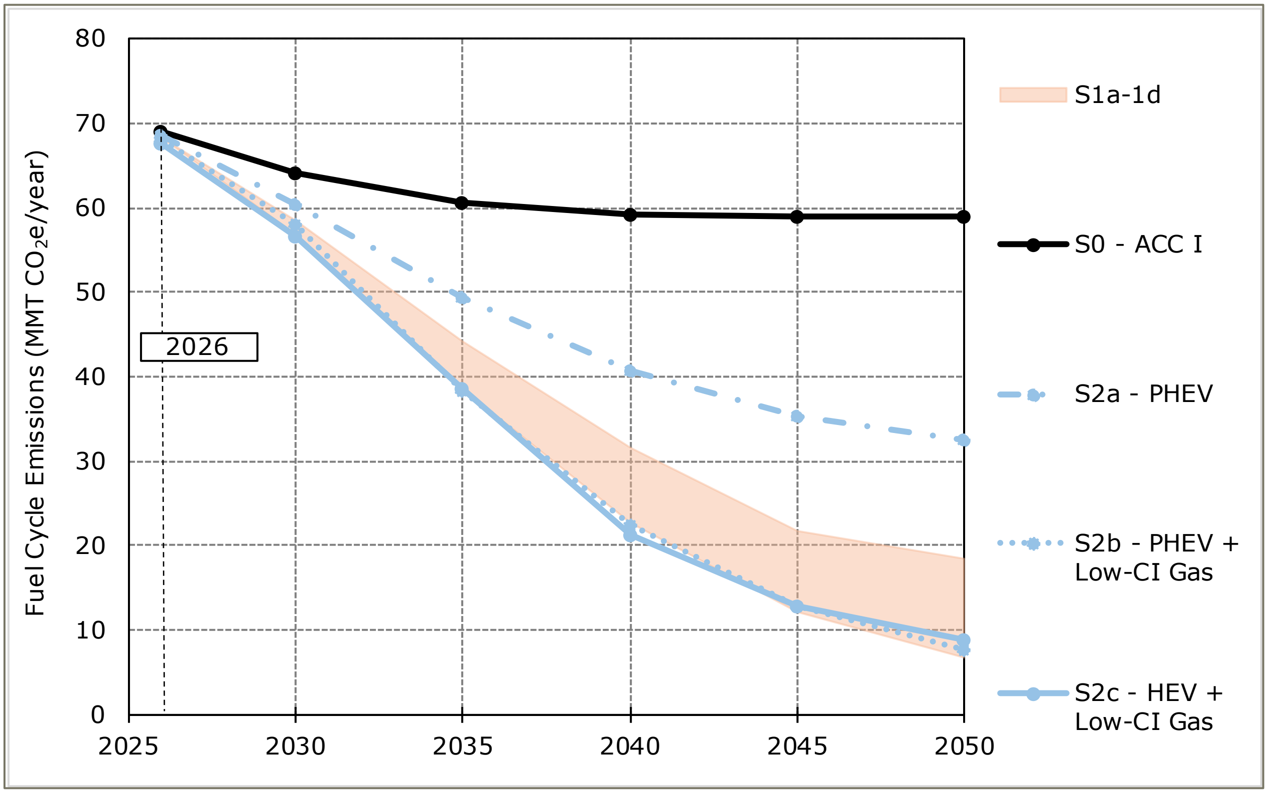
Figure 4-1: Fuel Cycle Emissions for Baseline Scenarios



As shown in **Figure 3-3**, AB32 Hydrogen pathway provides the lowest CI of all fuels considered, resulting in nearly carbon-free hydrogen with an upstream EER-adjusted CI less than 0.5 g CO_2e/MJ of gasoline displaced from 2030-2050. Aside from sensitivity scenario S1d-1 – ACC II (FCEV) + AB32 H_2, scenario S1a – ACC II (BEV), which assumes any additional ZEVs sales beyond those in the S0 – ACC I Scenario that are needed to meet the proposed ACC II ZEV sales requirements are met with BEVs, represents the lower bound of achievable GHG emissions under the draft ACC II proposal. Assuming the proposed ACC II sales requirements are met with the maximum allowable fraction of PHEVs in scenario S-1b – ACC II (BEV + PHEV) provides fewer fuel cycle GHG emission reductions than scenario S-1a – ACC II (BEV) in comparison to scenario S0 – ACC I. Results for S1c – ACC II (CARB SRIA) are similar to scenario S1b – ACC II (BEV + PHEV), although scenario S1c – ACC II (CARB SRIA) provides slightly lower fuel cycle GHG emission reductions in comparison to scenario S0 – ACC I in CY 2040-2050 due to the inclusion of FCEVs fueled by the CARB SRIA Hydrogen.

Figure 4-2 shows results for S2 - Alternative Scenarios Part 1, which estimate GHG emission reductions achievable from increased penetration of PHEVs or HEVs. Some of these scenarios include a phase-in of low-CI gasoline as a replacement for CaRFG that is used for ICEs in ICEVs, PHEVs, and HEVs.

Figure 4-2: Fuel Cycle Emissions for Alternative Scenarios Part 1



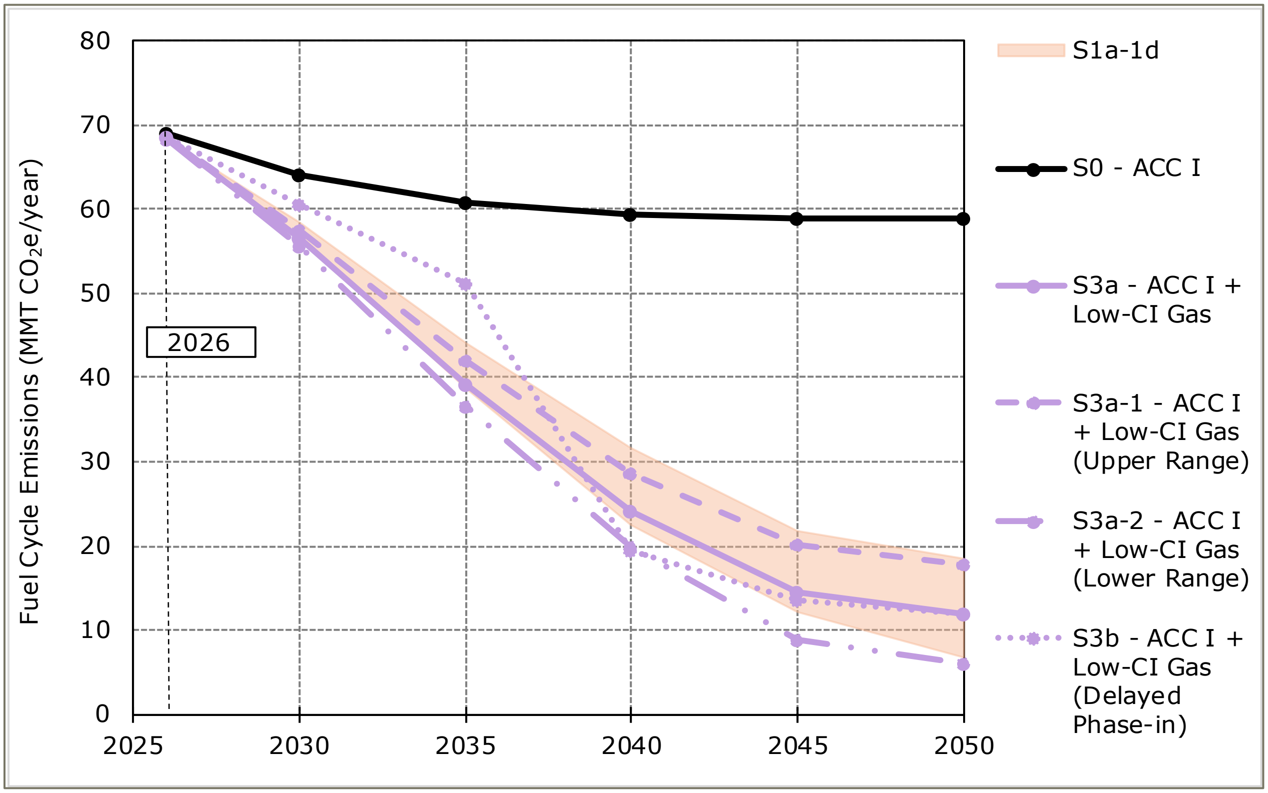
These results (**Figure 4-2**) show that we can achieve >50% of the estimated GHG reductions from the draft ACC-II proposal (scenarios S1a-1d, represented by the shaded pink region) as compared to S0 – ACC I (represented by the black solid line), by using PHEVs sales[71] to meet the ACC II ZEV sales requirements (S2a – PHEV, represented by the blue dash-dot-dash line). Phasing in Low-CI gasoline (S2b – PHEV + Low-CI Gas, represented by the blue dotted line) with these PHEVs sales could increase the GHG reductions so they are comparable to the reductions achieved with draft ACC-II proposal (scenarios S1a through S1d, represented by the shaded pink region). Similarly, a combination of HEVs sales[72] to meet the ACC II ZEV sales requirement and a phase-in of Low-CI gasoline to fuel ICEs in ICEVs, HEVs, and PHEVs (S2c – PHEV + Low-CI Gas, represented by the solid blue line) can also achieve GHG reductions that are comparable to the those from the draft ACC II proposal (scenarios S1a through S1d, represented by the shaded pink region) relative to Scenario S0 - ACC I.

Results for S3 - Alternative Scenarios Part 2, which explore the use of low-CI gasoline to generate GHG emission reductions needed to meet the State’s long-term climate goals with no change in fleet mix, are shown in **Figure 4-3**.

[71] Any additional ZEVs sales beyond those (BEVs and PHEVs) in the S0 - ACC I Scenario that are needed to meet the ZEV sales requirements in the draft ACC II proposal are met with PHEVs.

[72] Any additional ZEVs sales beyond those (BEVs and PHEVs) in the S0 - ACC I Scenario that are needed to meet the ZEV sales requirements in the draft ACC II proposal are met with HEVs.

Figure 4-3: Fuel Cycle Emissions for Alternative Scenarios Part 2

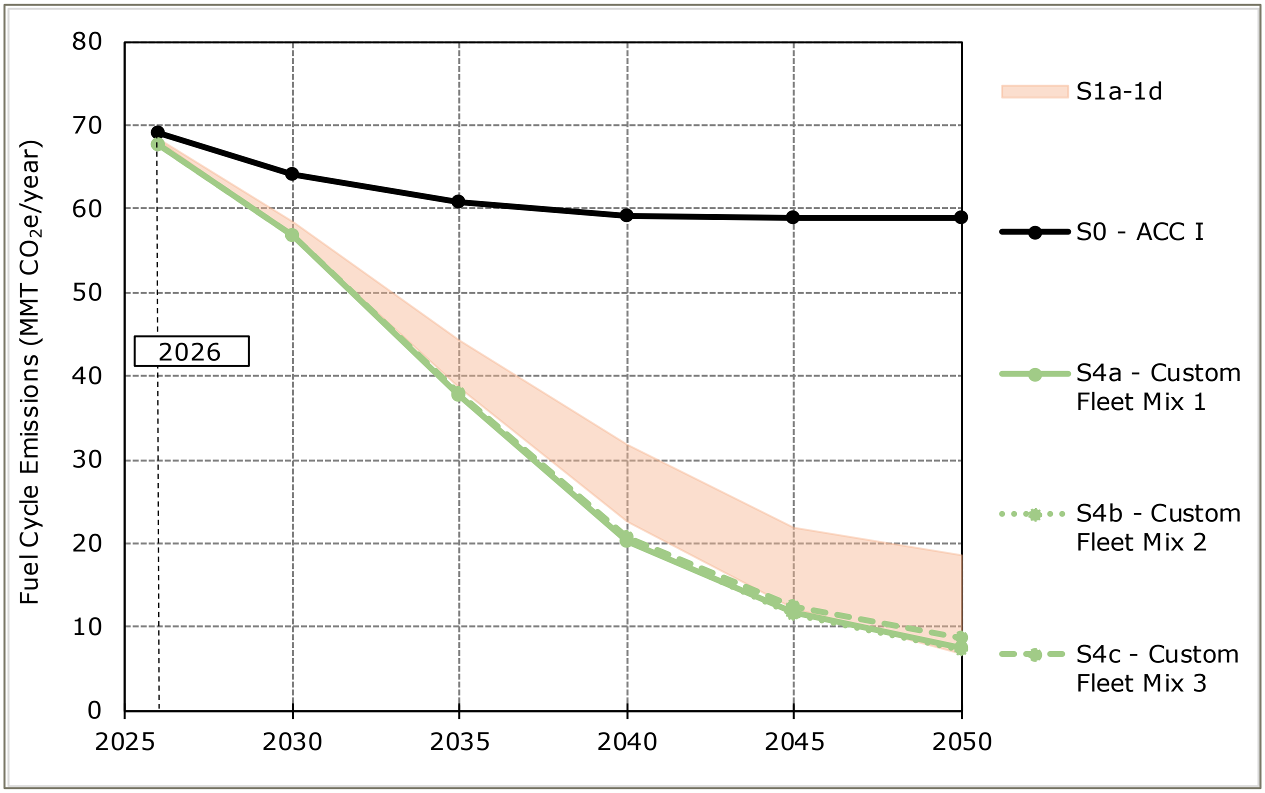


These results (**Figure 4-3**) show that a phase in of low-CI gasoline alone (represented by the purple lines) with no additional ZEV sales beyond those included in scenario S0 – ACC I (represented by the solid black line) can achieve fuel cycle GHG reductions similar to those achieved in the baseline ACC II scenarios (S1a through S1d, represented by the pink area) as compared to scenario S0 - ACC I. Results for scenario S3a-1 – Low-CI Gas indicate that phase in of low-CI gasoline (with a carbon intensity of 19 g CO_2e/MJ) could achieve similar or greater emission reductions than the lowest emission baseline ACC II scenario S1a - ACC II (BEV) through 2035, although emission reductions fall short of those estimated for Scenario S1a in 2040-2050. Reducing the carbon intensity of low-CI gasoline (S3a-2 – Low-CI Gas (Lower Range)) to 9 g CO_2e/MJ could generate further GHG emission reductions that exceed those estimated for the baseline ACC II scenarios relative to scenario S0 - ACC I. Even if the carbon intensity of low-CI gasoline was increased to 29 g CO_2e/MJ (S3a-1 – Low-CI Gas (Upper Range)), we can achieve GHG emission reductions (relative to S0 – ACC I) that are similar to the draft ACC II proposal (scenarios S1a through S1d).

The delayed phase in of low-CI gasoline considered in scenario S3b – Low-CI Gas (Delayed) decreases the emissions reductions (relative to S0 – ACC I) achieved through 2035 but achieves greater emission reductions from 2040-2050. Results for Alternative Scenarios Part 2 and Alternative Scenarios Part 3 show that low-CI gasoline could potentially achieve the State’s long-term climate goals and decarbonize the transportation sector at a rate comparable to a ZEV-only regulation like the draft ACC II proposal.

Figure 4-4 shows results for Alternative Scenarios Part 3, which explore the potential emission reductions achievable from a diverse deployment of vehicle technologies. These scenarios (S-4a through S-4c, represented by the green lines) all provide fuel cycle GHG emission reductions (relative to S0 – ACC I) that exceed those achieved in the baseline ACC II scenarios (S1a through S1d, represented by the pink area) for all calendar years except 2050. These results show that increased ZEV sales mandates are not the only way to achieve the State's climate goals and a combination of different vehicle technologies and fuel pathways could be utilized to meet California's GHG emission reduction targets.

Figure 4-4: Fuel Cycle Emissions for Alternative Scenarios Part 3



4.2 Life Cycle Emissions

Life cycle emissions include fuel cycle emissions and vehicle cycle emissions and provide a comprehensive life cycle-based assessment of the potential GHG emissions from all vehicle technologies. **Figure 4-5** through **Figure 4-8** below present the estimated total GHG life cycle emissions for calendar years 2026 to 2050 for each modeled scenario that does not include FCEVs,[73] using the same color scheme for each scenario described previously in **Section 4.1**.

The addition of vehicle cycle emissions to fuel cycle emissions increases the total GHG emissions in all calendar years in all scenarios relative to those shown in **Figure 4-1** through **Figure 4-4**. Additionally, because BEVs have the highest vehicle cycle GHG emissions (see **Figure 3-5** for vehicle cycle emissions for each vehicle type), scenarios with significant BEV penetration show the largest increase in life cycle GHG emissions relative to fuel cycle emissions. As a result, scenarios that focus on implementation of low-CI gasoline rather than

[73] As described in **Section 3.4**, life cycle emission results are not available for scenarios with FCEVs, so scenarios that include FCEVs are not shown in **Figure 4-5** through **Figure 4-8**.

increased penetration of BEVs generally achieve greater life cycle GHG emission reductions relative to scenario S0 – ACC I.

The results presented in **Figure 4-5** show that scenario S1a – ACC II (BEV) continues to provide greater GHG emission reductions (relative to S0 – ACC I) than scenario S1b – ACC II (BEV + PHEV), despite greater vehicle cycle emissions from more BEVs in scenario S1a – ACC II (BEV) than scenario S1b – ACC II (BEV + PHEV). Note that in **Figure 4-5** through **Figure 4-8**, life cycle emissions for Baseline ACC II Scenarios (pink shaded region) are bounded by scenarios S1a and S1b because scenarios with FCEVs (S1c, S1d, and S1d-1) are not included in the life cycle analysis.

Results for S3 - Alternative Scenarios Part 1 in **Figure 4-6** show that increased penetration of only PHEVs or HEVs combined with phase in of low-CI gasoline can provide greater life cycle GHG emission reductions than the draft ACC II proposal (scenarios S1a and S1b, represented by the shaded pink region). Similarly, GHG emission reductions from the phase in of low-CI gasoline (Alternative Scenarios Part 2, represented by purple lines in **Figure-4-7**) without any fleet mix changes from S0 – ACC I could exceed life cycle GHG emission reductions in the draft ACC II proposal (scenarios S1a and S1b, represented by the shaded pink region) in all years except 2050. Finally, **Figure 4-8** shows that a diverse mix of fuel and vehicle technologies (Alternative Scenarios Part 3, represented by green lines) can achieve greater life cycle GHG emission reductions relative to S0 – ACC I in all calendar years than the ZEV-centric approach in the draft ACC II proposal (scenarios S1a and S1b, represented by the shaded pink region).

Figure 4-5: Life Cycle Emissions for Baseline Scenarios

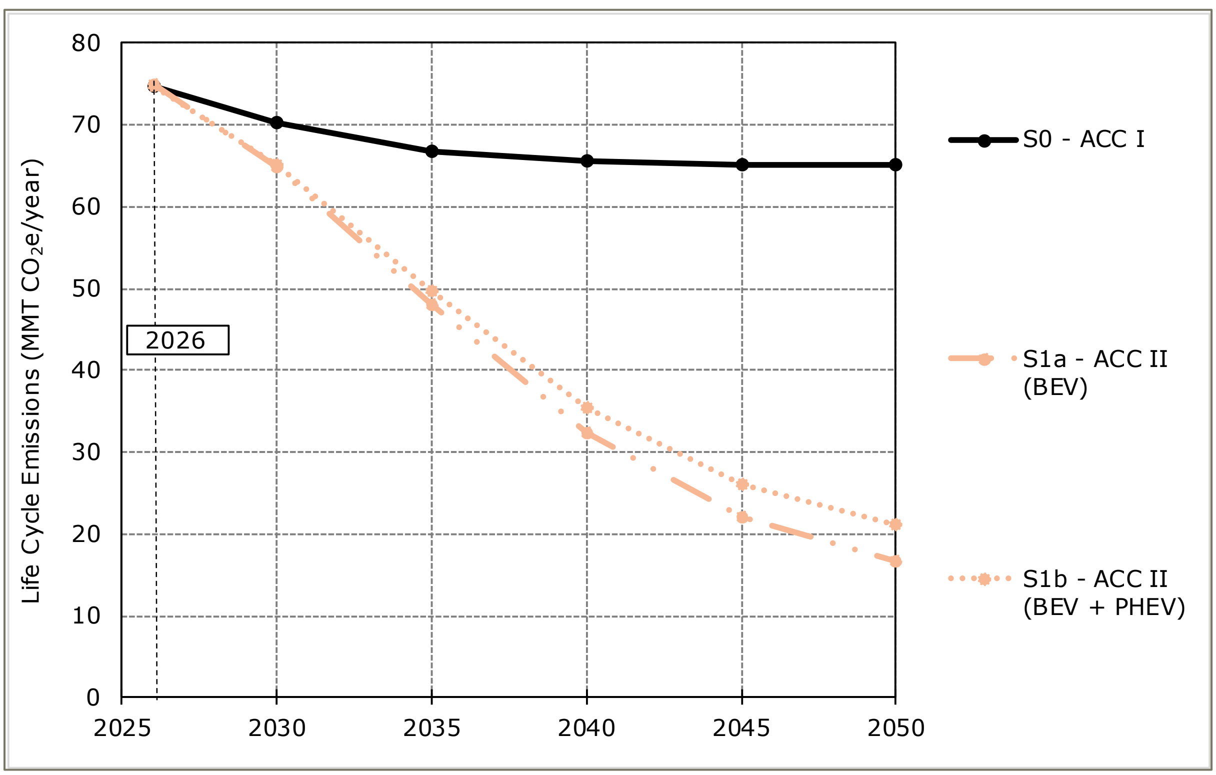


Figure 4-6: Life Cycle Emissions for Alternative Scenarios Part 1

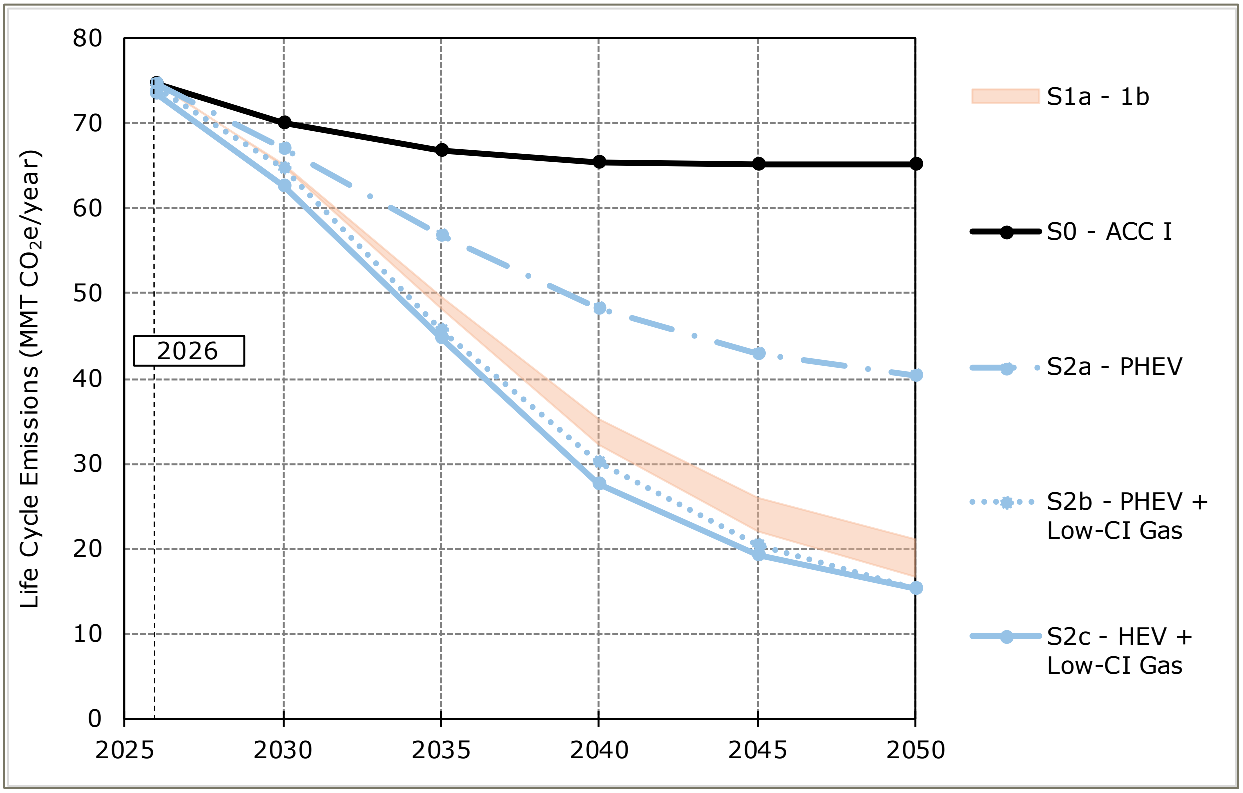


Figure 4-7: Life Cycle Emissions for Alternative Scenarios Part 2

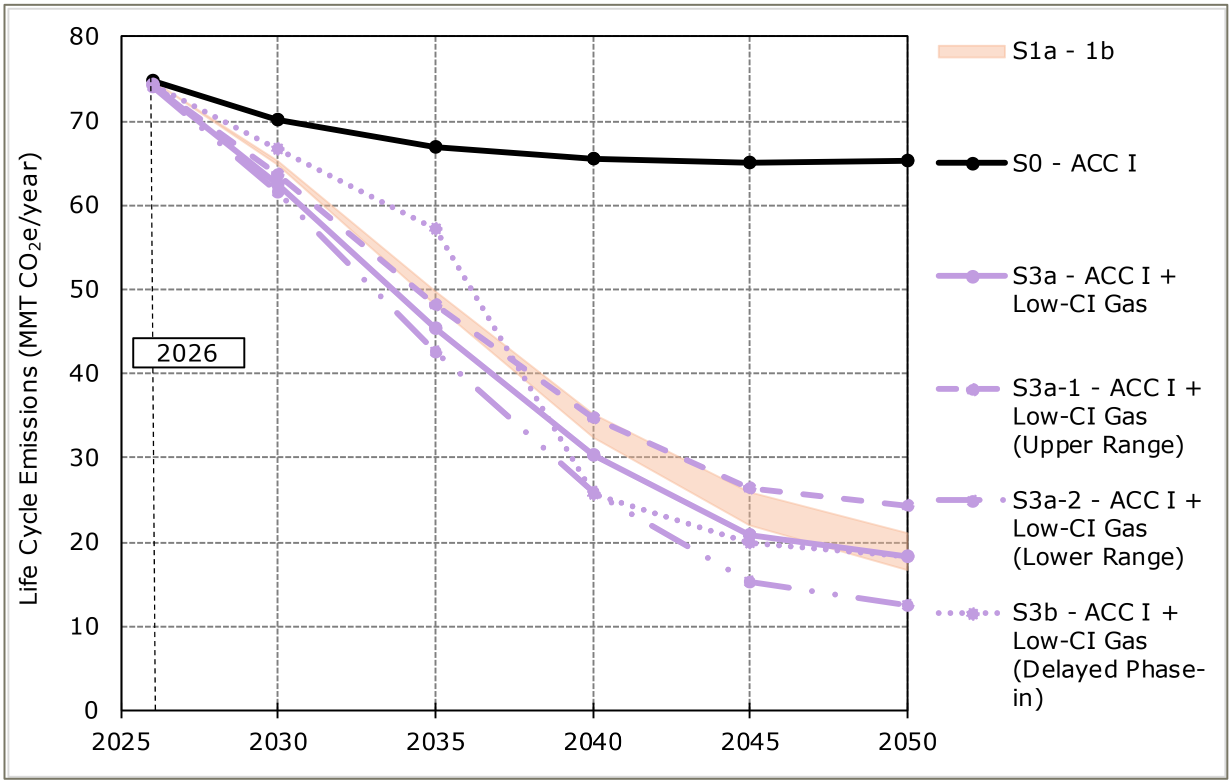
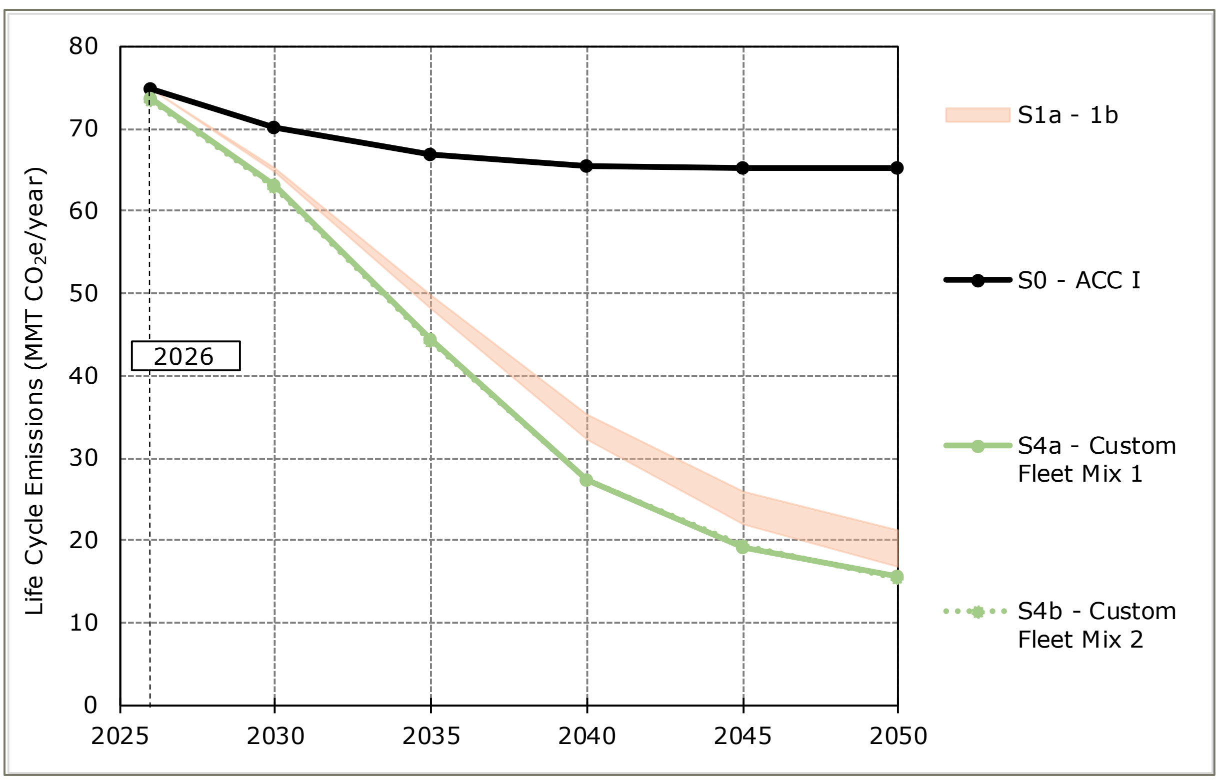


Figure 4-8: Life Cycle Emissions for Alternative Scenarios Part 3



4.3 Life Cycle Emissions with BEV Battery Replacement

Figure 4-9 through **Figure 4-12** show life cycle GHG emissions, including life cycle emissions associated with BEV battery replacement, for all scenarios without FCEVs[74] using the same color scheme for each scenario described previously. The inclusion of GHG emissions from BEV battery replacement increases the total GHG emissions in all calendar years for all scenarios with BEVs relative to the life cycle emission totals discussed in **Section 4.2**. As a result, scenarios that focus on implementation of low-CI gasoline rather than increased penetration of BEVs generally achieve greater GHG emission reductions relative to scenario S0 – ACC I.

Figure 4-9 shows that scenario S1a – ACC II (BEV) continues to provide greater GHG emission reductions (relative to S0 – ACC I) than scenario S1b – ACC II (BEV + PHEV), despite greater life cycle emissions from more BEV battery replacements in scenario S1a – ACC II (BEV) than scenario S1b – ACC II (BEV + PHEV). In **Figures 4-10** through **4-12**, the pink shaded region represents the range of life cycle emissions with BEV replacement for Baseline ACC II Scenarios S1a and S1b only, as other ACC II scenarios with FCEVs S1c, S1d, and S1d-a are not included in the life cycle analysis.

Results for S3 - Alternative Scenarios Part 1 in **Figure 4-10** show that increased penetration of only PHEVs or HEVs combined with phase in of low-CI gasoline provide even greater life cycle GHG emission reductions than the draft ACC II proposal (scenarios S1a and S1b, represented by the shaded pink region), when BEV replacement is included (compare with **Figure 4-6**, which does not include life cycle emissions for battery replacement). Similarly, phase in of low-CI gasoline alone (Alternative Scenarios Part 2, represented by purple lines in **Figure 4-11**), becomes a more attractive option to achieve similar to or greater GHG emission reductions (relative to S0 – ACC I) than those achieved by the draft ACC II proposal (S1a and S1b), when BEV battery replacement emissions are included. Finally, the mix of fuel and vehicle technologies in Alternative Scenarios Part 3 (represented by the green lines in **Figure 4-12**) provides even greater life cycle GHG emission reductions than the baseline ACC II scenarios when BEV battery replacement emissions are included (compare with **Figure 4-8**). Overall, inclusion of GHG emissions associated with the entire life cycle of the fuel and vehicle technologies including BEV battery replacement illustrates the importance of considering multiple vehicle technology and fuel pathways to achieve GHG emissions reductions rather than focusing on ZEV sales mandates as required in the draft ACC II proposal.

[74] As described in **Section 3.4**, life cycle emission results are not available for scenarios with FCEVs, so scenarios that include FCEVs are not shown in **Figure 4-9** through **Figure 4-12**.

Figure 4-9: Life Cycle Emissions with BEV Battery Replacement for Baseline Scenarios

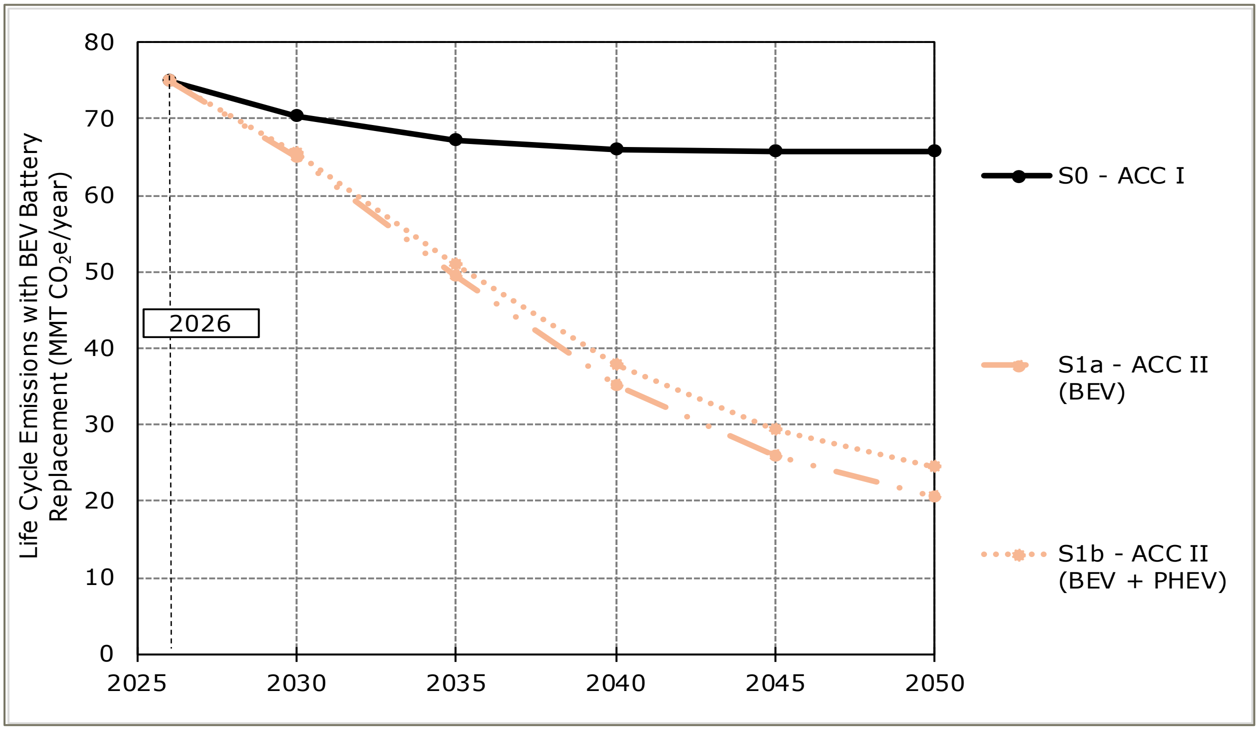


Figure 4-10: Life Cycle Emissions with BEV Battery Replacement for Alternative Scenarios Part 1

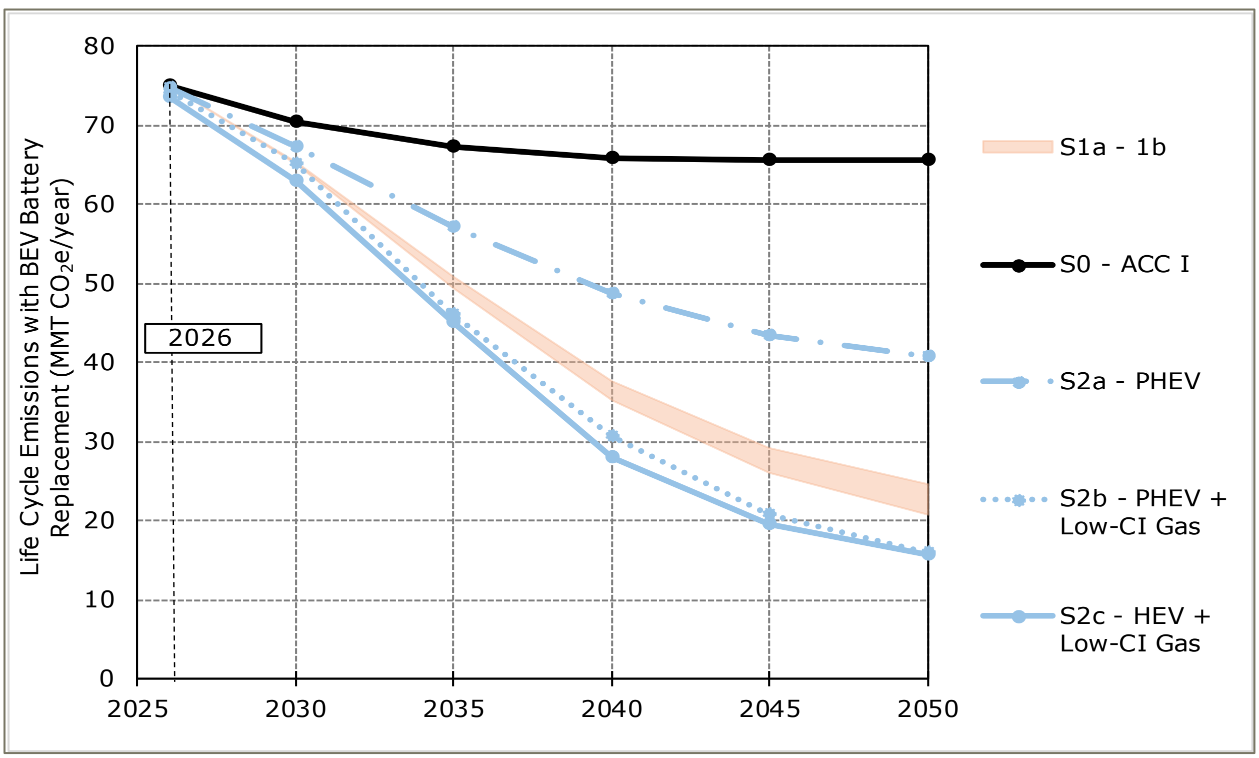


Figure 4-11: Life Cycle Emissions with BEV Battery Replacement for Alternative Scenarios Part 2

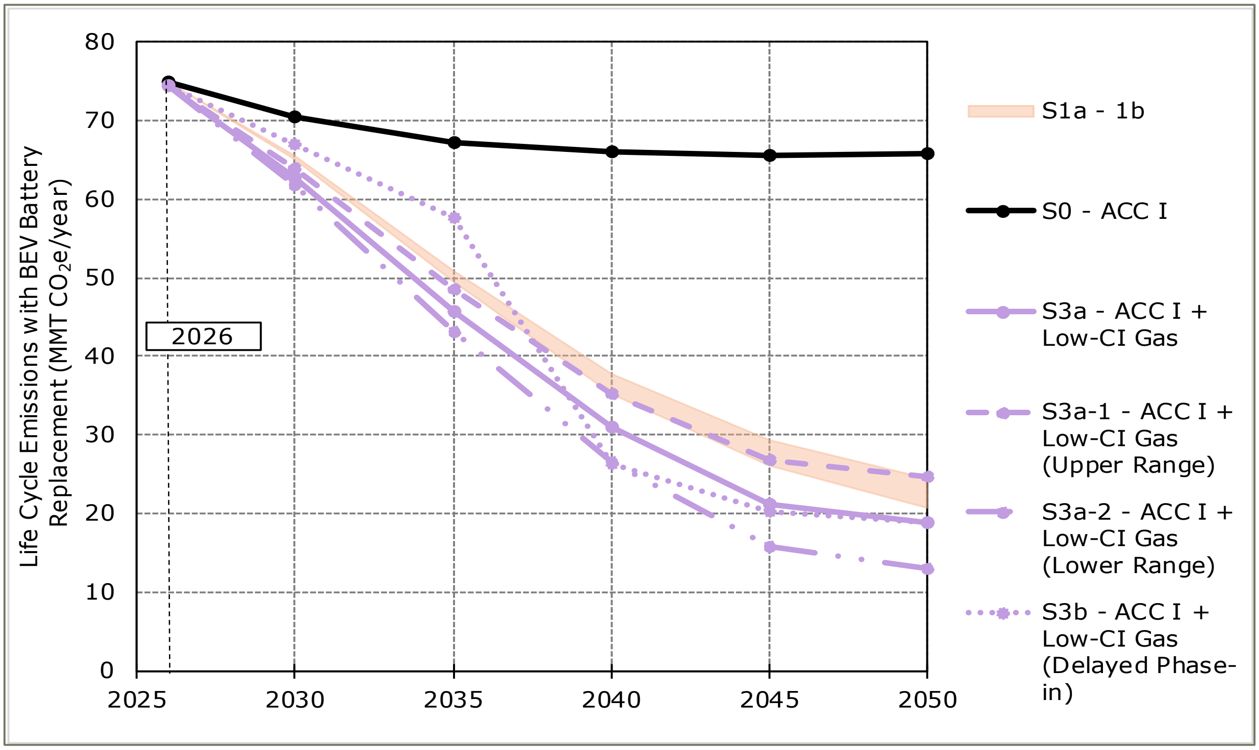
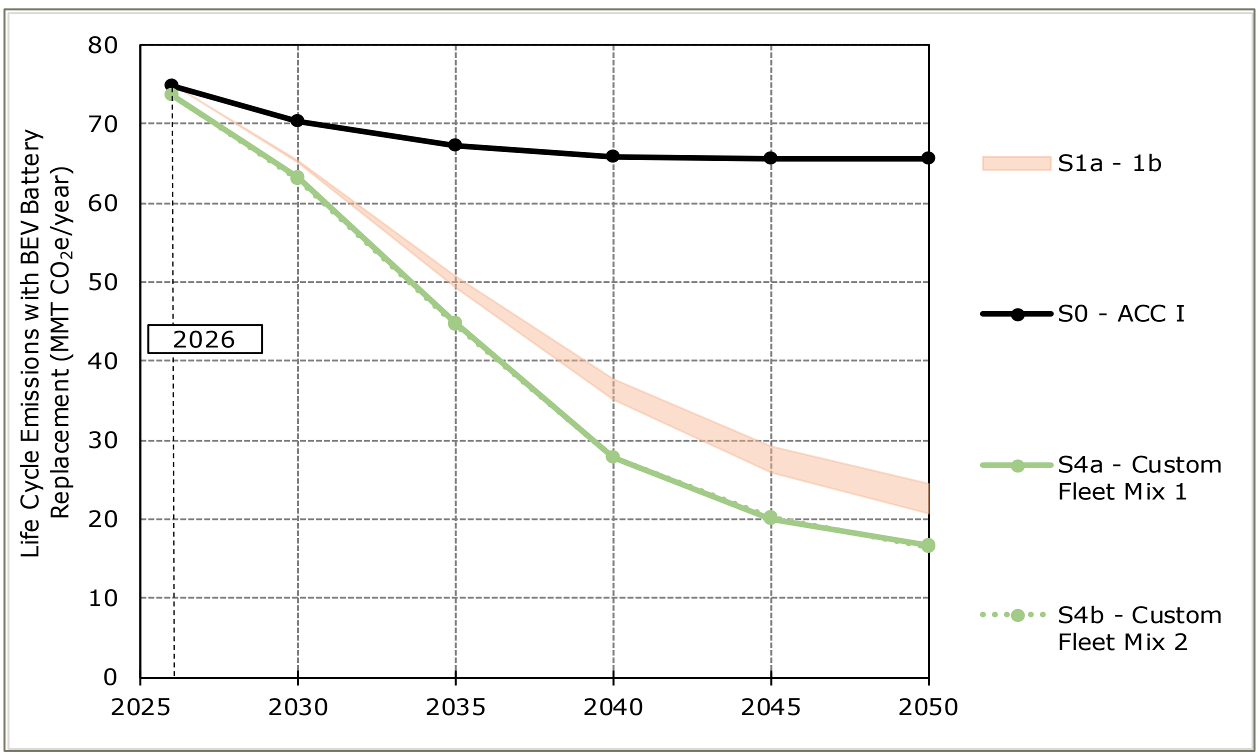


Figure 4-12: Life Cycle Emissions with BEV Battery Replacement for Alternative Scenarios Part 3



5. CONCLUSIONS

5.1 Summary of Analysis Conclusions

Ramboll's analysis demonstrates that there are a number of vehicle technology and fuel pathways that could achieve equal or greater GHG reductions as the proposed ACC II rulemaking. These alternative pathways would not require transformation of energy production and distribution infrastructure on an unprecedented short time scale, but they would allow battery, hydrogen, and low-CI gaseous and liquid fueled vehicles to compete to achieve the State's GHG targets in the quickest and most cost-effective manner. For example, a scenario that phases in low-CI gasoline as a drop-in fuel for ICEVs over a two-decade period could reduce GHG emission the same or more than the proposed ZEV-only mandate, when viewed on a life cycle basis. Other scenarios involving HEVs and PHEVs could be equally effective in providing GHG reductions when coupled with a phase in of low-CI gasoline. CARB could craft a regulation based on a GHG-reducing performance standard instead of instituting zero emission technology mandates, which is more consistent with traditional technology-forcing regulations that rely upon innovation within existing marketplaces. This study shows that such an approach could dramatically reduce GHG emissions without the systemic cost and delay risks associated with the current ZEV-centric strategy that include, but are not limited to, electric generation/infrastructure development, zero emission technology readiness, and cost.

The main conclusions of our analysis:

- Zero emission vehicle technology is only one of many different technology/fuel scenarios that could be utilized to meet California's GHG emission reduction targets;
- A full life cycle emission assessment is necessary if GHG reductions are a goal of the regulation, in order to understand the cradle-to-grave effects of a given vehicle/fuel technology pathway;
- BEV technology of the scope and schedule in ACC II would require technology and electrical generation/infrastructure developments that CARB has not analyzed and cannot mandate, control, or incentivize;
- There is a growing potential for renewable and low carbon fuels, including some with negative carbon intensity, to meet long-term GHG reductions;
- Low-CI gasoline could decarbonize the transportation sector at a rate comparable to a ZEV-only regulation; and
- Allowing the market flexibility to meet emission reduction targets could lead to a more diverse deployment of fuel and vehicle technologies to meet State targets.

These conclusions emphasize the need for CARB to conduct a similar analysis for the light and medium duty vehicle sector targeted in the draft ACC II proposal, to identify vehicle/fuel technology pathways that meet the emission reduction goals earlier and more cost effectively than the proposed ZEV-centric approach.

5.2 Next Steps – Technical

By focusing on a strategy that relies on ZEV sales mandates and not assessing the full life cycle GHG impacts of that strategy, CARB has overstated the potential emission benefits from PHEVs and BEVs while ignoring different vehicle/fuel pathways that could meet

California's GHG emission reduction targets. Finally, CARB has not demonstrated they have minimized leakage as required under AB32.

CARB should conduct a full life cycle GHG emission assessment to quantify the cradle-to-grave effects of the draft ACC II proposal and consider alternative GHG-reducing vehicle/fuel technologies in a technology-forcing (not technology mandating) rulemaking for California's LDV fleet that meets the State's emission goals. Such an analysis should build out and evaluate multiple scenarios beyond the singular ZEV-centric pathway proposed in the current ACC II regulation. These scenarios should be evaluated in the ACC II alternatives analyses presented in the SRIA and EA for technical feasibility, environmental impacts, and cost-effectiveness. These broader alternative analyses should include an assessment of the future availability of fueling (electric, hydrogen, and renewable and low carbon fuels) and related infrastructure to support this transition and help inform the final ACC II regulation.

APPENDIX A
SCENARIO ANALYSIS ASSUMPTIONS AND DETAILED METHODOLOGY

This Appendix describes the methodology used to calculate upstream, tailpipe, and vehicle cycle emissions for the Ramboll scenario analysis. A list of all tables accompanying this appendix is located after this analysis description. **Table A-1** provides a list of the analyzed scenarios. Refer to **Section 2** of the main document for further details on the scenarios.

Upstream Well-to-Tank Emissions

Ramboll estimated well-to-tank greenhouse gas (GHG) emission factors for each analyzed fuel type (California Reformulated Gasoline (CaRFG), low carbon intensity (CI) gasoline, electricity, and hydrogen) using carbon intensities obtained from the CA-GREET3.0 model,[1] Low Carbon Fuel Standard (LCFS) Lookup Pathways Tables,[2] LCFS Quarterly Summary data,[3] and assumptions used in California Air Resources Board's (CARB's) Standardized Regulatory Impact Assessment (SRIA)[4] for the Advanced Clean Cars II (ACC II) proposal and Assembly Bill (AB) 32 Initial Modeling.[5] Upstream GHG emission factors are typically represented as carbon intensities, i.e., the mass of GHG emissions in carbon dioxide equivalent (CO_2e) per unit of energy consumed in mega joules (MJ) for each fuel type. Upstream GHG emission factors for all fuel pathways considered in this analysis without and with EER adjustment are shown in **Table A-2** and **Table A-3** respectively.

<u>California Reformulated Gasoline</u>

Ramboll estimated the upstream CI of CaRFG as an energy-weighted average value of the upstream CIs of the two components that make up CaRFG: California reformulated gasoline blendstock for oxygenate blending (CARBOB), and ethanol. A summary of these emission factors and the ethanol content of CaRFG that is used to estimate the upstream GHG emission factor for CaRFG is provided in **Table A-4**.

<u>Low-CI Gasoline</u>

To estimate a carbon intensity for the low-CI gasoline considered in this analysis, a review of currently available and documented carbon intensities for low-CI renewable gasoline drop-in fuels was performed, as documented in **Table 3-1** of the main document. Sources for low-CI drop-in renewable gasoline fuels included the USEPA lifecycle GHG results, LCFS fuel pathways, Argonne National Laboratory (ANL) state-of-technology research, CARB-driven research, and a research paper published by the University of Chicago ANL. While the research yielded multiple pathways that spanned both renewable gasoline (e.g., bio-based feedstocks) as well as lower-CI gasoline alternatives, we chose to represent them as a single category due to their similar function as a drop-in replacement fuel. The average of these values was taken in order to find a representative carbon intensity for the low-CI gasoline fuel considered in this analysis, resulting in a CI of 19.0 g CO_2e/MJ, which is about 35% lower than the upstream CI for CaRFG.

---

1 CA-GREET 3.0 Model. Available at: https://www.arb.ca.gov/fuels/lcfs/ca-greet/ca-greet30-corrected.xlsm. Accessed: January 2021.

2 CARB. 2018. CA-GREET3.0 Lookup Table Pathways Technical Support Documentation. August 13. Available at: https://ww2.arb.ca.gov/sites/default/files/classic/fuels/lcfs/ca-greet/lut-doc.pdf. Accessed: May 2022.

3 CARB. LCFS Quarterly Summaries. Available at: https://ww2.arb.ca.gov/resources/documents/low-carbon-fuel-standard-reporting-tool-quarterly-summaries. Accessed: May 2022.

4 CARB. 2022. Appendix C-1: Standardized Regulatory Impact Assessment (SRIA). April 12. Available at: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/accii/appc1.pdf. Accessed: May 2022.

5 E3. 2022. AB 32 Initial Model Results. March 15. Available at: https://ww2.arb.ca.gov/sites/default/files/2022-03/SP22-Model-Results-E3-ppt.pdf. Accessed: May 2022.

In order to understand the impact of this carbon intensity on upstream and life cycle emissions, we also considered two sensitivity scenarios:

- Scenario 3a-1 – Low-CI Gas (Upper Range): For this scenario the low-CI gasoline CI was increased by 10 g CO2e/MJ to 29 g CO2e/MJ. This value is similar to the upstream CI for CaRFG.
- Scenario 3a-2 – Low CI-Gas (Lower Range): For this scenario the low-CI gasoline CI was reduced by 10 g CO_2e/MJ to 9 g CO_2e/MJ. This value is about 69% lower than the upstream CI for CaRFG.

Upstream GHG emission factors for low-CI gasoline compared to other fuels considered in this analysis without and with EER adjustment are shown in **Table A-2** and **Table A-3** respectively.

<u>Electricity</u>

Ramboll estimated upstream GHG emissions associated with the production and distribution of electricity consumed by PHEVs and BEVs in each modeled scenario using emission factors obtained from the CA-GREET 3.0 model.[6] Developed from ANL's GREET 2016 model,[7] the CA-GREET 3.0 model is used by CARB to calculate well-to-wheel emissions from transportation fuels under the California LCFS Program. Hence, use of this model to estimate upstream emissions is consistent with the CARB methodologies.

For purposes of this analysis, Ramboll adjusted the electricity grid mix inputs to the CA-GREET 3.0 model based on California Energy Commission (CEC) projections for each of the modeled calendar years 2026, 2030, 2035, 2040, 2045, and 2050.[8] The CA-GREET 3.0 California grid mix inputs for estimating upstream electricity GHG emission factors can be found in **Table A-5**.

<u>Hydrogen</u>

CARB SRIA Hydrogen

Ramboll assumed that 40% of the hydrogen for the CARB SRIA H_2 fuel pathway would come from renewable feedstocks and the remaining 60% from fossil feedstocks based on the methodology used in the SRIA for the proposed ACC II[9] and discussions with CARB ACC II staff.[10] The fossil feedstock for hydrogen is assumed to be fossil natural gas which is processed via a steam methane reformation

---

[6] CARB. 2019. CA-GREET3.0 Model - Current Version: Effective January 4, 2019 (released August 13, 2018). Available at: https://www.arb.ca.gov/fuels/lcfs/ca-greet/ca-greet30-corrected.xlsm?_ga=2.203396115.367263062.1651770761-1504446328.1547148412. Accessed: May 2022.

[7] Available at: https://greet.es.anl.gov/publication-greet-model. Accessed: January 2021.

[8] CEC 2018. Deep Decarbonization in a High Renewables Future - Implications for Renewable Integration and Electric System Flexibility, Docket 18-IEPR-06 - 223869, Slide 10. Available at: https://efiling.energy.ca.gov/GetDocument.aspx?tn=223869&DocumentContentId=54081. Accessed: January 2021.

[9] CARB. 2022. Appendix C-1: Standardized Regulatory Impact Assessment (SRIA). April 12. Available at: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/accii/appc1.pdf. Accessed: May 2022.

[10] Based on e-mail communication between S. Moca, Ramboll US Consulting and CARB ACC II Staff on February 15, 2022. CARB staff indicated in their email that hydrogen fuel in the SRIA for the proposed ACC II consisted of 3 major blends of fuel types: fossil natural gas (NG) hydrogen, renewable hydrogen from renewable NG, renewable hydrogen from curtailments. CARB assumed that renewable hydrogen levels off at 40% of the total hydrogen used, and that renewable hydrogen gradually transitions from renewable NG hydrogen to renewable hydrogen from curtailments. CARB shared that this transition was modelled with a log function assuming a market share (%) of renewable hydrogen at specific time points which are 6% at 2020, 10% at 2025, and 100% at 2045. Additionally, they shared that the renewable natural gas feedstock was assumed to be 100% from landfill biogas. Lastly, for renewable hydrogen from curtailments, CARB staff assumed zero GHG emissions given transmission/distribution and refilling phases using renewable energy.

(SMR) process to produce Fossil Hydrogen per the 2020 Mobile Source Strategy[11] and as cited in the SRIA. The renewable feedstock is assumed to be Landfill Biogas with hydrogen production via SMR (Landfill SMR Hydrogen) and electrolysis using curtailment electricity (Curtailment Electrolysis Hydrogen). Based on correspondence with CARB ACC II staff, the transition of hydrogen production from landfill biogas to curtailment electricity was modeled with a log function assuming specific feedstock shares at three points in time: 6% at 2020, 10% at 2025, and 100% at 2045.[12] A summary of these upstream GHG emission factors and fractions of the feedstocks used to estimate the upstream GHG emission factor for CARB SRIA hydrogen is provided in **Table A-6**.

CARB AB32 Hydrogen

The AB 32 Initial Modeling[13] for the draft 2022 Scoping Plan Update assumes that 100% of hydrogen production in the future would come from renewable sources, with the primary hydrogen production pathway being electrolysis using electricity generated by solar photovoltaic systems (Solar Electrolysis Hydrogen). We assumed that AB32 Hydrogen would be a combination of hydrogen produced using the following pathways: Landfill SMR Hydrogen and Solar Electrolysis Hydrogen. The volumes of Landfill SMR Hydrogen for the analysis years was assumed to not exceed the total renewable hydrogen volume (2,700,000 kg/year or 324,000,000 MJ/year) produced in 2021 per Annual Hydrogen Evaluation.[14] The remaining hydrogen demand in each analysis year was assumed to be met by Solar Electrolysis Hydrogen. The resulting CIs for the AB32 Hydrogen were estimated as a feedstock weighted average of the CIs for the individual feedstocks (Landfill SMR and Solar Electrolysis). A summary of these emission factors and fuel consumption for each feedstock for modelled sensitivity scenario S1d-1 – ACC II (FCEV) + AB32 H_2 is provided in **Table A-7**.

Tailpipe (Tank-to-Wheel) Emissions

CARB's EMFAC2021 model[15] was used to estimate tailpipe emissions for greenhouse gases (GHGs) for all light-duty vehicle (LDV) types included in this analysis. Specifically, Ramboll's analysis considers a sub-set of the statewide LDV fleet consisting of light-duty autos (LDAs), excluding those fueled by natural gas (NG) and diesel (DSL).[16] **Table 3-2** of the main document summarizes the assumptions used to estimate the tailpipe GHG emissions from various vehicle/fuel technologies that are included in this analysis. For this analysis, EMFAC2021[17] was queried at the statewide level for analysis years 2026, 2030, 2035, 2040, 2045 and 2050 to obtain daily total exhaust emissions, vehicle population, vehicle miles travelled (VMT), energy consumption, and fuel consumption data by model year for the

---

[11] CARB. 2021. 2020 Mobile Source Strategy. October 28. Available here: https://ww2.arb.ca.gov/sites/default/files/2021-12/2020_Mobile_Source_Strategy.pdf. Accessed: May 2022.

[12] Based on e-mail communications between S. Moca, Ramboll US Consulting and CARB ACC II Staff on February 15, 2022.

[13] E3. 2022. CARB Draft Scoping Plan: AB32 Source Emissions Initial Modeling Results. March 15. Available at: https://ww2.arb.ca.gov/sites/default/files/2022-03/SP22-Model-Results-E3-ppt.pdf. Accessed: May 2022.

[14] CARB. 2021 Annual Evaluation of Fuel Cell Electric Vehicle Deployment and Hydrogen Fuel Station Network Development. September. Available at: https://ww2.arb.ca.gov/sites/default/files/2021-09/2021_AB-8_FINAL.pdf. Accessed: May 2022.

[15] EMFAC2021 Database v1.0.1. Available at: https://arb.ca.gov/emfac/emissions-inventory. Accessed January 2022.

[16] Natural gas vehicles are excluded as they are not included in the default EMFAC2021 LDA fleet. Diesel vehicles are not included in this analysis because they comprise less than 0.3% of the total LDA population in EMFAC2021.

[17] EMFAC2021 Database v1.0.1. Available at: https://arb.ca.gov/emfac/emissions-inventory. Accessed January 2022.

following types of LDAs: gasoline-fueled internal combustion engine vehicles (ICEVs), battery electric vehicles (BEVs), and plug-in hybrid vehicles (PHEVs).

As described in **Section 3.1.3** of the main document, total VMT in EMFAC2021 is resolved by combustion VMT (cVMT), for miles traveled by vehicles powered by an internal combustion engine (ICE), and electric VMT (eVMT), for miles traveled by vehicles powered by energy from a battery.[18] Similarly, EMFAC2021 accounts for electric energy consumption separate from gasoline fuel consumption. In EMFAC2021, eVMT is defined as miles traveled during a pure electricity powered trip, and energy consumption is determined based on only pure electric trips during which an ICE does not turn on.[19] Thus, only PHEVs have both cVMT and eVMT and both energy consumption and fuel consumption in EMFAC2021. The remaining vehicle technologies in EMFAC2021 have either cVMT and fuel consumption (e.g., ICEVs), or eVMT and energy consumption (e.g., BEVs). Throughout this analysis, we utilize the term "fuel economy" as a fuel-neutral description of miles traveled per unit of fuel or energy consumed, whether the fuel is gasoline, hydrogen, or electricity.

Specific inputs used in the EMFAC2021 query are as follows:

- Run Mode: Emissions
- Region Type: Statewide
- Region: California
- Calendar Year: 2026, 2030, 2035, 2040, 2045 and 2050
- Season: Annual
- Vehicle Category: LDA[20]
- Model Year: All Model Years
- Speed: Aggregated
- Fuel Type: Gasoline, Electricity, and Plug-in Hybrid

EMFAC2021 was queried separately for each calendar year using the inputs above. Note, EMFAC2021 outputs are provided on a per day basis. Daily emissions calculated based on EMFAC2021 data are scaled to annual emissions based on 347 days of operation per year for LDAs reported in EMFAC technical documentation.[21]

The methodology used to calculate tailpipe emissions is summarized in **Section 3.2.2** of the main document and **Table A-8** through **Table A-91** in this Appendix. Tailpipe emissions in scenario S0 were obtained directly from EMFAC2021 and adjusted for the ethanol content of CaRFG. Tailpipe emissions in all other scenarios were estimated based on fleet mix composition and the VMT, fuel

[18] CARB. 2021. EMFAC2021 Volume I – User's Guide. January 15. Available at: https://ww2.arb.ca.gov/sites/default/files/2021-01/EMFAC202x_Users_Guide_01112021_final.pdf. Accessed: May 2022.

[19] CARB. 2021. EMFAC2021 Volume III Technical Document - Version 1.0.0. March 31. Available at: https://ww2.arb.ca.gov/sites/default/files/2021-03/emfac2021_volume_3_technical_document.pdf. Accessed: May 2022.

[20] The LDA vehicle category is the same in EMFAC2007, EMFAC2011, and EMFAC202x vehicle categories.

[21] CARB. 2018. EMFAC 2017 Volume III – Technical Documentation. July 20. Available at: https://ww3.arb.ca.gov/msei/downloads/emfac2017-volume-iii-technical-documentation.pdf. Accessed: May 2022.

economy, and emission factors for ICEVs, PHEVs, and HEVs. The following describes the procedure used to calculate tailpipe emissions in all scenarios other than S0:

1. **Fleet Mix:** The fleet mix composition for each model year in each calendar year was determined based on the specific vehicle technology penetration assumptions for each scenario, as described in **Section 2** of the main document and shown in **Table A-1**.
    a. Specifically, ICEVs in the EMFAC2021 default fleet were replaced with other vehicle technologies (e.g., BEVs, PHEVs, HEV, and/or FCEVs) based on the sales percentage of each vehicle technology for each model year in each scenario. Note, in all scenarios, the existing sales fraction and population of PHEVs and BEVs in EMFAC2021 defaults served as the minimum penetration of these vehicle technologies. Thus, while additional BEVs and/or PHEVs were added in some scenarios, only ICEVs in the EMFAC2021 default fleet were replaced with other vehicle types as applicable in each scenario.
    b. This step determines the vehicle population for each vehicle technology for each model year in each calendar year. The resulting fleet mix population data for each scenario, aggregated by model year, is presented in **Figure 2-3** and **Figure 2-4** of the main document. Detailed population breakdown by vehicle technology and model year for each calendar year is presented in **Table A-26 through Table A-91.**
2. **VMT:** The daily VMT for each vehicle technology was calculated based on the vehicle population data determined in step 1 and the miles per vehicle per day for ICEVs.
    a. Specifically, Ramboll’s scenario analysis assumes that any vehicle technology replacing an ICEV travels the same number of miles per vehicle as the ICEV it is replacing, as determined from EMFAC2021 data on a per model year basis for each calendar year. Thus, in each scenario, as ICEVs are replaced with other vehicle technologies, the population and corresponding VMT of ICEVs is reduced and allocated to the replacement vehicles in a one-to-one ratio.
    b. For PHEVs replacing ICEVs, total VMT from the ICEV is allocated to eVMT and cVMT for the replacement PHEV according to the EMFAC2021 default split between eVMT and cVMT for the replacement vehicle. The split between eVMT and cVMT for PHEVs varies by model year and calendar year, as described **Section 3.1.3** of the main document and shown in **Tables A-9, A-12, A-15, A-18, A-21**, and **A-24**.
3. **Fuel Consumption:** Fuel consumption for each vehicle technology was calculated based on the VMT determined in step 2 and the fuel economy for each vehicle.
    a. Fuel economy for each vehicle technology was determined based on EMFAC2021 data as described in **Section 3.1** of the main document and shown in **Tables A-8, A-11, A-14, A-17, A-20**, and **A-23**. Fuel consumption for each vehicle technology was first determined on a per model year basis to account for the variability in VMT and fuel economy by model year.
    b. Additionally, in order to account for upstream emissions and renewable fuel adjustments to tailpipe emissions, total fuel consumption for each fuel type across all vehicle technologies was calculated in each calendar year. Specifically, total gasoline fuel consumption was calculated as the sum of gasoline fuel usage from ICEVs, HEVs, and cVMT from PHEVs, while total electricity fuel consumption was calculated as the sum of electricity usage from BEVs and eVMT from PHEVs. Total hydrogen fuel consumption is equal to the total hydrogen usage from FCEVs are these are the only vehicles in this analysis fueled by hydrogen.

   c. Total fuel consumption for gasoline was then allocated to CaRFG and Low-CI Gasoline according to the phase-in of Low-CI Gasoline in each scenario, as described in **Section 2** of the main document. Fuel consumption for all vehicle technologies and fuel types is reported in megajoules per day (MJ/day).

4. **Unadjusted Tailpipe Emissions:** Tailpipe emissions for ICEVs, PHEVs, and HEVs were estimated using the fuel consumption values determined in step 3 and the emission factors for these vehicle technologies derived from EMFAC2021 as described in **Section 3.3** of the main document and shown in **Tables A-10, A-13, A-16, A-19, A-22** and **A-25**. Tailpipe emissions for FCEVs and BEVs are zero.

   a. Tailpipe emissions for each calendar year were determined first on a per model year basis to account for the variation in fuel economy, emission factors, VMT, and population of each vehicle technology in each model year. Total tailpipe emissions in each calendar year were calculated as the sum of tailpipe emissions across all vehicle types and all model years in that calendar year.

   b. Tailpipe emissions of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) are calculated separately. Additionally, in order to account for renewable fuel adjustments to tailpipe emissions (step 5), tailpipe CO_2 emissions for each gasoline fuel type in each calendar year were calculated based on the penetration of each fuel type and the total tailpipe CO_2 emissions in that calendar year.

5. **Renewable Fuel Adjustments:** Tailpipe emissions are also adjusted based on the use of renewable fuels. Ramboll's analysis includes two gasoline fuel types: CaRFG, the default fuel assumed in EMFAC2021, and Low-CI Gasoline, a lower CI renewable drop-in fuel used as a replacement for CaRFG that is used to fuel internal combustion engines (ICEs) in ICEVs, PHEVs, and HEVs. As described in **Section 3.2.2** of the main document, since the CO_2 emissions generated by the combustion of the renewable ethanol content in CaRFG and Low-CI gasoline are considered biogenic, they are excluded from this analysis.[22] Adjustment factors for CO_2 emissions for each fuel type are applied to the portion of the tailpipe CO_2 emissions from that fuel type as determined in step 4b. No adjustments were made to the tailpipe CH_4 and N_2O emissions.

   a. As described in **Section 3.2.2** of the main document, Ramboll adjusted tailpipe emissions from CaRFG to account for the elimination of CO_2 emissions from the renewable ethanol content of CaRFG. Specifically, assuming the 9.5 percent volume fraction of ethanol is renewable and therefore has zero CO_2 emissions. Ramboll applied a 6.3 percent reduction factor to all tailpipe CO_2 emissions resulting from the use of CaRFG to account for the elimination of CO_2 emissions from the renewable ethanol content.

      - This 6.3 percent reduction factor is estimated as the ratio of the CaRFG tailpipe CO2 emission factor to the gasoline tailpipe CO2 emission factor.

[22] This aligns CARB's methodology for estimating the statewide GHG emission inventory, as noted in the 2021 CARB Report on the *California Greenhouse Gas Emissions for 2000 to 2019*, which states that "carbon dioxide (CO_2) emissions from biofuels (the biofuel components of fuel blends) are classified as "biogenic CO_2". They are tracked separately from the rest of the emissions in the inventory and are not included in the total emissions when comparing to California's 2020 and 2030 GHG Limits." Available at: https://ww3.arb.ca.gov/cc/inventory/pubs/reports/2000_2019/ghg_inventory_trends_00-19.pdf?msclkid=9f56cab9d01611ec878dcdb49cca2c91. Accessed: May 2022.

- The CaRFG tailpipe CO_2 emission factor is calculated as a weighted sum of the tailpipe CO_2 emission factors for ethanol and gasoline, assuming a volume fraction of 9.5% for ethanol.
    - The tailpipe CO_2 emission factor for ethanol is derived from CARB's Mandatory Reporting of Greenhouse Gases data.[23]
    - The tailpipe CO_2 emission factor for gasoline is derived from EMFAC fuel combustion data.[24]

b. The low-CI gasoline included in this analysis is produced from renewable feedstocks (See **Section 3.2.1.2** of the main document) and tailpipe CO_2 emissions associated with the combustion of this fuel are biogenic and set to zero.

6. **Final Tailpipe Emissions:** Total tailpipe GHG emissions are reported in units of carbon dioxide equivalent (CO_2e). CO_2e is calculated based on final CO_2, CH_4, and N_2O emissions, after accounting for renewable fuel adjustments, using global warming potentials (GWPs) from the International Panel on Climate Change (IPCC) Fourth Assessment Report (AR4).[25] The GWPs used for CO_2, CH_4, and N_2O are 1, 25, and 298, respectively.

Vehicle Cycle Emissions

For this analysis, Ramboll used GREET 2 (and GREET 1 inputs as needed) to estimate vehicle life cycle emission factors for ICEV, HEV, BEV, and PHEV technologies. FCEVs were not included in the scope of Ramboll's vehicle cycle emissions analysis.[26] The vehicles are evaluated as model year 2026 passenger vehicles; while vehicle cycle emissions may decrease over time with the increase in the renewable content of the electricity used for vehicle production, we do not expect the reduction to significantly alter the results or conclusions of the study.

Battery recycling for BEVs and PHEVs is not included in this assessment. This assumption is informed by current end-of-life recycling rate of <1% globally for lithium and rare earth minerals noted in the 2021 International Energy Association (IEA) Study on the *Role of Critical Minerals in Clean Energy Transition.*[27] Furthermore, it is likely that the vast majority of batteries produced in the future would require virgin material given the significant increase in demand under a mass vehicle electrification scenario.

---

[23] Available at: https://www.arb.ca.gov/cc/reporting/ghg-rep/regulation/subpart_c_rule_part98.pdf. Accessed: May 2022.

[24] Available at: https://ww2.arb.ca.gov/sites/default/files/ghg-inventory-doc/doc/docs1/1a3bii_onroad_light-dutyvehicles_light-dutytrucks_fuelcombustion_gasoline_co2_2018.htm. Accessed: May 2022.

[25] Greenhouse Gas Protocol. Available at: https://www.ghgprotocol.org/sites/default/files/ghgp/Global-Warming-Potential-Values%20%28Feb%2016%202016%29_1.pdf. Accessed January 2021.

[26] FCEVs represented only a small fraction (<0.8%) of total 2020 ZEV sales and an even smaller fraction (<0.06%) of the total 2020 LDV sales in California. The vehicle material recovery and production, vehicle component fabrication, vehicle assembly, and vehicle disposal/recycling processes are still in the developmental stage, and it would be too speculative to estimate vehicle cycle emissions until the market for these vehicles mature. Sales data obtained from CEC data dashboard 'New ZEV Sales in California'. Available here: https://www.energy.ca.gov/data-reports/energy-almanac/zero-emission-vehicle-and-infrastructure-statistics/new-zev-sales. Accessed: May 2022.

[27] International Energy Agency (IEA). 2021. The Role of Critical Minerals in Clean Energy Transitions. May. Available at: https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions?msclkid=fa519918d01f11ecbcf188dc9fbbf9f2. Accessed: May 2022.

The vehicle emission and electric grid mix data input to the model is based on the most current information available at the time of this study as the scope of this analysis does not include forecasting or projecting future energy demands from vehicle and battery manufacturing.

GREET Inputs for ICEVs and HEVs

To model ICEVs and HEVs, Ramboll used default values in the GREET model for all vehicle production and assembly parameters except for the electricity mix used for material and fuel production. The US electric mix for stationary use in GREET 1 was updated with the 2020 national electricity mix published by the EPA's Emissions & Generation Resource Integrated Database (eGRID).[28] The non-default GREET inputs for U.S. stationary grid mix can be found in **Table A-92**. Ramboll also updated the GREET 1 electric grid mixes for fuel production for non-US countries where vehicle and battery components are produced or assembled. These grid mixes were updated using most recent available data from the IEA.[29] The non-default GREET inputs for international grid mixes can be found in **Table A-93**. A full matrix of all non-default GREET inputs can be found in **Table A-94.** The total life cycle emissions for each vehicle technology estimated from the GREET model can be found in **Table A-95**.

GREET Inputs for BEVs and PHEVs

For BEVs, Ramboll modeled a lithium-ion (Li-ion) battery with a nickel manganese cobalt (NMC 622) cathode material, which per a 2021 study from the International Council on Clean Transportation (ICCT) is the most common cathode material used in BEVs globally.[30] The Li-ion peak battery energy for BEVs is modeled as 81 kWh. This value was calculated as a product of BEV fuel economy, range, and charge utilization. The fuel economy is 2.59-mi/kWh based on EMFAC2021 data (described in **Section 3.1.2** of the main document), the range is 200 miles based on the minimum certified all-electric range in the draft ACC II regulation,[31] and the state of charge (SOC) utilization is 95% based on CARB's ZEV cost modeling worksheets.[32,33] Battery production and assembly share by country is derived from the number of battery cells supplied to the US BEV market by production location, reported in an Argonne National Laboratory publication on the 2010-2020 Lithium-Ion Battery Supply Chain for E-Drive Vehicles in the United States.[34] Production shares for 2020 were used in order to

[28] EPA. 2022. eGRID Summary Tables 2020. January 27. Available here: https://www.epa.gov/egrid/summary-data. Accessed: May 2022.

[29] IEA. 2022. Countries and regions. Available at: https://www.iea.org/countries. Accessed: May 2022.

[30] ICCT. 2021. A Global Comparison of The Life-Cycle Greenhouse Gas Emissions of Combustion Engine and Electric Passenger Cars. Available here: https://theicct.org/publication/a-global-comparison-of-the-life-cycle-greenhouse-gas-emissions-of-combustion-engine-and-electric-passenger-cars/. Accessed: May 2022.

[31] CARB. 2022. Appendix A-5: Proposed Regulation Order for Section 1962.4 Zero-Emission Vehicle Standards for 2026 and Subsequent Model Year Passenger Cars and Light-Duty Trucks. April 12. Available at: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/accii/appa5.pdf. Accessed: May 2022.

[32] CARB. 2021. ZEV Cost Modeling Workbook October 2021. Available at: https://ww2.arb.ca.gov/sites/default/files/2021-11/ZEV_Cost_Modeling_Workbook_Update_October2021.xlsx. Accessed: January 2022.

[33] The October 2021 version of CARB's ZEV Cost Modeling Workbook was referenced for this analysis. A newer version of this workbook was released in late April 2022 (after completion of this analysis), which assumed a lower SOC utilization for BEV batteries of 92.5%. However, this does not change the overall conclusions of the analysis.

[34] ANL. 2021. Lithium-Ion Battery Supply Chain for E-Drive Vehicles in the United States: 2010-2020. March. Available at: https://publications.anl.gov/anlpubs/2021/04/167369.pdf. Accessed: May 2022.

reflect the most current information available. A full matrix of all non-default GREET inputs can be found in **Table A-94.**

To model PHEVs, Ramboll assumed the NMC 111 cathode material (which is the GREET default) since NMC 622 is not an option provided in GREET 2 for PHEVs. The Li-ion peak battery energy for PHEVs is modeled as 14 kWh. This value was calculated as a product of PHEV fuel economy, range, and charge utilization. The fuel economy is 3.31 mi/kWh based on EMFAC2021 data (described in **Section 3.1.3** of the main document), the range is 40 miles based on the US-06 minimum certified all-electric range in the draft ACC II regulation,[35] and the SOC utilization is 85% based on CARB's ZEV cost modeling worksheets.[36,37] Battery production and assembly shares by country are assumed to be equivalent to those used in the BEV model. A full matrix of all non-default GREET inputs can be found in **Table A-94.**

All other vehicle and battery parameters for BEVs and PHEVs were left unchanged from GREET default values, and a full matrix of all non-default GREET inputs can be found in **Table A-94.** The total life cycle emissions for each vehicle technology estimated from the GREET model can be found in **Table A-95**.

Vehicle Cycle GHG Emissions in Scenario Analysis

Ramboll incorporated vehicle cycle GHG emissions for all ICEVs, PHEVs, BEVs, and HEVs in the scenario analysis by calculating GHG emissions for all vehicles of a given model year and attributing those emissions to the corresponding calendar year (assumed to be the same as the model year) in which they were produced as described in **Section 3.3.2** of the main document.

Ramboll assumed that the total number of vehicles produced for a given model year is equal to the peak population of that model year in EMFAC2021. **Figure 3-6** of the main document shows that the peak vehicle population for any given model year in EMFAC2021 occurs one year after the corresponding calendar year (CY) in which they were first introduced to the fleet. These values are summarized in **Table A-96**. Specific inputs used in the EMFAC2021 query used to generate the peak vehicle population for the analysis years are as follows:

- Run Mode: Emissions
- Region Type: Statewide
- Region: California
- Calendar Year: 2026, 2027, 2028, 2029, 2030, 2031, 2032, 2033, 2034, 2035, 2036, 2037, 2038, 2039, 2040, 2041, 2042, 2043, 2044, 2045, 2046, 2047, 2048, 2049, 2050
- Season: Annual

35 CARB. 2022. Appendix A-5: Proposed Regulation Order for Section 1962.4 Zero-Emission Vehicle Standards for 2026 and Subsequent Model Year Passenger Cars and Light-Duty Trucks. April 12. Available at: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/accii/appa5.pdf. Accessed: May 2022.

36 CARB. 2021. ZEV Cost Modeling Workbook October 2021. Available at: https://ww2.arb.ca.gov/sites/default/files/2021-11/ZEV_Cost_Modeling_Workbook_Update_October2021.xlsx. Accessed: January 2022.

37 The October 2021 version of CARB's ZEV Cost Modeling Workbook was referenced for this analysis. A newer version of this workbook was released in late April 2022 (after completion of this analysis), which assumed a lower SOC utilization for PHEV batteries of 80%. However, this does not change the overall conclusions of the analysis.

- Vehicle Category: LDA[38]
- Model Year: 2026, 2030, 2035, 2040, 2045, 2050
- Speed: Aggregated
- Fuel Type: Gasoline, Electricity, and Plug-in Hybrid

As noted in the **Table A-96**, number of vehicles produced for each vehicle technology in a calendar year is calculated based on the fleet mix for the model year vehicle and the total peak vehicle population for that model year. For example, the vehicle population produced in calendar year 2026, is based on the fleet mix of the 2026 model year vehicles and the peak population of model year 2026 vehicles. The vehicle cycle emissions for each calendar year are calculated using the vehicle cycle emission factors from **Table A-95** and the vehicle population for each vehicle technology in **Table A-96**. The total vehicle cycle emissions for each scenario in the analyzed calendar years are summarized in **Table A-96**.

GHG Emissions from Lithium Battery Replacement

In addition to GHG emissions from vehicle and battery production, Ramboll analyzed the GHG emissions associated with battery replacement for BEVs. Battery replacement for BEVs lithium-ion batteries is assumed to occur in the ninth year of use based on the 8-year warranty requirement proposed in the CARB ACC II Initial Statement of Reasons (ISOR) Staff Report.[39] Ramboll's scenario analysis assumes that one battery replacement occurs over the vehicle lifetime for all BEVs remaining in the vehicle fleet in the ninth year of operation (e.g., battery replacement emissions in CY 2026 are calculated based on the population of MY 2017 BEVs in CY 2026). This methodology accounts for the default retirement rate of vehicles in EMFAC2021, as illustrated in **Figure 3-6** in the main document.

The emissions per vehicle associated with this battery replacement were estimated from the results of the GREET modelling described in **Section 3.4.1** of the main document and in **Tables A-97 and A-98.** In particular, the emissions for battery production and assembly were combined to estimate battery replacement emissions on a per vehicle basis. For MY 2026-2050 BEVs, BEV battery replacement is assumed to occur for an 81-kWh battery as described in **Section 3.4.1** of the main report and in **Table A-97**. However, for pre-2026 BEVs, a peak battery energy of 62.5 kWh was assumed a weighted average of the battery sizes and cumulative sales of various BEV models from 2010-2020 in the United States.[40] Thus, battery replacement emission factors for BEVs MY <2026 and BEVs MY ≥2026 were estimated separately, as represented by the gray bars in **Figure 3-5** in the main document and **Table A-97**. Total emissions from the vehicle battery replacement in each scenario can be found in **Table A-98**.

[38] The LDA vehicle category is the same in EMFAC2007, EMFAC2011, and EMFAC202x vehicle categories.

[39] CARB. 2022. Staff Report: Initial Statement of Reasons. April 12. Available at: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/accii/isor.pdf. Accessed: May 2021.

[40] Lithium-Ion Battery Supply Chain for E-Drive Vehicles in the United States: 2010-2020. March. Available at: https://publications.anl.gov/anlpubs/2021/04/167369.pdf. Accessed: May 2022.

APPENDIX A TABLES
SCENARIO ANALYSIS ASSUMPTIONS AND DETAILED METHODOLOGY

APPENDIX A TABLES

A-1	Scenario Matrix
A-2	Upstream (EER-Unadjusted) GHG Emission Factors by Fuel Type
A-3	Upstream (EER-Adjusted) GHG Emission Factors by Fuel Type
A-4	Estimating Upstream GHG Emission Factors for CaRFG
A-5	CA-GREET 3.0 California Electricity Grid Mix Inputs for Estimating Upstream GHG Emission Factors
A-6	Estimating Upstream GHG Emission Factors for CARB SRIA Hydrogen
A-7	Estimating Upstream GHG Emission Factors for AB32 Hydrogen
A-8	Fuel Economies for Light Duty Auto Vehicles in Calendar Year 2026
A-9	Estimating Average Daily Mileage for LDA ICEVs and Fraction of Daily Electric Miles Traveled by LDA PHEVs in Calendar Year 2026
A-10	Tailpipe Greenhouse Gas Emission Factors for ICEV and PHEV Light Duty Autos in Calendar Year 2026
A-11	Fuel Economies for Light Duty Auto Vehicles in Calendar Year 2030
A-12	Estimating Average Daily Mileage for LDA ICEVs and Fraction of Daily Electric Miles Traveled by LDA PHEVs in Calendar Year 2030
A-13	Tailpipe Greenhouse Gas Emission Factors for ICEV and PHEV Light Duty Autos in Calendar Year 2030
A-14	Fuel Economies for Light Duty Auto Vehicles in Calendar Year 2035
A-15	Estimating Average Daily Mileage for LDA ICEVs and Fraction of Daily Electric Miles Traveled by LDA PHEVs in Calendar Year 2035
A-16	Tailpipe Greenhouse Gas Emission Factors for ICEV and PHEV Light Duty Autos in Calendar Year 2035
A-17	Fuel Economies for Light Duty Auto Vehicles in Calendar Year 2040
A-18	Estimating Average Daily Mileage for LDA ICEVs and Fraction of Daily Electric Miles Traveled by LDA PHEVs in Calendar Year 2040
A-19	Tailpipe Greenhouse Gas Emission Factors for ICEV and PHEV Light Duty Autos in Calendar Year 2040
A-20	Fuel Economies for Light Duty Auto Vehicles in Calendar Year 2045
A-21	Estimating Average Daily Mileage for LDA ICEVs and Fraction of Daily Electric Miles Traveled by LDA PHEVs in Calendar Year 2045
A-22	Tailpipe Greenhouse Gas Emission Factors for ICEV and PHEV Light Duty Autos in Calendar Year 2045
A-23	Fuel Economies for Light Duty Auto Vehicles in Calendar Year 2050
A-24	Estimating Average Daily Mileage for LDA ICEVs and Fraction of Daily Electric Miles Traveled by LDA PHEVs in Calendar Year 2050
A-25	Tailpipe Greenhouse Gas Emission Factors for ICEV and PHEV Light Duty Autos in Calendar Year 2050
A-26	Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 0 in Calendar Year 2026
A-27	Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 0 in Calendar Year 2030
A-28	Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 0 in Calendar Year 2035
A-29	Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 0 in Calendar Year 2040

A-30 Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 0 in Calendar Year 2045
A-31 Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 0 in Calendar Year 2050
A-32 Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 1a in Calendar Year 2026
A-33 Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 1a in Calendar Year 2030
A-34 Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 1a in Calendar Year 2035
A-35 Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 1a in Calendar Year 2040
A-36 Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 1a in Calendar Year 2045
A-37 Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 1a in Calendar Year 2050
A-38 Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 1b in Calendar Year 2026
A-39 Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 1b in Calendar Year 2030
A-40 Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 1b in Calendar Year 2035
A-41 Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 1b in Calendar Year 2040
A-42 Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 1b in Calendar Year 2045
A-43 Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 1b in Calendar Year 2050
A-44 Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 1c in Calendar Year 2026
A-45 Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 1c in Calendar Year 2030
A-46 Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 1c in Calendar Year 2035
A-47 Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 1c in Calendar Year 2040
A-48 Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 1c in Calendar Year 2045
A-49 Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 1c in Calendar Year 2050
A-50 Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenarios 1d & 1d-1 in Calendar Year 2026
A-51 Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenarios 1d & 1d-1 in Calendar Year 2030
A-52 Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenarios 1d & 1d-1 in Calendar Year 2035
A-53 Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenarios 1d & 1d-1 in Calendar Year 2040

A-54	Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenarios 1d & 1d-1 in Calendar Year 2045
A-55	Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenarios 1d & 1d-1 in Calendar Year 2050
A-56	Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenarios 2a & 2b in Calendar Year 2026
A-57	Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenarios 2a & 2b in Calendar Year 2030
A-58	Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenarios 2a & 2b in Calendar Year 2035
A-59	Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenarios 2a & 2b in Calendar Year 2040
A-60	Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenarios 2a & 2b in Calendar Year 2045
A-61	Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenarios 2a & 2b in Calendar Year 2050
A-62	Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 2c in Calendar Year 2026
A-63	Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 2c in Calendar Year 2030
A-64	Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 2c in Calendar Year 2035
A-65	Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 2c in Calendar Year 2040
A-66	Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 2c in Calendar Year 2045
A-67	Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 2c in Calendar Year 2050
A-68	Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenarios 3a, 3a-1, 3a-2, & 3b in Calendar Year 2026
A-69	Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenarios 3a, 3a-1, 3a-2, & 3b in Calendar Year 2030
A-70	Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenarios 3a, 3a-1, 3a-2, & 3b in Calendar Year 2035
A-71	Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenarios 3a, 3a-1, 3a-2, & 3b in Calendar Year 2040
A-72	Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenarios 3a, 3a-1, 3a-2, & 3b in Calendar Year 2045
A-73	Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenarios 3a, 3a-1, 3a-2, & 3b in Calendar Year 2050
A-74	Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 4a in Calendar Year 2026
A-75	Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 4a in Calendar Year 2030
A-76	Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 4a in Calendar Year 2035
A-77	Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 4a in Calendar Year 2040

A-78 Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 4a in Calendar Year 2045
A-79 Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 4a in Calendar Year 2050
A-80 Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 4b in Calendar Year 2026
A-81 Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 4b in Calendar Year 2030
A-82 Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 4b in Calendar Year 2035
A-83 Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 4b in Calendar Year 2040
A-84 Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 4b in Calendar Year 2045
A-85 Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 4b in Calendar Year 2050
A-86 Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 4c in Calendar Year 2026
A-87 Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 4c in Calendar Year 2030
A-88 Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 4c in Calendar Year 2035
A-89 Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 4c in Calendar Year 2040
A-90 Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 4c in Calendar Year 2045
A-91 Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 4c in Calendar Year 2050
A-92 GREET 2021 Model U.S. Electricity Grid Mix Inputs for Model Year 2026 Light Duty Autos
A-93 GREET 2021 Model International Electricity Grid Mix Inputs for Model Year 2026 Light Duty Autos
A-94 GREET 2021 Model Inputs for Model Year 2026 Light Duty Autos
A-95 Vehicle Cycle Emission Factors for Model Year 2026 Light-Duty Autos
A-96 Estimating Vehicle Cycle Emissions for Scenario Analysis
A-97 Vehicle Cycle Emission Factors for Battery Replacement in BEVs
A-98 Estimating Battery Replacement Emissions for Battery Electric Vehicles in the Scenario Analysis

Table A-1. Scenario Matrix

Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Scenario #	Scenario Name	Parameter	Battery Electric Vehicle	Plug-in Hybrid Electric Vehicle	Fuel Cell Electric Vehicle	Hybrid Electric Vehicle	Internal Combustion Engine Vehicle	Scenario Description
S0	ACC I	**Fleet Mix[1]**	EMFAC2021 default[3]					This scenario serves as the baseline and is based on EMFAC2021 fleet mix defaults, which represents ACC I PHEV and BEV sales requirements.
		Fuel Type[2]						
S1a	ACC II (BEV)	**Fleet Mix[1]**	EMFAC2021 default for pre-2026 MYs, meets ACC II ZEV sales requirement with PHEVs for MY 2026+	EMFAC2021 default[3]	N/A	N/A	Remaining fleet mix	This scenario assumes that any additional ZEVs sales beyond those (BEVs and PHEVs) in the S0-ACC I scenario that are needed to meet the ZEV sales requirements in the draft ACC II proposal are met with BEVs.
		Fuel Type[2]	Electricity	Electricity for eVMT and CaRFG for cVMT	N/A	N/A	CaRFG	
S1b	ACC II (BEV + PHEV)	**Fleet Mix[1]**	EMFAC2021 default for pre-2026 MYs, meets 80% of ACC II ZEV sales requirement for MY 2026+	EMFAC2021 default for pre-2026 MYs, meets 20% of ACC II ZEV sales requirement for MY 2026+	N/A	N/A	Remaining fleet mix	This scenario assumes that the ZEV sales needed to meet the ZEV sales requirements in the draft ACC II proposal are met with the maximum allowable fraction of PHEVs (20% of ZEV sales requirement) and BEVs (80% of ZEV sales requirement).
		Fuel Type[2]	Electricity	Electricity for eVMT and CaRFG for cVMT	N/A	N/A	CaRFG	
S1c	ACC II (CARB SRIA)	**Fleet Mix[1]**	EMFAC2021 default for pre-2026 MYs, fleet mix assumptions in CARB SRIA were applied to meet the ACC II sales requirements[4] for MY 2026+			N/A	Remaining fleet mix	This scenario assumes that the ZEV sales needed to meet the draft ACC II proposal are met with combination of PHEVs, BEVs, and FCEVs as noted in the CARB's SRIA for the ACC II proposal.
		Fuel Type[2]	Electricity	Electricity for eVMT and CaRFG for cVMT	CARB SRIA H_2	N/A	CaRFG	
S1d	ACC II (FCEV)	**Fleet Mix[1]**	EMFAC2021 default[3]	EMFAC2021 default[3]	EMFAC2021 default for pre-2026 MYs, meets ACC II ZEV sales requirement with BEVs and PHEVs for MY 2026+	N/A	Remaining fleet mix	This scenario assumes that any additional ZEVs sales beyond those (BEVs and PHEVs) in the S0-ACC I Scenario that are needed to meet the ZEV sales requirements in the draft ACC II proposal are met with FCEVs. The carbon intensity (CI) of hydrogen fuel used to power FCEVs in this scenario was developed based on the feedstock projections in CARB's SRIA for the ACC II proposal. Refer to Section 3.2.4 for further discussion of hydrogen pathways.
		Fuel Type[2]	Electricity	Electricity for eVMT and CaRFG for cVMT	CARB SRIA H_2	N/A	CaRFG	
S1d-1	ACC II (FCEV) + AB32 H_2	**Fleet Mix[1]**	Same as Scenario S1d					This sensitivity scenario is identical to scenario S1d – ACC II (FCEV) with the following exception: the CI for hydrogen fuel used to power FCEVs was developed based on the assumptions in the AB 32 Source Emissions Initial Modeling Results for the draft 2022 Scoping Plan Update.
		Fuel Type[2]	Same as Scenario S1d		CARB AB32 H_2	N/A	Same as Scenario S1d	
S2a	PHEV	**Fleet Mix[1]**	EMFAC2021 default[3]	EMFAC2021 default for pre-2026 MYs, meets ACC II ZEV sales requirement with BEVs for MY 2026+	N/A	N/A	Remaining fleet mix	This scenario assumes that any additional ZEVs sales beyond those (BEVs and PHEVs) in the S0-ACC I Scenario that are needed to meet the ZEV sales requirements in the draft ACC II proposal are met with PHEVs.
		Fuel Type[2]	Electricity	Electricity for eVMT and CaRFG for cVMT	N/A	N/A	CaRFG	
S2b	PHEV + Low-CI Gas	**Fleet Mix[1]**	EMFAC2021 default[3]	EMFAC2021 default for pre-2026 MYs, meets ACC II ZEV sales requirement with BEVs for MY 2026+	N/A	N/A	Remaining fleet mix	This vehicle fleet mix for this scenario is identical to scenario S2a – PHEV. However, it also includes the gradual phase-in of low-CI gasoline (see orange area in Figure 2-6) beginning as a replacement of 1% of CaRFG in 2026 and increasing to a replacement of 30% and 100% of CaRFG by 2035 and 2050 respectively.
		Fuel Type[2]	Electricity	Electricity for eVMT and a combination of CaRFG and Low-CI Gasoline for cVMT	N/A	N/A	A combination of CaRFG and Low-CI Gasoline	
S2c	HEV + Low-CI Gas	**Fleet Mix[1]**	EMFAC2021 default[3]	EMFAC2021 default[2]	N/A	EMFAC2021 default for pre-2026 MYs, meets ACC II ZEV sales requirement with BEVs and PHEVs for MY 2026+	Remaining fleet mix	This scenario assumes that any additional ZEVs sales beyond those (BEVs and PHEVs) in the S0-ACC I Scenario that are needed to meet the ZEV sales requirements in the draft ACC II proposal are met with all HEVs. It also includes a phase-in of low-CI gasoline (see orange area in Figure 2-6) beginning as a replacement of 2% of CaRFG in 2026 and increasing to a replacement of 35% and 100% of CaRFG by 2035 and 2050 respectively.
		Fuel Type[2]	Electricity	Electricity for eVMT and a combination of CaRFG and Low-CI Gasoline for cVMT	N/A	A combination of CaRFG and Low-CI Gas	A combination of CaRFG and Low-CI Gasoline	
S3a	Low-CI Gas	**Fleet Mix[1]**	EMFAC2021 default[3]					This scenario analyzes the same vehicle fleet mix as S0 – ACC I with a gradual phase-in of low-CI gasoline beginning as a replacement of 1% of CaRFG in 2026 and increasing to a replacement of 45% and 100% of CaRFG by 2035 and 2050 respectively. The CI of the low-CI gasoline used in this scenario is 19 g CO_2e/MJ.
		Fuel Type[2]	Electricity	Electricity for eVMT and a combination of CaRFG and Low-CI Gasoline for cVMT	EMFAC2021 default[3]		A combination of CaRFG and Low-CI Gasoline	
3a-1	Low-CI Gas (Upper Range)	**Fleet Mix[1]**	EMFAC2021 default[3]					This sensitivity scenario is identical to scenario S3a – Low CI Gas with the following exception: the carbon intensity of the low-CI gasoline is increased by 10 g CO_2e/MJ to 29 g CO_2e/MJ.
		Fuel Type[2]	Electricity	Electricity for eVMT and a combination of CaRFG and Low-CI Gasoline (upper range) for cVMT	EMFAC2021 default[3]		A combination of CaRFG and Low-CI Gasoline (upper range)	

Table A-1. Scenario Matrix

Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Scenario #	Scenario Name	Parameter	Battery Electric Vehicle	Plug-in Hybrid Electric Vehicle	Fuel Cell Electric Vehicle	Hybrid Electric Vehicle	Internal Combustion Engine Vehicle	Scenario Description
S3a-2	Low-CI Gas (Lower Range)	**Fleet Mix[1]**	EMFAC2021 default[3]					This sensitivity scenario is identical to scenario S3a – Low-CI Gas with the following exception: the carbon intensity of the low-CI gasoline is reduced by 10 g CO_2e/MJ to 9 g CO_2e/MJ.
		Fuel Type[2]	Electricity	Electricity for eVMT and a combination of CaRFG and Low-CI Gasoline (lower range) for cVMT	EMFAC2021 default[3]		A combination of CaRFG and Low-CI Gasoline (upper range)	
S3b	Low-CI Gas (Delayed)	**Fleet Mix[1]**	EMFAC2021 default[3]					This scenario is identical to scenario 3a with the following exception: the phase in of low-CI gasoline is delayed and occurs more slowly from 2026-2035 (replacement of 1% to 20% of CaRFG from 2026-2035) but increases rapidly from 2035-2040 (replacement of 97% and 100% of CaRFG by 2045 and 2050 respectively), as compared with scenario 3a.
		Fuel Type[2]	Electricity	Electricity for eVMT and a combination of CaRFG and Low-CI Gasoline for cVMT	EMFAC2021 default[3]		A combination of CaRFG and Low-CI Gasoline	
S4a	Custom Fleet Mix 1	**Fleet Mix[1]**	EMFAC2021 default for pre-2030 MYs, fleet fraction increases by 1% annually for MY 2030 to MY 2044 and 2% annually for subsequent MYs	EMFAC2021 default for pre-2026 MYs, fleet fraction increases by 1% annually for MY 2026 to MY 2040 and 2% annually for subsequent MYs	N/A	EMFAC2021 default for pre-2026 MYs, fleet fraction increases from 11% in MY 2026 to 72% in MY 2033 and then begins dropping with increases in BEVs and PHEVs	Remaining fleet mix up to MY 2032, no additional ICEVs in subsequent MYs	This scenario evaluates a custom fleet mix with a combination of HEVs, PHEVs, BEVs, and ICEVs. It also includes a phase-in of low-CI gasoline (CI of 19 g CO_2e/MJ) beginning as a replacement of 2% of CaRFG in 2026 and increasing to a replacement of 100% of CaRFG by 2050.
		Fuel Type[2]	Electricity	Electricity for eVMT and a combination of CaRFG and Low-CI Gasoline for cVMT	N/A	A combination of CaRFG and Low-CI Gasoline	A combination of CaRFG and Low-CI Gasoline	
S4b	Custom Fleet Mix 2	**Fleet Mix[1]**	EMFAC2021 default for pre-2036 MYs, fleet fraction of 19% in MY 2036, increases by 1% annually from MY 2037 to MY 2040, increases by 3.5% MY 2041 to MY 2045 and remains at 42% for subsequent MYs	EMFAC2021 default for pre-2028 MYs, increases 1% annually from MY 2028 to MY 2031, remains at 8% fleet fraction from MY 2031 to MY 2035, increases by 2% annually from MY 2036 to MY 2039, increases by 4% annually in MY 2040 and MY 2041, and remains at 39% for subsequent MYs	N/A	EMFAC2021 default for pre-2026 MYs, fleet fraction increases from 20% in MY 2026 to 80% for MY 2032 to MY 2035 and begins dropping with increases in BEVs and PHEVs.	Remaining fleet mix up to MY 2031, no additional ICEVs in subsequent MYs	This scenario evaluates a custom fleet mix with a combination of HEVs, PHEVs, BEVs, and ICEVs. It also includes a phase-in of low-CI gasoline (CI of 19 g CO_2e/MJ) beginning as a replacement of 2% of CaRFG in 2026 and increasing to a replacement of 100% of CaRFG by 2050.
		Fuel Type[2]	Electricity	Electricity for eVMT and a combination of CaRFG and Low-CI Gasoline for cVMT	N/A	A combination of CaRFG and Low-CI Gasoline	A combination of CaRFG and Low-CI Gasoline	
S4c	Custom Fleet Mix 3	**Fleet Mix[1]**	EMFAC2021 default for pre-2030 MYs, fleet fraction increases by 0.5% annually for MY 2030 to MY 2044 and 1.5% annually for subsequent MYs	EMFAC2021 default for pre-2026 MYs, fleet fraction increases by 1% annually for MY 2026 to MY 2040 and 2% annually for subsequent MYs	No FCEVs in pre-2030 MY, fleet fraction of 1% in MY 2030, increases by 0.5% annually for subsequent MYs	EMFAC2021 default for pre-2026 MYs, fleet fraction increases from 11% in MY 2026 to 72% in MY 2033 and then begins dropping with increases in BEVs, PHEVs, and FCEVs	Remaining fleet mix	This scenario evaluates a custom fleet mix with a combination of HEVs, PHEVs, BEVs, FCVEs, and ICEVs. This scenario also includes a phase-in of low-CI gasoline (CI of 19 g CO_2e/MJ) beginning as a replacement of 2% of CaRFG in 2026 and increasing to a replacement of 100% of CaRFG by 2050.
		Fuel Type[2]	Electricity	Electricity for eVMT and a combination of CaRFG and Low-CI Gasoline for cVMT	CARB SRIA H_2	A combination of CaRFG and Low-CI Gasoline	A combination of CaRFG and Low-CI Gasoline	

Notes:

[1] Fleet mix for each scenario is presented in Figures 2-3 and 2-4, and described in Section 2 of the report. Detailed fleet mix data is presented in Tables A-26 through A-91.

[2] Fuel mix for each scenario is presented in Figures 2-5 through 2-7, and described in Section 2 of the report. Additional details on the types of fuels is presented in Section 3.2.1.

[3] In all scenarios, the existing sales fraction and population of PHEVs and BEVs in EMFAC2021 defaults served as the minimum penetration of these vehicle technologies. Thus, while additional BEVs and/or PHEVs were added in some scenarios, only ICEVs in the EMFAC2021 default fleet were replaced with other vehicle types as applicable in each scenario. Note, EMFAC2021 default fleet mix does FCEVs. The EMFAC2021 v1.0.1 model is available at: https://arb.ca.gov/emfac/emissions-inventory/ (Accessed: January 2022).

[4] Fleet mix assumptions taken from the Standardized Regulatory Impact Assessment (SRIA) for the proposed ACC II. Available at: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/accii/appc1.pdf. Accessed: May 2022.

Abbreviations:

AB - Assembly Bill
ACC - Advanced Clean Cars
BEV - battery electric vehicle
CA - California
CARB - California Air Resources Board
CaRFG - California Reformulated Gasoline
CI - carbon intensity
CO_2e - carbon dioxide equivalent
cVMT - combustion vehicle miles traveled
CY - calendar year
EMFAC - EMission FACtor Model
eVMT - electric vehicle miles traveled
FCEV - fuel cell electric vehicle
g - gram
GHG - greenhouse gas
H_2 - hydrogen
HEV - hybrid electric vehicle
ICEV - internal combustion electric vehicle
MJ - megajoule
PHEV - plug-in hybrid electric vehicle
SRIA - Standardized Regulatory Impact Assessment
ZEV- zero emission vehicle
N/A - not applicable

Table A-2. Upstream (EER-Unadjusted) GHG Emission Factors by Fuel Type
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Calendar Year	Upstream (EER-Unadjusted) GHG Emission Factors ($g\ CO_2e$ / MJ fuel)						
	CaRFG[1]	Low-CI Gasoline[2]	Low-CI Gasoline (Upper Range)[3]	Low-CI Gasoline (Lower Range)[3]	Electricity[4]	CARB SRIA Hydrogen[5]	AB32 Hydrogen[6]
2026	29.1	19.0	29.0	9.0	65.3	102.6	7.4
2030	29.1	19.0	29.0	9.0	49.9	98.4	0.81
2035	29.1	19.0	29.0	9.0	36.8	91.8	0.28
2040	29.1	19.0	29.0	9.0	25.7	81.7	0.18
2045	29.1	19.0	29.0	9.0	16.7	65.2	0.14
2050	29.1	19.0	29.0	9.0	11.1	64.8	0.13

Notes:
[1] Upstream emission factors for CaRFG are estimated as shown in Table A-4 and described in Section 3.2.1.1 of the report.
[2] Upstream emission factors for Low-CI gasoline are estimated as shown in Table 3-1 and described in Section 3.2.1.2 of the report.
[3] Upper and lower ranges of the upstream emission factors for Low-CI gasoline used in sensitivity scenarios S3a-1 - Low-CI Gas (Upper Range) and S3a-2 - Low-CI Gas (Lower Range), are estimated as described in Section 3.2.1.2 of the report.
[4] Upstream emission factors for electricity used to fuel BEVs and PHEVs are estimated as described in Section 3.2.1.3 of the report.
[5] Upstream emission factors for CARB SRIA Hydrogen are estimated as shown in Table A-6 and described in Section 3.2.1.4 of the report.
[6] Upstream emission factors for AB32 Hydrogen are estimated as shown in Table A-7 and described in Section 3.2.1.4 of the report. This carbon intensity is specific to the hydrogen usage in scenario S1d-1 - ACC II (FCEV) + AB32 H_2.

Abbreviations:
AB - Assembly Bill
ACC - Advanced Clean Cars
BEV - battery electric vehicle
CARB - California Air Resources Board
CaRFG - California Reformulated Gasoline
CI - carbon intensity
CO_2e - carbon dioxide equivalent
EER - energy economy ratio
EMFAC - EMission FACtor Model
FCEV - fuel cell electric vehicle
g - gram
GHG - greenhouse gas
H_2 - hydrogen
MJ - megajoule
PHEV - plug-in hybrid electric vehicle
SRIA - Standardized Regulatory Impact Assessment

Table A-3. Upstream (EER-Adjusted) GHG Emission Factors by Fuel Type
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Calendar Year	Upstream (EER-Adjusted) GHG Emission Factors (g CO_2e / MJ of gasoline displaced)						
	CaRFG[1]	Low-CI Gasoline[1]	Low-CI Gasoline (Upper Range)[1]	Low-CI Gasoline (Lower Range)[1]	Electricity[2]	CARB SRIA Hydrogen[2]	AB32 Hydrogen[2]
2026	29.1	19.0	29.0	9.0	27.6	41.0	3.0
2030	29.1	19.0	29.0	9.0	21.0	39.3	0.32
2035	29.1	19.0	29.0	9.0	15.5	36.7	0.11
2040	29.1	19.0	29.0	9.0	10.8	32.7	0.07
2045	29.1	19.0	29.0	9.0	7.0	26.1	0.06
2050	29.1	19.0	29.0	9.0	4.7	25.9	0.05

Notes:

[1] Obtained from Table A-2.

[2] Upstream (EER-Adjusted) GHG emission factors for electricity and hydrogen are calculated based on EER-Unadjusted GHG emission factors shown in Table A-2 and the EER adjustment ratios for BEVs and FCEVs shown below.

[3] The EERs for BEVS were calculated from EMFAC2021 data. Available here: https://arb.ca.gov/emfac/. Accessed: January 2022.

[4] The EERs for FCEVs was obtained from the *LCFS Final Regulation Order* , Table 5. Available here: https://ww2.arb.ca.gov/sites/default/files/2020-07/2020_lcfs_fro_oal-approved_unofficial_06302020.pdf. Accessed: May 2022.

Energy Economy Ratios:

BEV[3]	CY 2026	2.3705
BEV[3]	CY 2030	2.3716
BEV[3]	CY 2035	2.3720
BEV[3]	CY 2040	2.3723
BEV[3]	CY 2045	2.3718
BEV[3]	CY 2050	2.3720
FCEV[4]	CY 2026 - 2050	2.5

Abbreviations:

AB - Assembly Bill
CARB - California Air Resources Board
CaRFG - California Reformulated Gasoline
CI - carbon intensity
CY - calendar year
CO_2e - carbon dioxide equivalent
EER - energy economy ratio
EMFAC - EMission FACtor Model
g - gram
GHG - greenhouse gas
MJ - megajoule
SRIA - Standardized Regulatory Impact Assessment

Table A-4. Estimating Upstream GHG Emission Factors for CaRFG

Upstream GHG Emission Factor for CARBOB[1] (g CO_2e/MJ)	Upstream GHG Emission Factor for Ethanol[2] (g CO_2e/MJ)	Ethanol Energy Content in CaRFG[3] (MJ Ethanol/MJ CaRFG)	Upstream GHG Emission Factor for CaRFG[4] (g CO_2e/MJ)
26.88	59.8	6.61%	29.1

Notes:

[1]Obtained from Table A.1 in *CA-GREET3.0 Lookup Table Pathways Technical Support Documentation* dated August 13, 2018. Available at: https://ww2.arb.ca.gov/sites/default/files/classic/fuels/lcfs/ca-greet/lut-doc.pdf. Accessed: May 2022.

[2]Estimated as an average of the ethanol carbon intensities available in the most recent LCFS Quarterly Reports at the time of this analysis (2020 Q1 to 2021 Q3). Available at: https://ww2.arb.ca.gov/sites/default/files/2022-01/quarterlysummary_013122_0.xlsx. Accessed: May 2022.

[3] The Ethanol energy content of CaRFG was obtained from the *CA-GREET3.0 Model - Current Version: Effective January 4, 2019 (released August 13, 2018)* . Available at: https://www.arb.ca.gov/fuels/lcfs/ca-greet/ca-greet30-corrected.xlsm?_ga=2.35180577.1071504132.1642096595-990540269.1603987774. Accessed: May 2022.

[4] Estimated as an energy weighted average of the upstream GHG emission factors of CARBOB and ethanol.

Abbreviations:

CA - California

CARBOB - California Reformulated Gasoline Blendstock for Oxygenate Blending

CaRFG - California Reformulated Gasoline

CI - carbon intensity

CO_2e - carbon dioxide equivalents

EtOH - ethanol

g - gram

GHG - greenhouse gas

GREET - Greenhouse gases, Regulated Emissions, and Energy use in Technologies Model

LCFS - Low Carbon Fuel Standard

MJ - megajoule

Table A-5. CA-GREET 3.0 California Electricity Grid Mix Inputs for Estimating Upstream GHG Emission Factors

Year[1]	Residual Oil	Natural Gas	Coal	Nuclear	Biomass	Hydro-electric	Geo-thermal	Wind	Solar
2026	0.00%	40.64%	0.00%	0.10%	2.87%	9.68%	7.76%	10.34%	28.61%
2030	0.00%	30.29%	0.00%	0.38%	2.56%	9.25%	9.93%	10.76%	36.83%
2035	0.00%	22.25%	0.00%	0.18%	0.30%	8.09%	9.00%	18.74%	41.43%
2040	0.00%	15.13%	0.00%	0.00%	0.00%	6.85%	8.80%	25.11%	44.11%
2045	0.00%	9.66%	0.00%	0.00%	0.00%	6.44%	6.71%	29.65%	47.54%
2050	0.00%	6.05%	0.00%	0.00%	0.00%	5.23%	6.64%	33.98%	48.11%

Notes:

[1] Electricity grid projections out to 2050 were sourced from Energy and Environmental Economics (E3) 2018 Deep Decarbonization report commissioned by the CEC. Available at: https://www.ethree.com/wp-content/uploads/2018/06/Deep_Decarbonization_in_a_High_Renewables_Future_CEC-500-2018-012-1.pdf. Accessed: May 2022.

Abbreviations:

CEC - California Energy Commission

Table A-6. Estimating Upstream GHG Emission Factors for CARB SRIA Hydrogen

Calendar Year	Composition of CARB SRIA Hydrogen[1]			Upstream GHG Emission Factors for the Components of CARB SRIA Hydrogen ($g\ CO_2e/MJ$)			Upstream GHG Emission Factor for CARB SRIA Hydrogen[4] ($g\ CO_2e/MJ$)
	Fossil Hydrogen	Landfill SMR Hydrogen	Curtailment Electrolysis Hydrogen	Fossil Hydrogen[2]	Landfill SMR Hydrogen[2]	Curtailment Electrolysis Hydrogen[3]	
2026	60%	35%	5%	114	96.1	0	103
2030	60%	33%	7%	113	94.3	0	98.4
2035	60%	27%	13%	111	92.8	0	91.8
2040	60%	17%	23%	110	91.5	0	81.7
2045	60%	0%	40%	109	90.4	0	65.2
2050	60%	0%	40%	108	89.7	0	64.8

Notes:

[1] Developed based on the methodology used in the Standardized Regulatory Impact Assessment for the proposed ACC II (available at: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/accii/appc1.pdf, accessed: May 2022) and discussions with CARB ACC II staff. Refer to Section 3.2.1.4 of the report for further details.

[2] The fuel pathway codes HYF and HYB from the *CA-GREET 3.0 Lookup Table Pathways Technical Support Documentation* (available at: https://ww2.arb.ca.gov/sites/default/files/classic/fuels/lcfs/ca-greet/lut-doc.pdf, accessed: May 2022) were used to represent Fossil Hydrogen and Landfill SMR Hydrogen respectively. The total carbon intensity CIs for these pathways (noted below) were adjusted for improvements in the CI of California average grid electricity used in the gaseous H_2 compression and precooling stage of the pathway process to estimate the upstream GHG emissions for each calendar year. For each calendar year, the adjustment was performed by replacing the portion of the total CI associated with the gaseous H_2 compression and precooling stage of the process with the product of the electricity used for this stage (shown below) and the upstream GHG emission factor for electricity obtained from Table A-2.

[3] It was assumed that Curtailment Electrolysis Hydrogen would have a CI of zero, as the hydrogen is produced by electrolysis using curtailment electricity.

[4] Estimated as a composition weighted average of the GHG emission factors for Fossil Hydrogen, Landfill SMR Hydrogen and Curtailment Electrolysis Hydrogen.

[5] Obtained from Table F.3 in *CA-GREET 3.0 Lookup Table Pathways Technical Support Documentation*. Available at: https://ww2.arb.ca.gov/sites/default/files/classic/fuels/lcfs/ca-greet/lut-doc.pdf. Accessed: May 2022.

[6] Estimated as the ratio of the CI for the gaseous H_2 compression and precooling stage to the total CI for California average grid electricity (93.75 g CO_2e/MJ) in the *CA-GREET3.0 Lookup Table Pathways Technical Support Documentation* (available at: https://ww2.arb.ca.gov/sites/default/files/classic/fuels/lcfs/ca-greet/lut-doc.pdf, accessed: May 2022).

Carbon Intensity Data for Hydrogen Pathways:

Fuel Pathway Code	Process Description	Total CI for the Process[5] ($g\ CO_2e/MJ\ H_2$)	CI for the Gaseous H_2 Compression and Precooling Stage of the Process[5] ($g\ CO_2e/MJ\ H_2$)	California Grid Electricity Used for the Gaseous H_2 Compression and Precooling Stage of the Process[6] (MJ Electricity/MJ H_2)
HYF	NG to Gaseous H_2 from SMR	117.67	11.04	0.118
HYB	Biomethane to Gaseous H_2 from SMR	99.48	11.04	0.118

Abbreviations:

CARB - California Air Resources Board

CI - carbon intensity

CO_2e - carbon dioxide equivalents

g - gram

H_2 - hydrogen

GREET - Greenhouse gases, Regulated Emissions, and Energy use in Technologies Model

Table A-7. Estimating Upstream GHG Emission Factors for AB32 Hydrogen

Calendar Year	Fuel Consumption in Scenario S1d-1 – ACC II (FCEV) + AB32 H_2 (MJ of hydrogen/day)			Upstream GHG Emission Factors for the Components of AB32 Hydrogen ($g\ CO_2e/MJ$)		Upstream GHG Emission Factors for AB32 Hydrogen[6] ($g\ CO_2e/MJ$)
	Total Hydrogen[1]	Landfill SMR Hydrogen[2]	Solar Electrolysis Hydrogen[3]	Landfill SMR Hydrogen[4]	Solar Electrolysis Hydrogen[5]	
2026	12,056,007	933,718	11,122,289	96.1	0	7.4
2030	109,330,786	933,718	108,397,068	94.3	0	0.81
2035	305,039,242	933,718	304,105,524	92.8	0	0.28
2040	478,787,295	933,718	477,853,578	91.5	0	0.18
2045	583,944,601	933,718	583,010,883	90.4	0	0.14
2050	635,526,470	933,718	634,592,752	89.7	0	0.13

Notes:

[1] Obtained from Tables A-51 through A-55.

[2] The amount of Landfill SMR Hydrogen consumed in future years is capped at the amount of renewable hydrogen produced in 2021. The annual production of renewable hydrogen in 2021 was obtained from Figure ES 8 in the *2021 Annual Hydrogen Evaluation* (available at: https://ww2.arb.ca.gov/sites/default/files/2021-09/2021_AB-8_FINAL.pdf, accessed: May 2021). This annual value was converted to a daily consumption value using 347 light duty auto operational days per year obtained from the *EMFAC2017 Volume III - Technical Documentation (* available at: https://ww3.arb.ca.gov/msei/downloads/emfac2017-volume-iii-technical-documentation.pdf, accessed: May 2022).

[3] Estimated as the difference of the total hydrogen consumed and Landfill SMR Hydrogen consumed.

[4] Obtained from Table A-6.

[5] The upstream GHG emission factor for Solar Electrolysis Hydrogen was assumed to be zero, as hydrogen is produced using electrolysis with zero CI electricity that is generated by solar photovoltaic systems.

[6] Estimated as an consumption weighted average of GHG emission factors for Landfill SMR Hydrogen and Solar Electrolysis Hydrogen.

Abbreviations:

CI - carbon intensity
CO_2e - carbon dioxide equivalents
EMFAC - EMission FACtors Model
g - gram
H_2 - Hydrogen
HYB - Gaseous Hydrogen from Fossil Natural Gas and Steam Reformation of Methane
HYF - Gaseous Hydrogen from Landfill Biomethane and Steam Reformation of Methane
GREET - Greenhouse gases, Regulated Emissions, and Energy use in Technologies Model
kg - kilogram
LCFS - Low Carbon Fuel Standard
LDA - light duty auto
MJ - megajoule
NG - natural gas
yr - year

Table A-8. Fuel Economies for Light Duty Auto Vehicles in Calendar Year 2026

Model Year[1]	Internal Combustion Engine Vehicle[1]		Battery Electric Vehicle[1,2]		Plug-in Hybrid Electric Vehicle[1,3]				Fuel Cell Electric Vehicle[4,5]	Hybrid Electric Vehicle[6,7]	
	(gal of gasoline/ mi)	(MJ of gasoline/ mi)	(kWh of electricity/ mi)	(MJ of electricity/ mi)	(gal of gasoline/ mi)	(MJ of gasoline/ mi)	(kWh of electricity/ mi)	(MJ of electricity/ mi)	(MJ of hydrogen/ mi)	(gal of gasoline/ mi)	(MJ of gasoline /mi)
1982	0.056	6.48	0.386	1.39	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1983	0.055	6.41	0.386	1.39	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1984	0.054	6.27	0.386	1.39	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1985	0.053	6.17	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1986	0.050	5.82	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1987	0.050	5.79	0.386	1.39	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1988	0.050	5.76	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1989	0.049	5.72	0.386	1.39	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1990	0.049	5.69	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1991	0.049	5.67	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1992	0.049	5.64	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1993	0.046	5.27	0.386	1.39	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1994	0.045	5.24	0.386	1.39	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1995	0.045	5.21	0.386	1.39	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1996	0.045	5.22	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1997	0.044	5.11	0.386	1.39	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1998	0.043	4.97	0.386	1.39	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1999	0.042	4.85	0.386	1.39	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2000	0.042	4.86	0.386	1.39	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2001	0.042	4.85	0.386	1.39	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2002	0.042	4.84	0.386	1.39	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2003	0.042	4.85	0.386	1.39	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2004	0.044	5.04	0.386	1.39	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2005	0.043	4.96	0.386	1.39	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table A-8. Fuel Economies for Light Duty Auto Vehicles in Calendar Year 2026
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Model Year[1]	Internal Combustion Engine Vehicle[1]		Battery Electric Vehicle[1,2]		Plug-in Hybrid Electric Vehicle[1,3]				Fuel Cell Electric Vehicle[4,5]	Hybrid Electric Vehicle[6,7]	
	(gal of gasoline/ mi)	(MJ of gasoline/ mi)	(kWh of electricity/ mi)	(MJ of electricity/ mi)	(gal of gasoline/ mi)	(MJ of gasoline/ mi)	(kWh of electricity/ mi)	(MJ of electricity/ mi)	(MJ of hydrogen/ mi)	(gal of gasoline/ mi)	(MJ of gasoline /mi)
2006	0.043	4.97	0.386	1.39	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2007	0.042	4.85	0.386	1.39	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2008	0.042	4.88	0.386	1.39	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2009	0.040	4.62	0.386	1.39	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2010	0.036	4.21	0.386	1.39	0.035	4.11	0.302	1.09	N/A	N/A	N/A
2011	0.038	4.38	0.386	1.39	0.035	4.11	0.302	1.09	N/A	N/A	N/A
2012	0.036	4.18	0.386	1.39	0.035	4.08	0.302	1.09	N/A	N/A	N/A
2013	0.035	4.06	0.386	1.39	0.035	4.07	0.302	1.09	N/A	N/A	N/A
2014	0.035	4.07	0.386	1.39	0.035	4.06	0.302	1.09	N/A	N/A	N/A
2015	0.034	3.99	0.386	1.39	0.035	4.05	0.302	1.09	N/A	N/A	N/A
2016	0.034	3.90	0.386	1.39	0.035	4.04	0.302	1.09	N/A	N/A	N/A
2017	0.034	3.94	0.386	1.39	0.035	4.04	0.302	1.09	N/A	N/A	N/A
2018	0.034	3.93	0.386	1.39	0.035	4.03	0.302	1.09	N/A	N/A	N/A
2019	0.033	3.88	0.386	1.39	0.035	4.02	0.302	1.09	N/A	N/A	N/A
2020	0.033	3.77	0.386	1.39	0.035	4.01	0.302	1.09	N/A	N/A	N/A
2021	0.032	3.68	0.386	1.39	0.035	4.00	0.302	1.09	N/A	N/A	N/A
2022	0.031	3.60	0.386	1.39	0.035	4.01	0.302	1.09	N/A	N/A	N/A
2023	0.030	3.52	0.386	1.39	0.035	4.01	0.302	1.09	N/A	N/A	N/A
2024	0.030	3.44	0.386	1.39	0.035	4.01	0.302	1.09	N/A	N/A	N/A
2025	0.029	3.37	0.386	1.39	0.035	4.01	0.302	1.09	N/A	N/A	N/A

Table A-8. Fuel Economies for Light Duty Auto Vehicles in Calendar Year 2026
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Model Year[1]	Internal Combustion Engine Vehicle[1]		Battery Electric Vehicle[1,2]		Plug-in Hybrid Electric Vehicle[1,3]				Fuel Cell Electric Vehicle[4,5]	Hybrid Electric Vehicle[6,7]	
	(gal of gasoline/ mi)	(MJ of gasoline/ mi)	(kWh of electricity/ mi)	(MJ of electricity/ mi)	(gal of gasoline/ mi)	(MJ of gasoline/ mi)	(kWh of electricity/ mi)	(MJ of electricity/ mi)	(MJ of hydrogen/ mi)	(gal of gasoline/ mi)	(MJ of gasoline /mi)
2026	0.028	3.29	0.386	1.39	0.035	4.02	0.302	1.09	1.32	0.020	2.34

Notes:

[1] Estimated using fuel consumption, energy consumption, and VMT outputs for LDA from EMFAC2021.

[2] Values in shaded cells are not applicable as the light duty auto vehicle fleet in EMFAC2021 does not include MY 1985-1986, 1988, 1990-1992, and 1996 BEVs.

[3] Values in shaded cells are not applicable as the light duty auto vehicle fleet in EMFAC2021 does not include MY 2009 and earlier PHEVs.

[4] Fuel economies for MY 2026+ FCEVs were estimated by applying an EER of 2.5 to the gasoline ICEV fuel economy. This EER value was obtained from: https://ww2.arb.ca.gov/sites/default/files/2020-07/2020_lcfs_fro_oal-approved_unofficial_06302020.pdf. Accessed: May 2022.

[5] For the purposes of this analysis, we assumed FCEVs do not exist prior to MY2026, so the values in shaded cells are not applicable.

[6] Fuel economies for MY 2026+ HEVs were estimated by applying an EER of 1.41 to the gasoline ICEV fuel economy. This EER value was derived from the relative fuel economies of the average MY 2020 HEV and ICEV as obtained from The 2020 EPA Automotive Trends Report. This factor was assumed to remain constant in future years and was used to estimate fuel economies for MY 2026 to 2050 HEVs. Available at: https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1010U68.pdf. Accessed: May 2022.

[7] For the purposes of this analysis, we assumed HEVs do not exist prior to MY2026, so the values in shaded cells are not applicable.

[8] California Reformulated Gasoline (CaRFG) energy density and the conversion factor from kWh to MJ were obtained from CARB's Low Carbon Fuel Standard (LCFS) Regulation. Available at: https://ww2.arb.ca.gov/sites/default/files/2020-07/2020_lcfs_fro_oal-approved_unofficial_06302020.pdf. Accessed: May 2022.

Constants and Conversion Factors:

CaRFG Energy Density[8]	115.83	MJ/gal
Conversion Factor[8]	3.6	MJ/kWh
FCEV EER[4]	2.5	
HEV EER[6]	1.41	

Abbreviations:

BEV - battery electric vehicle
CARB - California Air Resources Board
CaRFG - California Reformulated Gasoline
EER - energy economy ratio
EPA - Environmental Protection Agency
EMFAC - EMission FACtor Model
FCEV - fuel cell electric vehicle
gal - gallon
HEV - hybrid electric vehicle
ICEV - internal combustion engine vehicle
kWh - kilowatt hour
LDA - light duty auto
LCFS - Low Carbon Fuel Standard
mi - mile
MJ - megajoule
MY - model year
PHEV - plug-in hybrid electric vehicle
VMT - vehicle mile traveled

Table A-9. Estimating Average Daily Mileage for LDA ICEVs and Fraction of Daily Electric Miles Traveled by LDA PHEVs in Calendar Year 2026

Model Year	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle[1]				
	Population[2] (vehicles)	Daily VMT[2] (miles/day)	Average Daily Mileage per Vehicle (mi/vehicle/day)	Average Daily eVMT[2] (miles/day)	Average Daily cVMT[2] (miles/day)	Average Daily VMT[2] (miles/day)	eVMT (% of Average Daily VMT)	cVMT (% of Average Daily VMT)
1982	4,657	26,874	5.77	0	0	0	N/A	N/A
1983	5,273	32,227	6.11	0	0	0	N/A	N/A
1984	7,858	52,558	6.69	0	0	0	N/A	N/A
1985	10,024	70,578	7.04	0	0	0	N/A	N/A
1986	10,647	79,719	7.49	0	0	0	N/A	N/A
1987	12,832	101,240	7.89	0	0	0	N/A	N/A
1988	12,139	102,970	8.48	0	0	0	N/A	N/A
1989	14,970	135,380	9.04	0	0	0	N/A	N/A
1990	18,044	174,283	9.66	0	0	0	N/A	N/A
1991	21,281	217,683	10.2	0	0	0	N/A	N/A
1992	18,332	199,758	10.9	0	0	0	N/A	N/A
1993	20,138	233,503	11.6	0	0	0	N/A	N/A
1994	22,840	281,137	12.3	0	0	0	N/A	N/A
1995	29,675	387,901	13.1	0	0	0	N/A	N/A
1996	29,436	407,796	13.9	0	0	0	N/A	N/A
1997	39,761	583,473	14.7	0	0	0	N/A	N/A
1998	48,817	759,429	15.6	0	0	0	N/A	N/A
1999	56,921	938,152	16.5	0	0	0	N/A	N/A
2000	76,964	1,342,284	17.4	0	0	0	N/A	N/A
2001	87,221	1,606,469	18.4	0	0	0	N/A	N/A
2002	102,135	1,992,256	19.5	0	0	0	N/A	N/A
2003	127,287	2,622,480	20.6	0	0	0	N/A	N/A
2004	143,690	3,119,968	21.7	0	0	0	N/A	N/A
2005	191,623	4,384,633	22.9	0	0	0	N/A	N/A
2006	225,488	5,424,766	24.1	0	0	0	N/A	N/A
2007	275,180	6,939,253	25.2	0	0	0	N/A	N/A
2008	258,265	6,829,991	26.4	0	0	0	N/A	N/A

Table A-9. Estimating Average Daily Mileage for LDA ICEVs and Fraction of Daily Electric Miles Traveled by LDA PHEVs in Calendar Year 2026

Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Model Year	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle[1]				
	Population[2] (vehicles)	Daily VMT[2] (miles/day)	Average Daily Mileage per Vehicle (mi/vehicle/day)	Average Daily eVMT[2] (miles/day)	Average Daily cVMT[2] (miles/day)	Average Daily VMT[2] (miles/day)	eVMT (% of Average Daily VMT)	cVMT (% of Average Daily VMT)
2009	229,086	6,347,878	27.7	0	0	0	N/A	N/A
2010	292,924	8,485,008	29.0	141	167	308	46%	54%
2011	307,002	9,314,386	30.3	7,615	9,007	16,623	46%	54%
2012	465,759	14,799,666	31.8	81,301	96,163	177,464	46%	54%
2013	592,447	19,649,699	33.2	170,161	201,266	371,427	46%	54%
2014	599,553	20,804,616	34.7	261,690	309,525	571,215	46%	54%
2015	738,821	26,786,257	36.3	209,303	247,562	456,865	46%	54%
2016	754,102	28,526,656	37.8	238,915	282,587	521,502	46%	54%
2017	794,462	31,216,468	39.3	650,114	768,951	1,419,065	46%	54%
2018	705,513	28,851,497	40.9	625,674	740,043	1,365,716	46%	54%
2019	622,322	26,519,738	42.6	490,993	544,904	1,035,897	47%	53%
2020	508,892	22,556,130	44.3	525,700	564,979	1,090,679	48%	52%
2021	619,444	28,547,651	46.1	746,145	756,758	1,502,904	50%	50%
2022	724,703	34,701,680	47.9	1,045,860	869,457	1,915,316	55%	45%
2023	731,635	36,367,737	49.7	1,132,848	883,942	2,016,790	56%	44%
2024	747,543	38,509,686	51.5	1,225,174	897,466	2,122,640	58%	42%
2025	758,530	40,393,349	53.3	1,323,268	906,781	2,230,049	59%	41%
2026	706,862	38,782,248	54.9	1,122,062	768,903	1,890,965	59%	41%

Notes:

[1] Values in shaded cells are zero or not available as the light duty auto vehicle fleet in EMFAC2021 does not include MY 2009 and earlier PHEVs.

[2] Obtained from EMFAC2021 data.

Abbreviations:

cVMT - combustion vehicle mile traveled
EMFAC - EMission FACtor Model
eVMT - electric vehicle mile traveled
ICEV - internal combustion engine vehicle
LDA - light duty auto
mi - mile
MY - model year
PHEV - plug-in hybrid electric vehicle
VMT - vehicle miles traveled

Table A-10. Tailpipe Greenhouse Gas Emission Factors for ICEV and PHEV Light Duty Autos in Calendar Year 2026

Model Year	Internal Combustion Engine Vehicle						Plug-in Hybrid Electric Vehicle[1]					
	CO_2 Emission Factor[2]		CH_4 Emission Factor[2]		N_2O Emission Factor[2]		CO_2 Emission Factor[2]		CH_4 Emission Factor[2]		N_2O Emission Factor[2]	
	(tons/gal)	(tons/MJ)	(tons/gal)	(tons/MJ)	(tons/gal)	(tons/MJ)	(tons/gal)	(tons/MJ)	(tons/gal)	(tons/MJ)	(tons/gal)	(tons/MJ)
1982	9.48E-03	8.19E-05	5.07E-06	4.38E-08	2.05E-06	1.77E-08	N/A	N/A	N/A	N/A	N/A	N/A
1983	9.48E-03	8.19E-05	4.83E-06	4.17E-08	1.87E-06	1.61E-08	N/A	N/A	N/A	N/A	N/A	N/A
1984	9.48E-03	8.19E-05	4.20E-06	3.62E-08	1.86E-06	1.61E-08	N/A	N/A	N/A	N/A	N/A	N/A
1985	9.48E-03	8.19E-05	4.65E-06	4.02E-08	1.68E-06	1.45E-08	N/A	N/A	N/A	N/A	N/A	N/A
1986	9.48E-03	8.19E-05	4.82E-06	4.16E-08	1.76E-06	1.52E-08	N/A	N/A	N/A	N/A	N/A	N/A
1987	9.48E-03	8.19E-05	4.74E-06	4.10E-08	1.75E-06	1.51E-08	N/A	N/A	N/A	N/A	N/A	N/A
1988	9.48E-03	8.19E-05	4.63E-06	4.00E-08	1.74E-06	1.50E-08	N/A	N/A	N/A	N/A	N/A	N/A
1989	9.48E-03	8.19E-05	4.54E-06	3.92E-08	1.72E-06	1.48E-08	N/A	N/A	N/A	N/A	N/A	N/A
1990	9.48E-03	8.19E-05	4.44E-06	3.83E-08	1.71E-06	1.48E-08	N/A	N/A	N/A	N/A	N/A	N/A
1991	9.48E-03	8.19E-05	4.36E-06	3.76E-08	1.71E-06	1.47E-08	N/A	N/A	N/A	N/A	N/A	N/A
1992	9.48E-03	8.19E-05	4.27E-06	3.68E-08	1.70E-06	1.47E-08	N/A	N/A	N/A	N/A	N/A	N/A
1993	9.48E-03	8.19E-05	4.47E-06	3.86E-08	1.81E-06	1.56E-08	N/A	N/A	N/A	N/A	N/A	N/A
1994	9.48E-03	8.19E-05	4.44E-06	3.84E-08	1.80E-06	1.55E-08	N/A	N/A	N/A	N/A	N/A	N/A
1995	9.48E-03	8.19E-05	4.39E-06	3.79E-08	1.79E-06	1.54E-08	N/A	N/A	N/A	N/A	N/A	N/A
1996	9.48E-03	8.19E-05	5.07E-06	4.37E-08	1.98E-06	1.71E-08	N/A	N/A	N/A	N/A	N/A	N/A
1997	9.48E-03	8.19E-05	4.17E-06	3.60E-08	1.80E-06	1.55E-08	N/A	N/A	N/A	N/A	N/A	N/A
1998	9.48E-03	8.19E-05	3.30E-06	2.85E-08	1.61E-06	1.39E-08	N/A	N/A	N/A	N/A	N/A	N/A
1999	9.48E-03	8.19E-05	2.41E-06	2.08E-08	1.41E-06	1.22E-08	N/A	N/A	N/A	N/A	N/A	N/A
2000	9.48E-03	8.19E-05	1.48E-06	1.28E-08	1.18E-06	1.02E-08	N/A	N/A	N/A	N/A	N/A	N/A
2001	9.48E-03	8.19E-05	1.38E-06	1.19E-08	1.11E-06	9.61E-09	N/A	N/A	N/A	N/A	N/A	N/A
2002	9.48E-03	8.19E-05	1.31E-06	1.13E-08	1.07E-06	9.25E-09	N/A	N/A	N/A	N/A	N/A	N/A
2003	9.48E-03	8.19E-05	1.17E-06	1.01E-08	9.82E-07	8.48E-09	N/A	N/A	N/A	N/A	N/A	N/A
2004	9.48E-03	8.19E-05	4.91E-07	4.24E-09	2.79E-07	2.41E-09	N/A	N/A	N/A	N/A	N/A	N/A
2005	9.48E-03	8.19E-05	4.43E-07	3.82E-09	2.73E-07	2.35E-09	N/A	N/A	N/A	N/A	N/A	N/A
2006	9.48E-03	8.19E-05	3.77E-07	3.25E-09	2.53E-07	2.18E-09	N/A	N/A	N/A	N/A	N/A	N/A
2007	9.48E-03	8.19E-05	3.82E-07	3.30E-09	2.70E-07	2.33E-09	N/A	N/A	N/A	N/A	N/A	N/A
2008	9.48E-03	8.19E-05	3.57E-07	3.08E-09	2.61E-07	2.26E-09	N/A	N/A	N/A	N/A	N/A	N/A
2009	9.48E-03	8.19E-05	3.42E-07	2.96E-09	2.68E-07	2.31E-09	N/A	N/A	N/A	N/A	N/A	N/A
2010	9.48E-03	8.19E-05	3.53E-07	3.05E-09	2.87E-07	2.48E-09	9.48E-03	8.19E-05	3.53E-07	3.05E-09	1.89E-07	1.63E-09
2011	9.48E-03	8.19E-05	3.40E-07	2.94E-09	2.71E-07	2.34E-09	9.48E-03	8.19E-05	3.40E-07	2.94E-09	1.84E-07	1.59E-09
2012	9.48E-03	8.19E-05	3.27E-07	2.82E-09	2.74E-07	2.37E-09	9.48E-03	8.19E-05	3.30E-07	2.85E-09	1.80E-07	1.56E-09
2013	9.48E-03	8.19E-05	3.14E-07	2.71E-09	2.74E-07	2.36E-09	9.48E-03	8.19E-05	3.20E-07	2.76E-09	1.77E-07	1.53E-09
2014	9.48E-03	8.19E-05	3.07E-07	2.65E-09	2.66E-07	2.30E-09	9.48E-03	8.19E-05	3.10E-07	2.67E-09	1.73E-07	1.49E-09
2015	9.48E-03	8.19E-05	2.99E-07	2.59E-09	2.63E-07	2.27E-09	9.48E-03	8.19E-05	3.00E-07	2.59E-09	1.69E-07	1.46E-09

Table A-10. Tailpipe Greenhouse Gas Emission Factors for ICEV and PHEV Light Duty Autos in Calendar Year 2026

Model Year	Internal Combustion Engine Vehicle						Plug-in Hybrid Electric Vehicle[1]					
	CO_2 Emission Factor[2]		CH_4 Emission Factor[2]		N_2O Emission Factor[2]		CO_2 Emission Factor[2]		CH_4 Emission Factor[2]		N_2O Emission Factor[2]	
	(tons/gal)	(tons/MJ)	(tons/gal)	(tons/MJ)	(tons/gal)	(tons/MJ)	(tons/gal)	(tons/MJ)	(tons/gal)	(tons/MJ)	(tons/gal)	(tons/MJ)
2016	9.48E-03	8.19E-05	3.27E-07	2.82E-09	2.68E-07	2.31E-09	9.48E-03	8.19E-05	2.91E-07	2.51E-09	1.66E-07	1.43E-09
2017	9.48E-03	8.19E-05	2.97E-07	2.57E-09	2.54E-07	2.19E-09	9.48E-03	8.19E-05	2.83E-07	2.44E-09	1.62E-07	1.40E-09
2018	9.48E-03	8.19E-05	2.78E-07	2.40E-09	2.45E-07	2.12E-09	9.48E-03	8.19E-05	2.75E-07	2.37E-09	1.59E-07	1.38E-09
2019	9.48E-03	8.19E-05	2.58E-07	2.23E-09	2.37E-07	2.04E-09	9.48E-03	8.19E-05	2.73E-07	2.36E-09	1.59E-07	1.37E-09
2020	9.48E-03	8.19E-05	2.47E-07	2.13E-09	2.33E-07	2.01E-09	9.48E-03	8.19E-05	2.69E-07	2.32E-09	1.57E-07	1.36E-09
2021	9.48E-03	8.19E-05	2.28E-07	1.97E-09	2.25E-07	1.94E-09	9.48E-03	8.19E-05	2.67E-07	2.31E-09	1.57E-07	1.35E-09
2022	9.48E-03	8.19E-05	2.06E-07	1.77E-09	2.14E-07	1.85E-09	9.48E-03	8.19E-05	2.80E-07	2.42E-09	1.62E-07	1.40E-09
2023	9.48E-03	8.19E-05	1.85E-07	1.60E-09	2.02E-07	1.74E-09	9.48E-03	8.19E-05	2.80E-07	2.42E-09	1.62E-07	1.40E-09
2024	9.48E-03	8.19E-05	1.64E-07	1.42E-09	1.88E-07	1.62E-09	9.48E-03	8.19E-05	2.80E-07	2.41E-09	1.62E-07	1.39E-09
2025	9.48E-03	8.19E-05	1.32E-07	1.14E-09	1.68E-07	1.45E-09	9.48E-03	8.19E-05	2.80E-07	2.42E-09	1.62E-07	1.40E-09
2026	9.48E-03	8.19E-05	1.26E-07	1.09E-09	1.58E-07	1.36E-09	9.48E-03	8.19E-05	2.74E-07	2.36E-09	1.59E-07	1.37E-09

Notes:

[1] Values in shaded cells are not available as the light duty auto vehicle fleet in EMFAC2021 does not include MY 2009 and earlier PHEVs.

[2] Tailpipe greenhouse gas emission factors were estimated as a ratio of the greenhouse gas emissions (CO_2, CH_4, N_2O) to the gasoline fuel consumption outputs for each model year from EMFAC2021 data.

[3] California Reformulated Gasoline (CaRFG) energy density for the conversion factor from gal to MJ was obtained from CARB's Low Carbon Fuel Standard (LCFS) Regulation. Available at: https://ww2.arb.ca.gov/sites/default/files/2020-07/2020_lcfs_fro_oal-approved_unofficial_06302020.pdf. Accessed: May 2022.

Conversion Factor

CaRFG Energy Density[3]	115.83	MJ/gal

Abbreviations:

CARB - California Air Resources Board	EMFAC - EMission FACtor Model	MJ - megajoule
CaRFG - California Reformulated Gasoline	gal - gallon	MY - model year
CH_4 - methane	ICEV - internal combustion engine vehicle	N_2O - Nitrous oxide
CO_2 - carbon dioxide	LCFS - Low Carbon Fuel Standard	PHEV - plug-in hybrid electric vehicle

Table A-11. Fuel Economies for Light Duty Auto Vehicles in Calendar Year 2030
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Model Year[1]	Internal Combustion Engine Vehicle[1]		Battery Electric Vehicle[1,2]		Plug-in Hybrid Electric Vehicle[1,3]				Fuel Cell Electric Vehicle[4,5]	Hybrid Electric Vehicle[6,7]	
	(gal of gasoline/ mi)	(MJ of gasoline/ mi)	(kWh of electricity/ mi)	(MJ of electricity/ mi)	(gal of gasoline/ mi)	(MJ of gasoline/ mi)	(kWh of electricity/ mi)	(MJ of electricity/ mi)	(MJ of hydrogen/ mi)	(gal of gasoline/ mi)	(MJ of gasoline /mi)
1986	0.051	5.95	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1987	0.051	5.93	0.386	1.390	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1988	0.051	5.89	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1989	0.051	5.85	0.386	1.390	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1990	0.050	5.81	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1991	0.050	5.79	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1992	0.050	5.75	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1993	0.046	5.38	0.386	1.390	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1994	0.046	5.34	0.386	1.390	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1995	0.046	5.31	0.386	1.390	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1996	0.046	5.31	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1997	0.045	5.18	0.386	1.390	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1998	0.044	5.04	0.386	1.390	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1999	0.042	4.90	0.386	1.390	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2000	0.042	4.92	0.386	1.390	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2001	0.042	4.90	0.386	1.390	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2002	0.042	4.89	0.386	1.390	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2003	0.042	4.89	0.386	1.390	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2004	0.044	5.08	0.386	1.390	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2005	0.043	5.00	0.386	1.390	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2006	0.043	5.01	0.386	1.390	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2007	0.042	4.88	0.386	1.390	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table A-11. Fuel Economies for Light Duty Auto Vehicles in Calendar Year 2030
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Model Year[1]	Internal Combustion Engine Vehicle[1]		Battery Electric Vehicle[1,2]		Plug-in Hybrid Electric Vehicle[1,3]				Fuel Cell Electric Vehicle[4,5]	Hybrid Electric Vehicle[6,7]	
	(gal of gasoline/ mi)	(MJ of gasoline/ mi)	(kWh of electricity/ mi)	(MJ of electricity/ mi)	(gal of gasoline/ mi)	(MJ of gasoline/ mi)	(kWh of electricity/ mi)	(MJ of electricity/ mi)	(MJ of hydrogen/ mi)	(gal of gasoline/ mi)	(MJ of gasoline /mi)
2008	0.042	4.91	0.386	1.390	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2009	0.040	4.65	0.386	1.390	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2010	0.036	4.23	0.386	1.390	0.036	4.16	0.302	1.087	N/A	N/A	N/A
2011	0.038	4.40	0.386	1.390	0.036	4.16	0.302	1.087	N/A	N/A	N/A
2012	0.036	4.20	0.386	1.390	0.036	4.13	0.302	1.087	N/A	N/A	N/A
2013	0.035	4.07	0.386	1.390	0.035	4.11	0.302	1.087	N/A	N/A	N/A
2014	0.035	4.08	0.386	1.390	0.035	4.10	0.302	1.087	N/A	N/A	N/A
2015	0.035	4.00	0.386	1.390	0.035	4.09	0.302	1.087	N/A	N/A	N/A
2016	0.034	3.92	0.386	1.390	0.035	4.07	0.302	1.087	N/A	N/A	N/A
2017	0.034	3.95	0.386	1.390	0.035	4.07	0.302	1.087	N/A	N/A	N/A
2018	0.034	3.94	0.386	1.390	0.035	4.06	0.302	1.087	N/A	N/A	N/A
2019	0.034	3.89	0.386	1.390	0.035	4.05	0.302	1.087	N/A	N/A	N/A
2020	0.033	3.78	0.386	1.390	0.035	4.04	0.302	1.087	N/A	N/A	N/A
2021	0.032	3.69	0.386	1.390	0.035	4.03	0.302	1.087	N/A	N/A	N/A
2022	0.031	3.60	0.386	1.390	0.035	4.04	0.302	1.087	N/A	N/A	N/A
2023	0.030	3.52	0.386	1.390	0.035	4.03	0.302	1.087	N/A	N/A	N/A
2024	0.030	3.44	0.386	1.390	0.035	4.03	0.302	1.087	N/A	N/A	N/A
2025	0.029	3.37	0.386	1.390	0.035	4.03	0.302	1.087	N/A	N/A	N/A
2026	0.028	3.29	0.386	1.390	0.035	4.02	0.302	1.087	1.32	0.020	2.337
2027	0.028	3.29	0.386	1.390	0.035	4.01	0.302	1.087	1.32	0.020	2.336
2028	0.028	3.29	0.386	1.390	0.035	4.01	0.302	1.087	1.32	0.020	2.337
2029	0.028	3.30	0.386	1.390	0.035	4.01	0.302	1.087	1.32	0.020	2.337

Table A-11. Fuel Economies for Light Duty Auto Vehicles in Calendar Year 2030

Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Model Year[1]	Internal Combustion Engine Vehicle[1]		Battery Electric Vehicle[1,2]		Plug-in Hybrid Electric Vehicle[1,3]				Fuel Cell Electric Vehicle[4,5]	Hybrid Electric Vehicle[6,7]	
	(gal of gasoline/ mi)	(MJ of gasoline/ mi)	(kWh of electricity/ mi)	(MJ of electricity/ mi)	(gal of gasoline/ mi)	(MJ of gasoline/ mi)	(kWh of electricity/ mi)	(MJ of electricity/ mi)	(MJ of hydrogen/ mi)	(gal of gasoline/ mi)	(MJ of gasoline /mi)
2030	0.028	3.30	0.386	1.390	0.035	4.02	0.302	1.087	1.32	0.020	2.338

Notes:

[1] Estimated using fuel consumption, energy consumption, and VMT outputs for LDA from EMFAC2021.

[2] Values in shaded cells are not applicable as the light duty auto vehicle fleet in EMFAC2021 does not include MY 1986, 1988, 1990-1992, and 1996 BEVs.

[3] Values in shaded cells are not applicable as the light duty auto vehicle fleet in EMFAC2021 does not include MY 2009 and earlier PHEVs.

[4] Fuel economies for MY 2026+ FCEVs were estimated by applying an EER of 2.5 to the gasoline ICEV fuel economy. This EER value was obtained from: https://ww2.arb.ca.gov/sites/default/files/2020-07/2020_lcfs_fro_oal-approved_unofficial_06302020.pdf. Accessed: May 2022.

[5] For the purposes of this analysis, we assumed FCEVs do not exist prior to MY2026, so the values in shaded cells are not applicable.

[6] Fuel economies for MY 2026+ HEVs were estimated by applying an EER of 1.41 to the gasoline ICEV fuel economy. This EER value was derived from the relative fuel economies of the average MY 2020 HEV and ICEV as obtained from The 2020 EPA Automotive Trends Report. This factor was assumed to remain constant in future years and was used to estimate fuel economies for MY 2026 to 2050 HEVs. Available at: https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1010U68.pdf. Accessed: May 2022.

[7] For the purposes of this analysis, we assumed HEVs do not exist prior to MY2026, so the values in shaded cells are not applicable.

[8] California Reformulated Gasoline (CaRFG) energy density and the conversion factor from kWh to MJ were obtained from CARB's Low Carbon Fuel Standard (LCFS) Regulation. Available at: https://ww2.arb.ca.gov/sites/default/files/2020-07/2020_lcfs_fro_oal-approved_unofficial_06302020.pdf. Accessed: May 2022.

Constants and Conversion Factors:

CaRFG Energy Density[8]	115.83	MJ/gal
Conversion Factor[8]	3.6	MJ/kWh
FCEV EER[4]	2.5	
HEV EER[6]	1.41	

Abbreviations:

BEV - battery electric vehicle
CARB - California Air Resources Board
CaRFG - California Reformulated Gasoline
EER - energy economy ratio
EPA - Environmental Protection Agency
EMFAC - EMission FACtor Model
FCEV - fuel cell electric vehicle
gal - gallon
HEV - hybrid electric vehicle
ICEV - internal combustion engine vehicle
kWh - kilowatt hour
LDA - light duty auto
LCFS - Low Carbon Fuel Standard
mi - mile
MJ - megajoule
MY - model year
PHEV - plug-in hybrid electric vehicle
VMT - vehicle mile traveled

Table A-12. Estimating Average Daily Mileage for LDA ICEVs and Fraction of Daily Electric Miles Traveled by LDA PHEVs in Calendar Year 2030
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Model Year	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle[1]				
	Population[2] (vehicles)	Daily VMT[2] (miles/day)	Average Daily Mileage per Vehicle (mi/vehicle/day)	Average Daily eVMT[2] (miles/day)	Average Daily cVMT[2] (miles/day)	Average Daily VMT[2] (miles/day)	eVMT (% of Average Daily VMT)	cVMT (% of Average Daily VMT)
1986	9,277	53,700	5.8	0	0	0	N/A	N/A
1987	11,036	66,623	6.0	0	0	0	N/A	N/A
1988	10,287	66,938	6.5	0	0	0	N/A	N/A
1989	12,682	87,678	6.9	0	0	0	N/A	N/A
1990	15,335	113,727	7.4	0	0	0	N/A	N/A
1991	17,755	139,333	7.8	0	0	0	N/A	N/A
1992	14,968	125,543	8.4	0	0	0	N/A	N/A
1993	15,722	140,921	9.0	0	0	0	N/A	N/A
1994	16,938	161,630	10	0	0	0	N/A	N/A
1995	21,266	216,234	10	0	0	0	N/A	N/A
1996	20,041	216,378	11	0	0	0	N/A	N/A
1997	25,571	293,230	11	0	0	0	N/A	N/A
1998	29,544	360,282	12	0	0	0	N/A	N/A
1999	32,392	420,297	13	0	0	0	N/A	N/A
2000	41,346	570,135	14	0	0	0	N/A	N/A
2001	44,766	655,169	15	0	0	0	N/A	N/A
2002	49,911	776,791	16	0	0	0	N/A	N/A
2003	59,781	987,738	17	0	0	0	N/A	N/A
2004	65,751	1,150,109	17	0	0	0	N/A	N/A
2005	86,903	1,608,897	19	0	0	0	N/A	N/A
2006	103,055	2,015,934	20	0	0	0	N/A	N/A
2007	128,610	2,648,443	21	0	0	0	N/A	N/A
2008	125,543	2,723,177	22	0	0	0	N/A	N/A
2009	116,809	2,665,820	23	0	0	0	N/A	N/A
2010	158,274	3,790,216	24	63	75	138	46%	54%
2011	175,648	4,423,155	25	3,616	4,277	7,894	46%	54%
2012	282,481	7,476,616	26	41,072	48,580	89,652	46%	54%
2013	378,095	10,478,988	28	90,738	107,324	198,062	46%	54%
2014	402,992	11,724,588	29	147,458	174,412	321,870	46%	54%
2015	518,113	15,796,707	30	123,416	145,976	269,392	46%	54%

Table A-12. Estimating Average Daily Mileage for LDA ICEVs and Fraction of Daily Electric Miles Traveled by LDA PHEVs in Calendar Year 2030

Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Model Year	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle[1]				
	Population[2] (vehicles)	Daily VMT[2] (miles/day)	Average Daily Mileage per Vehicle (mi/vehicle/day)	Average Daily eVMT[2] (miles/day)	Average Daily cVMT[2] (miles/day)	Average Daily VMT[2] (miles/day)	eVMT (% of Average Daily VMT)	cVMT (% of Average Daily VMT)
2016	553,278	17,650,767	32	147,786	174,800	322,586	46%	54%
2017	604,853	20,084,898	33	418,135	494,567	912,702	46%	54%
2018	555,971	19,259,219	35	417,450	493,757	911,207	46%	54%
2019	505,059	18,279,445	36	338,461	375,624	714,084	47%	53%
2020	424,894	16,029,340	38	373,698	401,619	775,317	48%	52%
2021	528,088	20,762,889	39	542,857	550,578	1,093,435	50%	50%
2022	629,123	25,762,005	41	776,697	645,693	1,422,390	55%	45%
2023	652,013	27,788,406	43	865,876	675,628	1,541,504	56%	44%
2024	670,253	29,718,527	44	945,654	692,712	1,638,366	58%	42%
2025	697,118	32,142,427	46	1,052,876	721,492	1,774,368	59%	41%
2026	735,995	35,239,627	48	1,019,135	698,371	1,717,506	59%	41%
2027	753,379	37,425,433	50	1,081,272	740,951	1,822,223	59%	41%
2028	774,987	39,867,277	51	1,144,715	784,426	1,929,141	59%	41%
2029	786,767	41,769,541	53	1,188,690	814,560	2,003,250	59%	41%
2030	712,577	38,930,072	55	1,099,919	753,729	1,853,648	59%	41%

Notes:

[1] Values in shaded cells are zero or not available as the light duty auto vehicle fleet in EMFAC2021 does not include MY 2009 and earlier PHEVs.

[2] Obtained from EMFAC2021 data.

Abbreviations:

cVMT - combustion vehicle mile traveled
EMFAC - EMission FACtor Model
eVMT - electric vehicle mile traveled
ICEV - internal combustion engine vehicle
LDA - light duty auto
mi - mile
MY - model year
PHEV - plug-in hybrid electric vehicle
VMT - vehicle miles traveled

Table A-13. Tailpipe Greenhouse Gas Emission Factors for ICEV and PHEV Light Duty Autos in Calendar Year 2030
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Model Year	Internal Combustion Engine Vehicle						Plug-in Hybrid Electric Vehicle[1]					
	CO_2 Emission Factor[2]		CH_4 Emission Factor[2]		N_2O Emission Factor[2]		CO_2 Emission Factor[2]		CH_4 Emission Factor[2]		N_2O Emission Factor[2]	
	(tons/gal)	(tons/MJ)	(tons/gal)	(tons/MJ)	(tons/gal)	(tons/MJ)	(tons/gal)	(tons/MJ)	(tons/gal)	(tons/MJ)	(tons/gal)	(tons/MJ)
1986	9.48E-03	8.19E-05	5.23E-06	4.51E-08	1.78E-06	1.54E-08	N/A	N/A	N/A	N/A	N/A	N/A
1987	9.48E-03	8.19E-05	5.18E-06	4.47E-08	1.77E-06	1.53E-08	N/A	N/A	N/A	N/A	N/A	N/A
1988	9.48E-03	8.19E-05	5.06E-06	4.37E-08	1.76E-06	1.52E-08	N/A	N/A	N/A	N/A	N/A	N/A
1989	9.48E-03	8.19E-05	4.96E-06	4.28E-08	1.74E-06	1.50E-08	N/A	N/A	N/A	N/A	N/A	N/A
1990	9.48E-03	8.19E-05	4.85E-06	4.19E-08	1.73E-06	1.49E-08	N/A	N/A	N/A	N/A	N/A	N/A
1991	9.48E-03	8.19E-05	4.77E-06	4.11E-08	1.73E-06	1.49E-08	N/A	N/A	N/A	N/A	N/A	N/A
1992	9.48E-03	8.19E-05	4.66E-06	4.02E-08	1.72E-06	1.49E-08	N/A	N/A	N/A	N/A	N/A	N/A
1993	9.48E-03	8.19E-05	4.87E-06	4.20E-08	1.83E-06	1.58E-08	N/A	N/A	N/A	N/A	N/A	N/A
1994	9.48E-03	8.19E-05	4.83E-06	4.17E-08	1.82E-06	1.57E-08	N/A	N/A	N/A	N/A	N/A	N/A
1995	9.48E-03	8.19E-05	4.76E-06	4.11E-08	1.81E-06	1.56E-08	N/A	N/A	N/A	N/A	N/A	N/A
1996	9.48E-03	8.19E-05	5.50E-06	4.75E-08	2.01E-06	1.73E-08	N/A	N/A	N/A	N/A	N/A	N/A
1997	9.48E-03	8.19E-05	4.54E-06	3.92E-08	1.83E-06	1.58E-08	N/A	N/A	N/A	N/A	N/A	N/A
1998	9.48E-03	8.19E-05	3.60E-06	3.11E-08	1.64E-06	1.42E-08	N/A	N/A	N/A	N/A	N/A	N/A
1999	9.48E-03	8.19E-05	2.64E-06	2.28E-08	1.45E-06	1.26E-08	N/A	N/A	N/A	N/A	N/A	N/A
2000	9.48E-03	8.19E-05	1.65E-06	1.42E-08	1.22E-06	1.05E-08	N/A	N/A	N/A	N/A	N/A	N/A
2001	9.48E-03	8.19E-05	1.54E-06	1.33E-08	1.16E-06	9.99E-09	N/A	N/A	N/A	N/A	N/A	N/A
2002	9.48E-03	8.19E-05	1.46E-06	1.26E-08	1.12E-06	9.63E-09	N/A	N/A	N/A	N/A	N/A	N/A
2003	9.48E-03	8.19E-05	1.30E-06	1.12E-08	1.03E-06	8.87E-09	N/A	N/A	N/A	N/A	N/A	N/A
2004	9.48E-03	8.19E-05	5.56E-07	4.80E-09	2.96E-07	2.56E-09	N/A	N/A	N/A	N/A	N/A	N/A
2005	9.48E-03	8.19E-05	5.01E-07	4.33E-09	2.90E-07	2.51E-09	N/A	N/A	N/A	N/A	N/A	N/A
2006	9.48E-03	8.19E-05	4.26E-07	3.68E-09	2.71E-07	2.34E-09	N/A	N/A	N/A	N/A	N/A	N/A
2007	9.48E-03	8.19E-05	4.32E-07	3.73E-09	2.90E-07	2.51E-09	N/A	N/A	N/A	N/A	N/A	N/A
2008	9.48E-03	8.19E-05	4.04E-07	3.49E-09	2.82E-07	2.43E-09	N/A	N/A	N/A	N/A	N/A	N/A
2009	9.48E-03	8.19E-05	3.88E-07	3.35E-09	2.90E-07	2.51E-09	N/A	N/A	N/A	N/A	N/A	N/A
2010	9.48E-03	8.19E-05	4.00E-07	3.45E-09	3.12E-07	2.69E-09	9.48E-03	8.19E-05	4.06E-07	3.50E-09	2.08E-07	1.80E-09
2011	9.48E-03	8.19E-05	3.86E-07	3.33E-09	2.95E-07	2.55E-09	9.48E-03	8.19E-05	3.90E-07	3.37E-09	2.02E-07	1.75E-09
2012	9.48E-03	8.19E-05	3.70E-07	3.20E-09	3.00E-07	2.59E-09	9.48E-03	8.19E-05	3.78E-07	3.26E-09	1.98E-07	1.71E-09
2013	9.48E-03	8.19E-05	3.57E-07	3.08E-09	3.01E-07	2.60E-09	9.48E-03	8.19E-05	3.66E-07	3.16E-09	1.94E-07	1.67E-09
2014	9.48E-03	8.19E-05	3.50E-07	3.02E-09	2.94E-07	2.53E-09	9.48E-03	8.19E-05	3.53E-07	3.04E-09	1.89E-07	1.63E-09
2015	9.48E-03	8.19E-05	3.41E-07	2.95E-09	2.92E-07	2.52E-09	9.48E-03	8.19E-05	3.41E-07	2.94E-09	1.85E-07	1.59E-09

Table A-13. Tailpipe Greenhouse Gas Emission Factors for ICEV and PHEV Light Duty Autos in Calendar Year 2030

Model Year	Internal Combustion Engine Vehicle						Plug-in Hybrid Electric Vehicle[1]					
	CO_2 Emission Factor[2]		CH_4 Emission Factor[2]		N_2O Emission Factor[2]		CO_2 Emission Factor[2]		CH_4 Emission Factor[2]		N_2O Emission Factor[2]	
	(tons/gal)	(tons/MJ)	(tons/gal)	(tons/MJ)	(tons/gal)	(tons/MJ)	(tons/gal)	(tons/MJ)	(tons/gal)	(tons/MJ)	(tons/gal)	(tons/MJ)
2016	9.48E-03	8.19E-05	3.73E-07	3.22E-09	2.98E-07	2.57E-09	9.48E-03	8.19E-05	3.30E-07	2.85E-09	1.81E-07	1.56E-09
2017	9.48E-03	8.19E-05	3.40E-07	2.94E-09	2.85E-07	2.46E-09	9.48E-03	8.19E-05	3.20E-07	2.76E-09	1.77E-07	1.53E-09
2018	9.48E-03	8.19E-05	3.20E-07	2.76E-09	2.77E-07	2.39E-09	9.48E-03	8.19E-05	3.10E-07	2.68E-09	1.73E-07	1.49E-09
2019	9.48E-03	8.19E-05	2.98E-07	2.57E-09	2.70E-07	2.33E-09	9.48E-03	8.19E-05	3.07E-07	2.65E-09	1.72E-07	1.49E-09
2020	9.48E-03	8.19E-05	2.86E-07	2.47E-09	2.69E-07	2.32E-09	9.48E-03	8.19E-05	3.03E-07	2.61E-09	1.70E-07	1.47E-09
2021	9.48E-03	8.19E-05	2.66E-07	2.29E-09	2.63E-07	2.27E-09	9.48E-03	8.19E-05	3.00E-07	2.59E-09	1.69E-07	1.46E-09
2022	9.48E-03	8.19E-05	2.41E-07	2.08E-09	2.55E-07	2.20E-09	9.48E-03	8.19E-05	3.14E-07	2.72E-09	1.75E-07	1.51E-09
2023	9.48E-03	8.19E-05	2.19E-07	1.89E-09	2.45E-07	2.11E-09	9.48E-03	8.19E-05	3.14E-07	2.71E-09	1.75E-07	1.51E-09
2024	9.48E-03	8.19E-05	1.96E-07	1.69E-09	2.33E-07	2.01E-09	9.48E-03	8.19E-05	3.13E-07	2.70E-09	1.75E-07	1.51E-09
2025	9.48E-03	8.19E-05	1.60E-07	1.38E-09	2.14E-07	1.85E-09	9.48E-03	8.19E-05	3.13E-07	2.70E-09	1.75E-07	1.51E-09
2026	9.48E-03	8.19E-05	1.53E-07	1.32E-09	2.06E-07	1.78E-09	9.48E-03	8.19E-05	3.05E-07	2.63E-09	1.71E-07	1.48E-09
2027	9.48E-03	8.19E-05	1.45E-07	1.25E-09	1.94E-07	1.68E-09	9.48E-03	8.19E-05	2.96E-07	2.56E-09	1.68E-07	1.45E-09
2028	9.48E-03	8.19E-05	1.38E-07	1.19E-09	1.82E-07	1.57E-09	9.48E-03	8.19E-05	2.88E-07	2.49E-09	1.65E-07	1.42E-09
2029	9.48E-03	8.19E-05	1.32E-07	1.14E-09	1.70E-07	1.47E-09	9.48E-03	8.19E-05	2.81E-07	2.43E-09	1.62E-07	1.40E-09
2030	9.48E-03	8.19E-05	1.25E-07	1.08E-09	1.57E-07	1.36E-09	9.48E-03	8.19E-05	2.74E-07	2.37E-09	1.60E-07	1.38E-09

Notes:

[1] Values in shaded cells are not available as the light duty auto vehicle fleet in EMFAC2021 does not include MY 2009 and earlier PHEVs.

[2] Tailpipe greenhouse gas emission factors were estimated as a ratio of the greenhouse gas emissions (CO_2, CH_4, N_2O) to the gasoline fuel consumption outputs for each model year from EMFAC2021 data.

[3] California Reformulated Gasoline (CaRFG) energy density for the conversion factor from gal to MJ was obtained from CARB's Low Carbon Fuel Standard (LCFS) Regulation. Available at: https://ww2.arb.ca.gov/sites/default/files/2020-07/2020_lcfs_fro_oal-approved_unofficial_06302020.pdf. Accessed: May 2022.

Conversion Factor

CaRFG Energy Density[3]	115.83	MJ/gal

Abbreviations:

CARB - California Air Resources Board
CaRFG - California Reformulated Gasoline
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
gal - gallon
ICEV - internal combustion engine vehicle
LCFS - Low Carbon Fuel Standard
MJ - megajoule
MY - model year
N_2O - Nitrous oxide
PHEV - plug-in hybrid electric vehicle

Table A-14. Fuel Economies for Light Duty Auto Vehicles in Calendar Year 2035

Model Year[1]	Internal Combustion Engine Vehicle[1]		Battery Electric Vehicle[1,2]		Plug-in Hybrid Electric Vehicle[1,3]				Fuel Cell Electric Vehicle[4,5]	Hybrid Electric Vehicle[6,7]	
	(gal of gasoline/ mi)	(MJ of gasoline/ mi)	(kWh of electricity/ mi)	(MJ of electricity/ mi)	(gal of gasoline/ mi)	(MJ of gasoline/ mi)	(kWh of electricity/ mi)	(MJ of electricity/ mi)	(MJ of hydrogen/ mi)	(gal of gasoline/ mi)	(MJ of gasoline /mi)
1991	0.051	5.97	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1992	0.051	5.93	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1993	0.048	5.54	0.386	1.390	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1994	0.047	5.49	0.386	1.390	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1995	0.047	5.45	0.386	1.390	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1996	0.047	5.45	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1997	0.046	5.31	0.386	1.390	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1998	0.044	5.15	0.386	1.390	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1999	0.043	5.00	0.386	1.390	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2000	0.043	5.00	0.386	1.390	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2001	0.043	4.98	0.386	1.390	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2002	0.043	4.96	0.386	1.390	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2003	0.043	4.96	0.386	1.390	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2004	0.044	5.14	0.386	1.390	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2005	0.044	5.05	0.386	1.390	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2006	0.044	5.06	0.386	1.390	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2007	0.043	4.93	0.386	1.390	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2008	0.043	4.95	0.386	1.390	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2009	0.040	4.69	0.386	1.390	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2010	0.037	4.26	0.386	1.390	0.037	4.26	0.302	1.087	N/A	N/A	N/A
2011	0.038	4.44	0.386	1.390	0.037	4.25	0.302	1.087	N/A	N/A	N/A
2012	0.036	4.23	0.386	1.390	0.036	4.21	0.302	1.087	N/A	N/A	N/A

Table A-14. Fuel Economies for Light Duty Auto Vehicles in Calendar Year 2035
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Model Year[1]	Internal Combustion Engine Vehicle[1]		Battery Electric Vehicle[1,2]		Plug-in Hybrid Electric Vehicle[1,3]				Fuel Cell Electric Vehicle[4,5]	Hybrid Electric Vehicle[6,7]	
	(gal of gasoline/ mi)	(MJ of gasoline/ mi)	(kWh of electricity/ mi)	(MJ of electricity/ mi)	(gal of gasoline/ mi)	(MJ of gasoline/ mi)	(kWh of electricity/ mi)	(MJ of electricity/ mi)	(MJ of hydrogen/ mi)	(gal of gasoline/ mi)	(MJ of gasoline /mi)
2013	0.035	4.10	0.386	1.390	0.036	4.19	0.302	1.087	N/A	N/A	N/A
2014	0.035	4.11	0.386	1.390	0.036	4.17	0.302	1.087	N/A	N/A	N/A
2015	0.035	4.03	0.386	1.390	0.036	4.15	0.302	1.087	N/A	N/A	N/A
2016	0.034	3.94	0.386	1.390	0.036	4.13	0.302	1.087	N/A	N/A	N/A
2017	0.034	3.97	0.386	1.390	0.036	4.13	0.302	1.087	N/A	N/A	N/A
2018	0.034	3.96	0.386	1.390	0.036	4.11	0.302	1.087	N/A	N/A	N/A
2019	0.034	3.91	0.386	1.390	0.035	4.10	0.302	1.087	N/A	N/A	N/A
2020	0.033	3.80	0.386	1.390	0.035	4.09	0.302	1.087	N/A	N/A	N/A
2021	0.032	3.70	0.386	1.390	0.035	4.08	0.302	1.087	N/A	N/A	N/A
2022	0.031	3.62	0.386	1.390	0.035	4.09	0.302	1.087	N/A	N/A	N/A
2023	0.031	3.54	0.386	1.390	0.035	4.08	0.302	1.087	N/A	N/A	N/A
2024	0.030	3.46	0.386	1.390	0.035	4.08	0.302	1.087	N/A	N/A	N/A
2025	0.029	3.38	0.386	1.390	0.035	4.07	0.302	1.087	N/A	N/A	N/A
2026	0.029	3.30	0.386	1.390	0.035	4.06	0.302	1.087	1.32	0.020	2.343
2027	0.028	3.30	0.386	1.390	0.035	4.05	0.302	1.087	1.32	0.020	2.341
2028	0.028	3.30	0.386	1.390	0.035	4.04	0.302	1.087	1.32	0.020	2.340
2029	0.028	3.30	0.386	1.390	0.035	4.04	0.302	1.087	1.32	0.020	2.339
2030	0.028	3.30	0.386	1.390	0.035	4.03	0.302	1.087	1.32	0.020	2.338
2031	0.028	3.29	0.386	1.390	0.035	4.02	0.302	1.087	1.32	0.020	2.337
2032	0.028	3.29	0.386	1.390	0.035	4.02	0.302	1.087	1.32	0.020	2.337
2033	0.028	3.29	0.386	1.390	0.035	4.02	0.302	1.087	1.32	0.020	2.337
2034	0.028	3.30	0.386	1.390	0.035	4.02	0.302	1.087	1.32	0.020	2.337

Table A-14. Fuel Economies for Light Duty Auto Vehicles in Calendar Year 2035
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Model Year[1]	Internal Combustion Engine Vehicle[1]		Battery Electric Vehicle[1,2]		Plug-in Hybrid Electric Vehicle[1,3]				Fuel Cell Electric Vehicle[4,5]	Hybrid Electric Vehicle[6,7]	
	(gal of gasoline/ mi)	(MJ of gasoline/ mi)	(kWh of electricity/ mi)	(MJ of electricity/ mi)	(gal of gasoline/ mi)	(MJ of gasoline/ mi)	(kWh of electricity/ mi)	(MJ of electricity/ mi)	(MJ of hydrogen/ mi)	(gal of gasoline/ mi)	(MJ of gasoline /mi)
2035	0.028	3.30	0.386	1.390	0.035	4.02	0.302	1.087	1.32	0.020	2.338

Notes:

[1] Estimated using fuel consumption, energy consumption, and VMT outputs for LDA from EMFAC2021.

[2] Values in shaded cells are not applicable as the light duty auto vehicle fleet in EMFAC2021 does not include MY 1991-1992, and 1996 BEVs.

[3] Values in shaded cells are not applicable as the light duty auto vehicle fleet in EMFAC2021 does not include MY 2009 and earlier PHEVs.

[4] Fuel economies for MY 2026+ FCEVs were estimated by applying an EER of 2.5 to the gasoline ICEV fuel economy. This EER value was obtained from: https://ww2.arb.ca.gov/sites/default/files/2020-07/2020_lcfs_fro_oal-approved_unofficial_06302020.pdf. Accessed: May 2022.

[5] For the purposes of this analysis, we assumed FCEVs do not exist prior to MY2026, so the values in shaded cells are not applicable.

[6] Fuel economies for MY 2026+ HEVs were estimated by applying an EER of 1.41 to the gasoline ICEV fuel economy. This EER value was derived from the relative fuel economies of the average MY 2020 HEV and ICEV as obtained from The 2020 EPA Automotive Trends Report. This factor was assumed to remain constant in future years and was used to estimate fuel economies for MY 2026 to 2050 HEVs. Available at: https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1010U68.pdf. Accessed: May 2022.

[7] For the purposes of this analysis, we assumed HEVs do not exist prior to MY2026, so the values in shaded cells are not applicable.

[8] California Reformulated Gasoline (CaRFG) energy density and the conversion factor from kWh to MJ were obtained from CARB's Low Carbon Fuel Standard (LCFS) Regulation. Available at: https://ww2.arb.ca.gov/sites/default/files/2020-07/2020_lcfs_fro_oal-approved_unofficial_06302020.pdf. Accessed: May 2022.

Constants and Conversion Factors:

CaRFG Energy Density[8]	115.83	MJ/gal
Conversion Factor[8]	3.6	MJ/kWh
FCEV EER[4]	2.5	
HEV EER[6]	1.41	

Abbreviations:

BEV - battery electric vehicle
CARB - California Air Resources Board
CaRFG - California Reformulated Gasoline
EER - energy economy ratio
EPA - Environmental Protection Agency
EMFAC - EMission FACtor Model
FCEV - fuel cell electric vehicle
gal - gallon
HEV - hybrid electric vehicle
ICEV - internal combustion engine vehicle
kWh - kilowatt hour
LDA - light duty auto
LCFS - Low Carbon Fuel Standard
mi - mile
MJ - megajoule
MY - model year
PHEV - plug-in hybrid electric vehicle
VMT - vehicle mile traveled

Table A-15. Estimating Average Daily Mileage for LDA ICEVs and Fraction of Daily Electric Miles Traveled by LDA PHEVs in Calendar Year 2035

Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Model Year	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle[1]				
	Population[2] (vehicles)	Daily VMT[2] (miles/day)	Average Daily Mileage per Vehicle (mi/vehicle/day)	Average Daily eVMT[2] (miles/day)	Average Daily cVMT[2] (miles/day)	Average Daily VMT[2] (miles/day)	eVMT (% of Average Daily VMT)	cVMT (% of Average Daily VMT)
1991	14,887	83,238	5.6	0	0	0	N/A	N/A
1992	12,386	73,866	6.0	0	0	0	N/A	N/A
1993	12,876	82,099	6.4	0	0	0	N/A	N/A
1994	13,908	94,494	6.8	0	0	0	N/A	N/A
1995	17,011	123,543	7.3	0	0	0	N/A	N/A
1996	15,726	121,539	7.7	0	0	0	N/A	N/A
1997	19,249	158,576	8.2	0	0	0	N/A	N/A
1998	21,231	187,010	8.8	0	0	0	N/A	N/A
1999	21,841	205,304	9.4	0	0	0	N/A	N/A
2000	26,428	265,384	10	0	0	0	N/A	N/A
2001	26,524	283,726	11	0	0	0	N/A	N/A
2002	27,790	317,518	11	0	0	0	N/A	N/A
2003	30,887	376,225	12	0	0	0	N/A	N/A
2004	31,459	408,283	13	0	0	0	N/A	N/A
2005	38,743	535,327	14	0	0	0	N/A	N/A
2006	43,503	638,613	15	0	0	0	N/A	N/A
2007	51,445	799,312	16	0	0	0	N/A	N/A
2008	48,196	793,719	16	0	0	0	N/A	N/A
2009	43,832	763,803	17	0	0	0	N/A	N/A
2010	59,373	1,091,266	18	18	21	40	46%	54%
2011	67,186	1,306,293	19	1,068	1,263	2,331	46%	54%
2012	112,410	2,309,971	21	12,690	15,010	27,700	46%	54%
2013	158,581	3,430,157	22	29,703	35,132	64,835	46%	54%
2014	180,829	4,127,429	23	51,909	61,397	113,306	46%	54%
2015	248,911	5,985,259	24	46,760	55,307	102,067	46%	54%
2016	285,862	7,224,095	25	60,473	71,527	131,999	46%	54%

Table A-15. Estimating Average Daily Mileage for LDA ICEVs and Fraction of Daily Electric Miles Traveled by LDA PHEVs in Calendar Year 2035

Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle[1]				
Model Year	**Population[2] (vehicles)**	**Daily VMT[2] (miles/day)**	**Average Daily Mileage per Vehicle (mi/vehicle/day)**	**Average Daily eVMT[2] (miles/day)**	**Average Daily cVMT[2] (miles/day)**	**Average Daily VMT[2] (miles/day)**	**eVMT (% of Average Daily VMT)**	**cVMT (% of Average Daily VMT)**
2017	332,615	8,781,906	26	182,759	216,166	398,925	46%	54%
2018	327,985	9,068,940	28	196,448	232,358	428,806	46%	54%
2019	314,542	9,122,584	29	168,863	187,404	356,267	47%	53%
2020	281,575	8,538,414	30	199,152	214,033	413,185	48%	52%
2021	366,087	11,609,825	32	303,685	308,004	611,689	50%	50%
2022	459,912	15,239,652	33	459,675	382,142	841,817	55%	45%
2023	491,823	17,014,444	35	530,420	413,878	944,297	56%	44%
2024	528,134	19,062,159	36	606,875	444,549	1,051,424	58%	42%
2025	560,849	21,113,845	38	691,977	474,183	1,166,161	59%	41%
2026	611,788	23,987,125	39	694,031	475,591	1,169,622	59%	41%
2027	641,056	26,164,902	41	756,264	518,236	1,274,500	59%	41%
2028	673,388	28,593,522	42	821,257	562,774	1,384,031	59%	41%
2029	697,604	30,804,673	44	876,678	600,751	1,477,429	59%	41%
2030	724,988	33,263,210	46	939,492	643,795	1,583,287	59%	41%
2031	747,432	35,611,885	48	1,005,719	689,178	1,694,896	59%	41%
2032	766,329	37,880,091	49	1,069,693	733,017	1,802,710	59%	41%
2033	789,556	40,405,518	51	1,141,034	781,903	1,922,937	59%	41%
2034	801,955	42,330,283	53	1,195,570	819,275	2,014,845	59%	41%
2035	727,792	39,498,292	54	1,115,874	764,662	1,880,536	59%	41%

Notes:

[1] Values in shaded cells are zero or not available as the light duty auto vehicle fleet in EMFAC2021 does not include MY 2009 and earlier PHEVs.

[2] Obtained from EMFAC2021 data.

Abbreviations:

cVMT - combustion vehicle mile traveled
EMFAC - EMission FACtor Model
eVMT - electric vehicle mile traveled
ICEV - internal combustion engine vehicle
LDA - light duty auto
mi - mile
MY - model year
PHEV - plug-in hybrid electric vehicle
VMT - vehicle miles traveled

Table A-16. Tailpipe Greenhouse Gas Emission Factors for ICEV and PHEV Light Duty Autos in Calendar Year 2035

Model Year	Internal Combustion Engine Vehicle						Plug-in Hybrid Electric Vehicle[1]					
	CO_2 Emission Factor[2]		CH_4 Emission Factor[2]		N_2O Emission Factor[2]		CO_2 Emission Factor[2]		CH_4 Emission Factor[2]		N_2O Emission Factor[2]	
	(tons/gal)	(tons/MJ)	(tons/gal)	(tons/MJ)	(tons/gal)	(tons/MJ)	(tons/gal)	(tons/MJ)	(tons/gal)	(tons/MJ)	(tons/gal)	(tons/MJ)
1991	9.48E-03	8.19E-05	5.32E-06	4.59E-08	1.75E-06	1.51E-08	N/A	N/A	N/A	N/A	N/A	N/A
1992	9.48E-03	8.19E-05	5.22E-06	4.51E-08	1.75E-06	1.51E-08	N/A	N/A	N/A	N/A	N/A	N/A
1993	9.48E-03	8.19E-05	5.46E-06	4.71E-08	1.86E-06	1.60E-08	N/A	N/A	N/A	N/A	N/A	N/A
1994	9.48E-03	8.19E-05	5.41E-06	4.67E-08	1.85E-06	1.59E-08	N/A	N/A	N/A	N/A	N/A	N/A
1995	9.48E-03	8.19E-05	5.33E-06	4.60E-08	1.84E-06	1.59E-08	N/A	N/A	N/A	N/A	N/A	N/A
1996	9.48E-03	8.19E-05	6.18E-06	5.33E-08	2.05E-06	1.77E-08	N/A	N/A	N/A	N/A	N/A	N/A
1997	9.48E-03	8.19E-05	5.11E-06	4.41E-08	1.88E-06	1.63E-08	N/A	N/A	N/A	N/A	N/A	N/A
1998	9.48E-03	8.19E-05	4.07E-06	3.51E-08	1.70E-06	1.47E-08	N/A	N/A	N/A	N/A	N/A	N/A
1999	9.48E-03	8.19E-05	3.01E-06	2.59E-08	1.52E-06	1.31E-08	N/A	N/A	N/A	N/A	N/A	N/A
2000	9.48E-03	8.19E-05	1.90E-06	1.64E-08	1.29E-06	1.11E-08	N/A	N/A	N/A	N/A	N/A	N/A
2001	9.48E-03	8.19E-05	1.78E-06	1.53E-08	1.22E-06	1.05E-08	N/A	N/A	N/A	N/A	N/A	N/A
2002	9.48E-03	8.19E-05	1.68E-06	1.45E-08	1.17E-06	1.01E-08	N/A	N/A	N/A	N/A	N/A	N/A
2003	9.48E-03	8.19E-05	1.49E-06	1.29E-08	1.08E-06	9.32E-09	N/A	N/A	N/A	N/A	N/A	N/A
2004	9.48E-03	8.19E-05	6.51E-07	5.62E-09	3.20E-07	2.76E-09	N/A	N/A	N/A	N/A	N/A	N/A
2005	9.48E-03	8.19E-05	5.86E-07	5.06E-09	3.14E-07	2.71E-09	N/A	N/A	N/A	N/A	N/A	N/A
2006	9.48E-03	8.19E-05	4.98E-07	4.30E-09	2.94E-07	2.54E-09	N/A	N/A	N/A	N/A	N/A	N/A
2007	9.48E-03	8.19E-05	5.05E-07	4.36E-09	3.16E-07	2.72E-09	N/A	N/A	N/A	N/A	N/A	N/A
2008	9.48E-03	8.19E-05	4.72E-07	4.07E-09	3.07E-07	2.65E-09	N/A	N/A	N/A	N/A	N/A	N/A
2009	9.48E-03	8.19E-05	4.52E-07	3.90E-09	3.18E-07	2.74E-09	N/A	N/A	N/A	N/A	N/A	N/A
2010	9.48E-03	8.19E-05	4.67E-07	4.03E-09	3.42E-07	2.96E-09	9.48E-03	8.19E-05	4.92E-07	4.25E-09	2.39E-07	2.06E-09
2011	9.48E-03	8.19E-05	4.50E-07	3.88E-09	3.25E-07	2.80E-09	9.48E-03	8.19E-05	4.70E-07	4.06E-09	2.31E-07	1.99E-09
2012	9.48E-03	8.19E-05	4.32E-07	3.73E-09	3.31E-07	2.86E-09	9.48E-03	8.19E-05	4.54E-07	3.92E-09	2.26E-07	1.95E-09
2013	9.48E-03	8.19E-05	4.17E-07	3.60E-09	3.34E-07	2.88E-09	9.48E-03	8.19E-05	4.38E-07	3.78E-09	2.20E-07	1.90E-09
2014	9.48E-03	8.19E-05	4.09E-07	3.53E-09	3.26E-07	2.82E-09	9.48E-03	8.19E-05	4.21E-07	3.64E-09	2.14E-07	1.85E-09
2015	9.48E-03	8.19E-05	3.99E-07	3.45E-09	3.26E-07	2.82E-09	9.48E-03	8.19E-05	4.06E-07	3.50E-09	2.08E-07	1.80E-09
2016	9.48E-03	8.19E-05	4.37E-07	3.77E-09	3.32E-07	2.87E-09	9.48E-03	8.19E-05	3.91E-07	3.38E-09	2.03E-07	1.76E-09
2017	9.48E-03	8.19E-05	4.00E-07	3.45E-09	3.20E-07	2.76E-09	9.48E-03	8.19E-05	3.78E-07	3.27E-09	1.98E-07	1.71E-09
2018	9.48E-03	8.19E-05	3.76E-07	3.25E-09	3.13E-07	2.71E-09	9.48E-03	8.19E-05	3.66E-07	3.16E-09	1.94E-07	1.67E-09
2019	9.48E-03	8.19E-05	3.51E-07	3.03E-09	3.09E-07	2.67E-09	9.48E-03	8.19E-05	3.61E-07	3.12E-09	1.92E-07	1.66E-09

Table A-16. Tailpipe Greenhouse Gas Emission Factors for ICEV and PHEV Light Duty Autos in Calendar Year 2035

Model Year	Internal Combustion Engine Vehicle						Plug-in Hybrid Electric Vehicle[1]					
	CO_2 Emission Factor[2]		CH_4 Emission Factor[2]		N_2O Emission Factor[2]		CO_2 Emission Factor[2]		CH_4 Emission Factor[2]		N_2O Emission Factor[2]	
	(tons/gal)	(tons/MJ)	(tons/gal)	(tons/MJ)	(tons/gal)	(tons/MJ)	(tons/gal)	(tons/MJ)	(tons/gal)	(tons/MJ)	(tons/gal)	(tons/MJ)
2020	9.48E-03	8.19E-05	3.38E-07	2.92E-09	3.10E-07	2.68E-09	9.48E-03	8.19E-05	3.55E-07	3.07E-09	1.90E-07	1.64E-09
2021	9.48E-03	8.19E-05	3.15E-07	2.72E-09	3.07E-07	2.65E-09	9.48E-03	8.19E-05	3.51E-07	3.03E-09	1.89E-07	1.63E-09
2022	9.48E-03	8.19E-05	2.88E-07	2.49E-09	3.01E-07	2.60E-09	9.48E-03	8.19E-05	3.67E-07	3.17E-09	1.95E-07	1.68E-09
2023	9.48E-03	8.19E-05	2.63E-07	2.27E-09	2.93E-07	2.53E-09	9.48E-03	8.19E-05	3.66E-07	3.16E-09	1.94E-07	1.68E-09
2024	9.48E-03	8.19E-05	2.37E-07	2.05E-09	2.84E-07	2.45E-09	9.48E-03	8.19E-05	3.64E-07	3.15E-09	1.94E-07	1.67E-09
2025	9.48E-03	8.19E-05	1.96E-07	1.69E-09	2.64E-07	2.28E-09	9.48E-03	8.19E-05	3.64E-07	3.14E-09	1.94E-07	1.67E-09
2026	9.48E-03	8.19E-05	1.89E-07	1.63E-09	2.59E-07	2.24E-09	9.48E-03	8.19E-05	3.53E-07	3.05E-09	1.90E-07	1.64E-09
2027	9.48E-03	8.19E-05	1.80E-07	1.56E-09	2.48E-07	2.15E-09	9.48E-03	8.19E-05	3.43E-07	2.96E-09	1.86E-07	1.60E-09
2028	9.48E-03	8.19E-05	1.73E-07	1.50E-09	2.38E-07	2.06E-09	9.48E-03	8.19E-05	3.33E-07	2.87E-09	1.82E-07	1.57E-09
2029	9.48E-03	8.19E-05	1.66E-07	1.44E-09	2.28E-07	1.97E-09	9.48E-03	8.19E-05	3.23E-07	2.79E-09	1.78E-07	1.54E-09
2030	9.48E-03	8.19E-05	1.59E-07	1.37E-09	2.17E-07	1.87E-09	9.48E-03	8.19E-05	3.14E-07	2.71E-09	1.75E-07	1.51E-09
2031	9.48E-03	8.19E-05	1.52E-07	1.32E-09	2.06E-07	1.78E-09	9.48E-03	8.19E-05	3.06E-07	2.64E-09	1.72E-07	1.48E-09
2032	9.48E-03	8.19E-05	1.45E-07	1.26E-09	1.94E-07	1.68E-09	9.48E-03	8.19E-05	2.97E-07	2.57E-09	1.68E-07	1.45E-09
2033	9.48E-03	8.19E-05	1.39E-07	1.20E-09	1.82E-07	1.57E-09	9.48E-03	8.19E-05	2.89E-07	2.50E-09	1.65E-07	1.43E-09
2034	9.48E-03	8.19E-05	1.32E-07	1.14E-09	1.70E-07	1.47E-09	9.48E-03	8.19E-05	2.82E-07	2.43E-09	1.62E-07	1.40E-09
2035	9.48E-03	8.19E-05	1.26E-07	1.08E-09	1.57E-07	1.36E-09	9.48E-03	8.19E-05	2.76E-07	2.38E-09	1.60E-07	1.38E-09

Notes:

[1] Values in shaded cells are not available as the light duty auto vehicle fleet in EMFAC2021 does not include MY 2009 and earlier PHEVs.

[2] Tailpipe greenhouse gas emission factors were estimated as a ratio of the greenhouse gas emissions (CO_2, CH_4, N_2O) to the gasoline fuel consumption outputs for each model year from EMFAC2021 data.

[3] California Reformulated Gasoline (CaRFG) energy density for the conversion factor from gal to MJ was obtained from CARB's Low Carbon Fuel Standard (LCFS) Regulation. Available at: https://ww2.arb.ca.gov/sites/default/files/2020-07/2020_lcfs_fro_oal-approved_unofficial_06302020.pdf. Accessed: May 2022.

Conversion Factor

CaRFG Energy Density[3]	115.83	MJ/gal

Abbreviations:

CARB - California Air Resources Board
CaRFG - California Reformulated Gasoline
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
gal - gallon
ICEV - internal combustion engine vehicle
LCFS - Low Carbon Fuel Standard
MJ - megajoule
MY - model year
N_2O - Nitrous oxide
PHEV - plug-in hybrid electric vehicle

Table A-17. Fuel Economies for Light Duty Auto Vehicles in Calendar Year 2040
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Model Year[1]	Internal Combustion Engine Vehicle[1]		Battery Electric Vehicle[1,2]		Plug-in Hybrid Electric Vehicle[1,3]				Fuel Cell Electric Vehicle[4,5]	Hybrid Electric Vehicle[6,7]	
	(gal of gasoline/ mi)	(MJ of gasoline/ mi)	(kWh of electricity/ mi)	(MJ of electricity/ mi)	(gal of gasoline/ mi)	(MJ of gasoline/ mi)	(kWh of electricity/ mi)	(MJ of electricity/ mi)	(MJ of hydrogen/ mi)	(gal of gasoline/ mi)	(MJ of gasoline /mi)
1996	0.049	5.63	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1997	0.047	5.47	0.386	1.390	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1998	0.046	5.29	0.386	1.390	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1999	0.044	5.12	0.386	1.390	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2000	0.044	5.11	0.386	1.390	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2001	0.044	5.08	0.386	1.390	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2002	0.044	5.06	0.386	1.390	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2003	0.044	5.05	0.386	1.390	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2004	0.045	5.23	0.386	1.390	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2005	0.044	5.13	0.386	1.390	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2006	0.044	5.13	0.386	1.390	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2007	0.043	5.00	0.386	1.390	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2008	0.043	5.02	0.386	1.390	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2009	0.041	4.75	0.386	1.390	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2010	0.037	4.31	0.386	1.390	0.038	4.41	0.302	1.087	N/A	N/A	N/A
2011	0.039	4.49	0.386	1.390	0.038	4.39	0.302	1.087	N/A	N/A	N/A
2012	0.037	4.27	0.386	1.390	0.037	4.34	0.302	1.087	N/A	N/A	N/A
2013	0.036	4.14	0.386	1.390	0.037	4.30	0.302	1.087	N/A	N/A	N/A
2014	0.036	4.15	0.386	1.390	0.037	4.27	0.302	1.087	N/A	N/A	N/A
2015	0.035	4.06	0.386	1.390	0.037	4.25	0.302	1.087	N/A	N/A	N/A
2016	0.034	3.97	0.386	1.390	0.036	4.22	0.302	1.087	N/A	N/A	N/A
2017	0.035	4.00	0.386	1.390	0.036	4.21	0.302	1.087	N/A	N/A	N/A
2018	0.034	3.99	0.386	1.390	0.036	4.19	0.302	1.087	N/A	N/A	N/A
2019	0.034	3.94	0.386	1.390	0.036	4.17	0.302	1.087	N/A	N/A	N/A

Table A-17. Fuel Economies for Light Duty Auto Vehicles in Calendar Year 2040
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Model Year[1]	Internal Combustion Engine Vehicle[1]		Battery Electric Vehicle[1,2]		Plug-in Hybrid Electric Vehicle[1,3]				Fuel Cell Electric Vehicle[4,5]	Hybrid Electric Vehicle[6,7]	
	(gal of gasoline/ mi)	(MJ of gasoline/ mi)	(kWh of electricity/ mi)	(MJ of electricity/ mi)	(gal of gasoline/ mi)	(MJ of gasoline/ mi)	(kWh of electricity/ mi)	(MJ of electricity/ mi)	(MJ of hydrogen/ mi)	(gal of gasoline/ mi)	(MJ of gasoline /mi)
2020	0.033	3.82	0.386	1.390	0.036	4.15	0.302	1.087	N/A	N/A	N/A
2021	0.032	3.72	0.386	1.390	0.036	4.14	0.302	1.087	N/A	N/A	N/A
2022	0.031	3.64	0.386	1.390	0.036	4.15	0.302	1.087	N/A	N/A	N/A
2023	0.031	3.55	0.386	1.390	0.036	4.14	0.302	1.087	N/A	N/A	N/A
2024	0.030	3.47	0.386	1.390	0.036	4.13	0.302	1.087	N/A	N/A	N/A
2025	0.029	3.39	0.386	1.390	0.036	4.13	0.302	1.087	N/A	N/A	N/A
2026	0.029	3.32	0.386	1.390	0.035	4.11	0.302	1.087	1.33	0.020	2.353
2027	0.029	3.31	0.386	1.390	0.035	4.10	0.302	1.087	1.33	0.020	2.351
2028	0.029	3.31	0.386	1.390	0.035	4.09	0.302	1.087	1.32	0.020	2.349
2029	0.029	3.31	0.386	1.390	0.035	4.08	0.302	1.087	1.32	0.020	2.347
2030	0.029	3.31	0.386	1.390	0.035	4.07	0.302	1.087	1.32	0.020	2.345
2031	0.029	3.30	0.386	1.390	0.035	4.06	0.302	1.087	1.32	0.020	2.343
2032	0.028	3.30	0.386	1.390	0.035	4.06	0.302	1.087	1.32	0.020	2.341
2033	0.028	3.30	0.386	1.390	0.035	4.05	0.302	1.087	1.32	0.020	2.340
2034	0.028	3.30	0.386	1.390	0.035	4.04	0.302	1.087	1.32	0.020	2.339
2035	0.028	3.30	0.386	1.390	0.035	4.03	0.302	1.087	1.32	0.020	2.338
2036	0.028	3.29	0.386	1.390	0.035	4.03	0.302	1.087	1.32	0.020	2.337
2037	0.028	3.29	0.386	1.390	0.035	4.02	0.302	1.087	1.32	0.020	2.337
2038	0.028	3.29	0.386	1.390	0.035	4.02	0.302	1.087	1.32	0.020	2.337
2039	0.028	3.30	0.386	1.390	0.035	4.03	0.302	1.087	1.32	0.020	2.338

Table A-17. Fuel Economies for Light Duty Auto Vehicles in Calendar Year 2040

Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

	Internal Combustion Engine Vehicle[1]		Battery Electric Vehicle[1,2]		Plug-in Hybrid Electric Vehicle[1,3]				Fuel Cell Electric Vehicle[4,5]	Hybrid Electric Vehicle[6,7]	
Model Year[1]	(gal of gasoline/ mi)	(MJ of gasoline/ mi)	(kWh of electricity/ mi)	(MJ of electricity/ mi)	(gal of gasoline/ mi)	(MJ of gasoline/ mi)	(kWh of electricity/ mi)	(MJ of electricity/ mi)	(MJ of hydrogen/ mi)	(gal of gasoline/ mi)	(MJ of gasoline /mi)
2040	0.028	3.30	0.386	1.390	0.035	4.03	0.302	1.087	1.32	0.020	2.339

Notes:

[1] Estimated using fuel consumption, energy consumption, and VMT outputs for LDA from EMFAC2021.

[2] Values in shaded cells are not applicable as the light duty auto vehicle fleet in EMFAC2021 does not include MY 1996 BEVs.

[3] Values in shaded cells are not applicable as the light duty auto vehicle fleet in EMFAC2021 does not include MY 2009 and earlier PHEVs.

[4] Fuel economies for MY 2026+ FCEVs were estimated by applying an EER of 2.5 to the gasoline ICEV fuel economy. This EER value was obtained from: https://ww2.arb.ca.gov/sites/default/files/2020-07/2020_lcfs_fro_oal-approved_unofficial_06302020.pdf. Accessed: May 2022.

[5] For the purposes of this analysis, we assumed FCEVs do not exist prior to MY2026, so the values in shaded cells are not applicable.

[6] Fuel economies for MY 2026+ HEVs were estimated by applying an EER of 1.41 to the gasoline ICEV fuel economy. This EER value was derived from the relative fuel economies of the average MY 2020 HEV and ICEV as obtained from The 2020 EPA Automotive Trends Report. This factor was assumed to remain constant in future years and was used to estimate fuel economies for MY 2026 to 2050 HEVs. Available at: https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1010U68.pdf. Accessed: May 2022.

[7] For the purposes of this analysis, we assumed HEVs do not exist prior to MY2026, so the values in shaded cells are not applicable.

[8] California Reformulated Gasoline (CaRFG) energy density and the conversion factor from kWh to MJ were obtained from CARB's Low Carbon Fuel Standard (LCFS) Regulation. Available at: https://ww2.arb.ca.gov/sites/default/files/2020-07/2020_lcfs_fro_oal-approved_unofficial_06302020.pdf. Accessed: May 2022.

Constants and Conversion Factors:

CaRFG Energy Density[8]	115.83	MJ/gal
Conversion Factor[8]	3.6	MJ/kWh
FCEV EER[4]	2.5	
HEV EER[6]	1.41	

Abbreviations:

BEV - battery electric vehicle
CARB - California Air Resources Board
CaRFG - California Reformulated Gasoline
EER - energy economy ratio
EPA - Environmental Protection Agency
EMFAC - EMission FACtor Model
FCEV - fuel cell electric vehicle
gal - gallon
HEV - hybrid electric vehicle
ICEV - internal combustion engine vehicle
kWh - kilowatt hour
LDA - light duty auto
LCFS - Low Carbon Fuel Standard
mi - mile
MJ - megajoule
MY - model year
PHEV - plug-in hybrid electric vehicle
VMT - vehicle mile traveled

Table A-18. Estimating Average Daily Mileage for LDA ICEVs and Fraction of Daily Electric Miles Traveled by LDA PHEVs in Calendar Year 2040

Model Year	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle[1]				
	Population[2] (vehicles)	Daily VMT[2] (miles/day)	Average Daily Mileage per Vehicle (mi/vehicle/day)	Average Daily eVMT[2] (miles/day)	Average Daily cVMT[2] (miles/day)	Average Daily VMT[2] (miles/day)	eVMT (% of Average Daily VMT)	cVMT (% of Average Daily VMT)
1996	13,224	72,312	5.5	0	0	0	N/A	N/A
1997	15,957	92,752	5.8	0	0	0	N/A	N/A
1998	17,428	108,316	6.2	0	0	0	N/A	N/A
1999	17,981	119,531	6.6	0	0	0	N/A	N/A
2000	21,212	151,161	7.1	0	0	0	N/A	N/A
2001	20,869	159,156	7.6	0	0	0	N/A	N/A
2002	20,957	171,479	8.2	0	0	0	N/A	N/A
2003	22,226	195,022	8.8	0	0	0	N/A	N/A
2004	21,228	199,248	9.4	0	0	0	N/A	N/A
2005	24,808	249,161	10	0	0	0	N/A	N/A
2006	25,795	276,191	11	0	0	0	N/A	N/A
2007	28,657	326,097	11	0	0	0	N/A	N/A
2008	24,894	301,500	12	0	0	0	N/A	N/A
2009	20,958	270,212	13	0	0	0	N/A	N/A
2010	26,447	361,660	14	6.0	7.1	13	46%	54%
2011	28,341	412,245	15	337	399	736	46%	54%
2012	44,963	695,148	15	3,820	4,518	8,337	46%	54%
2013	60,869	996,499	16	8,631	10,209	18,841	46%	54%
2014	67,874	1,179,323	17	14,836	17,547	32,383	46%	54%
2015	93,376	1,719,251	18	13,435	15,891	29,326	46%	54%
2016	109,366	2,128,788	19	17,821	21,079	38,900	46%	54%
2017	132,055	2,699,673	20	56,183	66,452	122,635	46%	54%
2018	137,285	2,954,566	22	64,013	75,714	139,728	46%	54%
2019	141,083	3,200,331	23	59,257	65,763	125,020	47%	53%
2020	135,652	3,231,000	24	75,437	81,073	156,509	48%	52%
2021	189,590	4,743,853	25	124,202	125,969	250,170	50%	50%
2022	253,809	6,663,799	26	201,169	167,239	368,408	55%	45%
2023	291,017	8,008,938	28	249,865	194,966	444,831	56%	44%
2024	329,600	9,500,130	29	302,663	221,707	524,369	58%	42%
2025	371,783	11,216,709	30	367,851	252,073	619,924	59%	41%

Table A-18. Estimating Average Daily Mileage for LDA ICEVs and Fraction of Daily Electric Miles Traveled by LDA PHEVs in Calendar Year 2040

Model Year	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle[1]				
	Population[2] (vehicles)	Daily VMT[2] (miles/day)	Average Daily Mileage per Vehicle (mi/vehicle/day)	Average Daily eVMT[2] (miles/day)	Average Daily cVMT[2] (miles/day)	Average Daily VMT[2] (miles/day)	eVMT (% of Average Daily VMT)	cVMT (% of Average Daily VMT)
2026	424,233	13,376,857	32	387,238	265,358	652,596	59%	41%
2027	468,739	15,435,541	33	446,370	305,879	752,249	59%	41%
2028	508,037	17,458,838	34	501,706	343,798	845,504	59%	41%
2029	549,764	19,702,986	36	561,028	384,449	945,477	59%	41%
2030	583,369	21,789,367	37	615,754	421,951	1,037,705	59%	41%
2031	621,402	24,173,776	39	683,067	468,078	1,151,145	59%	41%
2032	652,332	26,418,301	40	746,398	511,476	1,257,874	59%	41%
2033	686,690	28,932,714	42	817,336	560,087	1,377,423	59%	41%
2034	712,396	31,215,626	44	881,714	604,202	1,485,917	59%	41%
2035	742,681	33,813,271	46	954,983	654,410	1,609,393	59%	41%
2036	764,974	36,168,195	47	1,021,378	699,908	1,721,285	59%	41%
2037	783,440	38,427,887	49	1,085,103	743,576	1,828,679	59%	41%
2038	805,975	40,923,252	51	1,155,587	791,876	1,947,462	59%	41%
2039	817,118	42,781,561	52	1,208,239	827,956	2,036,195	59%	41%
2040	739,955	39,816,664	54	1,124,791	770,773	1,895,564	59%	41%

Notes:

[1] Values in shaded cells are zero or not available as the light duty auto vehicle fleet in EMFAC2021 does not include MY 2009 and earlier PHEVs.

[2] Obtained from EMFAC2021 data.

Abbreviations:

cVMT - combustion vehicle mile traveled
EMFAC - EMission FACtor Model
eVMT - electric vehicle mile traveled
ICEV - internal combustion engine vehicle
LDA - light duty auto
mi - mile
MY - model year
PHEV - plug-in hybrid electric vehicle
VMT - vehicle miles traveled

Table A-19. Tailpipe Greenhouse Gas Emission Factors for ICEV and PHEV Light Duty Autos in Calendar Year 2040

Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Model Year	Internal Combustion Engine Vehicle						Plug-in Hybrid Electric Vehicle[1]					
	CO_2 Emission Factor[2]		CH_4 Emission Factor[2]		N_2O Emission Factor[2]		CO_2 Emission Factor[2]		CH_4 Emission Factor[2]		N_2O Emission Factor[2]	
	(tons/gal)	(tons/MJ)	(tons/gal)	(tons/MJ)	(tons/gal)	(tons/MJ)	(tons/gal)	(tons/MJ)	(tons/gal)	(tons/MJ)	(tons/gal)	(tons/MJ)
1996	9.48E-03	8.19E-05	6.93E-06	5.98E-08	2.10E-06	1.81E-08	N/A	N/A	N/A	N/A	N/A	N/A
1997	9.48E-03	8.19E-05	5.78E-06	4.99E-08	1.94E-06	1.68E-08	N/A	N/A	N/A	N/A	N/A	N/A
1998	9.48E-03	8.19E-05	4.63E-06	4.00E-08	1.77E-06	1.53E-08	N/A	N/A	N/A	N/A	N/A	N/A
1999	9.48E-03	8.19E-05	3.46E-06	2.99E-08	1.60E-06	1.38E-08	N/A	N/A	N/A	N/A	N/A	N/A
2000	9.48E-03	8.19E-05	2.23E-06	1.92E-08	1.37E-06	1.18E-08	N/A	N/A	N/A	N/A	N/A	N/A
2001	9.48E-03	8.19E-05	2.08E-06	1.79E-08	1.30E-06	1.12E-08	N/A	N/A	N/A	N/A	N/A	N/A
2002	9.48E-03	8.19E-05	1.96E-06	1.70E-08	1.25E-06	1.08E-08	N/A	N/A	N/A	N/A	N/A	N/A
2003	9.48E-03	8.19E-05	1.74E-06	1.50E-08	1.15E-06	9.89E-09	N/A	N/A	N/A	N/A	N/A	N/A
2004	9.48E-03	8.19E-05	7.73E-07	6.67E-09	3.49E-07	3.01E-09	N/A	N/A	N/A	N/A	N/A	N/A
2005	9.48E-03	8.19E-05	6.93E-07	5.98E-09	3.42E-07	2.95E-09	N/A	N/A	N/A	N/A	N/A	N/A
2006	9.48E-03	8.19E-05	5.88E-07	5.08E-09	3.22E-07	2.78E-09	N/A	N/A	N/A	N/A	N/A	N/A
2007	9.48E-03	8.19E-05	5.95E-07	5.13E-09	3.45E-07	2.98E-09	N/A	N/A	N/A	N/A	N/A	N/A
2008	9.48E-03	8.19E-05	5.55E-07	4.79E-09	3.35E-07	2.89E-09	N/A	N/A	N/A	N/A	N/A	N/A
2009	9.48E-03	8.19E-05	5.30E-07	4.57E-09	3.47E-07	2.99E-09	N/A	N/A	N/A	N/A	N/A	N/A
2010	9.48E-03	8.19E-05	5.46E-07	4.71E-09	3.74E-07	3.23E-09	9.48E-03	8.19E-05	6.07E-07	5.24E-09	2.77E-07	2.39E-09
2011	9.48E-03	8.19E-05	5.26E-07	4.54E-09	3.54E-07	3.06E-09	9.48E-03	8.19E-05	5.78E-07	4.99E-09	2.67E-07	2.31E-09
2012	9.48E-03	8.19E-05	5.05E-07	4.36E-09	3.62E-07	3.13E-09	9.48E-03	8.19E-05	5.57E-07	4.81E-09	2.61E-07	2.25E-09
2013	9.48E-03	8.19E-05	4.86E-07	4.20E-09	3.66E-07	3.16E-09	9.48E-03	8.19E-05	5.36E-07	4.63E-09	2.54E-07	2.19E-09
2014	9.48E-03	8.19E-05	4.77E-07	4.12E-09	3.58E-07	3.09E-09	9.48E-03	8.19E-05	5.13E-07	4.43E-09	2.46E-07	2.13E-09
2015	9.48E-03	8.19E-05	4.66E-07	4.02E-09	3.59E-07	3.10E-09	9.48E-03	8.19E-05	4.93E-07	4.25E-09	2.39E-07	2.06E-09
2016	9.48E-03	8.19E-05	5.11E-07	4.41E-09	3.66E-07	3.16E-09	9.48E-03	8.19E-05	4.74E-07	4.09E-09	2.33E-07	2.01E-09
2017	9.48E-03	8.19E-05	4.67E-07	4.03E-09	3.54E-07	3.05E-09	9.48E-03	8.19E-05	4.56E-07	3.94E-09	2.26E-07	1.95E-09
2018	9.48E-03	8.19E-05	4.40E-07	3.80E-09	3.48E-07	3.00E-09	9.48E-03	8.19E-05	4.39E-07	3.79E-09	2.21E-07	1.90E-09
2019	9.48E-03	8.19E-05	4.11E-07	3.54E-09	3.46E-07	2.98E-09	9.48E-03	8.19E-05	4.33E-07	3.74E-09	2.18E-07	1.88E-09
2020	9.48E-03	8.19E-05	3.96E-07	3.42E-09	3.49E-07	3.01E-09	9.48E-03	8.19E-05	4.24E-07	3.66E-09	2.15E-07	1.86E-09
2021	9.48E-03	8.19E-05	3.70E-07	3.19E-09	3.48E-07	3.00E-09	9.48E-03	8.19E-05	4.18E-07	3.61E-09	2.13E-07	1.84E-09
2022	9.48E-03	8.19E-05	3.38E-07	2.92E-09	3.44E-07	2.97E-09	9.48E-03	8.19E-05	4.36E-07	3.77E-09	2.20E-07	1.90E-09
2023	9.48E-03	8.19E-05	3.10E-07	2.68E-09	3.37E-07	2.91E-09	9.48E-03	8.19E-05	4.33E-07	3.74E-09	2.19E-07	1.89E-09
2024	9.48E-03	8.19E-05	2.80E-07	2.42E-09	3.29E-07	2.84E-09	9.48E-03	8.19E-05	4.30E-07	3.72E-09	2.18E-07	1.88E-09
2025	9.48E-03	8.19E-05	2.32E-07	2.01E-09	3.09E-07	2.67E-09	9.48E-03	8.19E-05	4.29E-07	3.70E-09	2.17E-07	1.88E-09

Table A-19. Tailpipe Greenhouse Gas Emission Factors for ICEV and PHEV Light Duty Autos in Calendar Year 2040
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Model Year	Internal Combustion Engine Vehicle						Plug-in Hybrid Electric Vehicle[1]					
	CO_2 Emission Factor[2]		CH_4 Emission Factor[2]		N_2O Emission Factor[2]		CO_2 Emission Factor[2]		CH_4 Emission Factor[2]		N_2O Emission Factor[2]	
	(tons/gal)	(tons/MJ)	(tons/gal)	(tons/MJ)	(tons/gal)	(tons/MJ)	(tons/gal)	(tons/MJ)	(tons/gal)	(tons/MJ)	(tons/gal)	(tons/MJ)
2026	9.48E-03	8.19E-05	2.26E-07	1.95E-09	3.06E-07	2.64E-09	9.48E-03	8.19E-05	4.15E-07	3.59E-09	2.13E-07	1.84E-09
2027	9.48E-03	8.19E-05	2.16E-07	1.87E-09	2.96E-07	2.56E-09	9.48E-03	8.19E-05	4.02E-07	3.47E-09	2.08E-07	1.79E-09
2028	9.48E-03	8.19E-05	2.09E-07	1.81E-09	2.87E-07	2.48E-09	9.48E-03	8.19E-05	3.90E-07	3.36E-09	2.03E-07	1.75E-09
2029	9.48E-03	8.19E-05	2.02E-07	1.75E-09	2.78E-07	2.40E-09	9.48E-03	8.19E-05	3.77E-07	3.26E-09	1.99E-07	1.72E-09
2030	9.48E-03	8.19E-05	1.95E-07	1.68E-09	2.68E-07	2.32E-09	9.48E-03	8.19E-05	3.66E-07	3.16E-09	1.94E-07	1.68E-09
2031	9.48E-03	8.19E-05	1.88E-07	1.62E-09	2.59E-07	2.23E-09	9.48E-03	8.19E-05	3.55E-07	3.06E-09	1.90E-07	1.64E-09
2032	9.48E-03	8.19E-05	1.81E-07	1.56E-09	2.49E-07	2.15E-09	9.48E-03	8.19E-05	3.45E-07	2.97E-09	1.86E-07	1.61E-09
2033	9.48E-03	8.19E-05	1.74E-07	1.50E-09	2.39E-07	2.06E-09	9.48E-03	8.19E-05	3.35E-07	2.89E-09	1.83E-07	1.58E-09
2034	9.48E-03	8.19E-05	1.67E-07	1.44E-09	2.28E-07	1.97E-09	9.48E-03	8.19E-05	3.25E-07	2.81E-09	1.79E-07	1.55E-09
2035	9.48E-03	8.19E-05	1.60E-07	1.38E-09	2.17E-07	1.88E-09	9.48E-03	8.19E-05	3.16E-07	2.73E-09	1.76E-07	1.52E-09
2036	9.48E-03	8.19E-05	1.53E-07	1.32E-09	2.06E-07	1.78E-09	9.48E-03	8.19E-05	3.07E-07	2.65E-09	1.72E-07	1.49E-09
2037	9.48E-03	8.19E-05	1.46E-07	1.26E-09	1.95E-07	1.68E-09	9.48E-03	8.19E-05	2.99E-07	2.58E-09	1.69E-07	1.46E-09
2038	9.48E-03	8.19E-05	1.39E-07	1.20E-09	1.83E-07	1.58E-09	9.48E-03	8.19E-05	2.91E-07	2.51E-09	1.66E-07	1.43E-09
2039	9.48E-03	8.19E-05	1.33E-07	1.15E-09	1.70E-07	1.47E-09	9.48E-03	8.19E-05	2.83E-07	2.45E-09	1.63E-07	1.41E-09
2040	9.48E-03	8.19E-05	1.26E-07	1.09E-09	1.58E-07	1.36E-09	9.48E-03	8.19E-05	2.77E-07	2.39E-09	1.60E-07	1.38E-09

Notes:

[1] Values in shaded cells are not available as the light duty auto vehicle fleet in EMFAC2021 does not include MY 2009 and earlier PHEVs.

[2] Tailpipe greenhouse gas emission factors were estimated as a ratio of the greenhouse gas emissions (CO_2, CH_4, N_2O) to the gasoline fuel consumption outputs for each model year from EMFAC2021 data.

[3] California Reformulated Gasoline (CaRFG) energy density for the conversion factor from gal to MJ was obtained from CARB's Low Carbon Fuel Standard (LCFS) Regulation. Available at: https://ww2.arb.ca.gov/sites/default/files/2020-07/2020_lcfs_fro_oal-approved_unofficial_06302020.pdf. Accessed: May 2022.

Conversion Factor

CaRFG Energy Density[3]	115.83	MJ/gal

Abbreviations:

CARB - California Air Resources Board
CaRFG - California Reformulated Gasoline
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
gal - gallon
ICEV - internal combustion engine vehicle
LCFS - Low Carbon Fuel Standard
MJ - megajoule
MY - model year
N_2O - Nitrous oxide
PHEV - plug-in hybrid electric vehicle

Table A-20. Fuel Economies for Light Duty Auto Vehicles in Calendar Year 2045
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Model Year[1]	Internal Combustion Engine Vehicle[1]		Battery Electric Vehicle[1,2]		Plug-in Hybrid Electric Vehicle[1,3]				Fuel Cell Electric Vehicle[4,5]	Hybrid Electric Vehicle[6,7]	
	(gal of gasoline/ mi)	(MJ of gasoline/ mi)	(kWh of electricity/ mi)	(MJ of electricity/ mi)	(gal of gasoline/ mi)	(MJ of gasoline/ mi)	(kWh of electricity/ mi)	(MJ of electricity/ mi)	(MJ of hydrogen/ mi)	(gal of gasoline/ mi)	(MJ of gasoline /mi)
2002	0.045	5.18	0.386	1.390	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2003	0.045	5.17	0.386	1.390	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2004	0.046	5.34	0.386	1.390	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2005	0.045	5.23	0.386	1.390	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2006	0.045	5.23	0.386	1.390	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2007	0.044	5.09	0.386	1.390	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2008	0.044	5.10	0.386	1.390	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2009	0.042	4.82	0.386	1.390	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2010	0.038	4.38	0.386	1.390	0.040	4.61	0.302	1.087	N/A	N/A	N/A
2011	0.039	4.55	0.386	1.390	0.040	4.59	0.302	1.087	N/A	N/A	N/A
2012	0.037	4.33	0.386	1.390	0.039	4.51	0.302	1.087	N/A	N/A	N/A
2013	0.036	4.19	0.386	1.390	0.038	4.46	0.302	1.087	N/A	N/A	N/A
2014	0.036	4.20	0.386	1.390	0.038	4.42	0.302	1.087	N/A	N/A	N/A
2015	0.035	4.11	0.386	1.390	0.038	4.37	0.302	1.087	N/A	N/A	N/A
2016	0.035	4.01	0.386	1.390	0.037	4.33	0.302	1.087	N/A	N/A	N/A
2017	0.035	4.04	0.386	1.390	0.037	4.32	0.302	1.087	N/A	N/A	N/A
2018	0.035	4.03	0.386	1.390	0.037	4.29	0.302	1.087	N/A	N/A	N/A
2019	0.034	3.97	0.386	1.390	0.037	4.27	0.302	1.087	N/A	N/A	N/A
2020	0.033	3.85	0.386	1.390	0.037	4.24	0.302	1.087	N/A	N/A	N/A
2021	0.032	3.75	0.386	1.390	0.036	4.22	0.302	1.087	N/A	N/A	N/A
2022	0.032	3.66	0.386	1.390	0.037	4.23	0.302	1.087	N/A	N/A	N/A
2023	0.031	3.58	0.386	1.390	0.036	4.22	0.302	1.087	N/A	N/A	N/A
2024	0.030	3.50	0.386	1.390	0.036	4.20	0.302	1.087	N/A	N/A	N/A
2025	0.029	3.41	0.386	1.390	0.036	4.19	0.302	1.087	N/A	N/A	N/A

Table A-20. Fuel Economies for Light Duty Auto Vehicles in Calendar Year 2045
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Model Year[1]	Internal Combustion Engine Vehicle[1] (gal of gasoline/ mi)	Internal Combustion Engine Vehicle[1] (MJ of gasoline/ mi)	Battery Electric Vehicle[1,2] (kWh of electricity/ mi)	Battery Electric Vehicle[1,2] (MJ of electricity/ mi)	Plug-in Hybrid Electric Vehicle[1,3] (gal of gasoline/ mi)	Plug-in Hybrid Electric Vehicle[1,3] (MJ of gasoline/ mi)	Plug-in Hybrid Electric Vehicle[1,3] (kWh of electricity/ mi)	Plug-in Hybrid Electric Vehicle[1,3] (MJ of electricity/ mi)	Fuel Cell Electric Vehicle[4,5] (MJ of hydrogen/ mi)	Hybrid Electric Vehicle[6,7] (gal of gasoline/ mi)	Hybrid Electric Vehicle[6,7] (MJ of gasoline /mi)
2026	0.029	3.34	0.386	1.390	0.036	4.17	0.302	1.087	1.33	0.020	2.366
2027	0.029	3.33	0.386	1.390	0.036	4.16	0.302	1.087	1.33	0.020	2.363
2028	0.029	3.33	0.386	1.390	0.036	4.14	0.302	1.087	1.33	0.020	2.360
2029	0.029	3.32	0.386	1.390	0.036	4.13	0.302	1.087	1.33	0.020	2.358
2030	0.029	3.32	0.386	1.390	0.036	4.12	0.302	1.087	1.33	0.020	2.355
2031	0.029	3.32	0.386	1.390	0.035	4.11	0.302	1.087	1.33	0.020	2.353
2032	0.029	3.31	0.386	1.390	0.035	4.10	0.302	1.087	1.33	0.020	2.351
2033	0.029	3.31	0.386	1.390	0.035	4.09	0.302	1.087	1.32	0.020	2.348
2034	0.029	3.31	0.386	1.390	0.035	4.08	0.302	1.087	1.32	0.020	2.346
2035	0.029	3.31	0.386	1.390	0.035	4.07	0.302	1.087	1.32	0.020	2.344
2036	0.029	3.30	0.386	1.390	0.035	4.06	0.302	1.087	1.32	0.020	2.342
2037	0.028	3.30	0.386	1.390	0.035	4.05	0.302	1.087	1.32	0.020	2.340
2038	0.028	3.30	0.386	1.390	0.035	4.05	0.302	1.087	1.32	0.020	2.339
2039	0.028	3.30	0.386	1.390	0.035	4.04	0.302	1.087	1.32	0.020	2.338
2040	0.028	3.30	0.386	1.390	0.035	4.03	0.302	1.087	1.32	0.020	2.337
2041	0.028	3.29	0.386	1.390	0.035	4.03	0.302	1.087	1.32	0.020	2.337
2042	0.028	3.29	0.386	1.390	0.035	4.02	0.302	1.087	1.32	0.020	2.336
2043	0.028	3.29	0.386	1.390	0.035	4.02	0.302	1.087	1.32	0.020	2.336
2044	0.028	3.29	0.386	1.390	0.035	4.02	0.302	1.087	1.32	0.020	2.337

Table A-20. Fuel Economies for Light Duty Auto Vehicles in Calendar Year 2045
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Model Year[1]	Internal Combustion Engine Vehicle[1]		Battery Electric Vehicle[1,2]		Plug-in Hybrid Electric Vehicle[1,3]				Fuel Cell Electric Vehicle[4,5]	Hybrid Electric Vehicle[6,7]	
	(gal of gasoline/ mi)	(MJ of gasoline/ mi)	(kWh of electricity/ mi)	(MJ of electricity/ mi)	(gal of gasoline/ mi)	(MJ of gasoline/ mi)	(kWh of electricity/ mi)	(MJ of electricity/ mi)	(MJ of hydrogen/ mi)	(gal of gasoline/ mi)	(MJ of gasoline /mi)
2045	0.028	3.30	0.386	1.390	0.035	4.03	0.302	1.087	1.32	0.020	2.338

Notes:

[1] Estimated using fuel consumption, energy consumption, and VMT outputs for LDA from EMFAC2021.

[2] Values in shaded cells are not applicable as the light duty auto vehicle fleet in EMFAC2021 does not include MY 2009 and earlier PHEVs.

[3] Fuel economies for MY 2026+ FCEVs were estimated by applying an EER of 2.5 to the gasoline ICEV fuel economy. This EER value was obtained from: https://ww2.arb.ca.gov/sites/default/files/2020-07/2020_lcfs_fro_oal-approved_unofficial_06302020.pdf. Accessed: May 2022.

[4] For the purposes of this analysis, we assumed FCEVs do not exist prior to MY2026, so the values in shaded cells are not applicable.

[5] Fuel economies for MY 2026+ HEVs were estimated by applying an EER of 1.41 to the gasoline ICEV fuel economy. This EER value was derived from the relative fuel economies of the average MY 2020 HEV and ICEV as obtained from The 2020 EPA Automotive Trends Report. This factor was assumed to remain constant in future years and was used to estimate fuel economies for MY 2026 to 2050 HEVs. Available at: https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1010U68.pdf. Accessed: May 2022.

[6] For the purposes of this analysis, we assumed HEVs do not exist prior to MY2026, so the values in shaded cells are not applicable.

[7] California Reformulated Gasoline (CaRFG) energy density and the conversion factor from kWh to MJ were obtained from CARB's Low Carbon Fuel Standard (LCFS) Regulation. Available at: https://ww2.arb.ca.gov/sites/default/files/2020-07/2020_lcfs_fro_oal-approved_unofficial_06302020.pdf. Accessed: May 2022.

Constants and Conversion Factors:

CaRFG Energy Density[8]	115.83	MJ/gal
Conversion Factor[8]	3.6	MJ/kWh
FCEV EER[4]	2.5	
HEV EER[6]	1.41	

Abbreviations:

BEV - battery electric vehicle
CARB - California Air Resources Board
CaRFG - California Reformulated Gasoline
EER - energy economy ratio
EPA - Environmental Protection Agency
EMFAC - EMission FACtor Model
FCEV - fuel cell electric vehicle
gal - gallon
HEV - hybrid electric vehicle
ICEV - internal combustion engine vehicle
kWh - kilowatt hour
LDA - light duty auto
LCFS - Low Carbon Fuel Standard
mi - mile
MJ - megajoule
MY - model year
PHEV - plug-in hybrid electric vehicle
VMT - vehicle mile traveled

Table A-21. Estimating Average Daily Mileage for LDA ICEVs and Fraction of Daily Electric Miles Traveled by LDA PHEVs in Calendar Year 2045

Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Model Year	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle[1]				
	Population[2] (vehicles)	Daily VMT[2] (miles/day)	Average Daily Mileage per Vehicle (mi/vehicle/day)	Average Daily eVMT[2] (miles/day)	Average Daily cVMT[2] (miles/day)	Average Daily VMT[2] (miles/day)	eVMT (% of Average Daily VMT)	cVMT (% of Average Daily VMT)
2001	17,581	94,583	5.4	0	0	0	N/A	N/A
2002	17,396	100,344	5.8	0	0	0	N/A	N/A
2003	18,261	112,979	6.2	0	0	0	N/A	N/A
2004	17,485	116,203	6.6	0	0	0	N/A	N/A
2005	19,931	142,143	7.1	0	0	0	N/A	N/A
2006	20,294	155,022	7.6	0	0	0	N/A	N/A
2007	21,610	176,019	8.1	0	0	0	N/A	N/A
2008	17,913	156,259	8.7	0	0	0	N/A	N/A
2009	14,142	131,698	9.3	0	0	0	N/A	N/A
2010	16,923	167,962	10	2.8	3.3	6.1	46%	54%
2011	16,799	177,929	11	146	172	318	46%	54%
2012	25,037	283,138	11	1,556	1,841	3,397	46%	54%
2013	31,446	377,741	12	3,274	3,873	7,147	46%	54%
2014	32,442	416,070	13	5,238	6,195	11,432	46%	54%
2015	41,547	568,350	14	4,445	5,257	9,702	46%	54%
2016	46,072	670,045	15	5,614	6,641	12,255	46%	54%
2017	52,700	809,463	15	16,866	19,949	36,816	46%	54%
2018	52,549	854,813	16	18,555	21,947	40,502	46%	54%
2019	52,919	912,275	17	16,914	18,772	35,686	47%	53%
2020	51,080	928,787	18	21,737	23,361	45,098	48%	52%
2021	72,808	1,399,143	19	36,713	37,235	73,949	50%	50%
2022	101,322	2,054,388	20	62,144	51,662	113,806	55%	45%
2023	122,476	2,616,978	21	81,791	63,820	145,610	56%	44%
2024	148,333	3,336,228	22	106,456	77,981	184,437	58%	42%
2025	179,162	4,238,753	24	139,197	95,386	234,583	59%	41%
2026	219,761	5,458,500	25	158,172	108,389	266,560	59%	41%
2027	258,741	6,740,091	26	195,082	133,681	328,763	59%	41%
2028	300,679	8,206,602	27	236,011	161,729	397,740	59%	41%

Table A-21. Estimating Average Daily Mileage for LDA ICEVs and Fraction of Daily Electric Miles Traveled by LDA PHEVs in Calendar Year 2045
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Model Year	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle[1]				
	Population[2] (vehicles)	Daily VMT[2] (miles/day)	Average Daily Mileage per Vehicle (mi/vehicle/day)	Average Daily eVMT[2] (miles/day)	Average Daily cVMT[2] (miles/day)	Average Daily VMT[2] (miles/day)	eVMT (% of Average Daily VMT)	cVMT (% of Average Daily VMT)
2029	343,168	9,805,520	29	279,399	191,461	470,860	59%	41%
2030	386,794	11,559,183	30	326,869	223,990	550,859	59%	41%
2031	431,003	13,462,108	31	380,619	260,822	641,441	59%	41%
2032	477,078	15,562,560	33	439,942	301,474	741,415	59%	41%
2033	518,165	17,640,250	34	498,612	341,678	840,290	59%	41%
2034	561,504	19,936,064	36	563,435	386,099	949,533	59%	41%
2035	597,713	22,117,686	37	625,020	428,301	1,053,321	59%	41%
2036	636,105	24,516,409	39	692,733	474,702	1,167,435	59%	41%
2037	667,180	26,769,914	40	756,313	518,270	1,274,583	59%	41%
2038	701,654	29,290,747	42	827,427	567,001	1,394,428	59%	41%
2039	727,252	31,573,998	43	891,808	611,119	1,502,927	59%	41%
2040	757,391	34,167,150	45	964,943	661,235	1,626,178	59%	41%
2041	779,333	36,510,552	47	1,031,005	706,505	1,737,509	59%	41%
2042	797,208	38,746,345	49	1,094,047	749,705	1,843,752	59%	41%
2043	818,902	41,198,116	50	1,163,291	797,155	1,960,447	59%	41%
2044	828,649	42,981,664	52	1,213,825	831,784	2,045,609	59%	41%
2045	748,769	39,907,881	53	1,127,300	772,492	1,899,793	59%	41%

Notes:
[1] Values in shaded cells are zero or not available as the light duty auto vehicle fleet in EMFAC2021 does not include MY 2009 and earlier PHEVs.
[2] Obtained from EMFAC2021 data.

Abbreviations:
cVMT - combustion vehicle mile traveled
EMFAC - EMission FACtor Model
eVMT - electric vehicle mile traveled
ICEV - internal combustion engine vehicle
LDA - light duty auto
mi - mile
MY - model year
PHEV - plug-in hybrid electric vehicle
VMT - vehicle miles traveled

Table A-22. Tailpipe Greenhouse Gas Emission Factors for ICEV and PHEV Light Duty Autos in Calendar Year 2045

Model Year	Internal Combustion Engine Vehicle						Plug-in Hybrid Electric Vehicle[1]					
	CO_2 Emission Factor[2]		CH_4 Emission Factor[2]		N_2O Emission Factor[2]		CO_2 Emission Factor[2]		CH_4 Emission Factor[2]		N_2O Emission Factor[2]	
	(tons/gal)	(tons/MJ)	(tons/gal)	(tons/MJ)	(tons/gal)	(tons/MJ)	(tons/gal)	(tons/MJ)	(tons/gal)	(tons/MJ)	(tons/gal)	(tons/MJ)
2001	9.48E-03	8.19E-05	2.42E-06	2.09E-08	1.38E-06	1.19E-08	N/A	N/A	N/A	N/A	N/A	N/A
2002	9.48E-03	8.19E-05	2.30E-06	1.98E-08	1.33E-06	1.15E-08	N/A	N/A	N/A	N/A	N/A	N/A
2003	9.48E-03	8.19E-05	2.04E-06	1.76E-08	1.22E-06	1.06E-08	N/A	N/A	N/A	N/A	N/A	N/A
2004	9.48E-03	8.19E-05	9.22E-07	7.96E-09	3.84E-07	3.31E-09	N/A	N/A	N/A	N/A	N/A	N/A
2005	9.48E-03	8.19E-05	8.27E-07	7.14E-09	3.77E-07	3.25E-09	N/A	N/A	N/A	N/A	N/A	N/A
2006	9.48E-03	8.19E-05	7.01E-07	6.05E-09	3.55E-07	3.07E-09	N/A	N/A	N/A	N/A	N/A	N/A
2007	9.48E-03	8.19E-05	7.08E-07	6.12E-09	3.81E-07	3.29E-09	N/A	N/A	N/A	N/A	N/A	N/A
2008	9.48E-03	8.19E-05	6.59E-07	5.69E-09	3.69E-07	3.19E-09	N/A	N/A	N/A	N/A	N/A	N/A
2009	9.48E-03	8.19E-05	6.28E-07	5.43E-09	3.83E-07	3.30E-09	N/A	N/A	N/A	N/A	N/A	N/A
2010	9.48E-03	8.19E-05	6.45E-07	5.57E-09	4.12E-07	3.56E-09	9.48E-03	8.19E-05	7.57E-07	6.54E-09	3.25E-07	2.80E-09
2011	9.48E-03	8.19E-05	6.21E-07	5.36E-09	3.90E-07	3.37E-09	9.48E-03	8.19E-05	7.19E-07	6.21E-09	3.13E-07	2.70E-09
2012	9.48E-03	8.19E-05	5.95E-07	5.14E-09	3.98E-07	3.43E-09	9.48E-03	8.19E-05	6.94E-07	5.99E-09	3.05E-07	2.63E-09
2013	9.48E-03	8.19E-05	5.72E-07	4.94E-09	4.01E-07	3.46E-09	9.48E-03	8.19E-05	6.68E-07	5.76E-09	2.97E-07	2.57E-09
2014	9.48E-03	8.19E-05	5.59E-07	4.83E-09	3.92E-07	3.39E-09	9.48E-03	8.19E-05	6.38E-07	5.51E-09	2.88E-07	2.48E-09
2015	9.48E-03	8.19E-05	5.45E-07	4.71E-09	3.93E-07	3.39E-09	9.48E-03	8.19E-05	6.10E-07	5.27E-09	2.79E-07	2.41E-09
2016	9.48E-03	8.19E-05	5.97E-07	5.16E-09	4.00E-07	3.45E-09	9.48E-03	8.19E-05	5.85E-07	5.05E-09	2.71E-07	2.34E-09
2017	9.48E-03	8.19E-05	5.45E-07	4.71E-09	3.87E-07	3.34E-09	9.48E-03	8.19E-05	5.61E-07	4.85E-09	2.63E-07	2.27E-09
2018	9.48E-03	8.19E-05	5.13E-07	4.43E-09	3.82E-07	3.30E-09	9.48E-03	8.19E-05	5.38E-07	4.65E-09	2.55E-07	2.20E-09
2019	9.48E-03	8.19E-05	4.79E-07	4.14E-09	3.81E-07	3.29E-09	9.48E-03	8.19E-05	5.29E-07	4.57E-09	2.52E-07	2.17E-09
2020	9.48E-03	8.19E-05	4.63E-07	4.00E-09	3.86E-07	3.33E-09	9.48E-03	8.19E-05	5.17E-07	4.46E-09	2.48E-07	2.14E-09
2021	9.48E-03	8.19E-05	4.32E-07	3.73E-09	3.86E-07	3.34E-09	9.48E-03	8.19E-05	5.08E-07	4.39E-09	2.45E-07	2.11E-09
2022	9.48E-03	8.19E-05	3.95E-07	3.41E-09	3.84E-07	3.31E-09	9.48E-03	8.19E-05	5.28E-07	4.56E-09	2.52E-07	2.18E-09
2023	9.48E-03	8.19E-05	3.62E-07	3.13E-09	3.79E-07	3.27E-09	9.48E-03	8.19E-05	5.23E-07	4.51E-09	2.50E-07	2.16E-09
2024	9.48E-03	8.19E-05	3.28E-07	2.83E-09	3.71E-07	3.20E-09	9.48E-03	8.19E-05	5.18E-07	4.47E-09	2.49E-07	2.15E-09
2025	9.48E-03	8.19E-05	2.72E-07	2.35E-09	3.51E-07	3.03E-09	9.48E-03	8.19E-05	5.14E-07	4.44E-09	2.48E-07	2.14E-09
2026	9.48E-03	8.19E-05	2.65E-07	2.28E-09	3.48E-07	3.01E-09	9.48E-03	8.19E-05	4.97E-07	4.29E-09	2.42E-07	2.09E-09
2027	9.48E-03	8.19E-05	2.55E-07	2.20E-09	3.39E-07	2.93E-09	9.48E-03	8.19E-05	4.79E-07	4.14E-09	2.36E-07	2.03E-09
2028	9.48E-03	8.19E-05	2.47E-07	2.13E-09	3.31E-07	2.86E-09	9.48E-03	8.19E-05	4.63E-07	4.00E-09	2.30E-07	1.98E-09

Table A-22. Tailpipe Greenhouse Gas Emission Factors for ICEV and PHEV Light Duty Autos in Calendar Year 2045
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Model Year	Internal Combustion Engine Vehicle						Plug-in Hybrid Electric Vehicle[1]					
	CO_2 Emission Factor[2]		CH_4 Emission Factor[2]		N_2O Emission Factor[2]		CO_2 Emission Factor[2]		CH_4 Emission Factor[2]		N_2O Emission Factor[2]	
	(tons/gal)	(tons/MJ)	(tons/gal)	(tons/MJ)	(tons/gal)	(tons/MJ)	(tons/gal)	(tons/MJ)	(tons/gal)	(tons/MJ)	(tons/gal)	(tons/MJ)
2029	9.48E-03	8.19E-05	2.39E-07	2.07E-09	3.23E-07	2.79E-09	9.48E-03	8.19E-05	4.48E-07	3.86E-09	2.24E-07	1.94E-09
2030	9.48E-03	8.19E-05	2.32E-07	2.00E-09	3.14E-07	2.71E-09	9.48E-03	8.19E-05	4.33E-07	3.74E-09	2.19E-07	1.89E-09
2031	9.48E-03	8.19E-05	2.25E-07	1.94E-09	3.06E-07	2.64E-09	9.48E-03	8.19E-05	4.19E-07	3.62E-09	2.14E-07	1.85E-09
2032	9.48E-03	8.19E-05	2.17E-07	1.88E-09	2.97E-07	2.56E-09	9.48E-03	8.19E-05	4.05E-07	3.50E-09	2.09E-07	1.80E-09
2033	9.48E-03	8.19E-05	2.10E-07	1.82E-09	2.88E-07	2.49E-09	9.48E-03	8.19E-05	3.93E-07	3.39E-09	2.04E-07	1.76E-09
2034	9.48E-03	8.19E-05	2.03E-07	1.75E-09	2.79E-07	2.41E-09	9.48E-03	8.19E-05	3.80E-07	3.28E-09	2.00E-07	1.73E-09
2035	9.48E-03	8.19E-05	1.96E-07	1.69E-09	2.69E-07	2.32E-09	9.48E-03	8.19E-05	3.69E-07	3.18E-09	1.96E-07	1.69E-09
2036	9.48E-03	8.19E-05	1.89E-07	1.63E-09	2.60E-07	2.24E-09	9.48E-03	8.19E-05	3.58E-07	3.09E-09	1.91E-07	1.65E-09
2037	9.48E-03	8.19E-05	1.82E-07	1.57E-09	2.50E-07	2.16E-09	9.48E-03	8.19E-05	3.47E-07	3.00E-09	1.87E-07	1.62E-09
2038	9.48E-03	8.19E-05	1.75E-07	1.51E-09	2.39E-07	2.07E-09	9.48E-03	8.19E-05	3.37E-07	2.91E-09	1.84E-07	1.59E-09
2039	9.48E-03	8.19E-05	1.68E-07	1.45E-09	2.29E-07	1.98E-09	9.48E-03	8.19E-05	3.27E-07	2.83E-09	1.80E-07	1.55E-09
2040	9.48E-03	8.19E-05	1.61E-07	1.39E-09	2.18E-07	1.88E-09	9.48E-03	8.19E-05	3.18E-07	2.75E-09	1.77E-07	1.52E-09
2041	9.48E-03	8.19E-05	1.54E-07	1.33E-09	2.07E-07	1.78E-09	9.48E-03	8.19E-05	3.09E-07	2.67E-09	1.73E-07	1.49E-09
2042	9.48E-03	8.19E-05	1.47E-07	1.27E-09	1.95E-07	1.68E-09	9.48E-03	8.19E-05	3.01E-07	2.60E-09	1.70E-07	1.47E-09
2043	9.48E-03	8.19E-05	1.40E-07	1.21E-09	1.83E-07	1.58E-09	9.48E-03	8.19E-05	2.93E-07	2.53E-09	1.67E-07	1.44E-09
2044	9.48E-03	8.19E-05	1.34E-07	1.15E-09	1.71E-07	1.48E-09	9.48E-03	8.19E-05	2.86E-07	2.47E-09	1.64E-07	1.41E-09
2045	9.48E-03	8.19E-05	1.27E-07	1.10E-09	1.58E-07	1.36E-09	9.48E-03	8.19E-05	2.79E-07	2.41E-09	1.61E-07	1.39E-09

Notes:

[1] Values in shaded cells are not available as the light duty auto vehicle fleet in EMFAC2021 does not include MY 2009 and earlier PHEVs.

[2] Tailpipe greenhouse gas emission factors were estimated as a ratio of the greenhouse gas emissions (CO_2, CH_4, N_2O) to the gasoline fuel consumption outputs for each model year from EMFAC2021 data.

[3] California Reformulated Gasoline (CaRFG) energy density for the conversion factor from gal to MJ was obtained from CARB's Low Carbon Fuel Standard (LCFS) Regulation. Available at: https://ww2.arb.ca.gov/sites/default/files/2020-07/2020_lcfs_fro_oal-approved_unofficial_06302020.pdf. Accessed: May 2022.

Conversion Factor

CaRFG Energy Density[3]	115.83	MJ/gal

Abbreviations:

CARB - California Air Resources Board
CaRFG - California Reformulated Gasoline
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
gal - gallon
ICEV - internal combustion engine vehicle
LCFS - Low Carbon Fuel Standard
MJ - megajoule
MY - model year
N_2O - Nitrous oxide
PHEV - plug-in hybrid electric vehicle

Table A-23. Fuel Economies for Light Duty Auto Vehicles in Calendar Year 2050

Model Year[1]	Internal Combustion Engine Vehicle[1]		Battery Electric Vehicle[1,2]		Plug-in Hybrid Electric Vehicle[1,3]				Fuel Cell Electric Vehicle[4,5]	Hybrid Electric Vehicle[6,7]	
	(gal of gasoline/ mi)	(MJ of gasoline/ mi)	(kWh of electricity/ mi)	(MJ of electricity/ mi)	(gal of gasoline/ mi)	(MJ of gasoline/ mi)	(kWh of electricity/ mi)	(MJ of electricity/ mi)	(MJ of hydrogen/ mi)	(gal of gasoline/ mi)	(MJ of gasoline /mi)
2006	0.046	5.35	0.386	1.390	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2007	0.045	5.20	0.386	1.390	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2008	0.045	5.21	0.386	1.390	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2009	0.043	4.92	0.386	1.390	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2010	0.039	4.46	0.386	1.390	0.042	4.91	0.302	1.087	N/A	N/A	N/A
2011	0.040	4.64	0.386	1.390	0.042	4.88	0.302	1.087	N/A	N/A	N/A
2012	0.038	4.41	0.386	1.390	0.041	4.76	0.302	1.087	N/A	N/A	N/A
2013	0.037	4.27	0.386	1.390	0.040	4.68	0.302	1.087	N/A	N/A	N/A
2014	0.037	4.26	0.386	1.390	0.040	4.63	0.302	1.087	N/A	N/A	N/A
2015	0.036	4.17	0.386	1.390	0.039	4.57	0.302	1.087	N/A	N/A	N/A
2016	0.035	4.07	0.386	1.390	0.039	4.51	0.302	1.087	N/A	N/A	N/A
2017	0.035	4.10	0.386	1.390	0.039	4.48	0.302	1.087	N/A	N/A	N/A
2018	0.035	4.08	0.386	1.390	0.038	4.44	0.302	1.087	N/A	N/A	N/A
2019	0.035	4.02	0.386	1.390	0.038	4.41	0.302	1.087	N/A	N/A	N/A
2020	0.034	3.90	0.386	1.390	0.038	4.37	0.302	1.087	N/A	0.024	2.765
2021	0.033	3.79	0.386	1.390	0.037	4.34	0.302	1.087	N/A	0.023	2.690
2022	0.032	3.70	0.386	1.390	0.038	4.35	0.302	1.087	N/A	0.023	2.626
2023	0.031	3.61	0.386	1.390	0.037	4.33	0.302	1.087	N/A	0.022	2.563
2024	0.030	3.53	0.386	1.390	0.037	4.31	0.302	1.087	N/A	0.022	2.502
2025	0.030	3.44	0.386	1.390	0.037	4.29	0.302	1.087	N/A	0.021	2.442
2026	0.029	3.36	0.386	1.390	0.037	4.26	0.302	1.087	1.34	0.021	2.385

Table A-23. Fuel Economies for Light Duty Auto Vehicles in Calendar Year 2050
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Model Year[1]	Internal Combustion Engine Vehicle[1]		Battery Electric Vehicle[1,2]		Plug-in Hybrid Electric Vehicle[1,3]				Fuel Cell Electric Vehicle[4,5]	Hybrid Electric Vehicle[6,7]	
	(gal of gasoline/ mi)	(MJ of gasoline/ mi)	(kWh of electricity/ mi)	(MJ of electricity/ mi)	(gal of gasoline/ mi)	(MJ of gasoline/ mi)	(kWh of electricity/ mi)	(MJ of electricity/ mi)	(MJ of hydrogen/ mi)	(gal of gasoline/ mi)	(MJ of gasoline /mi)
2027	0.029	3.36	0.386	1.390	0.037	4.24	0.302	1.087	1.34	0.021	2.381
2028	0.029	3.35	0.386	1.390	0.036	4.22	0.302	1.087	1.34	0.021	2.377
2029	0.029	3.35	0.386	1.390	0.036	4.20	0.302	1.087	1.34	0.020	2.373
2030	0.029	3.34	0.386	1.390	0.036	4.19	0.302	1.087	1.34	0.020	2.370
2031	0.029	3.34	0.386	1.390	0.036	4.17	0.302	1.087	1.33	0.020	2.367
2032	0.029	3.33	0.386	1.390	0.036	4.16	0.302	1.087	1.33	0.020	2.364
2033	0.029	3.33	0.386	1.390	0.036	4.14	0.302	1.087	1.33	0.020	2.361
2034	0.029	3.32	0.386	1.390	0.036	4.13	0.302	1.087	1.33	0.020	2.358
2035	0.029	3.32	0.386	1.390	0.036	4.12	0.302	1.087	1.33	0.020	2.356
2036	0.029	3.32	0.386	1.390	0.035	4.11	0.302	1.087	1.33	0.020	2.353
2037	0.029	3.31	0.386	1.390	0.035	4.10	0.302	1.087	1.33	0.020	2.351
2038	0.029	3.31	0.386	1.390	0.035	4.09	0.302	1.087	1.32	0.020	2.349
2039	0.029	3.31	0.386	1.390	0.035	4.08	0.302	1.087	1.32	0.020	2.347
2040	0.029	3.31	0.386	1.390	0.035	4.07	0.302	1.087	1.32	0.020	2.345
2041	0.029	3.30	0.386	1.390	0.035	4.06	0.302	1.087	1.32	0.020	2.343
2042	0.028	3.30	0.386	1.390	0.035	4.05	0.302	1.087	1.32	0.020	2.341
2043	0.028	3.30	0.386	1.390	0.035	4.05	0.302	1.087	1.32	0.020	2.340
2044	0.028	3.30	0.386	1.390	0.035	4.04	0.302	1.087	1.32	0.020	2.339
2045	0.028	3.30	0.386	1.390	0.035	4.03	0.302	1.087	1.32	0.020	2.338
2046	0.028	3.29	0.386	1.390	0.035	4.03	0.302	1.087	1.32	0.020	2.337
2047	0.028	3.29	0.386	1.390	0.035	4.02	0.302	1.087	1.32	0.020	2.336
2048	0.028	3.29	0.386	1.390	0.035	4.02	0.302	1.087	1.32	0.020	2.337
2049	0.028	3.30	0.386	1.390	0.035	4.02	0.302	1.087	1.32	0.020	2.337

Table A-23. Fuel Economies for Light Duty Auto Vehicles in Calendar Year 2050
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Model Year[1]	Internal Combustion Engine Vehicle[1]		Battery Electric Vehicle[1,2]		Plug-in Hybrid Electric Vehicle[1,3]				Fuel Cell Electric Vehicle[4,5]	Hybrid Electric Vehicle[6,7]	
	(gal of gasoline/ mi)	(MJ of gasoline/ mi)	(kWh of electricity/ mi)	(MJ of electricity/ mi)	(gal of gasoline/ mi)	(MJ of gasoline/ mi)	(kWh of electricity/ mi)	(MJ of electricity/ mi)	(MJ of hydrogen/ mi)	(gal of gasoline/ mi)	(MJ of gasoline /mi)
2050	0.028	3.30	0.386	1.390	0.035	4.03	0.302	1.087	1.32	0.020	2.338

Notes:

1 Estimated using fuel consumption, energy consumption, and VMT outputs for LDA from EMFAC2021.

2 Values in shaded cells are not applicable as the light duty auto vehicle fleet in EMFAC2021 does not include MY 2009 and earlier PHEVs.

3 Fuel economies for MY 2026+ FCEVs were estimated by applying an EER of 2.5 to the gasoline ICEV fuel economy. This EER value was obtained from: https://ww2.arb.ca.gov/sites/default/files/2020-07/2020_lcfs_fro_oal-approved_unofficial_06302020.pdf. Accessed: May 2022.

4 For the purposes of this analysis, we assumed FCEVs do not exist prior to MY2026, so the values in shaded cells are not applicable.

5 Fuel economies for MY 2026+ HEVs were estimated by applying an EER of 1.41 to the gasoline ICEV fuel economy. This EER value was derived from the relative fuel economies of the average MY 2020 HEV and ICEV as obtained from The 2020 EPA Automotive Trends Report. This factor was assumed to remain constant in future years and was used to estimate fuel economies for MY 2026 to 2050 HEVs. Available at: https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1010U68.pdf. Accessed: May 2022.

6 For the purposes of this analysis, we assumed HEVs do not exist prior to MY2026, so the values in shaded cells are not applicable.

7 California Reformulated Gasoline (CaRFG) energy density and the conversion factor from kWh to MJ were obtained from CARB's Low Carbon Fuel Standard (LCFS) Regulation. Available at: https://ww2.arb.ca.gov/sites/default/files/2020-07/2020_lcfs_fro_oal-approved_unofficial_06302020.pdf. Accessed: May 2022.

Constants

CaRFG Energy Density[8]	115.83	MJ/gal
Conversion Factor[8]	3.6	MJ/kWh
FCEV EER[4]	2.5	
HEV EER[6]	1.41	

Abbreviations:

BEV - battery electric vehicle
CARB - California Air Resources Board
CaRFG - California Reformulated Gasoline
EER - energy economy ratio
EPA - Environmental Protection Agency
EMFAC - EMission FACtor Model
FCEV - fuel cell electric vehicle
gal - gallon
HEV - hybrid electric vehicle
ICEV - internal combustion engine vehicle
kWh - kilowatt hour
LDA - light duty auto
LCFS - Low Carbon Fuel Standard
mi - mile
MJ - megajoule
MY - model year
PHEV - plug-in hybrid electric vehicle
VMT - vehicle mile traveled

Table A-24. Estimating Average Daily Mileage for LDA ICEVs and Fraction of Daily Electric Miles Traveled by LDA PHEVs in Calendar Year 2050

Model Year	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle[1]				
	Population[2] (vehicles)	Daily VMT[2] (miles/day)	Average Daily Mileage per Vehicle (mi/vehicle/day)	Average Daily eVMT[2] (miles/day)	Average Daily cVMT[2] (miles/day)	Average Daily VMT[2] (miles/day)	eVMT (% of Average Daily VMT)	cVMT (% of Average Daily VMT)
2006	17,095	92,566	5.4	0	0	0	N/A	N/A
2007	17,938	103,245	5.8	0	0	0	N/A	N/A
2008	14,711	90,788	6.2	0	0	0	N/A	N/A
2009	11,643	76,845	6.6	0	0	0	N/A	N/A
2010	13,584	95,789	7.1	1.6	1.9	3.5	46%	54%
2011	13,206	99,842	7.6	82	97	178	46%	54%
2012	18,883	153,117	8.1	842	996	1,838	46%	54%
2013	22,656	196,080	8.7	1,701	2,012	3,714	46%	54%
2014	21,908	203,097	9.3	2,559	3,027	5,586	46%	54%
2015	26,586	264,281	10	2,069	2,447	4,516	46%	54%
2016	27,295	289,355	11	2,428	2,872	5,300	46%	54%
2017	29,325	329,581	11	6,881	8,139	15,020	46%	54%
2018	27,113	323,766	12	7,059	8,349	15,408	46%	54%
2019	25,304	322,113	13	5,993	6,651	12,643	47%	53%
2020	22,760	307,409	14	7,225	7,765	14,991	48%	52%
2021	30,740	441,231	14	11,627	11,792	23,418	50%	50%
2022	40,577	617,884	15	18,766	15,601	34,367	55%	45%
2023	47,100	760,380	16	23,853	18,612	42,465	56%	44%
2024	55,817	953,752	17	30,538	22,370	52,908	58%	42%
2025	67,473	1,219,241	18	40,165	27,524	67,689	59%	41%
2026	84,407	1,610,993	19	46,792	32,065	78,857	59%	41%
2027	103,307	2,079,306	20	60,306	41,325	101,631	59%	41%
2028	126,564	2,683,403	21	77,308	52,976	130,285	59%	41%
2029	154,469	3,445,797	22	98,336	67,385	165,721	59%	41%
2030	186,433	4,371,092	23	123,768	84,813	208,582	59%	41%
2031	223,318	5,496,882	25	155,589	106,619	262,208	59%	41%
2032	263,400	6,799,816	26	192,410	131,851	324,261	59%	41%
2033	306,740	8,297,021	27	234,716	160,841	395,557	59%	41%
2034	350,568	9,927,424	28	280,777	192,405	473,181	59%	41%

Table A-24. Estimating Average Daily Mileage for LDA ICEVs and Fraction of Daily Electric Miles Traveled by LDA PHEVs in Calendar Year 2050

Model Year	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle[1]				
	Population[2] (vehicles)	Daily VMT[2] (miles/day)	Average Daily Mileage per Vehicle (mi/vehicle/day)	Average Daily eVMT[2] (miles/day)	Average Daily cVMT[2] (miles/day)	Average Daily VMT[2] (miles/day)	eVMT (% of Average Daily VMT)	cVMT (% of Average Daily VMT)
2035	396,387	11,740,282	30	331,991	227,499	559,490	59%	41%
2036	441,302	13,661,164	31	386,246	264,678	650,924	59%	41%
2037	488,028	15,778,407	32	446,041	305,654	751,695	59%	41%
2038	529,547	17,868,081	34	505,048	346,088	851,136	59%	41%
2039	573,298	20,175,045	35	570,183	390,723	960,906	59%	41%
2040	609,667	22,361,362	37	631,898	433,014	1,064,912	59%	41%
2041	648,178	24,762,485	38	699,675	479,458	1,179,133	59%	41%
2042	679,210	27,014,425	40	763,205	522,993	1,286,198	59%	41%
2043	713,632	29,531,415	41	834,205	571,646	1,405,852	59%	41%
2044	738,970	31,804,637	43	898,297	615,566	1,513,863	59%	41%
2045	768,833	34,383,859	45	971,032	665,408	1,636,440	59%	41%
2046	790,339	36,707,901	46	1,036,539	710,297	1,746,836	59%	41%
2047	807,527	38,911,156	48	1,098,655	752,863	1,851,517	59%	41%
2048	828,277	41,311,163	50	1,166,429	799,305	1,965,734	59%	41%
2049	836,615	43,017,876	51	1,214,783	832,441	2,047,224	59%	41%
2050	754,352	39,850,379	53	1,125,610	771,334	1,896,944	59%	41%

Notes:

[1] Values in shaded cells are zero or not available as the light duty auto vehicle fleet in EMFAC2021 does not include MY 2009 and earlier PHEVs.

[2] Obtained from EMFAC2021 data.

Abbreviations:

cVMT - combustion vehicle mile traveled
EMFAC - EMission FACtor Model
eVMT - electric vehicle mile traveled
ICEV - internal combustion engine vehicle
LDA - light duty auto
mi - mile
MY - model year
PHEV - plug-in hybrid electric vehicle
VMT - vehicle miles traveled

Table A-25. Tailpipe Greenhouse Gas Emission Factors for ICEV and PHEV Light Duty Autos in Calendar Year 2050

Model Year	Internal Combustion Engine Vehicle						Plug-in Hybrid Electric Vehicle[1]					
	CO_2 Emission Factor[2]		CH_4 Emission Factor[2]		N_2O Emission Factor[2]		CO_2 Emission Factor[2]		CH_4 Emission Factor[2]		N_2O Emission Factor[2]	
	(tons/gal)	(tons/MJ)	(tons/gal)	(tons/MJ)	(tons/gal)	(tons/MJ)	(tons/gal)	(tons/MJ)	(tons/gal)	(tons/MJ)	(tons/gal)	(tons/MJ)
2006	9.48E-03	8.19E-05	8.27E-07	7.14E-09	3.90E-07	3.37E-09	N/A	N/A	N/A	N/A	N/A	N/A
2007	9.48E-03	8.19E-05	8.41E-07	7.26E-09	4.21E-07	3.63E-09	N/A	N/A	N/A	N/A	N/A	N/A
2008	9.48E-03	8.19E-05	7.84E-07	6.77E-09	4.09E-07	3.53E-09	N/A	N/A	N/A	N/A	N/A	N/A
2009	9.48E-03	8.19E-05	7.49E-07	6.46E-09	4.25E-07	3.67E-09	N/A	N/A	N/A	N/A	N/A	N/A
2010	9.48E-03	8.19E-05	7.69E-07	6.64E-09	4.57E-07	3.95E-09	9.48E-03	8.19E-05	9.45E-07	8.16E-09	3.79E-07	3.27E-09
2011	9.48E-03	8.19E-05	7.40E-07	6.39E-09	4.32E-07	3.73E-09	9.48E-03	8.19E-05	8.96E-07	7.74E-09	3.65E-07	3.15E-09
2012	9.48E-03	8.19E-05	7.07E-07	6.10E-09	4.41E-07	3.81E-09	9.48E-03	8.19E-05	8.66E-07	7.48E-09	3.57E-07	3.08E-09
2013	9.48E-03	8.19E-05	6.79E-07	5.86E-09	4.44E-07	3.83E-09	9.48E-03	8.19E-05	8.34E-07	7.20E-09	3.48E-07	3.01E-09
2014	9.48E-03	8.19E-05	6.63E-07	5.72E-09	4.34E-07	3.74E-09	9.48E-03	8.19E-05	7.96E-07	6.87E-09	3.37E-07	2.91E-09
2015	9.48E-03	8.19E-05	6.44E-07	5.56E-09	4.33E-07	3.74E-09	9.48E-03	8.19E-05	7.61E-07	6.57E-09	3.27E-07	2.82E-09
2016	9.48E-03	8.19E-05	7.05E-07	6.08E-09	4.40E-07	3.80E-09	9.48E-03	8.19E-05	7.30E-07	6.30E-09	3.17E-07	2.74E-09
2017	9.48E-03	8.19E-05	6.42E-07	5.55E-09	4.25E-07	3.67E-09	9.48E-03	8.19E-05	6.98E-07	6.03E-09	3.07E-07	2.65E-09
2018	9.48E-03	8.19E-05	6.03E-07	5.21E-09	4.19E-07	3.62E-09	9.48E-03	8.19E-05	6.68E-07	5.77E-09	2.98E-07	2.57E-09
2019	9.48E-03	8.19E-05	5.61E-07	4.85E-09	4.18E-07	3.60E-09	9.48E-03	8.19E-05	6.55E-07	5.66E-09	2.94E-07	2.54E-09
2020	9.48E-03	8.19E-05	5.41E-07	4.67E-09	4.23E-07	3.65E-09	9.48E-03	8.19E-05	6.39E-07	5.52E-09	2.89E-07	2.49E-09
2021	9.48E-03	8.19E-05	5.04E-07	4.35E-09	4.24E-07	3.66E-09	9.48E-03	8.19E-05	6.26E-07	5.41E-09	2.85E-07	2.46E-09
2022	9.48E-03	8.19E-05	4.60E-07	3.97E-09	4.22E-07	3.64E-09	9.48E-03	8.19E-05	6.49E-07	5.60E-09	2.92E-07	2.52E-09
2023	9.48E-03	8.19E-05	4.21E-07	3.64E-09	4.18E-07	3.61E-09	9.48E-03	8.19E-05	6.40E-07	5.52E-09	2.89E-07	2.50E-09
2024	9.48E-03	8.19E-05	3.81E-07	3.29E-09	4.11E-07	3.55E-09	9.48E-03	8.19E-05	6.32E-07	5.45E-09	2.87E-07	2.48E-09
2025	9.48E-03	8.19E-05	3.16E-07	2.73E-09	3.90E-07	3.36E-09	9.48E-03	8.19E-05	6.26E-07	5.40E-09	2.85E-07	2.46E-09
2026	9.48E-03	8.19E-05	3.08E-07	2.66E-09	3.88E-07	3.35E-09	9.48E-03	8.19E-05	6.03E-07	5.21E-09	2.78E-07	2.40E-09
2027	9.48E-03	8.19E-05	2.97E-07	2.56E-09	3.80E-07	3.28E-09	9.48E-03	8.19E-05	5.80E-07	5.01E-09	2.70E-07	2.33E-09
2028	9.48E-03	8.19E-05	2.88E-07	2.49E-09	3.72E-07	3.21E-09	9.48E-03	8.19E-05	5.58E-07	4.82E-09	2.63E-07	2.27E-09
2029	9.48E-03	8.19E-05	2.80E-07	2.42E-09	3.64E-07	3.14E-09	9.48E-03	8.19E-05	5.38E-07	4.64E-09	2.56E-07	2.21E-09
2030	9.48E-03	8.19E-05	2.71E-07	2.34E-09	3.56E-07	3.07E-09	9.48E-03	8.19E-05	5.19E-07	4.48E-09	2.49E-07	2.15E-09
2031	9.48E-03	8.19E-05	2.64E-07	2.28E-09	3.48E-07	3.01E-09	9.48E-03	8.19E-05	5.00E-07	4.32E-09	2.43E-07	2.10E-09
2032	9.48E-03	8.19E-05	2.56E-07	2.21E-09	3.40E-07	2.94E-09	9.48E-03	8.19E-05	4.83E-07	4.17E-09	2.37E-07	2.04E-09
2033	9.48E-03	8.19E-05	2.48E-07	2.14E-09	3.32E-07	2.87E-09	9.48E-03	8.19E-05	4.66E-07	4.03E-09	2.31E-07	1.99E-09
2034	9.48E-03	8.19E-05	2.41E-07	2.08E-09	3.24E-07	2.79E-09	9.48E-03	8.19E-05	4.51E-07	3.89E-09	2.25E-07	1.95E-09

Table A-25. Tailpipe Greenhouse Gas Emission Factors for ICEV and PHEV Light Duty Autos in Calendar Year 2050

Model Year	Internal Combustion Engine Vehicle						Plug-in Hybrid Electric Vehicle[1]					
	CO_2 Emission Factor[2]		CH_4 Emission Factor[2]		N_2O Emission Factor[2]		CO_2 Emission Factor[2]		CH_4 Emission Factor[2]		N_2O Emission Factor[2]	
	(tons/gal)	(tons/MJ)	(tons/gal)	(tons/MJ)	(tons/gal)	(tons/MJ)	(tons/gal)	(tons/MJ)	(tons/gal)	(tons/MJ)	(tons/gal)	(tons/MJ)
2035	9.48E-03	8.19E-05	2.33E-07	2.01E-09	3.15E-07	2.72E-09	9.48E-03	8.19E-05	4.36E-07	3.76E-09	2.20E-07	1.90E-09
2036	9.48E-03	8.19E-05	2.26E-07	1.95E-09	3.07E-07	2.65E-09	9.48E-03	8.19E-05	4.22E-07	3.64E-09	2.15E-07	1.86E-09
2037	9.48E-03	8.19E-05	2.19E-07	1.89E-09	2.98E-07	2.57E-09	9.48E-03	8.19E-05	4.08E-07	3.52E-09	2.10E-07	1.81E-09
2038	9.48E-03	8.19E-05	2.11E-07	1.83E-09	2.89E-07	2.49E-09	9.48E-03	8.19E-05	3.95E-07	3.41E-09	2.05E-07	1.77E-09
2039	9.48E-03	8.19E-05	2.04E-07	1.76E-09	2.79E-07	2.41E-09	9.48E-03	8.19E-05	3.83E-07	3.31E-09	2.01E-07	1.73E-09
2040	9.48E-03	8.19E-05	1.97E-07	1.70E-09	2.70E-07	2.33E-09	9.48E-03	8.19E-05	3.71E-07	3.21E-09	1.97E-07	1.70E-09
2041	9.48E-03	8.19E-05	1.90E-07	1.64E-09	2.60E-07	2.25E-09	9.48E-03	8.19E-05	3.60E-07	3.11E-09	1.92E-07	1.66E-09
2042	9.48E-03	8.19E-05	1.83E-07	1.58E-09	2.50E-07	2.16E-09	9.48E-03	8.19E-05	3.50E-07	3.02E-09	1.88E-07	1.63E-09
2043	9.48E-03	8.19E-05	1.76E-07	1.52E-09	2.40E-07	2.07E-09	9.48E-03	8.19E-05	3.39E-07	2.93E-09	1.85E-07	1.59E-09
2044	9.48E-03	8.19E-05	1.69E-07	1.46E-09	2.29E-07	1.98E-09	9.48E-03	8.19E-05	3.30E-07	2.85E-09	1.81E-07	1.56E-09
2045	9.48E-03	8.19E-05	1.62E-07	1.40E-09	2.19E-07	1.89E-09	9.48E-03	8.19E-05	3.20E-07	2.77E-09	1.77E-07	1.53E-09
2046	9.48E-03	8.19E-05	1.55E-07	1.34E-09	2.07E-07	1.79E-09	9.48E-03	8.19E-05	3.11E-07	2.69E-09	1.74E-07	1.50E-09
2047	9.48E-03	8.19E-05	1.48E-07	1.28E-09	1.96E-07	1.69E-09	9.48E-03	8.19E-05	3.03E-07	2.61E-09	1.71E-07	1.47E-09
2048	9.48E-03	8.19E-05	1.41E-07	1.22E-09	1.84E-07	1.59E-09	9.48E-03	8.19E-05	2.95E-07	2.54E-09	1.67E-07	1.45E-09
2049	9.48E-03	8.19E-05	1.34E-07	1.16E-09	1.71E-07	1.48E-09	9.48E-03	8.19E-05	2.88E-07	2.48E-09	1.65E-07	1.42E-09
2050	9.48E-03	8.19E-05	1.28E-07	1.10E-09	1.58E-07	1.37E-09	9.48E-03	8.19E-05	2.81E-07	2.43E-09	1.62E-07	1.40E-09

Notes:

[1] Values in shaded cells are not available as the light duty auto vehicle fleet in EMFAC2021 does not include MY 2009 and earlier PHEVs.

[2] Tailpipe greenhouse gas emission factors were estimated as a ratio of the greenhouse gas emissions (CO_2, CH_4, N_2O) to the gasoline fuel consumption outputs for each model year from EMFAC2021 data.

[3] California Reformulated Gasoline (CaRFG) energy density for the conversion factor from gal to MJ was obtained from CARB's Low Carbon Fuel Standard (LCFS) Regulation. Available at: https://ww2.arb.ca.gov/sites/default/files/2020-07/2020_lcfs_fro_oal-approved_unofficial_06302020.pdf. Accessed: May 2022.

Conversion Factor

CaRFG Energy Density[3]	115.83	MJ/gal

Abbreviations:

CARB - California Air Resources Board
CaRFG - California Reformulated Gasoline
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
gal - gallon
ICEV - internal combustion engine vehicle
LCFS - Low Carbon Fuel Standard
MJ - megajoule
MY - model year
N_2O - Nitrous oxide
PHEV - plug-in hybrid electric vehicle

Table A-26. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 0 in Calendar Year 2026
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Model Year	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fuel Consumption[3] (MJ of electricity/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of electricity/day)
1982	100%	4,657	174,227	0%	0	0	0	0%	1	9
1983	100%	5,273	206,541	0%	0	0	0	0%	1	9
1984	100%	7,858	329,345	0%	0	0	0	0%	1	13
1985	100%	10,024	435,286	0%	0	0	0	0%	0	0
1986	100%	10,647	463,741	0%	0	0	0	0%	0	0
1987	100%	12,832	586,622	0%	0	0	0	0%	1	18
1988	100%	12,139	592,716	0%	0	0	0	0%	0	0
1989	100%	14,970	774,940	0%	0	0	0	0%	1	14
1990	100%	18,044	991,990	0%	0	0	0	0%	0	0
1991	100%	21,281	1,234,023	0%	0	0	0	0%	0	0
1992	100%	18,332	1,127,213	0%	0	0	0	0%	0	0
1993	100%	20,138	1,231,512	0%	0	0	0	0%	3	46
1994	100%	22,840	1,473,479	0%	0	0	0	0%	0	7
1995	100%	29,675	2,022,331	0%	0	0	0	0%	2	31
1996	100%	29,436	2,128,971	0%	0	0	0	0%	0	0
1997	100%	39,761	2,978,637	0%	0	0	0	0%	4	95
1998	100%	48,817	3,777,000	0%	0	0	0	0%	5	107
1999	100%	56,921	4,546,344	0%	0	0	0	0%	4	98
2000	100%	76,964	6,529,441	0%	0	0	0	0%	1	31
2001	100%	87,221	7,793,387	0%	0	0	0	0%	6	155
2002	100%	102,135	9,644,077	0%	0	0	0	0%	37	1,030
2003	100%	127,287	12,720,322	0%	0	0	0	0%	7	196
2004	100%	143,690	15,732,253	0%	0	0	0	0%	5	155
2005	100%	191,623	21,752,720	0%	0	0	0	0%	7	213
2006	100%	225,488	26,980,154	0%	0	0	0	0%	11	389
2007	100%	275,180	33,665,694	0%	0	0	0	0%	23	834
2008	100%	258,265	33,318,492	0%	0	0	0	0%	126	4,586
2009	100%	229,086	29,357,696	0%	0	0	0	0%	34	1,333
2010	100%	292,924	35,681,010	0%	11	154	687	0%	161	6,445
2011	99%	307,002	40,824,099	0%	548	8,280	37,013	1%	1,890	79,947
2012	98%	465,759	61,806,971	1%	5,585	88,399	392,722	1%	2,528	111,558
2013	97%	592,447	79,686,217	2%	11,199	185,018	819,056	1%	8,583	395,185
2014	96%	599,553	84,574,041	3%	16,462	284,537	1,256,341	1%	9,356	449,554
2015	96%	738,821	106,767,996	2%	12,602	227,577	1,002,629	2%	14,202	712,794
2016	95%	754,102	111,262,248	2%	13,790	259,774	1,141,452	3%	23,130	1,205,441
2017	91%	794,462	122,943,456	4%	36,125	706,874	3,105,093	5%	43,901	2,385,744
2018	86%	705,513	113,371,002	4%	33,412	680,299	2,980,537	10%	78,294	4,428,841
2019	88%	622,322	102,867,416	3%	24,317	533,860	2,191,127	8%	58,438	3,447,620
2020	86%	508,892	85,019,301	4%	24,600	571,597	2,264,467	9%	55,310	3,416,834
2021	85%	619,444	104,948,162	4%	32,604	811,289	3,029,262	10%	73,983	4,748,184
2022	84%	724,703	124,757,619	5%	39,994	1,137,171	3,486,691	11%	93,245	6,212,763
2023	84%	731,635	127,883,688	5%	40,571	1,231,754	3,543,090	11%	98,996	6,843,258
2024	83%	747,543	132,487,563	5%	41,200	1,332,140	3,598,733	12%	106,645	7,641,910
2025	83%	758,530	135,969,595	5%	41,866	1,438,799	3,640,575	12%	111,956	8,303,968
2026	85%	706,862	127,779,786	4%	34,449	1,220,027	3,088,034	11%	89,660	6,866,855

Table A-26. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 0 in Calendar Year 2026

	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
1982	0%	0	0	0%	0	0	14	0.008	0.003
1983	0%	0	0	0%	0	0	17	0.009	0.003
1984	0%	0	0	0%	0	0	27	0.01	0.005
1985	0%	0	0	0%	0	0	36	0.02	0.006
1986	0%	0	0	0%	0	0	38	0.02	0.007
1987	0%	0	0	0%	0	0	48	0.02	0.009
1988	0%	0	0	0%	0	0	49	0.02	0.009
1989	0%	0	0	0%	0	0	63	0.03	0.01
1990	0%	0	0	0%	0	0	81	0.04	0.01
1991	0%	0	0	0%	0	0	101	0.05	0.02
1992	0%	0	0	0%	0	0	92	0.04	0.02
1993	0%	0	0	0%	0	0	101	0.05	0.02
1994	0%	0	0	0%	0	0	121	0.06	0.02
1995	0%	0	0	0%	0	0	166	0.08	0.03
1996	0%	0	0	0%	0	0	174	0.09	0.04
1997	0%	0	0	0%	0	0	244	0.11	0.05
1998	0%	0	0	0%	0	0	309	0.11	0.05
1999	0%	0	0	0%	0	0	372	0.09	0.06
2000	0%	0	0	0%	0	0	535	0.08	0.07
2001	0%	0	0	0%	0	0	638	0.09	0.07
2002	0%	0	0	0%	0	0	790	0.11	0.09
2003	0%	0	0	0%	0	0	1,041	0.13	0.11
2004	0%	0	0	0%	0	0	1,288	0.07	0.04
2005	0%	0	0	0%	0	0	1,781	0.08	0.05
2006	0%	0	0	0%	0	0	2,209	0.09	0.06
2007	0%	0	0	0%	0	0	2,756	0.11	0.08
2008	0%	0	0	0%	0	0	2,728	0.10	0.08
2009	0%	0	0	0%	0	0	2,404	0.09	0.07
2010	0%	0	0	0%	0	0	2,921	0.11	0.09
2011	0%	0	0	0%	0	0	3,345	0.12	0.10
2012	0%	0	0	0%	0	0	5,092	0.18	0.15
2013	0%	0	0	0%	0	0	6,591	0.22	0.19
2014	0%	0	0	0%	0	0	7,027	0.23	0.20
2015	0%	0	0	0%	0	0	8,823	0.28	0.24
2016	0%	0	0	0%	0	0	9,203	0.32	0.26
2017	0%	0	0	0%	0	0	10,320	0.32	0.27
2018	0%	0	0	0%	0	0	9,526	0.28	0.24
2019	0%	0	0	0%	0	0	8,601	0.23	0.21
2020	0%	0	0	0%	0	0	7,146	0.19	0.17
2021	0%	0	0	0%	0	0	8,840	0.21	0.21
2022	0%	0	0	0%	0	0	10,500	0.23	0.24
2023	0%	0	0	0%	0	0	10,760	0.21	0.23
2024	0%	0	0	0%	0	0	11,142	0.20	0.22
2025	0%	0	0	0%	0	0	11,430	0.16	0.20
2026	0%	0	0	0%	0	0	10,714	0.15	0.18

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-8) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-10. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

Table A-27. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 0 in Calendar Year 2030
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Model Year	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fuel Consumption[3] (MJ of electricity/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of electricity/day)
1986	100%	9,277	319,606	0%	0	0	0	0%	0	0
1987	100%	11,036	395,358	0%	0	0	0	0%	1	13
1988	100%	10,287	394,106	0%	0	0	0	0%	0	0
1989	100%	12,682	513,141	0%	0	0	0	0%	1	10
1990	100%	15,335	660,988	0%	0	0	0	0%	0	0
1991	100%	17,755	806,207	0%	0	0	0	0%	0	0
1992	100%	14,968	722,403	0%	0	0	0	0%	0	0
1993	100%	15,722	757,504	0%	0	0	0	0%	2	30
1994	100%	16,938	862,749	0%	0	0	0	0%	0	4
1995	100%	21,266	1,147,175	0%	0	0	0	0%	1	18
1996	100%	20,041	1,148,835	0%	0	0	0	0%	0	0
1997	100%	25,571	1,519,989	0%	0	0	0	0%	3	55
1998	100%	29,544	1,816,366	0%	0	0	0	0%	3	55
1999	100%	32,392	2,061,329	0%	0	0	0	0%	2	47
2000	100%	41,346	2,802,701	0%	0	0	0	0%	1	14
2001	100%	44,766	3,209,806	0%	0	0	0	0%	3	65
2002	100%	49,911	3,795,455	0%	0	0	0	0%	18	424
2003	100%	59,781	4,832,777	0%	0	0	0	0%	3	76
2004	100%	65,751	5,844,031	0%	0	0	0	0%	2	59
2005	100%	86,903	8,039,211	0%	0	0	0	0%	3	81
2006	100%	103,055	10,092,547	0%	0	0	0	0%	5	144
2007	100%	128,610	12,929,139	0%	0	0	0	0%	11	328
2008	100%	125,543	13,361,675	0%	0	0	0	0%	60	1,794
2009	100%	116,809	12,395,606	0%	0	0	0	0%	18	572
2010	100%	158,274	16,020,574	0%	6	69	311	0%	86	2,863
2011	99%	175,648	19,479,572	0%	313	3,932	17,791	1%	1,076	37,957
2012	98%	282,481	31,367,919	1%	3,387	44,658	200,590	1%	1,526	56,296
2013	97%	378,095	42,683,040	2%	7,146	98,660	441,197	1%	5,433	209,483
2014	96%	402,992	47,862,257	3%	11,064	160,332	714,692	1%	6,227	251,167
2015	97%	518,113	63,218,662	2%	8,836	134,191	596,394	2%	9,879	417,410
2016	95%	553,278	69,108,331	2%	10,115	160,689	711,773	3%	16,817	738,736
2017	91%	604,853	79,402,357	4%	27,493	454,641	2,012,619	5%	33,194	1,524,212
2018	86%	555,971	75,960,952	4%	26,314	453,896	2,003,609	10%	61,332	2,941,765
2019	88%	505,059	71,135,364	3%	19,734	368,011	1,521,560	8%	47,387	2,378,873
2020	86%	424,894	60,588,792	4%	20,540	406,324	1,621,195	9%	46,181	2,435,627
2021	85%	528,088	76,514,975	4%	27,796	590,252	2,219,126	10%	63,072	3,464,139
2022	84%	629,123	92,802,888	5%	34,719	844,508	2,607,459	11%	80,947	4,626,137
2023	84%	652,013	97,885,688	5%	36,155	941,473	2,725,229	11%	88,223	5,242,684
2024	83%	670,253	102,369,934	5%	36,940	1,028,217	2,790,931	12%	95,619	5,905,793
2025	83%	697,118	108,259,056	5%	38,476	1,144,799	2,904,428	12%	102,891	6,603,088
2026	85%	735,995	116,097,140	4%	35,869	1,108,113	2,804,580	11%	93,356	6,216,252
2027	85%	753,379	123,273,035	4%	36,682	1,175,675	2,972,420	11%	97,957	6,763,472
2028	85%	774,987	131,327,881	4%	37,500	1,244,657	3,146,136	11%	103,726	7,417,910
2029	84%	786,767	137,631,182	4%	37,726	1,292,471	3,268,769	12%	107,741	7,961,945
2030	84%	712,577	128,326,917	4%	33,914	1,195,950	3,027,919	12%	101,252	7,716,317

Table A-27. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 0 in Calendar Year 2030

Model Year	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
1986	0%	0	0	0%	0	0	26	0.01	0.005
1987	0%	0	0	0%	0	0	32	0.02	0.006
1988	0%	0	0	0%	0	0	32	0.02	0.006
1989	0%	0	0	0%	0	0	42	0.02	0.008
1990	0%	0	0	0%	0	0	54	0.03	0.010
1991	0%	0	0	0%	0	0	66	0.03	0.01
1992	0%	0	0	0%	0	0	59	0.03	0.01
1993	0%	0	0	0%	0	0	62	0.03	0.01
1994	0%	0	0	0%	0	0	71	0.04	0.01
1995	0%	0	0	0%	0	0	94	0.05	0.02
1996	0%	0	0	0%	0	0	94	0.05	0.02
1997	0%	0	0	0%	0	0	124	0.06	0.02
1998	0%	0	0	0%	0	0	149	0.06	0.03
1999	0%	0	0	0%	0	0	169	0.05	0.03
2000	0%	0	0	0%	0	0	229	0.04	0.03
2001	0%	0	0	0%	0	0	263	0.04	0.03
2002	0%	0	0	0%	0	0	311	0.05	0.04
2003	0%	0	0	0%	0	0	396	0.05	0.04
2004	0%	0	0	0%	0	0	478	0.03	0.01
2005	0%	0	0	0%	0	0	658	0.03	0.02
2006	0%	0	0	0%	0	0	826	0.04	0.02
2007	0%	0	0	0%	0	0	1,059	0.05	0.03
2008	0%	0	0	0%	0	0	1,094	0.05	0.03
2009	0%	0	0	0%	0	0	1,015	0.04	0.03
2010	0%	0	0	0%	0	0	1,312	0.06	0.04
2011	0%	0	0	0%	0	0	1,596	0.06	0.05
2012	0%	0	0	0%	0	0	2,585	0.10	0.08
2013	0%	0	0	0%	0	0	3,531	0.13	0.11
2014	0%	0	0	0%	0	0	3,977	0.15	0.12
2015	0%	0	0	0%	0	0	5,225	0.19	0.16
2016	0%	0	0	0%	0	0	5,716	0.22	0.18
2017	0%	0	0	0%	0	0	6,666	0.24	0.20
2018	0%	0	0	0%	0	0	6,383	0.22	0.18
2019	0%	0	0	0%	0	0	5,949	0.19	0.17
2020	0%	0	0	0%	0	0	5,093	0.15	0.14
2021	0%	0	0	0%	0	0	6,446	0.18	0.18
2022	0%	0	0	0%	0	0	7,811	0.20	0.21
2023	0%	0	0	0%	0	0	8,237	0.19	0.21
2024	0%	0	0	0%	0	0	8,610	0.18	0.21
2025	0%	0	0	0%	0	0	9,101	0.16	0.20
2026	0%	0	0	0%	0	0	9,735	0.16	0.21
2027	0%	0	0	0%	0	0	10,336	0.16	0.21
2028	0%	0	0	0%	0	0	11,010	0.16	0.21
2029	0%	0	0	0%	0	0	11,536	0.16	0.21
2030	0%	0	0	0%	0	0	10,754	0.15	0.18

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-11) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-13. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
Model Year	**Fleet Mix[1] (%)**	**Population[2] (vehicles)**	**Fuel Consumption[3] (MJ of gasoline/day)**	**Fleet Mix[1] (%)**	**Population[2] (vehicles)**	**Fuel Consumption[3] (MJ of gasoline/day)**	**Fuel Consumption[3] (MJ of electricity/day)**	**Fleet Mix[1] (%)**	**Population[2] (vehicles)**	**Fuel Consumption[3] (MJ of electricity/day)**
1991	100%	14,887	496,519	0%	0	0	0	0%	0	0
1992	100%	12,386	437,879	0%	0	0	0	0%	0	0
1993	100%	12,876	454,610	0%	0	0	0	0%	2	20
1994	100%	13,908	519,028	0%	0	0	0	0%	0	3
1995	100%	17,011	673,579	0%	0	0	0	0%	1	11
1996	100%	15,726	662,566	0%	0	0	0	0%	0	0
1997	100%	19,249	841,793	0%	0	0	0	0%	3	36
1998	100%	21,231	962,917	0%	0	0	0	0%	2	32
1999	100%	21,841	1,026,080	0%	0	0	0	0%	2	27
2000	100%	26,428	1,326,406	0%	0	0	0	0%	0	7
2001	100%	26,524	1,412,096	0%	0	0	0	0%	2	30
2002	100%	27,790	1,574,561	0%	0	0	0	0%	11	189
2003	100%	30,887	1,866,413	0%	0	0	0	0%	2	31
2004	100%	31,459	2,100,346	0%	0	0	0	0%	1	22
2005	100%	38,743	2,705,815	0%	0	0	0	0%	1	29
2006	100%	43,503	3,231,279	0%	0	0	0	0%	2	47
2007	100%	51,445	3,941,697	0%	0	0	0	0%	4	103
2008	100%	48,196	3,931,397	0%	0	0	0	0%	23	522
2009	100%	43,832	3,583,029	0%	0	0	0	0%	7	170
2010	100%	59,373	4,651,159	0%	2	20	92	0%	32	847
2011	99%	67,186	5,797,667	0%	120	1,161	5,375	1%	409	11,360
2012	98%	112,410	9,761,699	1%	1,348	13,798	63,245	1%	603	17,549
2013	97%	158,581	14,066,520	2%	2,997	32,296	147,122	1%	2,255	68,707
2014	96%	180,829	16,955,018	3%	4,964	56,441	255,982	1%	2,764	88,302
2015	97%	248,911	24,094,495	2%	4,244	50,842	229,574	2%	4,701	157,841
2016	95%	285,862	28,441,636	2%	5,224	65,752	295,555	3%	8,578	300,098
2017	91%	332,615	34,903,768	4%	15,110	198,715	892,263	5%	18,042	661,811
2018	86%	327,985	35,952,376	4%	15,507	213,599	955,739	9%	35,779	1,376,403
2019	88%	314,542	35,673,840	3%	12,281	183,606	769,058	8%	29,273	1,183,116
2020	86%	281,575	32,424,569	4%	13,612	216,540	874,542	9%	30,604	1,303,564
2021	85%	366,087	42,975,928	4%	19,269	330,198	1,255,839	10%	43,723	1,945,314
2022	84%	459,912	55,139,274	5%	25,381	499,808	1,561,702	11%	59,175	2,747,832
2023	84%	491,823	60,167,945	5%	27,272	576,729	1,688,911	11%	66,548	3,223,016
2024	83%	528,134	65,889,598	5%	29,108	659,860	1,811,619	12%	75,344	3,803,598
2025	83%	560,849	71,323,875	5%	30,955	752,392	1,930,200	12%	82,779	4,355,000
2026	85%	611,788	79,227,267	4%	29,815	754,625	1,930,143	11%	77,601	4,248,646
2027	85%	641,056	86,348,005	4%	31,213	822,291	2,099,102	11%	83,353	4,746,114
2028	85%	673,388	94,321,799	4%	32,584	892,959	2,275,365	11%	90,128	5,333,845
2029	84%	697,604	101,572,012	4%	33,451	953,218	2,424,492	12%	95,531	5,873,508
2030	84%	724,988	109,636,518	4%	34,505	1,021,517	2,594,022	12%	103,016	6,575,282
2031	84%	747,432	117,336,964	4%	35,573	1,093,525	2,772,634	12%	106,205	7,033,396
2032	84%	766,329	124,786,645	4%	36,472	1,163,085	2,945,735	12%	108,890	7,476,741
2033	84%	789,556	133,116,841	4%	37,578	1,240,654	3,141,258	12%	112,190	7,976,623
2034	84%	801,955	139,496,654	4%	38,168	1,299,952	3,293,065	12%	113,952	8,366,832
2035	84%	727,792	130,218,515	4%	34,638	1,213,298	3,076,767	12%	103,414	7,823,380

Table A-28. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 0 in Calendar Year 2035

	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
1991	0%	0	0	0%	0	0	41	0.02	0.008
1992	0%	0	0	0%	0	0	36	0.02	0.007
1993	0%	0	0	0%	0	0	37	0.02	0.007
1994	0%	0	0	0%	0	0	42	0.02	0.008
1995	0%	0	0	0%	0	0	55	0.03	0.01
1996	0%	0	0	0%	0	0	54	0.04	0.01
1997	0%	0	0	0%	0	0	69	0.04	0.01
1998	0%	0	0	0%	0	0	79	0.03	0.01
1999	0%	0	0	0%	0	0	84	0.03	0.01
2000	0%	0	0	0%	0	0	109	0.02	0.01
2001	0%	0	0	0%	0	0	116	0.02	0.01
2002	0%	0	0	0%	0	0	129	0.02	0.02
2003	0%	0	0	0%	0	0	153	0.02	0.02
2004	0%	0	0	0%	0	0	172	0.01	0.006
2005	0%	0	0	0%	0	0	222	0.01	0.007
2006	0%	0	0	0%	0	0	265	0.01	0.008
2007	0%	0	0	0%	0	0	323	0.02	0.01
2008	0%	0	0	0%	0	0	322	0.02	0.01
2009	0%	0	0	0%	0	0	293	0.01	0.010
2010	0%	0	0	0%	0	0	381	0.02	0.01
2011	0%	0	0	0%	0	0	475	0.02	0.02
2012	0%	0	0	0%	0	0	804	0.04	0.03
2013	0%	0	0	0%	0	0	1,164	0.05	0.04
2014	0%	0	0	0%	0	0	1,409	0.06	0.05
2015	0%	0	0	0%	0	0	1,991	0.08	0.07
2016	0%	0	0	0%	0	0	2,353	0.11	0.08
2017	0%	0	0	0%	0	0	2,931	0.12	0.10
2018	0%	0	0	0%	0	0	3,022	0.12	0.10
2019	0%	0	0	0%	0	0	2,984	0.11	0.10
2020	0%	0	0	0%	0	0	2,726	0.10	0.09
2021	0%	0	0	0%	0	0	3,621	0.12	0.12
2022	0%	0	0	0%	0	0	4,642	0.14	0.15
2023	0%	0	0	0%	0	0	5,064	0.14	0.16
2024	0%	0	0	0%	0	0	5,543	0.14	0.16
2025	0%	0	0	0%	0	0	5,997	0.13	0.17
2026	0%	0	0	0%	0	0	6,645	0.14	0.18
2027	0%	0	0	0%	0	0	7,241	0.14	0.19
2028	0%	0	0	0%	0	0	7,909	0.15	0.20
2029	0%	0	0	0%	0	0	8,514	0.15	0.20
2030	0%	0	0	0%	0	0	9,189	0.16	0.21
2031	0%	0	0	0%	0	0	9,834	0.16	0.21
2032	0%	0	0	0%	0	0	10,458	0.16	0.21
2033	0%	0	0	0%	0	0	11,156	0.17	0.21
2034	0%	0	0	0%	0	0	11,691	0.17	0.21
2035	0%	0	0	0%	0	0	10,913	0.15	0.18

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-14) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-16. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

Table A-29. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 0 in Calendar Year 2040

	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fuel Consumption[3] (MJ of electricity/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of electricity/day)
1996	100%	13,224	407,390	0%	0	0	0	0%	0	0
1997	100%	15,957	507,603	0%	0	0	0	0%	2	27
1998	100%	17,428	573,388	0%	0	0	0	0%	2	23
1999	100%	17,981	612,358	0%	0	0	0	0%	2	19
2000	100%	21,212	772,196	0%	0	0	0	0%	0	5
2001	100%	20,869	808,569	0%	0	0	0	0%	1	19
2002	100%	20,957	866,980	0%	0	0	0	0%	8	114
2003	100%	22,226	985,080	0%	0	0	0	0%	1	18
2004	100%	21,228	1,041,890	0%	0	0	0	0%	1	12
2005	100%	24,808	1,278,892	0%	0	0	0	0%	1	16
2006	100%	25,795	1,417,856	0%	0	0	0	0%	1	22
2007	100%	28,657	1,630,516	0%	0	0	0	0%	2	44
2008	100%	24,894	1,513,071	0%	0	0	0	0%	12	206
2009	100%	20,958	1,283,229	0%	0	0	0	0%	3	64
2010	100%	26,447	1,559,497	0%	1	7	31	0%	15	295
2011	99%	28,341	1,849,619	0%	51	367	1,752	1%	172	3,720
2012	98%	44,963	2,967,860	1%	539	4,153	19,596	1%	240	5,433
2013	97%	60,869	4,125,844	2%	1,150	9,385	43,891	1%	858	20,372
2014	96%	67,874	4,888,299	3%	1,863	16,131	74,982	1%	1,028	25,649
2015	97%	93,376	6,979,373	2%	1,592	14,608	67,463	2%	1,750	45,992
2016	95%	109,366	8,447,742	2%	1,998	19,377	88,913	3%	3,230	88,645
2017	91%	132,055	10,809,831	4%	5,994	61,088	279,650	5%	7,052	203,451
2018	87%	137,285	11,794,487	4%	6,483	69,602	317,087	9%	14,800	449,301
2019	88%	141,083	12,595,274	3%	5,505	64,430	274,520	8%	13,018	416,452
2020	86%	135,652	12,343,563	4%	6,558	82,023	336,557	9%	14,744	498,290
2021	85%	189,590	17,659,856	4%	9,979	135,046	521,355	10%	22,644	801,678
2022	84%	253,809	24,240,958	5%	14,007	218,733	693,952	11%	32,657	1,210,322
2023	84%	291,017	28,467,215	5%	16,137	271,680	807,271	11%	39,377	1,526,695
2024	83%	329,600	32,998,938	5%	18,166	329,087	916,198	12%	47,021	1,906,128
2025	83%	371,783	38,066,268	5%	20,520	399,967	1,039,937	12%	54,873	2,325,226
2026	85%	424,233	44,379,743	4%	20,675	421,047	1,090,413	11%	53,811	2,380,112
2027	85%	468,739	51,160,857	4%	22,823	485,341	1,253,824	11%	60,947	2,812,115
2028	85%	508,037	57,813,793	4%	24,583	545,508	1,406,015	11%	67,997	3,270,853
2029	84%	549,764	65,186,938	4%	26,362	610,009	1,568,829	12%	75,286	3,773,157
2030	84%	583,369	72,028,242	4%	27,764	669,514	1,718,317	12%	82,893	4,325,829
2031	84%	621,402	79,845,628	4%	29,575	742,704	1,902,479	12%	88,297	4,795,314
2032	84%	652,332	87,185,723	4%	31,047	811,564	2,074,749	12%	92,692	5,235,411
2033	84%	686,690	95,441,034	4%	32,682	888,696	2,267,776	12%	97,574	5,728,006
2034	84%	712,396	102,926,116	4%	33,905	958,694	2,441,908	12%	101,227	6,173,591
2035	84%	742,681	111,447,763	4%	35,347	1,038,360	2,640,531	12%	105,530	6,681,472
2036	84%	764,974	119,166,985	4%	36,408	1,110,551	2,819,782	12%	108,697	7,140,339
2037	84%	783,440	126,588,190	4%	37,287	1,179,840	2,992,407	12%	111,321	7,581,528
2038	84%	805,975	134,822,728	4%	38,359	1,256,478	3,185,885	12%	114,524	8,075,024
2039	84%	817,118	140,992,663	4%	38,889	1,313,727	3,332,835	12%	116,107	8,451,703
2040	84%	739,955	131,287,793	4%	35,217	1,222,994	3,106,042	12%	105,142	7,882,098

Table A-29. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 0 in Calendar Year 2040
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Model Year	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
1996	0%	0	0	0%	0	0	33	0.02	0.007
1997	0%	0	0	0%	0	0	42	0.03	0.009
1998	0%	0	0	0%	0	0	47	0.02	0.009
1999	0%	0	0	0%	0	0	50	0.02	0.008
2000	0%	0	0	0%	0	0	63	0.01	0.009
2001	0%	0	0	0%	0	0	66	0.01	0.009
2002	0%	0	0	0%	0	0	71	0.01	0.009
2003	0%	0	0	0%	0	0	81	0.01	0.010
2004	0%	0	0	0%	0	0	85	0.007	0.003
2005	0%	0	0	0%	0	0	105	0.008	0.004
2006	0%	0	0	0%	0	0	116	0.007	0.004
2007	0%	0	0	0%	0	0	133	0.008	0.005
2008	0%	0	0	0%	0	0	124	0.007	0.004
2009	0%	0	0	0%	0	0	105	0.006	0.004
2010	0%	0	0	0%	0	0	128	0.007	0.005
2011	0%	0	0	0%	0	0	152	0.008	0.006
2012	0%	0	0	0%	0	0	245	0.01	0.009
2013	0%	0	0	0%	0	0	341	0.02	0.01
2014	0%	0	0	0%	0	0	406	0.02	0.02
2015	0%	0	0	0%	0	0	577	0.03	0.02
2016	0%	0	0	0%	0	0	699	0.04	0.03
2017	0%	0	0	0%	0	0	908	0.04	0.03
2018	0%	0	0	0%	0	0	992	0.05	0.04
2019	0%	0	0	0%	0	0	1,054	0.05	0.04
2020	0%	0	0	0%	0	0	1,038	0.04	0.04
2021	0%	0	0	0%	0	0	1,489	0.06	0.05
2022	0%	0	0	0%	0	0	2,041	0.07	0.07
2023	0%	0	0	0%	0	0	2,397	0.08	0.08
2024	0%	0	0	0%	0	0	2,777	0.08	0.10
2025	0%	0	0	0%	0	0	3,202	0.08	0.10
2026	0%	0	0	0%	0	0	3,723	0.09	0.12
2027	0%	0	0	0%	0	0	4,291	0.10	0.13
2028	0%	0	0	0%	0	0	4,848	0.11	0.15
2029	0%	0	0	0%	0	0	5,465	0.12	0.16
2030	0%	0	0	0%	0	0	6,038	0.13	0.17
2031	0%	0	0	0%	0	0	6,693	0.14	0.18
2032	0%	0	0	0%	0	0	7,308	0.14	0.19
2033	0%	0	0	0%	0	0	8,000	0.15	0.20
2034	0%	0	0	0%	0	0	8,627	0.16	0.21
2035	0%	0	0	0%	0	0	9,341	0.16	0.21
2036	0%	0	0	0%	0	0	9,987	0.16	0.22
2037	0%	0	0	0%	0	0	10,609	0.17	0.22
2038	0%	0	0	0%	0	0	11,299	0.17	0.22
2039	0%	0	0	0%	0	0	11,816	0.17	0.21
2040	0%	0	0	0%	0	0	11,003	0.15	0.18

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-17) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-19. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

Table A-30. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 0 in Calendar Year 2045

	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fuel Consumption[3] (MJ of electricity/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of electricity/day)
2001	100%	17,581	492,838	0%	0	0	0	0%	1	13
2002	100%	17,396	519,815	0%	0	0	0	0%	7	79
2003	100%	18,261	584,063	0%	0	0	0	0%	1	12
2004	100%	17,485	620,429	0%	0	0	0	0%	1	8
2005	100%	19,931	744,101	0%	0	0	0	0%	1	11
2006	100%	20,294	810,536	0%	0	0	0	0%	1	13
2007	100%	21,610	895,705	0%	0	0	0	0%	2	26
2008	100%	17,913	797,202	0%	0	0	0	0%	8	112
2009	100%	14,142	635,358	0%	0	0	0	0%	2	35
2010	100%	16,923	735,246	0%	1	3	15	0%	9	147
2011	99%	16,799	809,857	0%	30	158	790	1%	101	1,691
2012	98%	25,037	1,225,371	1%	300	1,692	8,301	1%	133	2,322
2013	97%	31,446	1,584,333	2%	594	3,560	17,255	1%	442	8,105
2014	96%	32,442	1,745,658	3%	890	5,695	27,363	1%	489	9,437
2015	97%	41,547	2,333,580	2%	708	4,833	22,999	2%	777	15,810
2016	95%	46,072	2,687,564	2%	841	6,105	28,783	3%	1,354	28,787
2017	91%	52,700	3,274,039	4%	2,391	18,339	86,121	5%	2,789	62,457
2018	87%	52,549	3,444,774	4%	2,479	20,175	94,087	9%	5,607	132,466
2019	88%	52,919	3,622,227	3%	2,063	18,391	80,115	8%	4,832	120,601
2020	86%	51,080	3,577,777	4%	2,469	23,635	98,982	9%	5,552	146,669
2021	85%	72,808	5,249,034	4%	3,832	39,919	157,067	10%	8,696	241,288
2022	84%	101,322	7,527,271	5%	5,592	67,570	218,488	11%	13,037	379,660
2023	84%	122,476	9,364,450	5%	6,792	88,932	269,022	11%	16,572	506,226
2024	83%	148,333	11,660,897	5%	8,175	115,750	327,717	12%	21,161	677,755
2025	83%	179,162	14,468,745	5%	9,889	151,350	399,826	12%	26,443	887,822
2026	85%	219,761	18,208,793	4%	10,710	171,981	451,908	11%	27,875	979,732
2027	85%	258,741	22,456,424	4%	12,598	212,114	555,489	11%	33,642	1,237,162
2028	85%	300,679	27,310,373	4%	14,549	256,617	669,890	11%	40,244	1,547,489
2029	84%	343,168	32,595,097	4%	16,455	303,793	790,664	12%	46,994	1,888,561
2030	84%	386,794	38,383,317	4%	18,409	355,407	922,379	12%	54,961	2,306,853
2031	84%	431,003	44,656,861	4%	20,513	413,850	1,071,177	12%	61,243	2,683,184
2032	84%	477,078	51,574,684	4%	22,706	478,352	1,235,027	12%	67,790	3,098,236
2033	84%	518,165	58,405,552	4%	24,661	542,144	1,396,451	12%	73,628	3,508,235
2034	84%	561,504	65,947,281	4%	26,724	612,627	1,574,494	12%	79,786	3,960,912
2035	84%	597,713	73,101,152	4%	28,447	679,589	1,742,931	12%	84,931	4,390,345
2036	84%	636,105	80,962,667	4%	30,274	753,214	1,927,965	12%	90,386	4,862,426
2037	84%	667,180	88,329,199	4%	31,753	822,345	2,100,691	12%	94,802	5,304,019
2038	84%	701,654	96,602,944	4%	33,394	899,667	2,293,959	12%	99,700	5,797,554
2039	84%	727,252	104,086,433	4%	34,612	969,669	2,467,860	12%	103,338	6,242,847
2040	84%	757,391	112,590,629	4%	36,047	1,049,189	2,665,871	12%	107,620	6,749,460
2041	84%	779,333	120,269,438	4%	37,091	1,121,019	2,843,979	12%	110,738	7,205,621
2042	84%	797,208	127,609,859	4%	37,942	1,189,565	3,014,512	12%	113,278	7,641,631
2043	84%	818,902	135,699,051	4%	38,974	1,264,855	3,204,367	12%	116,360	8,126,069
2044	84%	828,649	141,621,489	4%	39,438	1,319,800	3,345,305	12%	117,745	8,487,539
2045	84%	748,769	131,560,435	4%	35,636	1,225,722	3,110,204	12%	106,395	7,896,358

Table A-30. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 0 in Calendar Year 2045
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
2001	0%	0	0	0%	0	0	40	0.01	0.006
2002	0%	0	0	0%	0	0	43	0.01	0.006
2003	0%	0	0	0%	0	0	48	0.01	0.006
2004	0%	0	0	0%	0	0	51	0.005	0.002
2005	0%	0	0	0%	0	0	61	0.005	0.002
2006	0%	0	0	0%	0	0	66	0.005	0.002
2007	0%	0	0	0%	0	0	73	0.005	0.003
2008	0%	0	0	0%	0	0	65	0.005	0.003
2009	0%	0	0	0%	0	0	52	0.003	0.002
2010	0%	0	0	0%	0	0	60	0.004	0.003
2011	0%	0	0	0%	0	0	66	0.004	0.003
2012	0%	0	0	0%	0	0	101	0.006	0.004
2013	0%	0	0	0%	0	0	131	0.008	0.006
2014	0%	0	0	0%	0	0	145	0.009	0.006
2015	0%	0	0	0%	0	0	193	0.01	0.008
2016	0%	0	0	0%	0	0	222	0.01	0.009
2017	0%	0	0	0%	0	0	275	0.02	0.01
2018	0%	0	0	0%	0	0	290	0.02	0.01
2019	0%	0	0	0%	0	0	303	0.02	0.01
2020	0%	0	0	0%	0	0	301	0.01	0.01
2021	0%	0	0	0%	0	0	443	0.02	0.02
2022	0%	0	0	0%	0	0	634	0.03	0.03
2023	0%	0	0	0%	0	0	789	0.03	0.03
2024	0%	0	0	0%	0	0	982	0.03	0.04
2025	0%	0	0	0%	0	0	1,217	0.04	0.04
2026	0%	0	0	0%	0	0	1,528	0.04	0.06
2027	0%	0	0	0%	0	0	1,884	0.05	0.07
2028	0%	0	0	0%	0	0	2,291	0.06	0.08
2029	0%	0	0	0%	0	0	2,733	0.07	0.09
2030	0%	0	0	0%	0	0	3,218	0.08	0.11
2031	0%	0	0	0%	0	0	3,744	0.09	0.12
2032	0%	0	0	0%	0	0	4,324	0.10	0.13
2033	0%	0	0	0%	0	0	4,896	0.11	0.15
2034	0%	0	0	0%	0	0	5,528	0.12	0.16
2035	0%	0	0	0%	0	0	6,128	0.13	0.17
2036	0%	0	0	0%	0	0	6,786	0.14	0.18
2037	0%	0	0	0%	0	0	7,404	0.15	0.19
2038	0%	0	0	0%	0	0	8,097	0.15	0.20
2039	0%	0	0	0%	0	0	8,724	0.16	0.21
2040	0%	0	0	0%	0	0	9,436	0.16	0.22
2041	0%	0	0	0%	0	0	10,080	0.17	0.22
2042	0%	0	0	0%	0	0	10,695	0.17	0.22
2043	0%	0	0	0%	0	0	11,372	0.17	0.22
2044	0%	0	0	0%	0	0	11,869	0.17	0.21
2045	0%	0	0	0%	0	0	11,026	0.15	0.18

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-20) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-22. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

Table A-31. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 0 in Calendar Year 2050
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fuel Consumption[3] (MJ of electricity/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of electricity/day)
2006	100%	17,095	495,171	0%	0	0	0	0%	1	9
2007	100%	17,938	537,342	0%	0	0	0	0%	2	18
2008	100%	14,711	473,301	0%	0	0	0	0%	6	73
2009	100%	11,643	378,435	0%	0	0	0	0%	2	24
2010	100%	13,584	427,686	0%	0	2	9	0%	8	94
2011	99%	13,206	463,001	0%	24	89	472	1%	79	1,039
2012	98%	18,883	674,484	1%	226	915	4,745	1%	100	1,368
2013	97%	22,656	836,306	2%	428	1,850	9,427	1%	314	4,504
2014	96%	21,908	865,904	3%	601	2,783	14,018	1%	326	4,894
2015	97%	26,586	1,101,721	2%	453	2,250	11,180	2%	491	7,761
2016	95%	27,295	1,177,776	2%	498	2,640	12,955	3%	790	13,009
2017	91%	29,325	1,351,831	4%	1,329	7,482	36,484	5%	1,525	26,393
2018	87%	27,113	1,322,228	4%	1,278	7,675	37,071	9%	2,868	52,384
2019	89%	25,304	1,294,975	3%	986	6,516	29,339	8%	2,292	44,244
2020	86%	22,760	1,198,129	4%	1,100	7,856	33,925	9%	2,474	50,596
2021	85%	30,740	1,673,570	4%	1,618	12,642	51,178	10%	3,671	78,995
2022	84%	40,577	2,287,454	5%	2,239	20,404	67,892	11%	5,221	118,112
2023	84%	47,100	2,747,369	5%	2,612	25,936	80,590	11%	6,373	151,554
2024	83%	55,817	3,364,077	5%	3,076	33,204	96,428	12%	7,963	198,997
2025	83%	67,473	4,197,128	5%	3,724	43,672	118,177	12%	9,959	261,533
2026	85%	84,407	5,416,910	4%	4,114	50,877	136,660	11%	10,706	295,109
2027	85%	103,307	6,979,357	4%	5,030	65,571	175,255	11%	13,432	388,383
2028	85%	126,564	8,992,281	4%	6,124	84,058	223,637	11%	16,940	513,531
2029	84%	154,469	11,529,035	4%	7,407	106,921	283,234	12%	21,153	672,043
2030	84%	186,433	14,603,793	4%	8,873	134,574	355,060	12%	26,491	881,507
2031	84%	223,318	18,340,139	4%	10,628	169,173	444,687	12%	31,732	1,105,371
2032	84%	263,400	22,659,223	4%	12,536	209,209	548,060	12%	37,427	1,364,096
2033	84%	306,740	27,615,605	4%	14,599	255,208	666,413	12%	43,586	1,661,080
2034	84%	350,568	33,005,323	4%	16,685	305,290	794,782	12%	49,813	1,984,022
2035	84%	396,387	38,990,628	4%	18,865	360,976	937,068	12%	56,324	2,343,007
2036	84%	441,302	45,323,709	4%	21,003	419,968	1,087,267	12%	62,706	2,722,815
2037	84%	488,028	52,297,119	4%	23,227	484,984	1,252,421	12%	69,345	3,141,091
2038	84%	529,547	59,167,502	4%	25,203	549,142	1,414,757	12%	75,245	3,553,333
2039	84%	573,298	66,745,954	4%	27,285	619,964	1,593,644	12%	81,462	4,008,057
2040	84%	609,667	73,915,132	4%	29,016	687,067	1,762,410	12%	86,629	4,438,238
2041	84%	648,178	81,784,379	4%	30,849	760,761	1,947,591	12%	92,102	4,910,573
2042	84%	679,210	89,145,447	4%	32,326	829,839	2,120,143	12%	96,511	5,351,582
2043	84%	713,632	97,406,694	4%	33,964	907,037	2,313,062	12%	101,402	5,844,049
2044	84%	738,970	104,857,227	4%	35,170	976,725	2,486,125	12%	105,002	6,287,030
2045	84%	768,833	113,315,730	4%	36,591	1,055,810	2,682,995	12%	109,246	6,790,499
2046	84%	790,339	120,930,825	4%	37,615	1,127,036	2,859,529	12%	112,302	7,242,409
2047	84%	807,527	128,164,176	4%	38,433	1,194,575	3,027,460	12%	114,744	7,671,556
2048	84%	828,277	136,082,929	4%	39,420	1,268,267	3,213,196	12%	117,693	8,145,301
2049	84%	836,615	141,751,914	4%	39,817	1,320,843	3,348,041	12%	118,877	8,491,081
2050	84%	754,352	131,380,558	4%	35,902	1,223,884	3,105,533	12%	107,188	7,881,262

Table A-31. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 0 in Calendar Year 2050

	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
2006	0%	0	0	0%	0	0	41	0.004	0.002
2007	0%	0	0	0%	0	0	44	0.004	0.002
2008	0%	0	0	0%	0	0	39	0.003	0.002
2009	0%	0	0	0%	0	0	31	0.002	0.001
2010	0%	0	0	0%	0	0	35	0.003	0.002
2011	0%	0	0	0%	0	0	38	0.003	0.002
2012	0%	0	0	0%	0	0	56	0.004	0.003
2013	0%	0	0	0%	0	0	69	0.005	0.003
2014	0%	0	0	0%	0	0	72	0.005	0.003
2015	0%	0	0	0%	0	0	91	0.006	0.004
2016	0%	0	0	0%	0	0	97	0.007	0.005
2017	0%	0	0	0%	0	0	114	0.008	0.005
2018	0%	0	0	0%	0	0	111	0.007	0.005
2019	0%	0	0	0%	0	0	108	0.006	0.005
2020	0%	0	0	0%	0	0	101	0.006	0.004
2021	0%	0	0	0%	0	0	141	0.008	0.006
2022	0%	0	0	0%	0	0	193	0.009	0.009
2023	0%	0	0	0%	0	0	232	0.01	0.01
2024	0%	0	0	0%	0	0	283	0.01	0.01
2025	0%	0	0	0%	0	0	353	0.01	0.01
2026	0%	0	0	0%	0	0	455	0.02	0.02
2027	0%	0	0	0%	0	0	586	0.02	0.02
2028	0%	0	0	0%	0	0	755	0.02	0.03
2029	0%	0	0	0%	0	0	967	0.03	0.04
2030	0%	0	0	0%	0	0	1,225	0.04	0.05
2031	0%	0	0	0%	0	0	1,538	0.04	0.06
2032	0%	0	0	0%	0	0	1,900	0.05	0.07
2033	0%	0	0	0%	0	0	2,316	0.06	0.08
2034	0%	0	0	0%	0	0	2,767	0.07	0.09
2035	0%	0	0	0%	0	0	3,269	0.08	0.11
2036	0%	0	0	0%	0	0	3,800	0.09	0.12
2037	0%	0	0	0%	0	0	4,384	0.10	0.14
2038	0%	0	0	0%	0	0	4,960	0.11	0.15
2039	0%	0	0	0%	0	0	5,595	0.12	0.16
2040	0%	0	0	0%	0	0	6,196	0.13	0.18
2041	0%	0	0	0%	0	0	6,855	0.14	0.19
2042	0%	0	0	0%	0	0	7,472	0.15	0.20
2043	0%	0	0	0%	0	0	8,164	0.15	0.21
2044	0%	0	0	0%	0	0	8,788	0.16	0.21
2045	0%	0	0	0%	0	0	9,497	0.17	0.22
2046	0%	0	0	0%	0	0	10,135	0.17	0.22
2047	0%	0	0	0%	0	0	10,741	0.17	0.22
2048	0%	0	0	0%	0	0	11,405	0.17	0.22
2049	0%	0	0	0%	0	0	11,880	0.17	0.21
2050	0%	0	0	0%	0	0	11,011	0.15	0.18

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-23) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-25. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

Table A-32. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 1a in Calendar Year 2026
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Model Year	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fuel Consumption[3] (MJ of electricity/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of electricity/day)
1982	100%	4,657	174,227	0%	0	0	0	0%	1	9
1983	100%	5,273	206,541	0%	0	0	0	0%	1	9
1984	100%	7,858	329,345	0%	0	0	0	0%	1	13
1985	100%	10,024	435,286	0%	0	0	0	0%	0	0
1986	100%	10,647	463,741	0%	0	0	0	0%	0	0
1987	100%	12,832	586,622	0%	0	0	0	0%	1	18
1988	100%	12,139	592,716	0%	0	0	0	0%	0	0
1989	100%	14,970	774,940	0%	0	0	0	0%	1	14
1990	100%	18,044	991,990	0%	0	0	0	0%	0	0
1991	100%	21,281	1,234,023	0%	0	0	0	0%	0	0
1992	100%	18,332	1,127,213	0%	0	0	0	0%	0	0
1993	100%	20,138	1,231,512	0%	0	0	0	0%	3	46
1994	100%	22,840	1,473,479	0%	0	0	0	0%	0	7
1995	100%	29,675	2,022,331	0%	0	0	0	0%	2	31
1996	100%	29,436	2,128,971	0%	0	0	0	0%	0	0
1997	100%	39,761	2,978,637	0%	0	0	0	0%	4	95
1998	100%	48,817	3,777,000	0%	0	0	0	0%	5	107
1999	100%	56,921	4,546,344	0%	0	0	0	0%	4	98
2000	100%	76,964	6,529,441	0%	0	0	0	0%	1	31
2001	100%	87,221	7,793,387	0%	0	0	0	0%	6	155
2002	100%	102,135	9,644,077	0%	0	0	0	0%	37	1,030
2003	100%	127,287	12,720,322	0%	0	0	0	0%	7	196
2004	100%	143,690	15,732,253	0%	0	0	0	0%	5	155
2005	100%	191,623	21,752,720	0%	0	0	0	0%	7	213
2006	100%	225,488	26,980,154	0%	0	0	0	0%	11	389
2007	100%	275,180	33,665,694	0%	0	0	0	0%	23	834
2008	100%	258,265	33,318,492	0%	0	0	0	0%	126	4,586
2009	100%	229,086	29,357,696	0%	0	0	0	0%	34	1,333
2010	100%	292,924	35,681,010	0%	11	154	687	0%	161	6,445
2011	99%	307,002	40,824,099	0%	548	8,280	37,013	1%	1,890	79,947
2012	98%	465,759	61,806,971	1%	5,585	88,399	392,722	1%	2,528	111,558
2013	97%	592,447	79,686,217	2%	11,199	185,018	819,056	1%	8,583	395,185
2014	96%	599,553	84,574,041	3%	16,462	284,537	1,256,341	1%	9,356	449,554
2015	96%	738,821	106,767,996	2%	12,602	227,577	1,002,629	2%	14,202	712,794
2016	95%	754,102	111,262,248	2%	13,790	259,774	1,141,452	3%	23,130	1,205,441
2017	91%	794,462	122,943,456	4%	36,125	706,874	3,105,093	5%	43,901	2,385,744
2018	86%	705,513	113,371,002	4%	33,412	680,299	2,980,537	10%	78,294	4,428,841
2019	88%	622,322	102,867,416	3%	24,317	533,860	2,191,127	8%	58,438	3,447,620
2020	86%	508,892	85,019,301	4%	24,600	571,597	2,264,467	9%	55,310	3,416,834
2021	85%	619,444	104,948,162	4%	32,604	811,289	3,029,262	10%	73,983	4,748,184
2022	84%	724,703	124,757,619	5%	39,994	1,137,171	3,486,691	11%	93,245	6,212,763
2023	84%	731,635	127,883,688	5%	40,571	1,231,754	3,543,090	11%	98,996	6,843,258
2024	83%	747,543	132,487,563	5%	41,200	1,332,140	3,598,733	12%	106,645	7,641,910
2025	83%	758,530	135,969,595	5%	41,866	1,438,799	3,640,575	12%	111,956	8,303,968
2026	65%	540,131	97,639,769	4%	34,449	1,220,027	3,088,034	31%	256,391	19,581,287

Table A-32. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 1a in Calendar Year 2026

Model Year	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
1982	0%	0	0	0%	0	0	14	0.008	0.003
1983	0%	0	0	0%	0	0	17	0.009	0.003
1984	0%	0	0	0%	0	0	27	0.01	0.005
1985	0%	0	0	0%	0	0	36	0.02	0.006
1986	0%	0	0	0%	0	0	38	0.02	0.007
1987	0%	0	0	0%	0	0	48	0.02	0.009
1988	0%	0	0	0%	0	0	49	0.02	0.009
1989	0%	0	0	0%	0	0	63	0.03	0.01
1990	0%	0	0	0%	0	0	81	0.04	0.01
1991	0%	0	0	0%	0	0	101	0.05	0.02
1992	0%	0	0	0%	0	0	92	0.04	0.02
1993	0%	0	0	0%	0	0	101	0.05	0.02
1994	0%	0	0	0%	0	0	121	0.06	0.02
1995	0%	0	0	0%	0	0	166	0.08	0.03
1996	0%	0	0	0%	0	0	174	0.09	0.04
1997	0%	0	0	0%	0	0	244	0.11	0.05
1998	0%	0	0	0%	0	0	309	0.11	0.05
1999	0%	0	0	0%	0	0	372	0.09	0.06
2000	0%	0	0	0%	0	0	535	0.08	0.07
2001	0%	0	0	0%	0	0	638	0.09	0.07
2002	0%	0	0	0%	0	0	790	0.11	0.09
2003	0%	0	0	0%	0	0	1,041	0.13	0.11
2004	0%	0	0	0%	0	0	1,288	0.07	0.04
2005	0%	0	0	0%	0	0	1,781	0.08	0.05
2006	0%	0	0	0%	0	0	2,209	0.09	0.06
2007	0%	0	0	0%	0	0	2,756	0.11	0.08
2008	0%	0	0	0%	0	0	2,728	0.10	0.08
2009	0%	0	0	0%	0	0	2,404	0.09	0.07
2010	0%	0	0	0%	0	0	2,921	0.11	0.09
2011	0%	0	0	0%	0	0	3,345	0.12	0.10
2012	0%	0	0	0%	0	0	5,092	0.18	0.15
2013	0%	0	0	0%	0	0	6,591	0.22	0.19
2014	0%	0	0	0%	0	0	7,027	0.23	0.20
2015	0%	0	0	0%	0	0	8,823	0.28	0.24
2016	0%	0	0	0%	0	0	9,203	0.32	0.26
2017	0%	0	0	0%	0	0	10,320	0.32	0.27
2018	0%	0	0	0%	0	0	9,526	0.28	0.24
2019	0%	0	0	0%	0	0	8,601	0.23	0.21
2020	0%	0	0	0%	0	0	7,146	0.19	0.17
2021	0%	0	0	0%	0	0	8,840	0.21	0.21
2022	0%	0	0	0%	0	0	10,500	0.23	0.24
2023	0%	0	0	0%	0	0	10,760	0.21	0.23
2024	0%	0	0	0%	0	0	11,142	0.20	0.22
2025	0%	0	0	0%	0	0	11,430	0.16	0.20
2026	0%	0	0	0%	0	0	8,247	0.11	0.14

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-8) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-10. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

Table A-33. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 1a in Calendar Year 2030
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fuel Consumption[3] (MJ of electricity/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of electricity/day)
1986	100%	9,277	319,606	0%	0	0	0	0%	0	0
1987	100%	11,036	395,358	0%	0	0	0	0%	1	13
1988	100%	10,287	394,106	0%	0	0	0	0%	0	0
1989	100%	12,682	513,141	0%	0	0	0	0%	1	10
1990	100%	15,335	660,988	0%	0	0	0	0%	0	0
1991	100%	17,755	806,207	0%	0	0	0	0%	0	0
1992	100%	14,968	722,403	0%	0	0	0	0%	0	0
1993	100%	15,722	757,504	0%	0	0	0	0%	2	30
1994	100%	16,938	862,749	0%	0	0	0	0%	0	4
1995	100%	21,266	1,147,175	0%	0	0	0	0%	1	18
1996	100%	20,041	1,148,835	0%	0	0	0	0%	0	0
1997	100%	25,571	1,519,989	0%	0	0	0	0%	3	55
1998	100%	29,544	1,816,366	0%	0	0	0	0%	3	55
1999	100%	32,392	2,061,329	0%	0	0	0	0%	2	47
2000	100%	41,346	2,802,701	0%	0	0	0	0%	1	14
2001	100%	44,766	3,209,806	0%	0	0	0	0%	3	65
2002	100%	49,911	3,795,455	0%	0	0	0	0%	18	424
2003	100%	59,781	4,832,777	0%	0	0	0	0%	3	76
2004	100%	65,751	5,844,031	0%	0	0	0	0%	2	59
2005	100%	86,903	8,039,211	0%	0	0	0	0%	3	81
2006	100%	103,055	10,092,547	0%	0	0	0	0%	5	144
2007	100%	128,610	12,929,139	0%	0	0	0	0%	11	328
2008	100%	125,543	13,361,675	0%	0	0	0	0%	60	1,794
2009	100%	116,809	12,395,606	0%	0	0	0	0%	18	572
2010	100%	158,274	16,020,574	0%	6	69	311	0%	86	2,863
2011	99%	175,648	19,479,572	0%	313	3,932	17,791	1%	1,076	37,957
2012	98%	282,481	31,367,919	1%	3,387	44,658	200,590	1%	1,526	56,296
2013	97%	378,095	42,683,040	2%	7,146	98,660	441,197	1%	5,433	209,483
2014	96%	402,992	47,862,257	3%	11,064	160,332	714,692	1%	6,227	251,167
2015	97%	518,113	63,218,662	2%	8,836	134,191	596,394	2%	9,879	417,410
2016	95%	553,278	69,108,331	2%	10,115	160,689	711,773	3%	16,817	738,736
2017	91%	604,853	79,402,357	4%	27,493	454,641	2,012,619	5%	33,194	1,524,212
2018	86%	555,971	75,960,952	4%	26,314	453,896	2,003,609	10%	61,332	2,941,765
2019	88%	505,059	71,135,364	3%	19,734	368,011	1,521,560	8%	47,387	2,378,873
2020	86%	424,894	60,588,792	4%	20,540	406,324	1,621,195	9%	46,181	2,435,627
2021	85%	528,088	76,514,975	4%	27,796	590,252	2,219,126	10%	63,072	3,464,139
2022	84%	629,123	92,802,888	5%	34,719	844,508	2,607,459	11%	80,947	4,626,137
2023	84%	652,013	97,885,688	5%	36,155	941,473	2,725,229	11%	88,223	5,242,684
2024	83%	670,253	102,369,934	5%	36,940	1,028,217	2,790,931	12%	95,619	5,905,793
2025	83%	697,118	108,259,056	5%	38,476	1,144,799	2,904,428	12%	102,891	6,603,088
2026	65%	562,392	88,712,763	4%	35,869	1,108,113	2,804,580	31%	266,958	17,769,266
2027	57%	506,170	82,823,038	4%	36,682	1,175,675	2,972,420	39%	345,166	23,832,150
2028	49%	448,945	76,077,298	4%	37,500	1,244,657	3,146,136	47%	429,769	30,729,889
2029	41%	382,216	66,862,077	4%	37,726	1,292,471	3,268,769	55%	512,292	37,813,655
2030	32%	271,278	48,854,015	4%	33,914	1,195,950	3,027,919	64%	542,551	41,225,912

Table A-33. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 1a in Calendar Year 2030

	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
1986	0%	0	0	0%	0	0	26	0.01	0.005
1987	0%	0	0	0%	0	0	32	0.02	0.006
1988	0%	0	0	0%	0	0	32	0.02	0.006
1989	0%	0	0	0%	0	0	42	0.02	0.008
1990	0%	0	0	0%	0	0	54	0.03	0.010
1991	0%	0	0	0%	0	0	66	0.03	0.01
1992	0%	0	0	0%	0	0	59	0.03	0.01
1993	0%	0	0	0%	0	0	62	0.03	0.01
1994	0%	0	0	0%	0	0	71	0.04	0.01
1995	0%	0	0	0%	0	0	94	0.05	0.02
1996	0%	0	0	0%	0	0	94	0.05	0.02
1997	0%	0	0	0%	0	0	124	0.06	0.02
1998	0%	0	0	0%	0	0	149	0.06	0.03
1999	0%	0	0	0%	0	0	169	0.05	0.03
2000	0%	0	0	0%	0	0	229	0.04	0.03
2001	0%	0	0	0%	0	0	263	0.04	0.03
2002	0%	0	0	0%	0	0	311	0.05	0.04
2003	0%	0	0	0%	0	0	396	0.05	0.04
2004	0%	0	0	0%	0	0	478	0.03	0.01
2005	0%	0	0	0%	0	0	658	0.03	0.02
2006	0%	0	0	0%	0	0	826	0.04	0.02
2007	0%	0	0	0%	0	0	1,059	0.05	0.03
2008	0%	0	0	0%	0	0	1,094	0.05	0.03
2009	0%	0	0	0%	0	0	1,015	0.04	0.03
2010	0%	0	0	0%	0	0	1,312	0.06	0.04
2011	0%	0	0	0%	0	0	1,596	0.06	0.05
2012	0%	0	0	0%	0	0	2,585	0.10	0.08
2013	0%	0	0	0%	0	0	3,531	0.13	0.11
2014	0%	0	0	0%	0	0	3,977	0.15	0.12
2015	0%	0	0	0%	0	0	5,225	0.19	0.16
2016	0%	0	0	0%	0	0	5,716	0.22	0.18
2017	0%	0	0	0%	0	0	6,666	0.24	0.20
2018	0%	0	0	0%	0	0	6,383	0.22	0.18
2019	0%	0	0	0%	0	0	5,949	0.19	0.17
2020	0%	0	0	0%	0	0	5,093	0.15	0.14
2021	0%	0	0	0%	0	0	6,446	0.18	0.18
2022	0%	0	0	0%	0	0	7,811	0.20	0.21
2023	0%	0	0	0%	0	0	8,237	0.19	0.21
2024	0%	0	0	0%	0	0	8,610	0.18	0.21
2025	0%	0	0	0%	0	0	9,101	0.16	0.20
2026	0%	0	0	0%	0	0	7,493	0.12	0.16
2027	0%	0	0	0%	0	0	7,024	0.11	0.14
2028	0%	0	0	0%	0	0	6,486	0.10	0.12
2029	0%	0	0	0%	0	0	5,742	0.08	0.10
2030	0%	0	0	0%	0	0	4,248	0.06	0.07

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-11) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-13. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

Table A-34. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 1a in Calendar Year 2035
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Model Year	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fuel Consumption[3] (MJ of electricity/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of electricity/day)
1991	100%	14,887	496,519	0%	0	0	0	0%	0	0
1992	100%	12,386	437,879	0%	0	0	0	0%	0	0
1993	100%	12,876	454,610	0%	0	0	0	0%	2	20
1994	100%	13,908	519,028	0%	0	0	0	0%	0	3
1995	100%	17,011	673,579	0%	0	0	0	0%	1	11
1996	100%	15,726	662,566	0%	0	0	0	0%	0	0
1997	100%	19,249	841,793	0%	0	0	0	0%	3	36
1998	100%	21,231	962,917	0%	0	0	0	0%	2	32
1999	100%	21,841	1,026,080	0%	0	0	0	0%	2	27
2000	100%	26,428	1,326,406	0%	0	0	0	0%	0	7
2001	100%	26,524	1,412,096	0%	0	0	0	0%	2	30
2002	100%	27,790	1,574,561	0%	0	0	0	0%	11	189
2003	100%	30,887	1,866,413	0%	0	0	0	0%	2	31
2004	100%	31,459	2,100,346	0%	0	0	0	0%	1	22
2005	100%	38,743	2,705,815	0%	0	0	0	0%	1	29
2006	100%	43,503	3,231,279	0%	0	0	0	0%	2	47
2007	100%	51,445	3,941,697	0%	0	0	0	0%	4	103
2008	100%	48,196	3,931,397	0%	0	0	0	0%	23	522
2009	100%	43,832	3,583,029	0%	0	0	0	0%	7	170
2010	100%	59,373	4,651,159	0%	2	20	92	0%	32	847
2011	99%	67,186	5,797,667	0%	120	1,161	5,375	1%	409	11,360
2012	98%	112,410	9,761,699	1%	1,348	13,798	63,245	1%	603	17,549
2013	97%	158,581	14,066,520	2%	2,997	32,296	147,122	1%	2,255	68,707
2014	96%	180,829	16,955,018	3%	4,964	56,441	255,982	1%	2,764	88,302
2015	97%	248,911	24,094,495	2%	4,244	50,842	229,574	2%	4,701	157,841
2016	95%	285,862	28,441,636	2%	5,224	65,752	295,555	3%	8,578	300,098
2017	91%	332,615	34,903,768	4%	15,110	198,715	892,263	5%	18,042	661,811
2018	86%	327,985	35,952,376	4%	15,507	213,599	955,739	9%	35,779	1,376,403
2019	88%	314,542	35,673,840	3%	12,281	183,606	769,058	8%	29,273	1,183,116
2020	86%	281,575	32,424,569	4%	13,612	216,540	874,542	9%	30,604	1,303,564
2021	85%	366,087	42,975,928	4%	19,269	330,198	1,255,839	10%	43,723	1,945,314
2022	84%	459,912	55,139,274	5%	25,381	499,808	1,561,702	11%	59,175	2,747,832
2023	84%	491,823	60,167,945	5%	27,272	576,729	1,688,911	11%	66,548	3,223,016
2024	83%	528,134	65,889,598	5%	29,108	659,860	1,811,619	12%	75,344	3,803,598
2025	83%	560,849	71,323,875	5%	30,955	752,392	1,930,200	12%	82,779	4,355,000
2026	65%	467,482	60,539,560	4%	29,815	754,625	1,930,143	31%	221,906	12,112,622
2027	57%	430,704	58,014,343	4%	31,213	822,291	2,099,102	39%	293,704	16,679,184
2028	49%	390,089	54,639,940	4%	32,584	892,959	2,275,365	47%	373,427	22,053,612
2029	41%	338,901	49,344,310	4%	33,451	953,218	2,424,492	55%	454,235	27,888,884
2030	32%	276,003	41,738,586	4%	34,505	1,021,517	2,594,022	64%	552,001	35,207,048
2031	24%	213,410	33,502,607	4%	35,573	1,093,525	2,772,634	72%	640,226	42,397,675
2032	18%	164,104	26,722,257	4%	36,472	1,163,085	2,945,735	78%	711,115	48,851,635
2033	12%	112,719	19,004,076	4%	37,578	1,240,654	3,141,258	84%	789,027	56,118,670
2034	6%	57,245	9,957,437	4%	38,168	1,299,952	3,293,065	90%	858,663	63,001,878
2035	0%	0	0	4%	34,638	1,213,298	3,076,767	96%	831,206	62,721,943

Table A-34. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 1a in Calendar Year 2035
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
1991	0%	0	0	0%	0	0	41	0.02	0.008
1992	0%	0	0	0%	0	0	36	0.02	0.007
1993	0%	0	0	0%	0	0	37	0.02	0.007
1994	0%	0	0	0%	0	0	42	0.02	0.008
1995	0%	0	0	0%	0	0	55	0.03	0.01
1996	0%	0	0	0%	0	0	54	0.04	0.01
1997	0%	0	0	0%	0	0	69	0.04	0.01
1998	0%	0	0	0%	0	0	79	0.03	0.01
1999	0%	0	0	0%	0	0	84	0.03	0.01
2000	0%	0	0	0%	0	0	109	0.02	0.01
2001	0%	0	0	0%	0	0	116	0.02	0.01
2002	0%	0	0	0%	0	0	129	0.02	0.02
2003	0%	0	0	0%	0	0	153	0.02	0.02
2004	0%	0	0	0%	0	0	172	0.01	0.006
2005	0%	0	0	0%	0	0	222	0.01	0.007
2006	0%	0	0	0%	0	0	265	0.01	0.008
2007	0%	0	0	0%	0	0	323	0.02	0.01
2008	0%	0	0	0%	0	0	322	0.02	0.01
2009	0%	0	0	0%	0	0	293	0.01	0.010
2010	0%	0	0	0%	0	0	381	0.02	0.01
2011	0%	0	0	0%	0	0	475	0.02	0.02
2012	0%	0	0	0%	0	0	804	0.04	0.03
2013	0%	0	0	0%	0	0	1,164	0.05	0.04
2014	0%	0	0	0%	0	0	1,409	0.06	0.05
2015	0%	0	0	0%	0	0	1,991	0.08	0.07
2016	0%	0	0	0%	0	0	2,353	0.11	0.08
2017	0%	0	0	0%	0	0	2,931	0.12	0.10
2018	0%	0	0	0%	0	0	3,022	0.12	0.10
2019	0%	0	0	0%	0	0	2,984	0.11	0.10
2020	0%	0	0	0%	0	0	2,726	0.10	0.09
2021	0%	0	0	0%	0	0	3,621	0.12	0.12
2022	0%	0	0	0%	0	0	4,642	0.14	0.15
2023	0%	0	0	0%	0	0	5,064	0.14	0.16
2024	0%	0	0	0%	0	0	5,543	0.14	0.16
2025	0%	0	0	0%	0	0	5,997	0.13	0.17
2026	0%	0	0	0%	0	0	5,115	0.10	0.14
2027	0%	0	0	0%	0	0	4,922	0.10	0.13
2028	0%	0	0	0%	0	0	4,660	0.09	0.12
2029	0%	0	0	0%	0	0	4,238	0.08	0.10
2030	0%	0	0	0%	0	0	3,630	0.06	0.08
2031	0%	0	0	0%	0	0	2,970	0.05	0.06
2032	0%	0	0	0%	0	0	2,429	0.04	0.05
2033	0%	0	0	0%	0	0	1,813	0.03	0.03
2034	0%	0	0	0%	0	0	1,085	0.02	0.02
2035	0%	0	0	0%	0	0	252	0.007	0.004

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-14) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-16. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

Table A-35. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 1a in Calendar Year 2040
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Model Year	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fuel Consumption[3] (MJ of electricity/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of electricity/day)
1996	100%	13,224	407,390	0%	0	0	0	0%	0	0
1997	100%	15,957	507,603	0%	0	0	0	0%	2	27
1998	100%	17,428	573,388	0%	0	0	0	0%	2	23
1999	100%	17,981	612,358	0%	0	0	0	0%	2	19
2000	100%	21,212	772,196	0%	0	0	0	0%	0	5
2001	100%	20,869	808,569	0%	0	0	0	0%	1	19
2002	100%	20,957	866,980	0%	0	0	0	0%	8	114
2003	100%	22,226	985,080	0%	0	0	0	0%	1	18
2004	100%	21,228	1,041,890	0%	0	0	0	0%	1	12
2005	100%	24,808	1,278,892	0%	0	0	0	0%	1	16
2006	100%	25,795	1,417,856	0%	0	0	0	0%	1	22
2007	100%	28,657	1,630,516	0%	0	0	0	0%	2	44
2008	100%	24,894	1,513,071	0%	0	0	0	0%	12	206
2009	100%	20,958	1,283,229	0%	0	0	0	0%	3	64
2010	100%	26,447	1,559,497	0%	1	7	31	0%	15	295
2011	99%	28,341	1,849,619	0%	51	367	1,752	1%	172	3,720
2012	98%	44,963	2,967,860	1%	539	4,153	19,596	1%	240	5,433
2013	97%	60,869	4,125,844	2%	1,150	9,385	43,891	1%	858	20,372
2014	96%	67,874	4,888,299	3%	1,863	16,131	74,982	1%	1,028	25,649
2015	97%	93,376	6,979,373	2%	1,592	14,608	67,463	2%	1,750	45,992
2016	95%	109,366	8,447,742	2%	1,998	19,377	88,913	3%	3,230	88,645
2017	91%	132,055	10,809,831	4%	5,994	61,088	279,650	5%	7,052	203,451
2018	87%	137,285	11,794,487	4%	6,483	69,602	317,087	9%	14,800	449,301
2019	88%	141,083	12,595,274	3%	5,505	64,430	274,520	8%	13,018	416,452
2020	86%	135,652	12,343,563	4%	6,558	82,023	336,557	9%	14,744	498,290
2021	85%	189,590	17,659,856	4%	9,979	135,046	521,355	10%	22,644	801,678
2022	84%	253,809	24,240,958	5%	14,007	218,733	693,952	11%	32,657	1,210,322
2023	84%	291,017	28,467,215	5%	16,137	271,680	807,271	11%	39,377	1,526,695
2024	83%	329,600	32,998,938	5%	18,166	329,087	916,198	12%	47,021	1,906,128
2025	83%	371,783	38,066,268	5%	20,520	399,967	1,039,937	12%	54,873	2,325,226
2026	65%	324,168	33,911,685	4%	20,675	421,047	1,090,413	31%	153,877	6,765,602
2027	57%	314,930	34,373,272	4%	22,823	485,341	1,253,824	39%	214,756	9,851,828
2028	49%	294,302	33,491,115	4%	24,583	545,508	1,406,015	47%	281,732	13,479,728
2029	41%	267,079	31,668,216	4%	26,362	610,009	1,568,829	55%	357,971	17,854,418
2030	32%	222,088	27,421,128	4%	27,764	669,514	1,718,317	64%	444,173	23,081,327
2031	24%	177,426	22,797,903	4%	29,575	742,704	1,902,479	72%	532,274	28,801,012
2032	18%	139,693	18,670,261	4%	31,047	811,564	2,074,749	78%	605,331	34,091,054
2033	12%	98,033	13,625,389	4%	32,682	888,696	2,267,776	84%	686,230	40,200,527
2034	6%	50,852	7,346,988	4%	33,905	958,694	2,441,908	90%	762,771	46,463,120
2035	0%	0	0	4%	35,347	1,038,360	2,640,531	96%	848,210	53,678,440
2036	0%	0	0	4%	36,408	1,110,551	2,819,782	96%	873,671	57,410,409
2037	0%	0	0	4%	37,287	1,179,840	2,992,407	96%	894,762	60,992,337
2038	0%	0	0	4%	38,359	1,256,478	3,185,885	96%	920,499	64,954,134
2039	0%	0	0	4%	38,889	1,313,727	3,332,835	96%	933,225	67,913,671
2040	0%	0	0	4%	35,217	1,222,994	3,106,042	96%	845,097	63,223,164

Table A-35. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 1a in Calendar Year 2040

	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
1996	0%	0	0	0%	0	0	33	0.02	0.007
1997	0%	0	0	0%	0	0	42	0.03	0.009
1998	0%	0	0	0%	0	0	47	0.02	0.009
1999	0%	0	0	0%	0	0	50	0.02	0.008
2000	0%	0	0	0%	0	0	63	0.01	0.009
2001	0%	0	0	0%	0	0	66	0.01	0.009
2002	0%	0	0	0%	0	0	71	0.01	0.009
2003	0%	0	0	0%	0	0	81	0.01	0.010
2004	0%	0	0	0%	0	0	85	0.007	0.003
2005	0%	0	0	0%	0	0	105	0.008	0.004
2006	0%	0	0	0%	0	0	116	0.007	0.004
2007	0%	0	0	0%	0	0	133	0.008	0.005
2008	0%	0	0	0%	0	0	124	0.007	0.004
2009	0%	0	0	0%	0	0	105	0.006	0.004
2010	0%	0	0	0%	0	0	128	0.007	0.005
2011	0%	0	0	0%	0	0	152	0.008	0.006
2012	0%	0	0	0%	0	0	245	0.01	0.009
2013	0%	0	0	0%	0	0	341	0.02	0.01
2014	0%	0	0	0%	0	0	406	0.02	0.02
2015	0%	0	0	0%	0	0	577	0.03	0.02
2016	0%	0	0	0%	0	0	699	0.04	0.03
2017	0%	0	0	0%	0	0	908	0.04	0.03
2018	0%	0	0	0%	0	0	992	0.05	0.04
2019	0%	0	0	0%	0	0	1,054	0.05	0.04
2020	0%	0	0	0%	0	0	1,038	0.04	0.04
2021	0%	0	0	0%	0	0	1,489	0.06	0.05
2022	0%	0	0	0%	0	0	2,041	0.07	0.07
2023	0%	0	0	0%	0	0	2,397	0.08	0.08
2024	0%	0	0	0%	0	0	2,777	0.08	0.10
2025	0%	0	0	0%	0	0	3,202	0.08	0.10
2026	0%	0	0	0%	0	0	2,866	0.07	0.09
2027	0%	0	0	0%	0	0	2,917	0.07	0.09
2028	0%	0	0	0%	0	0	2,857	0.07	0.09
2029	0%	0	0	0%	0	0	2,721	0.06	0.08
2030	0%	0	0	0%	0	0	2,386	0.05	0.07
2031	0%	0	0	0%	0	0	2,022	0.04	0.05
2032	0%	0	0	0%	0	0	1,698	0.04	0.04
2033	0%	0	0	0%	0	0	1,301	0.03	0.03
2034	0%	0	0	0%	0	0	801	0.02	0.02
2035	0%	0	0	0%	0	0	216	0.007	0.004
2036	0%	0	0	0%	0	0	231	0.007	0.004
2037	0%	0	0	0%	0	0	245	0.008	0.004
2038	0%	0	0	0%	0	0	261	0.008	0.005
2039	0%	0	0	0%	0	0	273	0.008	0.005
2040	0%	0	0	0%	0	0	254	0.007	0.004

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-17) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-19. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

Table A-36. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 1a in Calendar Year 2045
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fuel Consumption[3] (MJ of electricity/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of electricity/day)
2001	100%	17,581	492,838	0%	0	0	0	0%	1	13
2002	100%	17,396	519,815	0%	0	0	0	0%	7	79
2003	100%	18,261	584,063	0%	0	0	0	0%	1	12
2004	100%	17,485	620,429	0%	0	0	0	0%	1	8
2005	100%	19,931	744,101	0%	0	0	0	0%	1	11
2006	100%	20,294	810,536	0%	0	0	0	0%	1	13
2007	100%	21,610	895,705	0%	0	0	0	0%	2	26
2008	100%	17,913	797,202	0%	0	0	0	0%	8	112
2009	100%	14,142	635,358	0%	0	0	0	0%	2	35
2010	100%	16,923	735,246	0%	1	3	15	0%	9	147
2011	99%	16,799	809,857	0%	30	158	790	1%	101	1,691
2012	98%	25,037	1,225,371	1%	300	1,692	8,301	1%	133	2,322
2013	97%	31,446	1,584,333	2%	594	3,560	17,255	1%	442	8,105
2014	96%	32,442	1,745,658	3%	890	5,695	27,363	1%	489	9,437
2015	97%	41,547	2,333,580	2%	708	4,833	22,999	2%	777	15,810
2016	95%	46,072	2,687,564	2%	841	6,105	28,783	3%	1,354	28,787
2017	91%	52,700	3,274,039	4%	2,391	18,339	86,121	5%	2,789	62,457
2018	87%	52,549	3,444,774	4%	2,479	20,175	94,087	9%	5,607	132,466
2019	88%	52,919	3,622,227	3%	2,063	18,391	80,115	8%	4,832	120,601
2020	86%	51,080	3,577,777	4%	2,469	23,635	98,982	9%	5,552	146,669
2021	85%	72,808	5,249,034	4%	3,832	39,919	157,067	10%	8,696	241,288
2022	84%	101,322	7,527,271	5%	5,592	67,570	218,488	11%	13,037	379,660
2023	84%	122,476	9,364,450	5%	6,792	88,932	269,022	11%	16,572	506,226
2024	83%	148,333	11,660,897	5%	8,175	115,750	327,717	12%	21,161	677,755
2025	83%	179,162	14,468,745	5%	9,889	151,350	399,826	12%	26,443	887,822
2026	65%	167,925	13,913,800	4%	10,710	171,981	451,908	31%	79,711	2,769,255
2027	57%	173,839	15,087,722	4%	12,598	212,114	555,489	39%	118,544	4,311,126
2028	49%	174,181	15,820,703	4%	14,549	256,617	669,890	47%	166,741	6,346,215
2029	41%	166,713	15,834,899	4%	16,455	303,793	790,664	55%	223,449	8,896,336
2030	32%	147,252	14,612,516	4%	18,409	355,407	922,379	64%	294,502	12,256,579
2031	24%	123,062	12,750,639	4%	20,513	413,850	1,071,177	72%	369,184	16,051,691
2032	18%	102,163	11,044,387	4%	22,706	478,352	1,235,027	78%	442,705	20,096,591
2033	12%	73,974	8,338,115	4%	24,661	542,144	1,396,451	84%	517,818	24,526,102
2034	6%	40,081	4,707,395	4%	26,724	612,627	1,574,494	90%	601,209	29,692,084
2035	0%	0	0	4%	28,447	679,589	1,742,931	96%	682,644	35,131,652
2036	0%	0	0	4%	30,274	753,214	1,927,965	96%	726,491	38,937,712
2037	0%	0	0	4%	31,753	822,345	2,100,691	96%	761,982	42,511,445
2038	0%	0	0	4%	33,394	899,667	2,293,959	96%	801,354	46,508,679
2039	0%	0	0	4%	34,612	969,669	2,467,860	96%	830,590	50,127,457
2040	0%	0	0	4%	36,047	1,049,189	2,665,871	96%	865,011	54,238,284
2041	0%	0	0	4%	37,091	1,121,019	2,843,979	96%	890,071	57,951,532
2042	0%	0	0	4%	37,942	1,189,565	3,014,512	96%	910,486	61,495,065
2043	0%	0	0	4%	38,974	1,264,855	3,204,367	96%	935,263	65,387,212
2044	0%	0	0	4%	39,438	1,319,800	3,345,305	96%	946,394	68,227,630
2045	0%	0	0	4%	35,636	1,225,722	3,110,204	96%	855,164	63,364,207

Table A-36. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 1a in Calendar Year 2045

Model Year	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
2001	0%	0	0	0%	0	0	40	0.01	0.006
2002	0%	0	0	0%	0	0	43	0.01	0.006
2003	0%	0	0	0%	0	0	48	0.01	0.006
2004	0%	0	0	0%	0	0	51	0.005	0.002
2005	0%	0	0	0%	0	0	61	0.005	0.002
2006	0%	0	0	0%	0	0	66	0.005	0.002
2007	0%	0	0	0%	0	0	73	0.005	0.003
2008	0%	0	0	0%	0	0	65	0.005	0.003
2009	0%	0	0	0%	0	0	52	0.003	0.002
2010	0%	0	0	0%	0	0	60	0.004	0.003
2011	0%	0	0	0%	0	0	66	0.004	0.003
2012	0%	0	0	0%	0	0	101	0.006	0.004
2013	0%	0	0	0%	0	0	131	0.008	0.006
2014	0%	0	0	0%	0	0	145	0.009	0.006
2015	0%	0	0	0%	0	0	193	0.01	0.008
2016	0%	0	0	0%	0	0	222	0.01	0.009
2017	0%	0	0	0%	0	0	275	0.02	0.01
2018	0%	0	0	0%	0	0	290	0.02	0.01
2019	0%	0	0	0%	0	0	303	0.02	0.01
2020	0%	0	0	0%	0	0	301	0.01	0.01
2021	0%	0	0	0%	0	0	443	0.02	0.02
2022	0%	0	0	0%	0	0	634	0.03	0.03
2023	0%	0	0	0%	0	0	789	0.03	0.03
2024	0%	0	0	0%	0	0	982	0.03	0.04
2025	0%	0	0	0%	0	0	1,217	0.04	0.04
2026	0%	0	0	0%	0	0	1,176	0.03	0.04
2027	0%	0	0	0%	0	0	1,281	0.04	0.05
2028	0%	0	0	0%	0	0	1,350	0.04	0.05
2029	0%	0	0	0%	0	0	1,361	0.04	0.05
2030	0%	0	0	0%	0	0	1,272	0.03	0.04
2031	0%	0	0	0%	0	0	1,132	0.03	0.04
2032	0%	0	0	0%	0	0	1,005	0.03	0.03
2033	0%	0	0	0%	0	0	797	0.02	0.02
2034	0%	0	0	0%	0	0	514	0.01	0.01
2035	0%	0	0	0%	0	0	143	0.006	0.003
2036	0%	0	0	0%	0	0	158	0.006	0.003
2037	0%	0	0	0%	0	0	172	0.006	0.003
2038	0%	0	0	0%	0	0	188	0.007	0.004
2039	0%	0	0	0%	0	0	202	0.007	0.004
2040	0%	0	0	0%	0	0	218	0.007	0.004
2041	0%	0	0	0%	0	0	233	0.008	0.004
2042	0%	0	0	0%	0	0	247	0.008	0.004
2043	0%	0	0	0%	0	0	262	0.008	0.005
2044	0%	0	0	0%	0	0	274	0.008	0.005
2045	0%	0	0	0%	0	0	255	0.007	0.004

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-20) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-22. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

Table A-37. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 1a in Calendar Year 2050

	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
Model Year	**Fleet Mix[1] (%)**	**Population[2] (vehicles)**	**Fuel Consumption[3] (MJ of gasoline/day)**	**Fleet Mix[1] (%)**	**Population[2] (vehicles)**	**Fuel Consumption[3] (MJ of gasoline/day)**	**Fuel Consumption[3] (MJ of electricity/day)**	**Fleet Mix[1] (%)**	**Population[2] (vehicles)**	**Fuel Consumption[3] (MJ of electricity/day)**
2006	100%	17,095	495,171	0%	0	0	0	0%	1	9
2007	100%	17,938	537,342	0%	0	0	0	0%	2	18
2008	100%	14,711	473,301	0%	0	0	0	0%	6	73
2009	100%	11,643	378,435	0%	0	0	0	0%	2	24
2010	100%	13,584	427,686	0%	0	2	9	0%	8	94
2011	99%	13,206	463,001	0%	24	89	472	1%	79	1,039
2012	98%	18,883	674,484	1%	226	915	4,745	1%	100	1,368
2013	97%	22,656	836,306	2%	428	1,850	9,427	1%	314	4,504
2014	96%	21,908	865,904	3%	601	2,783	14,018	1%	326	4,894
2015	97%	26,586	1,101,721	2%	453	2,250	11,180	2%	491	7,761
2016	95%	27,295	1,177,776	2%	498	2,640	12,955	3%	790	13,009
2017	91%	29,325	1,351,831	4%	1,329	7,482	36,484	5%	1,525	26,393
2018	87%	27,113	1,322,228	4%	1,278	7,675	37,071	9%	2,868	52,384
2019	89%	25,304	1,294,975	3%	986	6,516	29,339	8%	2,292	44,244
2020	86%	22,760	1,198,129	4%	1,100	7,856	33,925	9%	2,474	50,596
2021	85%	30,740	1,673,570	4%	1,618	12,642	51,178	10%	3,671	78,995
2022	84%	40,577	2,287,454	5%	2,239	20,404	67,892	11%	5,221	118,112
2023	84%	47,100	2,747,369	5%	2,612	25,936	80,590	11%	6,373	151,554
2024	83%	55,817	3,364,077	5%	3,076	33,204	96,428	12%	7,963	198,997
2025	83%	67,473	4,197,128	5%	3,724	43,672	118,177	12%	9,959	261,533
2026	65%	64,497	4,139,198	4%	4,114	50,877	136,660	31%	30,616	823,259
2027	57%	69,408	4,689,197	4%	5,030	65,571	175,255	39%	47,331	1,336,696
2028	49%	73,318	5,209,164	4%	6,124	84,058	223,637	47%	70,186	2,082,624
2029	41%	75,042	5,600,876	4%	7,407	106,921	283,234	55%	100,580	3,134,673
2030	32%	70,975	5,559,659	4%	8,873	134,574	355,060	64%	141,949	4,643,985
2031	24%	63,763	5,236,564	4%	10,628	169,173	444,687	72%	191,287	6,564,034
2032	18%	56,405	4,852,327	4%	12,536	209,209	548,060	78%	244,422	8,791,260
2033	12%	43,791	3,942,469	4%	14,599	255,208	666,413	84%	306,534	11,546,749
2034	6%	25,024	2,355,959	4%	16,685	305,290	794,782	90%	375,357	14,797,195
2035	0%	0	0	4%	18,865	360,976	937,068	96%	452,711	18,660,792
2036	0%	0	0	4%	21,003	419,968	1,087,267	96%	504,008	21,710,427
2037	0%	0	0	4%	23,227	484,984	1,252,421	96%	557,374	25,071,454
2038	0%	0	0	4%	25,203	549,142	1,414,757	96%	604,792	28,388,128
2039	0%	0	0	4%	27,285	619,964	1,593,644	96%	654,759	32,049,293
2040	0%	0	0	4%	29,016	687,067	1,762,410	96%	696,296	35,518,231
2041	0%	0	0	4%	30,849	760,761	1,947,591	96%	740,279	39,327,879
2042	0%	0	0	4%	32,326	829,839	2,120,143	96%	775,721	42,898,853
2043	0%	0	0	4%	33,964	907,037	2,313,062	96%	815,034	46,889,677
2044	0%	0	0	4%	35,170	976,725	2,486,125	96%	843,972	50,492,203
2045	0%	0	0	4%	36,591	1,055,810	2,682,995	96%	878,079	54,580,526
2046	0%	0	0	4%	37,615	1,127,036	2,859,529	96%	902,640	58,262,615
2047	0%	0	0	4%	38,433	1,194,575	3,027,460	96%	922,271	61,754,060
2048	0%	0	0	4%	39,420	1,268,267	3,213,196	96%	945,970	65,563,567
2049	0%	0	0	4%	39,817	1,320,843	3,348,041	96%	955,492	68,281,503
2050	0%	0	0	4%	35,902	1,223,884	3,105,533	96%	861,541	63,269,189

Table A-37. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 1a in Calendar Year 2050
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Model Year	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
2006	0%	0	0	0%	0	0	41	0.004	0.002
2007	0%	0	0	0%	0	0	44	0.004	0.002
2008	0%	0	0	0%	0	0	39	0.003	0.002
2009	0%	0	0	0%	0	0	31	0.002	0.001
2010	0%	0	0	0%	0	0	35	0.003	0.002
2011	0%	0	0	0%	0	0	38	0.003	0.002
2012	0%	0	0	0%	0	0	56	0.004	0.003
2013	0%	0	0	0%	0	0	69	0.005	0.003
2014	0%	0	0	0%	0	0	72	0.005	0.003
2015	0%	0	0	0%	0	0	91	0.006	0.004
2016	0%	0	0	0%	0	0	97	0.007	0.005
2017	0%	0	0	0%	0	0	114	0.008	0.005
2018	0%	0	0	0%	0	0	111	0.007	0.005
2019	0%	0	0	0%	0	0	108	0.006	0.005
2020	0%	0	0	0%	0	0	101	0.006	0.004
2021	0%	0	0	0%	0	0	141	0.008	0.006
2022	0%	0	0	0%	0	0	193	0.009	0.009
2023	0%	0	0	0%	0	0	232	0.01	0.01
2024	0%	0	0	0%	0	0	283	0.01	0.01
2025	0%	0	0	0%	0	0	353	0.01	0.01
2026	0%	0	0	0%	0	0	350	0.01	0.01
2027	0%	0	0	0%	0	0	398	0.01	0.02
2028	0%	0	0	0%	0	0	445	0.01	0.02
2029	0%	0	0	0%	0	0	482	0.01	0.02
2030	0%	0	0	0%	0	0	484	0.01	0.02
2031	0%	0	0	0%	0	0	465	0.01	0.02
2032	0%	0	0	0%	0	0	442	0.01	0.02
2033	0%	0	0	0%	0	0	377	0.01	0.01
2034	0%	0	0	0%	0	0	258	0.008	0.008
2035	0%	0	0	0%	0	0	77	0.004	0.002
2036	0%	0	0	0%	0	0	89	0.004	0.002
2037	0%	0	0	0%	0	0	103	0.004	0.002
2038	0%	0	0	0%	0	0	116	0.005	0.003
2039	0%	0	0	0%	0	0	130	0.005	0.003
2040	0%	0	0	0%	0	0	144	0.006	0.003
2041	0%	0	0	0%	0	0	159	0.006	0.003
2042	0%	0	0	0%	0	0	174	0.006	0.003
2043	0%	0	0	0%	0	0	189	0.007	0.004
2044	0%	0	0	0%	0	0	204	0.007	0.004
2045	0%	0	0	0%	0	0	220	0.007	0.004
2046	0%	0	0	0%	0	0	234	0.008	0.004
2047	0%	0	0	0%	0	0	248	0.008	0.004
2048	0%	0	0	0%	0	0	263	0.008	0.005
2049	0%	0	0	0%	0	0	274	0.008	0.005
2050	0%	0	0	0%	0	0	254	0.008	0.004

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-23) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-25. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

Table A-38. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 1b in Calendar Year 2026
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fuel Consumption[3] (MJ of electricity/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of electricity/day)
1982	100%	4,657	174,227	0%	0	0	0	0%	1	9
1983	100%	5,273	206,541	0%	0	0	0	0%	1	9
1984	100%	7,858	329,345	0%	0	0	0	0%	1	13
1985	100%	10,024	435,286	0%	0	0	0	0%	0	0
1986	100%	10,647	463,741	0%	0	0	0	0%	0	0
1987	100%	12,832	586,622	0%	0	0	0	0%	1	18
1988	100%	12,139	592,716	0%	0	0	0	0%	0	0
1989	100%	14,970	774,940	0%	0	0	0	0%	1	14
1990	100%	18,044	991,990	0%	0	0	0	0%	0	0
1991	100%	21,281	1,234,023	0%	0	0	0	0%	0	0
1992	100%	18,332	1,127,213	0%	0	0	0	0%	0	0
1993	100%	20,138	1,231,512	0%	0	0	0	0%	3	46
1994	100%	22,840	1,473,479	0%	0	0	0	0%	0	7
1995	100%	29,675	2,022,331	0%	0	0	0	0%	2	31
1996	100%	29,436	2,128,971	0%	0	0	0	0%	0	0
1997	100%	39,761	2,978,637	0%	0	0	0	0%	4	95
1998	100%	48,817	3,777,000	0%	0	0	0	0%	5	107
1999	100%	56,921	4,546,344	0%	0	0	0	0%	4	98
2000	100%	76,964	6,529,441	0%	0	0	0	0%	1	31
2001	100%	87,221	7,793,387	0%	0	0	0	0%	6	155
2002	100%	102,135	9,644,077	0%	0	0	0	0%	37	1,030
2003	100%	127,287	12,720,322	0%	0	0	0	0%	7	196
2004	100%	143,690	15,732,253	0%	0	0	0	0%	5	155
2005	100%	191,623	21,752,720	0%	0	0	0	0%	7	213
2006	100%	225,488	26,980,154	0%	0	0	0	0%	11	389
2007	100%	275,180	33,665,694	0%	0	0	0	0%	23	834
2008	100%	258,265	33,318,492	0%	0	0	0	0%	126	4,586
2009	100%	229,086	29,357,696	0%	0	0	0	0%	34	1,333
2010	100%	292,924	35,681,010	0%	11	154	687	0%	161	6,445
2011	99%	307,002	40,824,099	0%	548	8,280	37,013	1%	1,890	79,947
2012	98%	465,759	61,806,971	1%	5,585	88,399	392,722	1%	2,528	111,558
2013	97%	592,447	79,686,217	2%	11,199	185,018	819,056	1%	8,583	395,185
2014	96%	599,553	84,574,041	3%	16,462	284,537	1,256,341	1%	9,356	449,554
2015	96%	738,821	106,767,996	2%	12,602	227,577	1,002,629	2%	14,202	712,794
2016	95%	754,102	111,262,248	2%	13,790	259,774	1,141,452	3%	23,130	1,205,441
2017	91%	794,462	122,943,456	4%	36,125	706,874	3,105,093	5%	43,901	2,385,744
2018	86%	705,513	113,371,002	4%	33,412	680,299	2,980,537	10%	78,294	4,428,841
2019	88%	622,322	102,867,416	3%	24,317	533,860	2,191,127	8%	58,438	3,447,620
2020	86%	508,892	85,019,301	4%	24,600	571,597	2,264,467	9%	55,310	3,416,834
2021	85%	619,444	104,948,162	4%	32,604	811,289	3,029,262	10%	73,983	4,748,184
2022	84%	724,703	124,757,619	5%	39,994	1,137,171	3,486,691	11%	93,245	6,212,763
2023	84%	731,635	127,883,688	5%	40,571	1,231,754	3,543,090	11%	98,996	6,843,258
2024	83%	747,543	132,487,563	5%	41,200	1,332,140	3,598,733	12%	106,645	7,641,910
2025	83%	758,530	135,969,595	5%	41,866	1,438,799	3,640,575	12%	111,956	8,303,968
2026	65%	540,131	97,639,769	7%	58,168	2,059,650	5,213,221	28%	232,672	17,772,525

Model Year	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
1982	0%	0	0	0%	0	0	14	0.008	0.003
1983	0%	0	0	0%	0	0	17	0.009	0.003
1984	0%	0	0	0%	0	0	27	0.01	0.005
1985	0%	0	0	0%	0	0	36	0.02	0.006
1986	0%	0	0	0%	0	0	38	0.02	0.007
1987	0%	0	0	0%	0	0	48	0.02	0.009
1988	0%	0	0	0%	0	0	49	0.02	0.009
1989	0%	0	0	0%	0	0	63	0.03	0.01
1990	0%	0	0	0%	0	0	81	0.04	0.01
1991	0%	0	0	0%	0	0	101	0.05	0.02
1992	0%	0	0	0%	0	0	92	0.04	0.02
1993	0%	0	0	0%	0	0	101	0.05	0.02
1994	0%	0	0	0%	0	0	121	0.06	0.02
1995	0%	0	0	0%	0	0	166	0.08	0.03
1996	0%	0	0	0%	0	0	174	0.09	0.04
1997	0%	0	0	0%	0	0	244	0.11	0.05
1998	0%	0	0	0%	0	0	309	0.11	0.05
1999	0%	0	0	0%	0	0	372	0.09	0.06
2000	0%	0	0	0%	0	0	535	0.08	0.07
2001	0%	0	0	0%	0	0	638	0.09	0.07
2002	0%	0	0	0%	0	0	790	0.11	0.09
2003	0%	0	0	0%	0	0	1,041	0.13	0.11
2004	0%	0	0	0%	0	0	1,288	0.07	0.04
2005	0%	0	0	0%	0	0	1,781	0.08	0.05
2006	0%	0	0	0%	0	0	2,209	0.09	0.06
2007	0%	0	0	0%	0	0	2,756	0.11	0.08
2008	0%	0	0	0%	0	0	2,728	0.10	0.08
2009	0%	0	0	0%	0	0	2,404	0.09	0.07
2010	0%	0	0	0%	0	0	2,921	0.11	0.09
2011	0%	0	0	0%	0	0	3,345	0.12	0.10
2012	0%	0	0	0%	0	0	5,092	0.18	0.15
2013	0%	0	0	0%	0	0	6,591	0.22	0.19
2014	0%	0	0	0%	0	0	7,027	0.23	0.20
2015	0%	0	0	0%	0	0	8,823	0.28	0.24
2016	0%	0	0	0%	0	0	9,203	0.32	0.26
2017	0%	0	0	0%	0	0	10,320	0.32	0.27
2018	0%	0	0	0%	0	0	9,526	0.28	0.24
2019	0%	0	0	0%	0	0	8,601	0.23	0.21
2020	0%	0	0	0%	0	0	7,146	0.19	0.17
2021	0%	0	0	0%	0	0	8,840	0.21	0.21
2022	0%	0	0	0%	0	0	10,500	0.23	0.24
2023	0%	0	0	0%	0	0	10,760	0.21	0.23
2024	0%	0	0	0%	0	0	11,142	0.20	0.22
2025	0%	0	0	0%	0	0	11,430	0.16	0.20
2026	0%	0	0	0%	0	0	8,421	0.12	0.14

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-8) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-10. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

Table A-39. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 1b in Calendar Year 2030

	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fuel Consumption[3] (MJ of electricity/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of electricity/day)
1986	100%	9,277	319,606	0%	0	0	0	0%	0	0
1987	100%	11,036	395,358	0%	0	0	0	0%	1	13
1988	100%	10,287	394,106	0%	0	0	0	0%	0	0
1989	100%	12,682	513,141	0%	0	0	0	0%	1	10
1990	100%	15,335	660,988	0%	0	0	0	0%	0	0
1991	100%	17,755	806,207	0%	0	0	0	0%	0	0
1992	100%	14,968	722,403	0%	0	0	0	0%	0	0
1993	100%	15,722	757,504	0%	0	0	0	0%	2	30
1994	100%	16,938	862,749	0%	0	0	0	0%	0	4
1995	100%	21,266	1,147,175	0%	0	0	0	0%	1	18
1996	100%	20,041	1,148,835	0%	0	0	0	0%	0	0
1997	100%	25,571	1,519,989	0%	0	0	0	0%	3	55
1998	100%	29,544	1,816,366	0%	0	0	0	0%	3	55
1999	100%	32,392	2,061,329	0%	0	0	0	0%	2	47
2000	100%	41,346	2,802,701	0%	0	0	0	0%	1	14
2001	100%	44,766	3,209,806	0%	0	0	0	0%	3	65
2002	100%	49,911	3,795,455	0%	0	0	0	0%	18	424
2003	100%	59,781	4,832,777	0%	0	0	0	0%	3	76
2004	100%	65,751	5,844,031	0%	0	0	0	0%	2	59
2005	100%	86,903	8,039,211	0%	0	0	0	0%	3	81
2006	100%	103,055	10,092,547	0%	0	0	0	0%	5	144
2007	100%	128,610	12,929,139	0%	0	0	0	0%	11	328
2008	100%	125,543	13,361,675	0%	0	0	0	0%	60	1,794
2009	100%	116,809	12,395,606	0%	0	0	0	0%	18	572
2010	100%	158,274	16,020,574	0%	6	69	311	0%	86	2,863
2011	99%	175,648	19,479,572	0%	313	3,932	17,791	1%	1,076	37,957
2012	98%	282,481	31,367,919	1%	3,387	44,658	200,590	1%	1,526	56,296
2013	97%	378,095	42,683,040	2%	7,146	98,660	441,197	1%	5,433	209,483
2014	96%	402,992	47,862,257	3%	11,064	160,332	714,692	1%	6,227	251,167
2015	97%	518,113	63,218,662	2%	8,836	134,191	596,394	2%	9,879	417,410
2016	95%	553,278	69,108,331	2%	10,115	160,689	711,773	3%	16,817	738,736
2017	91%	604,853	79,402,357	4%	27,493	454,641	2,012,619	5%	33,194	1,524,212
2018	86%	555,971	75,960,952	4%	26,314	453,896	2,003,609	10%	61,332	2,941,765
2019	88%	505,059	71,135,364	3%	19,734	368,011	1,521,560	8%	47,387	2,378,873
2020	86%	424,894	60,588,792	4%	20,540	406,324	1,621,195	9%	46,181	2,435,627
2021	85%	528,088	76,514,975	4%	27,796	590,252	2,219,126	10%	63,072	3,464,139
2022	84%	629,123	92,802,888	5%	34,719	844,508	2,607,459	11%	80,947	4,626,137
2023	84%	652,013	97,885,688	5%	36,155	941,473	2,725,229	11%	88,223	5,242,684
2024	83%	670,253	102,369,934	5%	36,940	1,028,217	2,790,931	12%	95,619	5,905,793
2025	83%	697,118	108,259,056	5%	38,476	1,144,799	2,904,428	12%	102,891	6,603,088
2026	65%	562,392	88,712,763	7%	60,565	1,871,040	4,735,510	28%	242,261	16,125,728
2027	57%	506,170	82,823,038	9%	76,370	2,447,705	6,188,454	34%	305,478	21,091,873
2028	49%	448,945	76,077,298	10%	93,454	3,101,764	7,840,373	41%	373,815	26,729,208
2029	41%	382,216	66,862,077	12%	110,004	3,768,193	9,530,078	47%	440,015	32,480,322
2030	32%	271,278	48,854,015	14%	115,293	4,064,433	10,290,377	54%	461,172	35,046,471

Table A-39. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 1b in Calendar Year 2030

	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
1986	0%	0	0	0%	0	0	26	0.01	0.005
1987	0%	0	0	0%	0	0	32	0.02	0.006
1988	0%	0	0	0%	0	0	32	0.02	0.006
1989	0%	0	0	0%	0	0	42	0.02	0.008
1990	0%	0	0	0%	0	0	54	0.03	0.010
1991	0%	0	0	0%	0	0	66	0.03	0.01
1992	0%	0	0	0%	0	0	59	0.03	0.01
1993	0%	0	0	0%	0	0	62	0.03	0.01
1994	0%	0	0	0%	0	0	71	0.04	0.01
1995	0%	0	0	0%	0	0	94	0.05	0.02
1996	0%	0	0	0%	0	0	94	0.05	0.02
1997	0%	0	0	0%	0	0	124	0.06	0.02
1998	0%	0	0	0%	0	0	149	0.06	0.03
1999	0%	0	0	0%	0	0	169	0.05	0.03
2000	0%	0	0	0%	0	0	229	0.04	0.03
2001	0%	0	0	0%	0	0	263	0.04	0.03
2002	0%	0	0	0%	0	0	311	0.05	0.04
2003	0%	0	0	0%	0	0	396	0.05	0.04
2004	0%	0	0	0%	0	0	478	0.03	0.01
2005	0%	0	0	0%	0	0	658	0.03	0.02
2006	0%	0	0	0%	0	0	826	0.04	0.02
2007	0%	0	0	0%	0	0	1,059	0.05	0.03
2008	0%	0	0	0%	0	0	1,094	0.05	0.03
2009	0%	0	0	0%	0	0	1,015	0.04	0.03
2010	0%	0	0	0%	0	0	1,312	0.06	0.04
2011	0%	0	0	0%	0	0	1,596	0.06	0.05
2012	0%	0	0	0%	0	0	2,585	0.10	0.08
2013	0%	0	0	0%	0	0	3,531	0.13	0.11
2014	0%	0	0	0%	0	0	3,977	0.15	0.12
2015	0%	0	0	0%	0	0	5,225	0.19	0.16
2016	0%	0	0	0%	0	0	5,716	0.22	0.18
2017	0%	0	0	0%	0	0	6,666	0.24	0.20
2018	0%	0	0	0%	0	0	6,383	0.22	0.18
2019	0%	0	0	0%	0	0	5,949	0.19	0.17
2020	0%	0	0	0%	0	0	5,093	0.15	0.14
2021	0%	0	0	0%	0	0	6,446	0.18	0.18
2022	0%	0	0	0%	0	0	7,811	0.20	0.21
2023	0%	0	0	0%	0	0	8,237	0.19	0.21
2024	0%	0	0	0%	0	0	8,610	0.18	0.21
2025	0%	0	0	0%	0	0	9,101	0.16	0.20
2026	0%	0	0	0%	0	0	7,651	0.13	0.16
2027	0%	0	0	0%	0	0	7,288	0.12	0.15
2028	0%	0	0	0%	0	0	6,871	0.11	0.13
2029	0%	0	0	0%	0	0	6,254	0.10	0.11
2030	0%	0	0	0%	0	0	4,842	0.08	0.08

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-11) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-13. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

Table A-40. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 1b in Calendar Year 2035
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fuel Consumption[3] (MJ of electricity/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of electricity/day)
1991	100%	14,887	496,519	0%	0	0	0	0%	0	0
1992	100%	12,386	437,879	0%	0	0	0	0%	0	0
1993	100%	12,876	454,610	0%	0	0	0	0%	2	20
1994	100%	13,908	519,028	0%	0	0	0	0%	0	3
1995	100%	17,011	673,579	0%	0	0	0	0%	1	11
1996	100%	15,726	662,566	0%	0	0	0	0%	0	0
1997	100%	19,249	841,793	0%	0	0	0	0%	3	36
1998	100%	21,231	962,917	0%	0	0	0	0%	2	32
1999	100%	21,841	1,026,080	0%	0	0	0	0%	2	27
2000	100%	26,428	1,326,406	0%	0	0	0	0%	0	7
2001	100%	26,524	1,412,096	0%	0	0	0	0%	2	30
2002	100%	27,790	1,574,561	0%	0	0	0	0%	11	189
2003	100%	30,887	1,866,413	0%	0	0	0	0%	2	31
2004	100%	31,459	2,100,346	0%	0	0	0	0%	1	22
2005	100%	38,743	2,705,815	0%	0	0	0	0%	1	29
2006	100%	43,503	3,231,279	0%	0	0	0	0%	2	47
2007	100%	51,445	3,941,697	0%	0	0	0	0%	4	103
2008	100%	48,196	3,931,397	0%	0	0	0	0%	23	522
2009	100%	43,832	3,583,029	0%	0	0	0	0%	7	170
2010	100%	59,373	4,651,159	0%	2	20	92	0%	32	847
2011	99%	67,186	5,797,667	0%	120	1,161	5,375	1%	409	11,360
2012	98%	112,410	9,761,699	1%	1,348	13,798	63,245	1%	603	17,549
2013	97%	158,581	14,066,520	2%	2,997	32,296	147,122	1%	2,255	68,707
2014	96%	180,829	16,955,018	3%	4,964	56,441	255,982	1%	2,764	88,302
2015	97%	248,911	24,094,495	2%	4,244	50,842	229,574	2%	4,701	157,841
2016	95%	285,862	28,441,636	2%	5,224	65,752	295,555	3%	8,578	300,098
2017	91%	332,615	34,903,768	4%	15,110	198,715	892,263	5%	18,042	661,811
2018	86%	327,985	35,952,376	4%	15,507	213,599	955,739	9%	35,779	1,376,403
2019	88%	314,542	35,673,840	3%	12,281	183,606	769,058	8%	29,273	1,183,116
2020	86%	281,575	32,424,569	4%	13,612	216,540	874,542	9%	30,604	1,303,564
2021	85%	366,087	42,975,928	4%	19,269	330,198	1,255,839	10%	43,723	1,945,314
2022	84%	459,912	55,139,274	5%	25,381	499,808	1,561,702	11%	59,175	2,747,832
2023	84%	491,823	60,167,945	5%	27,272	576,729	1,688,911	11%	66,548	3,223,016
2024	83%	528,134	65,889,598	5%	29,108	659,860	1,811,619	12%	75,344	3,803,598
2025	83%	560,849	71,323,875	5%	30,955	752,392	1,930,200	12%	82,779	4,355,000
2026	65%	467,482	60,539,560	7%	50,344	1,273,939	3,258,418	28%	201,377	10,993,889
2027	57%	430,704	58,014,343	9%	64,983	1,711,595	4,369,269	34%	259,934	14,763,399
2028	49%	390,089	54,639,940	10%	81,202	2,224,910	5,669,333	41%	324,809	19,184,252
2029	41%	338,901	49,344,310	12%	97,537	2,779,042	7,068,436	47%	390,149	23,955,597
2030	32%	276,003	41,738,586	14%	117,301	3,472,448	8,817,878	54%	469,205	29,927,118
2031	24%	213,410	33,502,607	15%	135,160	4,154,869	10,534,670	61%	540,639	35,802,764
2032	18%	164,104	26,722,257	16%	149,517	4,768,321	12,076,679	66%	598,069	41,085,042
2033	12%	112,719	19,004,076	18%	165,321	5,458,416	13,820,362	70%	661,284	47,032,540
2034	6%	57,245	9,957,437	19%	179,366	6,108,530	15,474,249	75%	717,465	52,642,980
2035	0%	0	0	20%	173,169	6,063,983	15,377,477	80%	692,675	52,272,334

Table A-40. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 1b in Calendar Year 2035
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
1991	0%	0	0	0%	0	0	41	0.02	0.008
1992	0%	0	0	0%	0	0	36	0.02	0.007
1993	0%	0	0	0%	0	0	37	0.02	0.007
1994	0%	0	0	0%	0	0	42	0.02	0.008
1995	0%	0	0	0%	0	0	55	0.03	0.01
1996	0%	0	0	0%	0	0	54	0.04	0.01
1997	0%	0	0	0%	0	0	69	0.04	0.01
1998	0%	0	0	0%	0	0	79	0.03	0.01
1999	0%	0	0	0%	0	0	84	0.03	0.01
2000	0%	0	0	0%	0	0	109	0.02	0.01
2001	0%	0	0	0%	0	0	116	0.02	0.01
2002	0%	0	0	0%	0	0	129	0.02	0.02
2003	0%	0	0	0%	0	0	153	0.02	0.02
2004	0%	0	0	0%	0	0	172	0.01	0.006
2005	0%	0	0	0%	0	0	222	0.01	0.007
2006	0%	0	0	0%	0	0	265	0.01	0.008
2007	0%	0	0	0%	0	0	323	0.02	0.01
2008	0%	0	0	0%	0	0	322	0.02	0.01
2009	0%	0	0	0%	0	0	293	0.01	0.010
2010	0%	0	0	0%	0	0	381	0.02	0.01
2011	0%	0	0	0%	0	0	475	0.02	0.02
2012	0%	0	0	0%	0	0	804	0.04	0.03
2013	0%	0	0	0%	0	0	1,164	0.05	0.04
2014	0%	0	0	0%	0	0	1,409	0.06	0.05
2015	0%	0	0	0%	0	0	1,991	0.08	0.07
2016	0%	0	0	0%	0	0	2,353	0.11	0.08
2017	0%	0	0	0%	0	0	2,931	0.12	0.10
2018	0%	0	0	0%	0	0	3,022	0.12	0.10
2019	0%	0	0	0%	0	0	2,984	0.11	0.10
2020	0%	0	0	0%	0	0	2,726	0.10	0.09
2021	0%	0	0	0%	0	0	3,621	0.12	0.12
2022	0%	0	0	0%	0	0	4,642	0.14	0.15
2023	0%	0	0	0%	0	0	5,064	0.14	0.16
2024	0%	0	0	0%	0	0	5,543	0.14	0.16
2025	0%	0	0	0%	0	0	5,997	0.13	0.17
2026	0%	0	0	0%	0	0	5,223	0.11	0.14
2027	0%	0	0	0%	0	0	5,107	0.10	0.13
2028	0%	0	0	0%	0	0	4,938	0.10	0.12
2029	0%	0	0	0%	0	0	4,619	0.09	0.11
2030	0%	0	0	0%	0	0	4,139	0.08	0.09
2031	0%	0	0	0%	0	0	3,605	0.07	0.08
2032	0%	0	0	0%	0	0	3,177	0.06	0.06
2033	0%	0	0	0%	0	0	2,687	0.06	0.05
2034	0%	0	0	0%	0	0	2,082	0.05	0.04
2035	0%	0	0	0%	0	0	1,259	0.04	0.02

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-14) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-16. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

Table A-41. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 1b in Calendar Year 2040
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fuel Consumption[3] (MJ of electricity/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of electricity/day)
1996	100%	13,224	407,390	0%	0	0	0	0%	0	0
1997	100%	15,957	507,603	0%	0	0	0	0%	2	27
1998	100%	17,428	573,388	0%	0	0	0	0%	2	23
1999	100%	17,981	612,358	0%	0	0	0	0%	2	19
2000	100%	21,212	772,196	0%	0	0	0	0%	0	5
2001	100%	20,869	808,569	0%	0	0	0	0%	1	19
2002	100%	20,957	866,980	0%	0	0	0	0%	8	114
2003	100%	22,226	985,080	0%	0	0	0	0%	1	18
2004	100%	21,228	1,041,890	0%	0	0	0	0%	1	12
2005	100%	24,808	1,278,892	0%	0	0	0	0%	1	16
2006	100%	25,795	1,417,856	0%	0	0	0	0%	1	22
2007	100%	28,657	1,630,516	0%	0	0	0	0%	2	44
2008	100%	24,894	1,513,071	0%	0	0	0	0%	12	206
2009	100%	20,958	1,283,229	0%	0	0	0	0%	3	64
2010	100%	26,447	1,559,497	0%	1	7	31	0%	15	295
2011	99%	28,341	1,849,619	0%	51	367	1,752	1%	172	3,720
2012	98%	44,963	2,967,860	1%	539	4,153	19,596	1%	240	5,433
2013	97%	60,869	4,125,844	2%	1,150	9,385	43,891	1%	858	20,372
2014	96%	67,874	4,888,299	3%	1,863	16,131	74,982	1%	1,028	25,649
2015	97%	93,376	6,979,373	2%	1,592	14,608	67,463	2%	1,750	45,992
2016	95%	109,366	8,447,742	2%	1,998	19,377	88,913	3%	3,230	88,645
2017	91%	132,055	10,809,831	4%	5,994	61,088	279,650	5%	7,052	203,451
2018	87%	137,285	11,794,487	4%	6,483	69,602	317,087	9%	14,800	449,301
2019	88%	141,083	12,595,274	3%	5,505	64,430	274,520	8%	13,018	416,452
2020	86%	135,652	12,343,563	4%	6,558	82,023	336,557	9%	14,744	498,290
2021	85%	189,590	17,659,856	4%	9,979	135,046	521,355	10%	22,644	801,678
2022	84%	253,809	24,240,958	5%	14,007	218,733	693,952	11%	32,657	1,210,322
2023	84%	291,017	28,467,215	5%	16,137	271,680	807,271	11%	39,377	1,526,695
2024	83%	329,600	32,998,938	5%	18,166	329,087	916,198	12%	47,021	1,906,128
2025	83%	371,783	38,066,268	5%	20,520	399,967	1,039,937	12%	54,873	2,325,226
2026	65%	324,168	33,911,685	7%	34,910	710,651	1,840,421	28%	139,641	6,141,720
2027	57%	314,930	34,373,272	9%	47,516	1,009,971	2,609,145	34%	190,063	8,721,643
2028	49%	294,302	33,491,115	10%	61,263	1,358,780	3,502,176	41%	245,052	11,727,734
2029	41%	267,079	31,668,216	12%	76,867	1,777,825	4,572,229	47%	307,466	15,338,648
2030	32%	222,088	27,421,128	14%	94,388	2,275,019	5,838,867	54%	377,550	19,622,661
2031	24%	177,426	22,797,903	15%	112,370	2,820,780	7,225,594	61%	449,479	24,324,307
2032	18%	139,693	18,670,261	16%	127,276	3,325,924	8,502,665	66%	509,102	28,674,484
2033	12%	98,033	13,625,389	18%	143,782	3,908,860	9,974,635	70%	575,130	33,694,327
2034	6%	50,852	7,346,988	19%	159,335	4,504,684	11,473,962	75%	637,341	38,824,156
2035	0%	0	0	20%	176,711	5,190,882	13,200,325	80%	706,846	44,732,852
2036	0%	0	0	20%	182,016	5,552,276	14,097,691	80%	728,063	47,841,806
2037	0%	0	0	20%	186,410	5,899,072	14,961,705	80%	745,638	50,825,913
2038	0%	0	0	20%	191,772	6,282,159	15,928,844	80%	767,086	54,127,540
2039	0%	0	0	20%	194,423	6,567,623	16,661,603	80%	777,691	56,595,445
2040	0%	0	0	20%	176,063	6,112,778	15,524,648	80%	704,251	52,689,327

Table A-41. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 1b in Calendar Year 2040

Model Year	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
1996	0%	0	0	0%	0	0	33	0.02	0.007
1997	0%	0	0	0%	0	0	42	0.03	0.009
1998	0%	0	0	0%	0	0	47	0.02	0.009
1999	0%	0	0	0%	0	0	50	0.02	0.008
2000	0%	0	0	0%	0	0	63	0.01	0.009
2001	0%	0	0	0%	0	0	66	0.01	0.009
2002	0%	0	0	0%	0	0	71	0.01	0.009
2003	0%	0	0	0%	0	0	81	0.01	0.010
2004	0%	0	0	0%	0	0	85	0.007	0.003
2005	0%	0	0	0%	0	0	105	0.008	0.004
2006	0%	0	0	0%	0	0	116	0.007	0.004
2007	0%	0	0	0%	0	0	133	0.008	0.005
2008	0%	0	0	0%	0	0	124	0.007	0.004
2009	0%	0	0	0%	0	0	105	0.006	0.004
2010	0%	0	0	0%	0	0	128	0.007	0.005
2011	0%	0	0	0%	0	0	152	0.008	0.006
2012	0%	0	0	0%	0	0	245	0.01	0.009
2013	0%	0	0	0%	0	0	341	0.02	0.01
2014	0%	0	0	0%	0	0	406	0.02	0.02
2015	0%	0	0	0%	0	0	577	0.03	0.02
2016	0%	0	0	0%	0	0	699	0.04	0.03
2017	0%	0	0	0%	0	0	908	0.04	0.03
2018	0%	0	0	0%	0	0	992	0.05	0.04
2019	0%	0	0	0%	0	0	1,054	0.05	0.04
2020	0%	0	0	0%	0	0	1,038	0.04	0.04
2021	0%	0	0	0%	0	0	1,489	0.06	0.05
2022	0%	0	0	0%	0	0	2,041	0.07	0.07
2023	0%	0	0	0%	0	0	2,397	0.08	0.08
2024	0%	0	0	0%	0	0	2,777	0.08	0.10
2025	0%	0	0	0%	0	0	3,202	0.08	0.10
2026	0%	0	0	0%	0	0	2,927	0.07	0.09
2027	0%	0	0	0%	0	0	3,028	0.07	0.09
2028	0%	0	0	0%	0	0	3,029	0.07	0.09
2029	0%	0	0	0%	0	0	2,967	0.07	0.08
2030	0%	0	0	0%	0	0	2,723	0.06	0.07
2031	0%	0	0	0%	0	0	2,458	0.06	0.06
2032	0%	0	0	0%	0	0	2,225	0.05	0.05
2033	0%	0	0	0%	0	0	1,932	0.05	0.04
2034	0%	0	0	0%	0	0	1,541	0.04	0.03
2035	0%	0	0	0%	0	0	1,081	0.04	0.02
2036	0%	0	0	0%	0	0	1,154	0.04	0.02
2037	0%	0	0	0%	0	0	1,225	0.04	0.02
2038	0%	0	0	0%	0	0	1,304	0.04	0.02
2039	0%	0	0	0%	0	0	1,364	0.04	0.02
2040	0%	0	0	0%	0	0	1,271	0.04	0.02

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-17) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-19. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

Table A-42. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 1b in Calendar Year 2045
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Model Year	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fuel Consumption[3] (MJ of electricity/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of electricity/day)
2001	100%	17,581	492,838	0%	0	0	0	0%	1	13
2002	100%	17,396	519,815	0%	0	0	0	0%	7	79
2003	100%	18,261	584,063	0%	0	0	0	0%	1	12
2004	100%	17,485	620,429	0%	0	0	0	0%	1	8
2005	100%	19,931	744,101	0%	0	0	0	0%	1	11
2006	100%	20,294	810,536	0%	0	0	0	0%	1	13
2007	100%	21,610	895,705	0%	0	0	0	0%	2	26
2008	100%	17,913	797,202	0%	0	0	0	0%	8	112
2009	100%	14,142	635,358	0%	0	0	0	0%	2	35
2010	100%	16,923	735,246	0%	1	3	15	0%	9	147
2011	99%	16,799	809,857	0%	30	158	790	1%	101	1,691
2012	98%	25,037	1,225,371	1%	300	1,692	8,301	1%	133	2,322
2013	97%	31,446	1,584,333	2%	594	3,560	17,255	1%	442	8,105
2014	96%	32,442	1,745,658	3%	890	5,695	27,363	1%	489	9,437
2015	97%	41,547	2,333,580	2%	708	4,833	22,999	2%	777	15,810
2016	95%	46,072	2,687,564	2%	841	6,105	28,783	3%	1,354	28,787
2017	91%	52,700	3,274,039	4%	2,391	18,339	86,121	5%	2,789	62,457
2018	87%	52,549	3,444,774	4%	2,479	20,175	94,087	9%	5,607	132,466
2019	88%	52,919	3,622,227	3%	2,063	18,391	80,115	8%	4,832	120,601
2020	86%	51,080	3,577,777	4%	2,469	23,635	98,982	9%	5,552	146,669
2021	85%	72,808	5,249,034	4%	3,832	39,919	157,067	10%	8,696	241,288
2022	84%	101,322	7,527,271	5%	5,592	67,570	218,488	11%	13,037	379,660
2023	84%	122,476	9,364,450	5%	6,792	88,932	269,022	11%	16,572	506,226
2024	83%	148,333	11,660,897	5%	8,175	115,750	327,717	12%	21,161	677,755
2025	83%	179,162	14,468,745	5%	9,889	151,350	399,826	12%	26,443	887,822
2026	65%	167,925	13,913,800	7%	18,084	290,156	762,432	28%	72,337	2,514,676
2027	57%	173,839	15,087,722	9%	26,228	441,199	1,155,422	34%	104,913	3,817,619
2028	49%	174,181	15,820,703	10%	36,258	638,899	1,667,826	41%	145,032	5,522,683
2029	41%	166,713	15,834,899	12%	47,981	884,975	2,303,275	47%	191,924	7,644,321
2030	32%	147,252	14,612,516	14%	62,582	1,207,122	3,132,813	54%	250,329	10,421,769
2031	24%	123,062	12,750,639	15%	77,939	1,571,107	4,066,536	61%	311,757	13,558,663
2032	18%	102,163	11,044,387	16%	93,082	1,959,517	5,059,160	66%	372,328	16,905,784
2033	12%	73,974	8,338,115	18%	108,496	2,383,535	6,139,495	70%	433,983	20,559,277
2034	6%	40,081	4,707,395	19%	125,587	2,877,296	7,394,855	75%	502,346	24,813,410
2035	0%	0	0	20%	142,218	3,395,806	8,709,165	80%	568,873	29,280,231
2036	0%	0	0	20%	151,353	3,764,012	9,634,558	80%	605,413	32,451,688
2037	0%	0	0	20%	158,747	4,109,890	10,498,771	80%	634,988	35,429,237
2038	0%	0	0	20%	166,950	4,496,790	11,465,849	80%	667,799	38,759,563
2039	0%	0	0	20%	173,040	4,847,192	12,336,363	80%	692,162	41,774,287
2040	0%	0	0	20%	180,212	5,245,171	13,327,383	80%	720,847	45,199,074
2041	0%	0	0	20%	185,432	5,604,787	14,219,115	80%	741,730	48,292,355
2042	0%	0	0	20%	189,685	5,947,906	15,072,761	80%	758,742	51,244,390
2043	0%	0	0	20%	194,847	6,324,292	16,021,877	80%	779,390	54,487,900
2044	0%	0	0	20%	197,166	6,598,270	16,724,671	80%	788,666	56,856,466
2045	0%	0	0	20%	178,160	6,126,708	15,546,194	80%	712,640	52,806,238

Table A-42. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 1b in Calendar Year 2045
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
2001	0%	0	0	0%	0	0	40	0.01	0.006
2002	0%	0	0	0%	0	0	43	0.01	0.006
2003	0%	0	0	0%	0	0	48	0.01	0.006
2004	0%	0	0	0%	0	0	51	0.005	0.002
2005	0%	0	0	0%	0	0	61	0.005	0.002
2006	0%	0	0	0%	0	0	66	0.005	0.002
2007	0%	0	0	0%	0	0	73	0.005	0.003
2008	0%	0	0	0%	0	0	65	0.005	0.003
2009	0%	0	0	0%	0	0	52	0.003	0.002
2010	0%	0	0	0%	0	0	60	0.004	0.003
2011	0%	0	0	0%	0	0	66	0.004	0.003
2012	0%	0	0	0%	0	0	101	0.006	0.004
2013	0%	0	0	0%	0	0	131	0.008	0.006
2014	0%	0	0	0%	0	0	145	0.009	0.006
2015	0%	0	0	0%	0	0	193	0.01	0.008
2016	0%	0	0	0%	0	0	222	0.01	0.009
2017	0%	0	0	0%	0	0	275	0.02	0.01
2018	0%	0	0	0%	0	0	290	0.02	0.01
2019	0%	0	0	0%	0	0	303	0.02	0.01
2020	0%	0	0	0%	0	0	301	0.01	0.01
2021	0%	0	0	0%	0	0	443	0.02	0.02
2022	0%	0	0	0%	0	0	634	0.03	0.03
2023	0%	0	0	0%	0	0	789	0.03	0.03
2024	0%	0	0	0%	0	0	982	0.03	0.04
2025	0%	0	0	0%	0	0	1,217	0.04	0.04
2026	0%	0	0	0%	0	0	1,202	0.04	0.04
2027	0%	0	0	0%	0	0	1,330	0.04	0.05
2028	0%	0	0	0%	0	0	1,432	0.04	0.05
2029	0%	0	0	0%	0	0	1,485	0.04	0.05
2030	0%	0	0	0%	0	0	1,453	0.04	0.05
2031	0%	0	0	0%	0	0	1,377	0.04	0.04
2032	0%	0	0	0%	0	0	1,318	0.04	0.04
2033	0%	0	0	0%	0	0	1,185	0.04	0.03
2034	0%	0	0	0%	0	0	991	0.03	0.02
2035	0%	0	0	0%	0	0	713	0.03	0.01
2036	0%	0	0	0%	0	0	789	0.03	0.02
2037	0%	0	0	0%	0	0	860	0.03	0.02
2038	0%	0	0	0%	0	0	939	0.03	0.02
2039	0%	0	0	0%	0	0	1,010	0.03	0.02
2040	0%	0	0	0%	0	0	1,091	0.04	0.02
2041	0%	0	0	0%	0	0	1,164	0.04	0.02
2042	0%	0	0	0%	0	0	1,234	0.04	0.02
2043	0%	0	0	0%	0	0	1,312	0.04	0.02
2044	0%	0	0	0%	0	0	1,369	0.04	0.02
2045	0%	0	0	0%	0	0	1,273	0.04	0.02

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-20) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-22. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

Table A-43. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 1b in Calendar Year 2050
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fuel Consumption[3] (MJ of electricity/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of electricity/day)
2006	100%	17,095	495,171	0%	0	0	0	0%	1	9
2007	100%	17,938	537,342	0%	0	0	0	0%	2	18
2008	100%	14,711	473,301	0%	0	0	0	0%	6	73
2009	100%	11,643	378,435	0%	0	0	0	0%	2	24
2010	100%	13,584	427,686	0%	0	2	9	0%	8	94
2011	99%	13,206	463,001	0%	24	89	472	1%	79	1,039
2012	98%	18,883	674,484	1%	226	915	4,745	1%	100	1,368
2013	97%	22,656	836,306	2%	428	1,850	9,427	1%	314	4,504
2014	96%	21,908	865,904	3%	601	2,783	14,018	1%	326	4,894
2015	97%	26,586	1,101,721	2%	453	2,250	11,180	2%	491	7,761
2016	95%	27,295	1,177,776	2%	498	2,640	12,955	3%	790	13,009
2017	91%	29,325	1,351,831	4%	1,329	7,482	36,484	5%	1,525	26,393
2018	87%	27,113	1,322,228	4%	1,278	7,675	37,071	9%	2,868	52,384
2019	89%	25,304	1,294,975	3%	986	6,516	29,339	8%	2,292	44,244
2020	86%	22,760	1,198,129	4%	1,100	7,856	33,925	9%	2,474	50,596
2021	85%	30,740	1,673,570	4%	1,618	12,642	51,178	10%	3,671	78,995
2022	84%	40,577	2,287,454	5%	2,239	20,404	67,892	11%	5,221	118,112
2023	84%	47,100	2,747,369	5%	2,612	25,936	80,590	11%	6,373	151,554
2024	83%	55,817	3,364,077	5%	3,076	33,204	96,428	12%	7,963	198,997
2025	83%	67,473	4,197,128	5%	3,724	43,672	118,177	12%	9,959	261,533
2026	65%	64,497	4,139,198	7%	6,946	85,755	230,344	28%	27,783	748,124
2027	57%	69,408	4,689,197	9%	10,472	136,243	364,145	34%	41,888	1,184,450
2028	49%	73,318	5,209,164	10%	15,262	209,057	556,198	41%	61,048	1,813,344
2029	41%	75,042	5,600,876	12%	21,597	311,157	824,254	47%	86,390	2,694,697
2030	32%	70,975	5,559,659	14%	30,164	456,649	1,204,821	54%	120,658	3,950,154
2031	24%	63,763	5,236,564	15%	40,383	641,707	1,686,787	61%	161,532	5,546,074
2032	18%	56,405	4,852,327	16%	51,392	856,381	2,243,442	66%	205,566	7,397,087
2033	12%	43,791	3,942,469	18%	64,227	1,121,299	2,927,997	70%	256,907	9,680,969
2034	6%	25,024	2,355,959	19%	78,408	1,433,012	3,730,649	75%	313,633	12,367,796
2035	0%	0	0	20%	94,315	1,802,770	4,679,868	80%	377,261	15,554,800
2036	0%	0	0	20%	105,002	2,097,661	5,430,694	80%	420,009	18,096,250
2037	0%	0	0	20%	116,120	2,422,690	6,256,345	80%	464,480	20,897,143
2038	0%	0	0	20%	125,999	2,743,476	7,068,030	80%	503,996	23,660,975
2039	0%	0	0	20%	136,409	3,097,610	7,962,540	80%	545,636	26,711,814
2040	0%	0	0	20%	145,063	3,433,210	8,806,594	80%	580,250	29,602,343
2041	0%	0	0	20%	154,226	3,801,780	9,732,766	80%	616,903	32,776,753
2042	0%	0	0	20%	161,609	4,147,412	10,596,165	80%	646,437	35,751,957
2043	0%	0	0	20%	169,800	4,533,716	11,561,556	80%	679,199	39,076,891
2044	0%	0	0	20%	175,828	4,882,572	12,427,947	80%	703,314	42,078,016
2045	0%	0	0	20%	182,934	5,278,405	13,413,338	80%	731,736	45,483,984
2046	0%	0	0	20%	188,051	5,635,041	14,297,285	80%	752,204	48,551,228
2047	0%	0	0	20%	192,141	5,973,156	15,138,009	80%	768,563	51,459,783
2048	0%	0	0	20%	197,078	6,341,586	16,066,621	80%	788,312	54,634,347
2049	0%	0	0	20%	199,062	6,603,759	16,739,054	80%	796,247	56,900,758
2050	0%	0	0	20%	179,489	6,117,808	15,523,574	80%	717,954	52,726,433

Table A-43. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 1b in Calendar Year 2050
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Model Year	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
2006	0%	0	0	0%	0	0	41	0.004	0.002
2007	0%	0	0	0%	0	0	44	0.004	0.002
2008	0%	0	0	0%	0	0	39	0.003	0.002
2009	0%	0	0	0%	0	0	31	0.002	0.001
2010	0%	0	0	0%	0	0	35	0.003	0.002
2011	0%	0	0	0%	0	0	38	0.003	0.002
2012	0%	0	0	0%	0	0	56	0.004	0.003
2013	0%	0	0	0%	0	0	69	0.005	0.003
2014	0%	0	0	0%	0	0	72	0.005	0.003
2015	0%	0	0	0%	0	0	91	0.006	0.004
2016	0%	0	0	0%	0	0	97	0.007	0.005
2017	0%	0	0	0%	0	0	114	0.008	0.005
2018	0%	0	0	0%	0	0	111	0.007	0.005
2019	0%	0	0	0%	0	0	108	0.006	0.005
2020	0%	0	0	0%	0	0	101	0.006	0.004
2021	0%	0	0	0%	0	0	141	0.008	0.006
2022	0%	0	0	0%	0	0	193	0.009	0.009
2023	0%	0	0	0%	0	0	232	0.01	0.01
2024	0%	0	0	0%	0	0	283	0.01	0.01
2025	0%	0	0	0%	0	0	353	0.01	0.01
2026	0%	0	0	0%	0	0	358	0.01	0.01
2027	0%	0	0	0%	0	0	414	0.01	0.02
2028	0%	0	0	0%	0	0	472	0.02	0.02
2029	0%	0	0	0%	0	0	526	0.02	0.02
2030	0%	0	0	0%	0	0	554	0.02	0.02
2031	0%	0	0	0%	0	0	567	0.02	0.02
2032	0%	0	0	0%	0	0	581	0.02	0.02
2033	0%	0	0	0%	0	0	563	0.02	0.02
2034	0%	0	0	0%	0	0	498	0.02	0.01
2035	0%	0	0	0%	0	0	383	0.02	0.009
2036	0%	0	0	0%	0	0	445	0.02	0.01
2037	0%	0	0	0%	0	0	512	0.02	0.01
2038	0%	0	0	0%	0	0	579	0.02	0.01
2039	0%	0	0	0%	0	0	652	0.03	0.01
2040	0%	0	0	0%	0	0	721	0.03	0.01
2041	0%	0	0	0%	0	0	797	0.03	0.02
2042	0%	0	0	0%	0	0	868	0.03	0.02
2043	0%	0	0	0%	0	0	947	0.03	0.02
2044	0%	0	0	0%	0	0	1,018	0.04	0.02
2045	0%	0	0	0%	0	0	1,098	0.04	0.02
2046	0%	0	0	0%	0	0	1,171	0.04	0.02
2047	0%	0	0	0%	0	0	1,239	0.04	0.02
2048	0%	0	0	0%	0	0	1,315	0.04	0.02
2049	0%	0	0	0%	0	0	1,370	0.04	0.02
2050	0%	0	0	0%	0	0	1,271	0.04	0.02

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-23) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-25. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

Table A-44. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 1c in Calendar Year 2026

	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fuel Consumption[3] (MJ of electricity/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of electricity/day)
1982	100%	4,657	174,227	0%	0	0	0	0%	1	9
1983	100%	5,273	206,541	0%	0	0	0	0%	1	9
1984	100%	7,858	329,345	0%	0	0	0	0%	1	13
1985	100%	10,024	435,286	0%	0	0	0	0%	0	0
1986	100%	10,647	463,741	0%	0	0	0	0%	0	0
1987	100%	12,832	586,622	0%	0	0	0	0%	1	18
1988	100%	12,139	592,716	0%	0	0	0	0%	0	0
1989	100%	14,970	774,940	0%	0	0	0	0%	1	14
1990	100%	18,044	991,990	0%	0	0	0	0%	0	0
1991	100%	21,281	1,234,023	0%	0	0	0	0%	0	0
1992	100%	18,332	1,127,213	0%	0	0	0	0%	0	0
1993	100%	20,138	1,231,512	0%	0	0	0	0%	3	46
1994	100%	22,840	1,473,479	0%	0	0	0	0%	0	7
1995	100%	29,675	2,022,331	0%	0	0	0	0%	2	31
1996	100%	29,436	2,128,971	0%	0	0	0	0%	0	0
1997	100%	39,761	2,978,637	0%	0	0	0	0%	4	95
1998	100%	48,817	3,777,000	0%	0	0	0	0%	5	107
1999	100%	56,921	4,546,344	0%	0	0	0	0%	4	98
2000	100%	76,964	6,529,441	0%	0	0	0	0%	1	31
2001	100%	87,221	7,793,387	0%	0	0	0	0%	6	155
2002	100%	102,135	9,644,077	0%	0	0	0	0%	37	1,030
2003	100%	127,287	12,720,322	0%	0	0	0	0%	7	196
2004	100%	143,690	15,732,253	0%	0	0	0	0%	5	155
2005	100%	191,623	21,752,720	0%	0	0	0	0%	7	213
2006	100%	225,488	26,980,154	0%	0	0	0	0%	11	389
2007	100%	275,180	33,665,694	0%	0	0	0	0%	23	834
2008	100%	258,265	33,318,492	0%	0	0	0	0%	126	4,586
2009	100%	229,086	29,357,696	0%	0	0	0	0%	34	1,333
2010	100%	292,924	35,681,010	0%	11	154	687	0%	161	6,445
2011	99%	307,002	40,824,099	0%	548	8,280	37,013	1%	1,890	79,947
2012	98%	465,759	61,806,971	1%	5,585	88,399	392,722	1%	2,528	111,558
2013	97%	592,447	79,686,217	2%	11,199	185,018	819,056	1%	8,583	395,185
2014	96%	599,553	84,574,041	3%	16,462	284,537	1,256,341	1%	9,356	449,554
2015	96%	738,821	106,767,996	2%	12,602	227,577	1,002,629	2%	14,202	712,794
2016	95%	754,102	111,262,248	2%	13,790	259,774	1,141,452	3%	23,130	1,205,441
2017	91%	794,462	122,943,456	4%	36,125	706,874	3,105,093	5%	43,901	2,385,744
2018	86%	705,513	113,371,002	4%	33,412	680,299	2,980,537	10%	78,294	4,428,841
2019	88%	622,322	102,867,416	3%	24,317	533,860	2,191,127	8%	58,438	3,447,620
2020	86%	508,892	85,019,301	4%	24,600	571,597	2,264,467	9%	55,310	3,416,834
2021	85%	619,444	104,948,162	4%	32,604	811,289	3,029,262	10%	73,983	4,748,184
2022	84%	724,703	124,757,619	5%	39,994	1,137,171	3,486,691	11%	93,245	6,212,763
2023	84%	731,635	127,883,688	5%	40,571	1,231,754	3,543,090	11%	98,996	6,843,258
2024	83%	747,543	132,487,563	5%	41,200	1,332,140	3,598,733	12%	106,645	7,641,910
2025	83%	758,530	135,969,595	5%	41,866	1,438,799	3,640,575	12%	111,956	8,303,968
2026	65%	540,131	97,639,769	4%	34,449	1,220,027	3,088,034	31%	256,391	19,581,287

Table A-44. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 1c in Calendar Year 2026
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
1982	0%	0	0	0%	0	0	14	0.008	0.003
1983	0%	0	0	0%	0	0	17	0.009	0.003
1984	0%	0	0	0%	0	0	27	0.01	0.005
1985	0%	0	0	0%	0	0	36	0.02	0.006
1986	0%	0	0	0%	0	0	38	0.02	0.007
1987	0%	0	0	0%	0	0	48	0.02	0.009
1988	0%	0	0	0%	0	0	49	0.02	0.009
1989	0%	0	0	0%	0	0	63	0.03	0.01
1990	0%	0	0	0%	0	0	81	0.04	0.01
1991	0%	0	0	0%	0	0	101	0.05	0.02
1992	0%	0	0	0%	0	0	92	0.04	0.02
1993	0%	0	0	0%	0	0	101	0.05	0.02
1994	0%	0	0	0%	0	0	121	0.06	0.02
1995	0%	0	0	0%	0	0	166	0.08	0.03
1996	0%	0	0	0%	0	0	174	0.09	0.04
1997	0%	0	0	0%	0	0	244	0.11	0.05
1998	0%	0	0	0%	0	0	309	0.11	0.05
1999	0%	0	0	0%	0	0	372	0.09	0.06
2000	0%	0	0	0%	0	0	535	0.08	0.07
2001	0%	0	0	0%	0	0	638	0.09	0.07
2002	0%	0	0	0%	0	0	790	0.11	0.09
2003	0%	0	0	0%	0	0	1,041	0.13	0.11
2004	0%	0	0	0%	0	0	1,288	0.07	0.04
2005	0%	0	0	0%	0	0	1,781	0.08	0.05
2006	0%	0	0	0%	0	0	2,209	0.09	0.06
2007	0%	0	0	0%	0	0	2,756	0.11	0.08
2008	0%	0	0	0%	0	0	2,728	0.10	0.08
2009	0%	0	0	0%	0	0	2,404	0.09	0.07
2010	0%	0	0	0%	0	0	2,921	0.11	0.09
2011	0%	0	0	0%	0	0	3,345	0.12	0.10
2012	0%	0	0	0%	0	0	5,092	0.18	0.15
2013	0%	0	0	0%	0	0	6,591	0.22	0.19
2014	0%	0	0	0%	0	0	7,027	0.23	0.20
2015	0%	0	0	0%	0	0	8,823	0.28	0.24
2016	0%	0	0	0%	0	0	9,203	0.32	0.26
2017	0%	0	0	0%	0	0	10,320	0.32	0.27
2018	0%	0	0	0%	0	0	9,526	0.28	0.24
2019	0%	0	0	0%	0	0	8,601	0.23	0.21
2020	0%	0	0	0%	0	0	7,146	0.19	0.17
2021	0%	0	0	0%	0	0	8,840	0.21	0.21
2022	0%	0	0	0%	0	0	10,500	0.23	0.24
2023	0%	0	0	0%	0	0	10,760	0.21	0.23
2024	0%	0	0	0%	0	0	11,142	0.20	0.22
2025	0%	0	0	0%	0	0	11,430	0.16	0.20
2026	0%	0	0	0%	0	0	8,247	0.11	0.14

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-8) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-10. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fuel Consumption[3] (MJ of electricity/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of electricity/day)
1986	100%	9,277	319,606	0%	0	0	0	0%	0	0
1987	100%	11,036	395,358	0%	0	0	0	0%	1	13
1988	100%	10,287	394,106	0%	0	0	0	0%	0	0
1989	100%	12,682	513,141	0%	0	0	0	0%	1	10
1990	100%	15,335	660,988	0%	0	0	0	0%	0	0
1991	100%	17,755	806,207	0%	0	0	0	0%	0	0
1992	100%	14,968	722,403	0%	0	0	0	0%	0	0
1993	100%	15,722	757,504	0%	0	0	0	0%	2	30
1994	100%	16,938	862,749	0%	0	0	0	0%	0	4
1995	100%	21,266	1,147,175	0%	0	0	0	0%	1	18
1996	100%	20,041	1,148,835	0%	0	0	0	0%	0	0
1997	100%	25,571	1,519,989	0%	0	0	0	0%	3	55
1998	100%	29,544	1,816,366	0%	0	0	0	0%	3	55
1999	100%	32,392	2,061,329	0%	0	0	0	0%	2	47
2000	100%	41,346	2,802,701	0%	0	0	0	0%	1	14
2001	100%	44,766	3,209,806	0%	0	0	0	0%	3	65
2002	100%	49,911	3,795,455	0%	0	0	0	0%	18	424
2003	100%	59,781	4,832,777	0%	0	0	0	0%	3	76
2004	100%	65,751	5,844,031	0%	0	0	0	0%	2	59
2005	100%	86,903	8,039,211	0%	0	0	0	0%	3	81
2006	100%	103,055	10,092,547	0%	0	0	0	0%	5	144
2007	100%	128,610	12,929,139	0%	0	0	0	0%	11	328
2008	100%	125,543	13,361,675	0%	0	0	0	0%	60	1,794
2009	100%	116,809	12,395,606	0%	0	0	0	0%	18	572
2010	100%	158,274	16,020,574	0%	6	69	311	0%	86	2,863
2011	99%	175,648	19,479,572	0%	313	3,932	17,791	1%	1,076	37,957
2012	98%	282,481	31,367,919	1%	3,387	44,658	200,590	1%	1,526	56,296
2013	97%	378,095	42,683,040	2%	7,146	98,660	441,197	1%	5,433	209,483
2014	96%	402,992	47,862,257	3%	11,064	160,332	714,692	1%	6,227	251,167
2015	97%	518,113	63,218,662	2%	8,836	134,191	596,394	2%	9,879	417,410
2016	95%	553,278	69,108,331	2%	10,115	160,689	711,773	3%	16,817	738,736
2017	91%	604,853	79,402,357	4%	27,493	454,641	2,012,619	5%	33,194	1,524,212
2018	86%	555,971	75,960,952	4%	26,314	453,896	2,003,609	10%	61,332	2,941,765
2019	88%	505,059	71,135,364	3%	19,734	368,011	1,521,560	8%	47,387	2,378,873
2020	86%	424,894	60,588,792	4%	20,540	406,324	1,621,195	9%	46,181	2,435,627
2021	85%	528,088	76,514,975	4%	27,796	590,252	2,219,126	10%	63,072	3,464,139
2022	84%	629,123	92,802,888	5%	34,719	844,508	2,607,459	11%	80,947	4,626,137
2023	84%	652,013	97,885,688	5%	36,155	941,473	2,725,229	11%	88,223	5,242,684
2024	83%	670,253	102,369,934	5%	36,940	1,028,217	2,790,931	12%	95,619	5,905,793
2025	83%	697,118	108,259,056	5%	38,476	1,144,799	2,904,428	12%	102,891	6,603,088
2026	65%	562,392	88,712,763	4%	35,869	1,108,113	2,804,580	31%	266,958	17,769,266
2027	57%	506,170	82,823,038	4%	36,682	1,175,675	2,972,420	39%	345,166	23,832,150
2028	49%	448,945	76,077,298	4%	37,500	1,244,657	3,146,136	47%	429,769	30,729,889
2029	41%	382,216	66,862,077	4%	37,726	1,292,471	3,268,769	55%	512,292	37,813,655
2030	32%	271,278	48,854,015	11%	96,110	3,388,276	8,578,476	57%	480,355	36,503,084

Table A-45. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 1c in Calendar Year 2030

Model Year	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
1986	0%	0	0	0%	0	0	26	0.01	0.005
1987	0%	0	0	0%	0	0	32	0.02	0.006
1988	0%	0	0	0%	0	0	32	0.02	0.006
1989	0%	0	0	0%	0	0	42	0.02	0.008
1990	0%	0	0	0%	0	0	54	0.03	0.010
1991	0%	0	0	0%	0	0	66	0.03	0.01
1992	0%	0	0	0%	0	0	59	0.03	0.01
1993	0%	0	0	0%	0	0	62	0.03	0.01
1994	0%	0	0	0%	0	0	71	0.04	0.01
1995	0%	0	0	0%	0	0	94	0.05	0.02
1996	0%	0	0	0%	0	0	94	0.05	0.02
1997	0%	0	0	0%	0	0	124	0.06	0.02
1998	0%	0	0	0%	0	0	149	0.06	0.03
1999	0%	0	0	0%	0	0	169	0.05	0.03
2000	0%	0	0	0%	0	0	229	0.04	0.03
2001	0%	0	0	0%	0	0	263	0.04	0.03
2002	0%	0	0	0%	0	0	311	0.05	0.04
2003	0%	0	0	0%	0	0	396	0.05	0.04
2004	0%	0	0	0%	0	0	478	0.03	0.01
2005	0%	0	0	0%	0	0	658	0.03	0.02
2006	0%	0	0	0%	0	0	826	0.04	0.02
2007	0%	0	0	0%	0	0	1,059	0.05	0.03
2008	0%	0	0	0%	0	0	1,094	0.05	0.03
2009	0%	0	0	0%	0	0	1,015	0.04	0.03
2010	0%	0	0	0%	0	0	1,312	0.06	0.04
2011	0%	0	0	0%	0	0	1,596	0.06	0.05
2012	0%	0	0	0%	0	0	2,585	0.10	0.08
2013	0%	0	0	0%	0	0	3,531	0.13	0.11
2014	0%	0	0	0%	0	0	3,977	0.15	0.12
2015	0%	0	0	0%	0	0	5,225	0.19	0.16
2016	0%	0	0	0%	0	0	5,716	0.22	0.18
2017	0%	0	0	0%	0	0	6,666	0.24	0.20
2018	0%	0	0	0%	0	0	6,383	0.22	0.18
2019	0%	0	0	0%	0	0	5,949	0.19	0.17
2020	0%	0	0	0%	0	0	5,093	0.15	0.14
2021	0%	0	0	0%	0	0	6,446	0.18	0.18
2022	0%	0	0	0%	0	0	7,811	0.20	0.21
2023	0%	0	0	0%	0	0	8,237	0.19	0.21
2024	0%	0	0	0%	0	0	8,610	0.18	0.21
2025	0%	0	0	0%	0	0	9,101	0.16	0.20
2026	0%	0	0	0%	0	0	7,493	0.12	0.16
2027	0%	0	0	0%	0	0	7,024	0.111	0.143
2028	0%	0	0	0%	0	0	6,486	0.099	0.124
2029	0%	0	0	0%	0	0	5,742	0.084	0.103
2030	0%	0	0	0%	0	0	4,702	0.073	0.078

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-11) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-13. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

Table A-46. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 1c in Calendar Year 2035
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fuel Consumption[3] (MJ of electricity/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of electricity/day)
1991	100%	14,887	496,519	0%	0	0	0	0%	0	0
1992	100%	12,386	437,879	0%	0	0	0	0%	0	0
1993	100%	12,876	454,610	0%	0	0	0	0%	2	20
1994	100%	13,908	519,028	0%	0	0	0	0%	0	3
1995	100%	17,011	673,579	0%	0	0	0	0%	1	11
1996	100%	15,726	662,566	0%	0	0	0	0%	0	0
1997	100%	19,249	841,793	0%	0	0	0	0%	3	36
1998	100%	21,231	962,917	0%	0	0	0	0%	2	32
1999	100%	21,841	1,026,080	0%	0	0	0	0%	2	27
2000	100%	26,428	1,326,406	0%	0	0	0	0%	0	7
2001	100%	26,524	1,412,096	0%	0	0	0	0%	2	30
2002	100%	27,790	1,574,561	0%	0	0	0	0%	11	189
2003	100%	30,887	1,866,413	0%	0	0	0	0%	2	31
2004	100%	31,459	2,100,346	0%	0	0	0	0%	1	22
2005	100%	38,743	2,705,815	0%	0	0	0	0%	1	29
2006	100%	43,503	3,231,279	0%	0	0	0	0%	2	47
2007	100%	51,445	3,941,697	0%	0	0	0	0%	4	103
2008	100%	48,196	3,931,397	0%	0	0	0	0%	23	522
2009	100%	43,832	3,583,029	0%	0	0	0	0%	7	170
2010	100%	59,373	4,651,159	0%	2	20	92	0%	32	847
2011	99%	67,186	5,797,667	0%	120	1,161	5,375	1%	409	11,360
2012	98%	112,410	9,761,699	1%	1,348	13,798	63,245	1%	603	17,549
2013	97%	158,581	14,066,520	2%	2,997	32,296	147,122	1%	2,255	68,707
2014	96%	180,829	16,955,018	3%	4,964	56,441	255,982	1%	2,764	88,302
2015	97%	248,911	24,094,495	2%	4,244	50,842	229,574	2%	4,701	157,841
2016	95%	285,862	28,441,636	2%	5,224	65,752	295,555	3%	8,578	300,098
2017	91%	332,615	34,903,768	4%	15,110	198,715	892,263	5%	18,042	661,811
2018	86%	327,985	35,952,376	4%	15,507	213,599	955,739	9%	35,779	1,376,403
2019	88%	314,542	35,673,840	3%	12,281	183,606	769,058	8%	29,273	1,183,116
2020	86%	281,575	32,424,569	4%	13,612	216,540	874,542	9%	30,604	1,303,564
2021	85%	366,087	42,975,928	4%	19,269	330,198	1,255,839	10%	43,723	1,945,314
2022	84%	459,912	55,139,274	5%	25,381	499,808	1,561,702	11%	59,175	2,747,832
2023	84%	491,823	60,167,945	5%	27,272	576,729	1,688,911	11%	66,548	3,223,016
2024	83%	528,134	65,889,598	5%	29,108	659,860	1,811,619	12%	75,344	3,803,598
2025	83%	560,849	71,323,875	5%	30,955	752,392	1,930,200	12%	82,779	4,355,000
2026	65%	467,482	60,539,560	4%	29,815	754,625	1,930,143	31%	221,906	12,112,622
2027	57%	430,704	58,014,343	4%	31,213	822,291	2,099,102	39%	293,704	16,679,184
2028	49%	390,089	54,639,940	4%	32,584	892,959	2,275,365	47%	373,427	22,053,612
2029	41%	338,901	49,344,310	4%	33,451	953,218	2,424,492	55%	454,235	27,888,884
2030	32%	276,003	41,738,586	11%	97,784	2,894,717	7,350,796	57%	488,721	31,171,698
2031	24%	213,410	33,502,607	17%	151,894	4,669,292	11,838,991	59%	523,905	34,694,565
2032	18%	164,104	26,722,257	18%	162,392	5,178,913	13,116,584	64%	585,195	40,200,521
2033	12%	112,719	19,004,076	18%	166,766	5,506,139	13,941,195	64%	603,670	42,934,541
2034	6%	57,245	9,957,437	18%	168,918	5,752,729	14,572,928	68%	651,167	47,779,136
2035	0%	0	0	19%	160,651	5,625,686	14,266,011	69%	594,609	44,875,060

Table A-46. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 1c in Calendar Year 2035

	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
1991	0%	0	0	0%	0	0	41	0.02	0.008
1992	0%	0	0	0%	0	0	36	0.02	0.007
1993	0%	0	0	0%	0	0	37	0.02	0.007
1994	0%	0	0	0%	0	0	42	0.02	0.008
1995	0%	0	0	0%	0	0	55	0.03	0.01
1996	0%	0	0	0%	0	0	54	0.04	0.01
1997	0%	0	0	0%	0	0	69	0.04	0.01
1998	0%	0	0	0%	0	0	79	0.03	0.01
1999	0%	0	0	0%	0	0	84	0.03	0.01
2000	0%	0	0	0%	0	0	109	0.02	0.01
2001	0%	0	0	0%	0	0	116	0.02	0.01
2002	0%	0	0	0%	0	0	129	0.02	0.02
2003	0%	0	0	0%	0	0	153	0.02	0.02
2004	0%	0	0	0%	0	0	172	0.01	0.006
2005	0%	0	0	0%	0	0	222	0.01	0.007
2006	0%	0	0	0%	0	0	265	0.01	0.008
2007	0%	0	0	0%	0	0	323	0.02	0.01
2008	0%	0	0	0%	0	0	322	0.02	0.01
2009	0%	0	0	0%	0	0	293	0.01	0.010
2010	0%	0	0	0%	0	0	381	0.02	0.01
2011	0%	0	0	0%	0	0	475	0.02	0.02
2012	0%	0	0	0%	0	0	804	0.04	0.03
2013	0%	0	0	0%	0	0	1,164	0.05	0.04
2014	0%	0	0	0%	0	0	1,409	0.06	0.05
2015	0%	0	0	0%	0	0	1,991	0.08	0.07
2016	0%	0	0	0%	0	0	2,353	0.11	0.08
2017	0%	0	0	0%	0	0	2,931	0.12	0.10
2018	0%	0	0	0%	0	0	3,022	0.12	0.10
2019	0%	0	0	0%	0	0	2,984	0.11	0.10
2020	0%	0	0	0%	0	0	2,726	0.10	0.09
2021	0%	0	0	0%	0	0	3,621	0.12	0.12
2022	0%	0	0	0%	0	0	4,642	0.14	0.15
2023	0%	0	0	0%	0	0	5,064	0.14	0.16
2024	0%	0	0	0%	0	0	5,543	0.14	0.16
2025	0%	0	0	0%	0	0	5,997	0.13	0.17
2026	0%	0	0	0%	0	0	5,115	0.10	0.14
2027	0%	0	0	0%	0	0	4,922	0.10	0.13
2028	0%	0	0	0%	0	0	4,660	0.09	0.12
2029	0%	0	0	0%	0	0	4,238	0.08	0.10
2030	0%	0	0	0%	0	0	4,019	0.08	0.09
2031	0%	0	0	0%	0	0	3,712	0.08	0.08
2032	0%	0	0	0%	0	0	3,262	0.07	0.06
2033	6%	56,169	3,787,976	0%	0	0	2,697	0.06	0.05
2034	8%	76,745	5,339,785	0%	0	0	2,008	0.05	0.04
2035	13%	110,583	7,914,341	0%	0	0	1,168	0.03	0.02

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-14) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-16. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

Table A-47. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 1c in Calendar Year 2040
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Model Year	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fuel Consumption[3] (MJ of electricity/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of electricity/day)
1996	100%	13,224	407,390	0%	0	0	0	0%	0	0
1997	100%	15,957	507,603	0%	0	0	0	0%	2	27
1998	100%	17,428	573,388	0%	0	0	0	0%	2	23
1999	100%	17,981	612,358	0%	0	0	0	0%	2	19
2000	100%	21,212	772,196	0%	0	0	0	0%	0	5
2001	100%	20,869	808,569	0%	0	0	0	0%	1	19
2002	100%	20,957	866,980	0%	0	0	0	0%	8	114
2003	100%	22,226	985,080	0%	0	0	0	0%	1	18
2004	100%	21,228	1,041,890	0%	0	0	0	0%	1	12
2005	100%	24,808	1,278,892	0%	0	0	0	0%	1	16
2006	100%	25,795	1,417,856	0%	0	0	0	0%	1	22
2007	100%	28,657	1,630,516	0%	0	0	0	0%	2	44
2008	100%	24,894	1,513,071	0%	0	0	0	0%	12	206
2009	100%	20,958	1,283,229	0%	0	0	0	0%	3	64
2010	100%	26,447	1,559,497	0%	1	7	31	0%	15	295
2011	99%	28,341	1,849,619	0%	51	367	1,752	1%	172	3,720
2012	98%	44,963	2,967,860	1%	539	4,153	19,596	1%	240	5,433
2013	97%	60,869	4,125,844	2%	1,150	9,385	43,891	1%	858	20,372
2014	96%	67,874	4,888,299	3%	1,863	16,131	74,982	1%	1,028	25,649
2015	97%	93,376	6,979,373	2%	1,592	14,608	67,463	2%	1,750	45,992
2016	95%	109,366	8,447,742	2%	1,998	19,377	88,913	3%	3,230	88,645
2017	91%	132,055	10,809,831	4%	5,994	61,088	279,650	5%	7,052	203,451
2018	87%	137,285	11,794,487	4%	6,483	69,602	317,087	9%	14,800	449,301
2019	88%	141,083	12,595,274	3%	5,505	64,430	274,520	8%	13,018	416,452
2020	86%	135,652	12,343,563	4%	6,558	82,023	336,557	9%	14,744	498,290
2021	85%	189,590	17,659,856	4%	9,979	135,046	521,355	10%	22,644	801,678
2022	84%	253,809	24,240,958	5%	14,007	218,733	693,952	11%	32,657	1,210,322
2023	84%	291,017	28,467,215	5%	16,137	271,680	807,271	11%	39,377	1,526,695
2024	83%	329,600	32,998,938	5%	18,166	329,087	916,198	12%	47,021	1,906,128
2025	83%	371,783	38,066,268	5%	20,520	399,967	1,039,937	12%	54,873	2,325,226
2026	65%	324,168	33,911,685	4%	20,675	421,047	1,090,413	31%	153,877	6,765,602
2027	57%	314,930	34,373,272	4%	22,823	485,341	1,253,824	39%	214,756	9,851,828
2028	49%	294,302	33,491,115	4%	24,583	545,508	1,406,015	47%	281,732	13,479,728
2029	41%	267,079	31,668,216	4%	26,362	610,009	1,568,829	55%	357,971	17,854,418
2030	32%	222,088	27,421,128	11%	78,683	1,896,571	4,867,575	57%	393,255	20,437,935
2031	24%	177,426	22,797,903	17%	126,282	3,169,977	8,120,082	59%	435,566	23,572,048
2032	18%	139,693	18,670,261	18%	138,235	3,612,279	9,234,728	64%	498,143	28,057,602
2033	12%	98,033	13,625,389	18%	145,039	3,943,033	10,061,837	64%	525,021	30,759,919
2034	6%	50,852	7,346,988	18%	150,054	4,242,306	10,805,654	68%	578,448	35,237,411
2035	0%	0	0	19%	163,938	4,815,669	12,246,165	69%	606,774	38,400,274
2036	0%	0	0	18%	165,245	5,040,700	12,798,757	68%	621,364	40,830,105
2037	0%	0	0	18%	171,983	5,442,528	13,803,780	69%	641,862	43,750,953
2038	0%	0	0	18%	173,156	5,672,337	14,382,598	68%	656,521	46,324,739
2039	0%	0	0	18%	175,550	5,930,109	15,044,275	68%	665,597	48,438,322
2040	0%	0	0	18%	160,244	5,563,583	14,129,856	68%	602,698	45,094,194

	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
1996	0%	0	0	0%	0	0	33	0.02	0.007
1997	0%	0	0	0%	0	0	42	0.03	0.009
1998	0%	0	0	0%	0	0	47	0.02	0.009
1999	0%	0	0	0%	0	0	50	0.02	0.008
2000	0%	0	0	0%	0	0	63	0.01	0.009
2001	0%	0	0	0%	0	0	66	0.01	0.009
2002	0%	0	0	0%	0	0	71	0.01	0.009
2003	0%	0	0	0%	0	0	81	0.01	0.010
2004	0%	0	0	0%	0	0	85	0.007	0.003
2005	0%	0	0	0%	0	0	105	0.008	0.004
2006	0%	0	0	0%	0	0	116	0.007	0.004
2007	0%	0	0	0%	0	0	133	0.008	0.005
2008	0%	0	0	0%	0	0	124	0.007	0.004
2009	0%	0	0	0%	0	0	105	0.006	0.004
2010	0%	0	0	0%	0	0	128	0.007	0.005
2011	0%	0	0	0%	0	0	152	0.008	0.006
2012	0%	0	0	0%	0	0	245	0.01	0.009
2013	0%	0	0	0%	0	0	341	0.02	0.01
2014	0%	0	0	0%	0	0	406	0.02	0.02
2015	0%	0	0	0%	0	0	577	0.03	0.02
2016	0%	0	0	0%	0	0	699	0.04	0.03
2017	0%	0	0	0%	0	0	908	0.04	0.03
2018	0%	0	0	0%	0	0	992	0.05	0.04
2019	0%	0	0	0%	0	0	1,054	0.05	0.04
2020	0%	0	0	0%	0	0	1,038	0.04	0.04
2021	0%	0	0	0%	0	0	1,489	0.06	0.05
2022	0%	0	0	0%	0	0	2,041	0.07	0.07
2023	0%	0	0	0%	0	0	2,397	0.08	0.08
2024	0%	0	0	0%	0	0	2,777	0.08	0.10
2025	0%	0	0	0%	0	0	3,202	0.08	0.10
2026	0%	0	0	0%	0	0	2,866	0.07	0.09
2027	0%	0	0	0%	0	0	2,917	0.07	0.09
2028	0%	0	0	0%	0	0	2,857	0.07	0.09
2029	0%	0	0	0%	0	0	2,721	0.06	0.08
2030	0%	0	0	0%	0	0	2,644	0.06	0.07
2031	0%	0	0	0%	0	0	2,531	0.06	0.06
2032	0%	0	0	0%	0	0	2,285	0.06	0.05
2033	6%	48,851	2,715,872	0%	0	0	1,939	0.05	0.04
2034	8%	68,174	3,939,903	0%	0	0	1,486	0.04	0.03
2035	13%	112,845	6,773,504	0%	0	0	1,003	0.03	0.02
2036	14%	123,469	7,693,588	0%	0	0	1,048	0.03	0.02
2037	13%	118,203	7,639,708	0%	0	0	1,130	0.04	0.02
2038	13%	129,181	8,643,687	0%	0	0	1,178	0.04	0.02
2039	13%	130,967	9,039,251	0%	0	0	1,232	0.04	0.02
2040	13%	117,372	8,329,984	0%	0	0	1,157	0.03	0.02

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-17) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-19. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

Table A-48. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 1c in Calendar Year 2045
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fuel Consumption[3] (MJ of electricity/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of electricity/day)
2001	100%	17,581	492,838	0%	0	0	0	0%	1	13
2002	100%	17,396	519,815	0%	0	0	0	0%	7	79
2003	100%	18,261	584,063	0%	0	0	0	0%	1	12
2004	100%	17,485	620,429	0%	0	0	0	0%	1	8
2005	100%	19,931	744,101	0%	0	0	0	0%	1	11
2006	100%	20,294	810,536	0%	0	0	0	0%	1	13
2007	100%	21,610	895,705	0%	0	0	0	0%	2	26
2008	100%	17,913	797,202	0%	0	0	0	0%	8	112
2009	100%	14,142	635,358	0%	0	0	0	0%	2	35
2010	100%	16,923	735,246	0%	1	3	15	0%	9	147
2011	99%	16,799	809,857	0%	30	158	790	1%	101	1,691
2012	98%	25,037	1,225,371	1%	300	1,692	8,301	1%	133	2,322
2013	97%	31,446	1,584,333	2%	594	3,560	17,255	1%	442	8,105
2014	96%	32,442	1,745,658	3%	890	5,695	27,363	1%	489	9,437
2015	97%	41,547	2,333,580	2%	708	4,833	22,999	2%	777	15,810
2016	95%	46,072	2,687,564	2%	841	6,105	28,783	3%	1,354	28,787
2017	91%	52,700	3,274,039	4%	2,391	18,339	86,121	5%	2,789	62,457
2018	87%	52,549	3,444,774	4%	2,479	20,175	94,087	9%	5,607	132,466
2019	88%	52,919	3,622,227	3%	2,063	18,391	80,115	8%	4,832	120,601
2020	86%	51,080	3,577,777	4%	2,469	23,635	98,982	9%	5,552	146,669
2021	85%	72,808	5,249,034	4%	3,832	39,919	157,067	10%	8,696	241,288
2022	84%	101,322	7,527,271	5%	5,592	67,570	218,488	11%	13,037	379,660
2023	84%	122,476	9,364,450	5%	6,792	88,932	269,022	11%	16,572	506,226
2024	83%	148,333	11,660,897	5%	8,175	115,750	327,717	12%	21,161	677,755
2025	83%	179,162	14,468,745	5%	9,889	151,350	399,826	12%	26,443	887,822
2026	65%	167,925	13,913,800	4%	10,710	171,981	451,908	31%	79,711	2,769,255
2027	57%	173,839	15,087,722	4%	12,598	212,114	555,489	39%	118,544	4,311,126
2028	49%	174,181	15,820,703	4%	14,549	256,617	669,890	47%	166,741	6,346,215
2029	41%	166,713	15,834,899	4%	16,455	303,793	790,664	55%	223,449	8,896,336
2030	32%	147,252	14,612,516	11%	52,170	1,006,357	2,611,771	57%	260,741	10,854,269
2031	24%	123,062	12,750,639	17%	87,589	1,765,571	4,569,872	59%	302,108	13,139,739
2032	18%	102,163	11,044,387	18%	101,097	2,128,204	5,494,682	64%	364,313	16,542,390
2033	12%	73,974	8,338,115	18%	109,444	2,404,371	6,193,162	64%	396,173	18,770,171
2034	6%	40,081	4,707,395	18%	118,271	2,709,727	6,964,190	68%	455,927	22,522,711
2035	0%	0	0	19%	131,938	3,150,375	8,079,711	69%	488,335	25,138,012
2036	0%	0	0	18%	137,408	3,417,243	8,746,950	68%	516,688	27,698,846
2037	0%	0	0	18%	146,461	3,791,849	9,686,329	69%	546,611	30,500,627
2038	0%	0	0	18%	150,744	4,060,311	10,352,921	68%	571,544	33,174,722
2039	0%	0	0	18%	156,243	4,376,689	11,138,907	68%	592,396	35,754,101
2040	0%	0	0	18%	164,020	4,773,900	12,129,938	68%	616,901	38,681,600
2041	0%	0	0	18%	168,771	5,101,194	12,941,520	68%	634,772	41,327,871
2042	0%	0	0	18%	172,642	5,413,474	13,718,442	68%	649,331	43,853,423
2043	0%	0	0	18%	177,341	5,756,043	14,582,282	68%	667,002	46,629,251
2044	0%	0	0	18%	179,451	6,005,420	15,221,972	68%	674,940	48,657,601
2045	0%	0	0	18%	162,153	5,576,255	14,149,450	68%	609,877	45,193,705

Table A-48. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 1c in Calendar Year 2045

	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
2001	0%	0	0	0%	0	0	40	0.01	0.006
2002	0%	0	0	0%	0	0	43	0.01	0.006
2003	0%	0	0	0%	0	0	48	0.01	0.006
2004	0%	0	0	0%	0	0	51	0.005	0.002
2005	0%	0	0	0%	0	0	61	0.005	0.002
2006	0%	0	0	0%	0	0	66	0.005	0.002
2007	0%	0	0	0%	0	0	73	0.005	0.003
2008	0%	0	0	0%	0	0	65	0.005	0.003
2009	0%	0	0	0%	0	0	52	0.003	0.002
2010	0%	0	0	0%	0	0	60	0.004	0.003
2011	0%	0	0	0%	0	0	66	0.004	0.003
2012	0%	0	0	0%	0	0	101	0.006	0.004
2013	0%	0	0	0%	0	0	131	0.008	0.006
2014	0%	0	0	0%	0	0	145	0.009	0.006
2015	0%	0	0	0%	0	0	193	0.01	0.008
2016	0%	0	0	0%	0	0	222	0.01	0.009
2017	0%	0	0	0%	0	0	275	0.02	0.01
2018	0%	0	0	0%	0	0	290	0.02	0.01
2019	0%	0	0	0%	0	0	303	0.02	0.01
2020	0%	0	0	0%	0	0	301	0.01	0.01
2021	0%	0	0	0%	0	0	443	0.02	0.02
2022	0%	0	0	0%	0	0	634	0.03	0.03
2023	0%	0	0	0%	0	0	789	0.03	0.03
2024	0%	0	0	0%	0	0	982	0.03	0.04
2025	0%	0	0	0%	0	0	1,217	0.04	0.04
2026	0%	0	0	0%	0	0	1,176	0.03	0.04
2027	0%	0	0	0%	0	0	1,281	0.04	0.05
2028	0%	0	0	0%	0	0	1,350	0.04	0.05
2029	0%	0	0	0%	0	0	1,361	0.04	0.05
2030	0%	0	0	0%	0	0	1,410	0.04	0.04
2031	0%	0	0	0%	0	0	1,418	0.04	0.04
2032	0%	0	0	0%	0	0	1,354	0.04	0.04
2033	6%	36,862	1,661,990	0%	0	0	1,190	0.04	0.03
2034	8%	53,734	2,524,392	0%	0	0	956	0.03	0.02
2035	13%	90,819	4,442,897	0%	0	0	662	0.03	0.01
2036	14%	102,670	5,227,063	0%	0	0	716	0.03	0.01
2037	13%	100,662	5,330,745	0%	0	0	793	0.03	0.02
2038	13%	112,460	6,193,359	0%	0	0	848	0.03	0.02
2039	13%	116,563	6,673,137	0%	0	0	912	0.03	0.02
2040	13%	120,138	7,143,681	0%	0	0	993	0.03	0.02
2041	13%	123,618	7,630,888	0%	0	0	1,060	0.03	0.02
2042	13%	126,454	8,096,626	0%	0	0	1,123	0.04	0.02
2043	13%	129,895	8,609,871	0%	0	0	1,194	0.04	0.02
2044	13%	131,441	8,985,639	0%	0	0	1,246	0.04	0.02
2045	13%	118,770	8,347,283	0%	0	0	1,158	0.03	0.02

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-20) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-22. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

Table A-49. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 1c in Calendar Year 2050

Model Year	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
	Fleet Mix[1] (%)	**Population[2] (vehicles)**	**Fuel Consumption[3] (MJ of gasoline/day)**	**Fleet Mix[1] (%)**	**Population[2] (vehicles)**	**Fuel Consumption[3] (MJ of gasoline/day)**	**Fuel Consumption[3] (MJ of electricity/day)**	**Fleet Mix[1] (%)**	**Population[2] (vehicles)**	**Fuel Consumption[3] (MJ of electricity/day)**
2006	100%	17,095	495,171	0%	0	0	0	0%	1	9
2007	100%	17,938	537,342	0%	0	0	0	0%	2	18
2008	100%	14,711	473,301	0%	0	0	0	0%	6	73
2009	100%	11,643	378,435	0%	0	0	0	0%	2	24
2010	100%	13,584	427,686	0%	0	2	9	0%	8	94
2011	99%	13,206	463,001	0%	24	89	472	1%	79	1,039
2012	98%	18,883	674,484	1%	226	915	4,745	1%	100	1,368
2013	97%	22,656	836,306	2%	428	1,850	9,427	1%	314	4,504
2014	96%	21,908	865,904	3%	601	2,783	14,018	1%	326	4,894
2015	97%	26,586	1,101,721	2%	453	2,250	11,180	2%	491	7,761
2016	95%	27,295	1,177,776	2%	498	2,640	12,955	3%	790	13,009
2017	91%	29,325	1,351,831	4%	1,329	7,482	36,484	5%	1,525	26,393
2018	87%	27,113	1,322,228	4%	1,278	7,675	37,071	9%	2,868	52,384
2019	89%	25,304	1,294,975	3%	986	6,516	29,339	8%	2,292	44,244
2020	86%	22,760	1,198,129	4%	1,100	7,856	33,925	9%	2,474	50,596
2021	85%	30,740	1,673,570	4%	1,618	12,642	51,178	10%	3,671	78,995
2022	84%	40,577	2,287,454	5%	2,239	20,404	67,892	11%	5,221	118,112
2023	84%	47,100	2,747,369	5%	2,612	25,936	80,590	11%	6,373	151,554
2024	83%	55,817	3,364,077	5%	3,076	33,204	96,428	12%	7,963	198,997
2025	83%	67,473	4,197,128	5%	3,724	43,672	118,177	12%	9,959	261,533
2026	65%	64,497	4,139,198	4%	4,114	50,877	136,660	31%	30,616	823,259
2027	57%	69,408	4,689,197	4%	5,030	65,571	175,255	39%	47,331	1,336,696
2028	49%	73,318	5,209,164	4%	6,124	84,058	223,637	47%	70,186	2,082,624
2029	41%	75,042	5,600,876	4%	7,407	106,921	283,234	55%	100,580	3,134,673
2030	32%	70,975	5,559,659	11%	25,146	380,730	1,004,516	57%	125,676	4,113,703
2031	24%	63,763	5,236,564	17%	45,383	721,111	1,895,508	59%	156,532	5,375,018
2032	18%	56,405	4,852,327	18%	55,817	930,086	2,436,526	64%	201,141	7,238,307
2033	12%	43,791	3,942,469	18%	64,788	1,131,099	2,953,586	64%	234,524	8,839,470
2034	6%	25,024	2,355,959	18%	73,841	1,349,569	3,513,416	68%	284,652	11,227,112
2035	0%	0	0	19%	87,498	1,672,493	4,341,677	69%	323,850	13,356,070
2036	0%	0	0	18%	95,328	1,904,433	4,930,439	68%	358,456	15,447,846
2037	0%	0	0	18%	107,133	2,235,234	5,772,259	69%	399,835	17,992,179
2038	0%	0	0	18%	113,768	2,477,213	6,382,055	68%	431,351	20,254,083
2039	0%	0	0	18%	123,168	2,796,970	7,189,731	68%	466,989	22,865,056
2040	0%	0	0	18%	132,029	3,124,778	8,015,428	68%	496,578	25,336,854
2041	0%	0	0	18%	140,369	3,460,229	8,858,376	68%	527,945	28,053,244
2042	0%	0	0	18%	147,089	3,774,800	9,644,183	68%	553,221	30,598,885
2043	0%	0	0	18%	154,543	4,126,387	10,522,814	68%	581,258	33,443,696
2044	0%	0	0	18%	160,030	4,443,888	11,311,334	68%	601,896	36,011,198
2045	0%	0	0	18%	166,498	4,804,145	12,208,162	68%	626,220	38,925,172
2046	0%	0	0	18%	171,155	5,128,726	13,012,656	68%	643,736	41,549,099
2047	0%	0	0	18%	174,877	5,436,451	13,777,817	68%	657,736	44,037,378
2048	0%	0	0	18%	179,371	5,771,778	14,622,992	68%	674,638	46,754,135
2049	0%	0	0	18%	181,176	6,010,410	15,235,046	68%	681,428	48,694,986
2050	0%	0	0	18%	163,362	5,568,149	14,128,846	68%	614,425	45,124,868

Table A-49. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 1c in Calendar Year 2050
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
2006	0%	0	0	0%	0	0	41	0.004	0.002
2007	0%	0	0	0%	0	0	44	0.004	0.002
2008	0%	0	0	0%	0	0	39	0.003	0.002
2009	0%	0	0	0%	0	0	31	0.002	0.001
2010	0%	0	0	0%	0	0	35	0.003	0.002
2011	0%	0	0	0%	0	0	38	0.003	0.002
2012	0%	0	0	0%	0	0	56	0.004	0.003
2013	0%	0	0	0%	0	0	69	0.005	0.003
2014	0%	0	0	0%	0	0	72	0.005	0.003
2015	0%	0	0	0%	0	0	91	0.006	0.004
2016	0%	0	0	0%	0	0	97	0.007	0.005
2017	0%	0	0	0%	0	0	114	0.008	0.005
2018	0%	0	0	0%	0	0	111	0.007	0.005
2019	0%	0	0	0%	0	0	108	0.006	0.005
2020	0%	0	0	0%	0	0	101	0.006	0.004
2021	0%	0	0	0%	0	0	141	0.008	0.006
2022	0%	0	0	0%	0	0	193	0.009	0.009
2023	0%	0	0	0%	0	0	232	0.01	0.01
2024	0%	0	0	0%	0	0	283	0.01	0.01
2025	0%	0	0	0%	0	0	353	0.01	0.01
2026	0%	0	0	0%	0	0	350	0.01	0.01
2027	0%	0	0	0%	0	0	398	0.01	0.02
2028	0%	0	0	0%	0	0	445	0.01	0.02
2029	0%	0	0	0%	0	0	482	0.01	0.02
2030	0%	0	0	0%	0	0	537	0.02	0.02
2031	0%	0	0	0%	0	0	584	0.02	0.02
2032	0%	0	0	0%	0	0	597	0.02	0.02
2033	6%	21,821	785,830	0%	0	0	565	0.02	0.02
2034	8%	33,548	1,263,409	0%	0	0	481	0.02	0.01
2035	13%	60,228	2,369,748	0%	0	0	355	0.02	0.008
2036	14%	71,228	2,926,162	0%	0	0	404	0.02	0.009
2037	13%	73,632	3,156,177	0%	0	0	473	0.02	0.01
2038	13%	84,875	3,793,317	0%	0	0	523	0.02	0.01
2039	13%	91,887	4,279,183	0%	0	0	589	0.02	0.01
2040	13%	96,706	4,689,788	0%	0	0	656	0.03	0.01
2041	13%	102,814	5,189,078	0%	0	0	725	0.03	0.01
2042	13%	107,737	5,656,125	0%	0	0	790	0.03	0.02
2043	13%	113,197	6,180,287	0%	0	0	862	0.03	0.02
2044	13%	117,216	6,653,010	0%	0	0	926	0.03	0.02
2045	13%	121,953	7,189,688	0%	0	0	1000	0.03	0.02
2046	13%	125,364	7,672,852	0%	0	0	1,065	0.03	0.02
2047	13%	128,090	8,131,796	0%	0	0	1,128	0.04	0.02
2048	13%	131,382	8,634,227	0%	0	0	1,197	0.04	0.02
2049	13%	132,704	8,993,915	0%	0	0	1,247	0.04	0.02
2050	13%	119,656	8,335,870	0%	0	0	1,157	0.03	0.02

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-23) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-25. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

Table A-50. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenarios 1d and 1d-1 in Calendar Year 2026
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fuel Consumption[3] (MJ of electricity/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of electricity/day)
1982	100%	4,657	174,227	0%	0	0	0	0%	1	9
1983	100%	5,273	206,541	0%	0	0	0	0%	1	9
1984	100%	7,858	329,345	0%	0	0	0	0%	1	13
1985	100%	10,024	435,286	0%	0	0	0	0%	0	0
1986	100%	10,647	463,741	0%	0	0	0	0%	0	0
1987	100%	12,832	586,622	0%	0	0	0	0%	1	18
1988	100%	12,139	592,716	0%	0	0	0	0%	0	0
1989	100%	14,970	774,940	0%	0	0	0	0%	1	14
1990	100%	18,044	991,990	0%	0	0	0	0%	0	0
1991	100%	21,281	1,234,023	0%	0	0	0	0%	0	0
1992	100%	18,332	1,127,213	0%	0	0	0	0%	0	0
1993	100%	20,138	1,231,512	0%	0	0	0	0%	3	46
1994	100%	22,840	1,473,479	0%	0	0	0	0%	0	7
1995	100%	29,675	2,022,331	0%	0	0	0	0%	2	31
1996	100%	29,436	2,128,971	0%	0	0	0	0%	0	0
1997	100%	39,761	2,978,637	0%	0	0	0	0%	4	95
1998	100%	48,817	3,777,000	0%	0	0	0	0%	5	107
1999	100%	56,921	4,546,344	0%	0	0	0	0%	4	98
2000	100%	76,964	6,529,441	0%	0	0	0	0%	1	31
2001	100%	87,221	7,793,387	0%	0	0	0	0%	6	155
2002	100%	102,135	9,644,077	0%	0	0	0	0%	37	1,030
2003	100%	127,287	12,720,322	0%	0	0	0	0%	7	196
2004	100%	143,690	15,732,253	0%	0	0	0	0%	5	155
2005	100%	191,623	21,752,720	0%	0	0	0	0%	7	213
2006	100%	225,488	26,980,154	0%	0	0	0	0%	11	389
2007	100%	275,180	33,665,694	0%	0	0	0	0%	23	834
2008	100%	258,265	33,318,492	0%	0	0	0	0%	126	4,586
2009	100%	229,086	29,357,696	0%	0	0	0	0%	34	1,333
2010	100%	292,924	35,681,010	0%	11	154	687	0%	161	6,445
2011	99%	307,002	40,824,099	0%	548	8,280	37,013	1%	1,890	79,947
2012	98%	465,759	61,806,971	1%	5,585	88,399	392,722	1%	2,528	111,558
2013	97%	592,447	79,686,217	2%	11,199	185,018	819,056	1%	8,583	395,185
2014	96%	599,553	84,574,041	3%	16,462	284,537	1,256,341	1%	9,356	449,554
2015	96%	738,821	106,767,996	2%	12,602	227,577	1,002,629	2%	14,202	712,794
2016	95%	754,102	111,262,248	2%	13,790	259,774	1,141,452	3%	23,130	1,205,441
2017	91%	794,462	122,943,456	4%	36,125	706,874	3,105,093	5%	43,901	2,385,744
2018	86%	705,513	113,371,002	4%	33,412	680,299	2,980,537	10%	78,294	4,428,841
2019	88%	622,322	102,867,416	3%	24,317	533,860	2,191,127	8%	58,438	3,447,620
2020	86%	508,892	85,019,301	4%	24,600	571,597	2,264,467	9%	55,310	3,416,834
2021	85%	619,444	104,948,162	4%	32,604	811,289	3,029,262	10%	73,983	4,748,184
2022	84%	724,703	124,757,619	5%	39,994	1,137,171	3,486,691	11%	93,245	6,212,763
2023	84%	731,635	127,883,688	5%	40,571	1,231,754	3,543,090	11%	98,996	6,843,258
2024	83%	747,543	132,487,563	5%	41,200	1,332,140	3,598,733	12%	106,645	7,641,910
2025	83%	758,530	135,969,595	5%	41,866	1,438,799	3,640,575	12%	111,956	8,303,968
2026	65%	540,131	97,639,769	4%	34,449	1,220,027	3,088,034	11%	89,660	6,866,855

Table A-50. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenarios 1d and 1d-1 in Calendar Year 2026

	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
1982	0%	0	0	0%	0	0	14	0.008	0.003
1983	0%	0	0	0%	0	0	17	0.009	0.003
1984	0%	0	0	0%	0	0	27	0.01	0.005
1985	0%	0	0	0%	0	0	36	0.02	0.006
1986	0%	0	0	0%	0	0	38	0.02	0.007
1987	0%	0	0	0%	0	0	48	0.02	0.009
1988	0%	0	0	0%	0	0	49	0.02	0.009
1989	0%	0	0	0%	0	0	63	0.03	0.01
1990	0%	0	0	0%	0	0	81	0.04	0.01
1991	0%	0	0	0%	0	0	101	0.05	0.02
1992	0%	0	0	0%	0	0	92	0.04	0.02
1993	0%	0	0	0%	0	0	101	0.05	0.02
1994	0%	0	0	0%	0	0	121	0.06	0.02
1995	0%	0	0	0%	0	0	166	0.08	0.03
1996	0%	0	0	0%	0	0	174	0.09	0.04
1997	0%	0	0	0%	0	0	244	0.11	0.05
1998	0%	0	0	0%	0	0	309	0.11	0.05
1999	0%	0	0	0%	0	0	372	0.09	0.06
2000	0%	0	0	0%	0	0	535	0.08	0.07
2001	0%	0	0	0%	0	0	638	0.09	0.07
2002	0%	0	0	0%	0	0	790	0.11	0.09
2003	0%	0	0	0%	0	0	1,041	0.13	0.11
2004	0%	0	0	0%	0	0	1,288	0.07	0.04
2005	0%	0	0	0%	0	0	1,781	0.08	0.05
2006	0%	0	0	0%	0	0	2,209	0.09	0.06
2007	0%	0	0	0%	0	0	2,756	0.11	0.08
2008	0%	0	0	0%	0	0	2,728	0.10	0.08
2009	0%	0	0	0%	0	0	2,404	0.09	0.07
2010	0%	0	0	0%	0	0	2,921	0.11	0.09
2011	0%	0	0	0%	0	0	3,345	0.12	0.10
2012	0%	0	0	0%	0	0	5,092	0.18	0.15
2013	0%	0	0	0%	0	0	6,591	0.22	0.19
2014	0%	0	0	0%	0	0	7,027	0.23	0.20
2015	0%	0	0	0%	0	0	8,823	0.28	0.24
2016	0%	0	0	0%	0	0	9,203	0.32	0.26
2017	0%	0	0	0%	0	0	10,320	0.32	0.27
2018	0%	0	0	0%	0	0	9,526	0.28	0.24
2019	0%	0	0	0%	0	0	8,601	0.23	0.21
2020	0%	0	0	0%	0	0	7,146	0.19	0.17
2021	0%	0	0	0%	0	0	8,840	0.21	0.21
2022	0%	0	0	0%	0	0	10,500	0.23	0.24
2023	0%	0	0	0%	0	0	10,760	0.21	0.23
2024	0%	0	0	0%	0	0	11,142	0.20	0.22
2025	0%	0	0	0%	0	0	11,430	0.16	0.20
2026	20%	166,731	12,056,007	0%	0	0	8,247	0.11	0.14

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-8) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-10. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

Table A-51. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenarios 1d and 1d-1 in Calendar Year 2030
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fuel Consumption[3] (MJ of electricity/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of electricity/day)
1986	100%	9,277	319,606	0%	0	0	0	0%	0	0
1987	100%	11,036	395,358	0%	0	0	0	0%	1	13
1988	100%	10,287	394,106	0%	0	0	0	0%	0	0
1989	100%	12,682	513,141	0%	0	0	0	0%	1	10
1990	100%	15,335	660,988	0%	0	0	0	0%	0	0
1991	100%	17,755	806,207	0%	0	0	0	0%	0	0
1992	100%	14,968	722,403	0%	0	0	0	0%	0	0
1993	100%	15,722	757,504	0%	0	0	0	0%	2	30
1994	100%	16,938	862,749	0%	0	0	0	0%	0	4
1995	100%	21,266	1,147,175	0%	0	0	0	0%	1	18
1996	100%	20,041	1,148,835	0%	0	0	0	0%	0	0
1997	100%	25,571	1,519,989	0%	0	0	0	0%	3	55
1998	100%	29,544	1,816,366	0%	0	0	0	0%	3	55
1999	100%	32,392	2,061,329	0%	0	0	0	0%	2	47
2000	100%	41,346	2,802,701	0%	0	0	0	0%	1	14
2001	100%	44,766	3,209,806	0%	0	0	0	0%	3	65
2002	100%	49,911	3,795,455	0%	0	0	0	0%	18	424
2003	100%	59,781	4,832,777	0%	0	0	0	0%	3	76
2004	100%	65,751	5,844,031	0%	0	0	0	0%	2	59
2005	100%	86,903	8,039,211	0%	0	0	0	0%	3	81
2006	100%	103,055	10,092,547	0%	0	0	0	0%	5	144
2007	100%	128,610	12,929,139	0%	0	0	0	0%	11	328
2008	100%	125,543	13,361,675	0%	0	0	0	0%	60	1,794
2009	100%	116,809	12,395,606	0%	0	0	0	0%	18	572
2010	100%	158,274	16,020,574	0%	6	69	311	0%	86	2,863
2011	99%	175,648	19,479,572	0%	313	3,932	17,791	1%	1,076	37,957
2012	98%	282,481	31,367,919	1%	3,387	44,658	200,590	1%	1,526	56,296
2013	97%	378,095	42,683,040	2%	7,146	98,660	441,197	1%	5,433	209,483
2014	96%	402,992	47,862,257	3%	11,064	160,332	714,692	1%	6,227	251,167
2015	97%	518,113	63,218,662	2%	8,836	134,191	596,394	2%	9,879	417,410
2016	95%	553,278	69,108,331	2%	10,115	160,689	711,773	3%	16,817	738,736
2017	91%	604,853	79,402,357	4%	27,493	454,641	2,012,619	5%	33,194	1,524,212
2018	86%	555,971	75,960,952	4%	26,314	453,896	2,003,609	10%	61,332	2,941,765
2019	88%	505,059	71,135,364	3%	19,734	368,011	1,521,560	8%	47,387	2,378,873
2020	86%	424,894	60,588,792	4%	20,540	406,324	1,621,195	9%	46,181	2,435,627
2021	85%	528,088	76,514,975	4%	27,796	590,252	2,219,126	10%	63,072	3,464,139
2022	84%	629,123	92,802,888	5%	34,719	844,508	2,607,459	11%	80,947	4,626,137
2023	84%	652,013	97,885,688	5%	36,155	941,473	2,725,229	11%	88,223	5,242,684
2024	83%	670,253	102,369,934	5%	36,940	1,028,217	2,790,931	12%	95,619	5,905,793
2025	83%	697,118	108,259,056	5%	38,476	1,144,799	2,904,428	12%	102,891	6,603,088
2026	65%	562,392	88,712,763	4%	35,869	1,108,113	2,804,580	11%	93,356	6,216,252
2027	57%	506,170	82,823,038	4%	36,682	1,175,675	2,972,420	11%	97,957	6,763,472
2028	49%	448,945	76,077,298	4%	37,500	1,244,657	3,146,136	11%	103,726	7,417,910
2029	41%	382,216	66,862,077	4%	37,726	1,292,471	3,268,769	12%	107,741	7,961,945
2030	32%	271,278	48,854,015	4%	33,914	1,195,950	3,027,919	12%	101,252	7,716,317

Table A-51. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenarios 1d and 1d-1 in Calendar Year 2030

	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
1986	0%	0	0	0%	0	0	26	0.01	0.005
1987	0%	0	0	0%	0	0	32	0.02	0.006
1988	0%	0	0	0%	0	0	32	0.02	0.006
1989	0%	0	0	0%	0	0	42	0.02	0.008
1990	0%	0	0	0%	0	0	54	0.03	0.010
1991	0%	0	0	0%	0	0	66	0.03	0.01
1992	0%	0	0	0%	0	0	59	0.03	0.01
1993	0%	0	0	0%	0	0	62	0.03	0.01
1994	0%	0	0	0%	0	0	71	0.04	0.01
1995	0%	0	0	0%	0	0	94	0.05	0.02
1996	0%	0	0	0%	0	0	94	0.05	0.02
1997	0%	0	0	0%	0	0	124	0.06	0.02
1998	0%	0	0	0%	0	0	149	0.06	0.03
1999	0%	0	0	0%	0	0	169	0.05	0.03
2000	0%	0	0	0%	0	0	229	0.04	0.03
2001	0%	0	0	0%	0	0	263	0.04	0.03
2002	0%	0	0	0%	0	0	311	0.05	0.04
2003	0%	0	0	0%	0	0	396	0.05	0.04
2004	0%	0	0	0%	0	0	478	0.03	0.01
2005	0%	0	0	0%	0	0	658	0.03	0.02
2006	0%	0	0	0%	0	0	826	0.04	0.02
2007	0%	0	0	0%	0	0	1,059	0.05	0.03
2008	0%	0	0	0%	0	0	1,094	0.05	0.03
2009	0%	0	0	0%	0	0	1,015	0.04	0.03
2010	0%	0	0	0%	0	0	1,312	0.06	0.04
2011	0%	0	0	0%	0	0	1,596	0.06	0.05
2012	0%	0	0	0%	0	0	2,585	0.10	0.08
2013	0%	0	0	0%	0	0	3,531	0.13	0.11
2014	0%	0	0	0%	0	0	3,977	0.15	0.12
2015	0%	0	0	0%	0	0	5,225	0.19	0.16
2016	0%	0	0	0%	0	0	5,716	0.22	0.18
2017	0%	0	0	0%	0	0	6,666	0.24	0.20
2018	0%	0	0	0%	0	0	6,383	0.22	0.18
2019	0%	0	0	0%	0	0	5,949	0.19	0.17
2020	0%	0	0	0%	0	0	5,093	0.15	0.14
2021	0%	0	0	0%	0	0	6,446	0.18	0.18
2022	0%	0	0	0%	0	0	7,811	0.20	0.21
2023	0%	0	0	0%	0	0	8,237	0.19	0.21
2024	0%	0	0	0%	0	0	8,610	0.18	0.21
2025	0%	0	0	0%	0	0	9,101	0.16	0.20
2026	20%	173,603	10,953,751	0%	0	0	7,493	0.12	0.16
2027	28%	247,209	16,179,999	0%	0	0	7,024	0.11	0.14
2028	36%	326,043	22,100,233	0%	0	0	6,486	0.10	0.12
2029	43%	404,551	28,307,642	0%	0	0	5,742	0.08	0.10
2030	52%	441,299	31,789,161	0%	0	0	4,248	0.06	0.07

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-11) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-13. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

Table A-52. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenarios 1d and 1d-1 in Calendar Year 2035
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fuel Consumption[3] (MJ of electricity/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of electricity/day)
1991	100%	14,887	496,519	0%	0	0	0	0%	0	0
1992	100%	12,386	437,879	0%	0	0	0	0%	0	0
1993	100%	12,876	454,610	0%	0	0	0	0%	2	20
1994	100%	13,908	519,028	0%	0	0	0	0%	0	3
1995	100%	17,011	673,579	0%	0	0	0	0%	1	11
1996	100%	15,726	662,566	0%	0	0	0	0%	0	0
1997	100%	19,249	841,793	0%	0	0	0	0%	3	36
1998	100%	21,231	962,917	0%	0	0	0	0%	2	32
1999	100%	21,841	1,026,080	0%	0	0	0	0%	2	27
2000	100%	26,428	1,326,406	0%	0	0	0	0%	0	7
2001	100%	26,524	1,412,096	0%	0	0	0	0%	2	30
2002	100%	27,790	1,574,561	0%	0	0	0	0%	11	189
2003	100%	30,887	1,866,413	0%	0	0	0	0%	2	31
2004	100%	31,459	2,100,346	0%	0	0	0	0%	1	22
2005	100%	38,743	2,705,815	0%	0	0	0	0%	1	29
2006	100%	43,503	3,231,279	0%	0	0	0	0%	2	47
2007	100%	51,445	3,941,697	0%	0	0	0	0%	4	103
2008	100%	48,196	3,931,397	0%	0	0	0	0%	23	522
2009	100%	43,832	3,583,029	0%	0	0	0	0%	7	170
2010	100%	59,373	4,651,159	0%	2	20	92	0%	32	847
2011	99%	67,186	5,797,667	0%	120	1,161	5,375	1%	409	11,360
2012	98%	112,410	9,761,699	1%	1,348	13,798	63,245	1%	603	17,549
2013	97%	158,581	14,066,520	2%	2,997	32,296	147,122	1%	2,255	68,707
2014	96%	180,829	16,955,018	3%	4,964	56,441	255,982	1%	2,764	88,302
2015	97%	248,911	24,094,495	2%	4,244	50,842	229,574	2%	4,701	157,841
2016	95%	285,862	28,441,636	2%	5,224	65,752	295,555	3%	8,578	300,098
2017	91%	332,615	34,903,768	4%	15,110	198,715	892,263	5%	18,042	661,811
2018	86%	327,985	35,952,376	4%	15,507	213,599	955,739	9%	35,779	1,376,403
2019	88%	314,542	35,673,840	3%	12,281	183,606	769,058	8%	29,273	1,183,116
2020	86%	281,575	32,424,569	4%	13,612	216,540	874,542	9%	30,604	1,303,564
2021	85%	366,087	42,975,928	4%	19,269	330,198	1,255,839	10%	43,723	1,945,314
2022	84%	459,912	55,139,274	5%	25,381	499,808	1,561,702	11%	59,175	2,747,832
2023	84%	491,823	60,167,945	5%	27,272	576,729	1,688,911	11%	66,548	3,223,016
2024	83%	528,134	65,889,598	5%	29,108	659,860	1,811,619	12%	75,344	3,803,598
2025	83%	560,849	71,323,875	5%	30,955	752,392	1,930,200	12%	82,779	4,355,000
2026	65%	467,482	60,539,560	4%	29,815	754,625	1,930,143	11%	77,601	4,248,646
2027	57%	430,704	58,014,343	4%	31,213	822,291	2,099,102	11%	83,353	4,746,114
2028	49%	390,089	54,639,940	4%	32,584	892,959	2,275,365	11%	90,128	5,333,845
2029	41%	338,901	49,344,310	4%	33,451	953,218	2,424,492	12%	95,531	5,873,508
2030	32%	276,003	41,738,586	4%	34,505	1,021,517	2,594,022	12%	103,016	6,575,282
2031	24%	213,410	33,502,607	4%	35,573	1,093,525	2,772,634	12%	106,205	7,033,396
2032	18%	164,104	26,722,257	4%	36,472	1,163,085	2,945,735	12%	108,890	7,476,741
2033	12%	112,719	19,004,076	4%	37,578	1,240,654	3,141,258	12%	112,190	7,976,623
2034	6%	57,245	9,957,437	4%	38,168	1,299,952	3,293,065	12%	113,952	8,366,832
2035	0%	0	0	4%	34,638	1,213,298	3,076,767	12%	103,414	7,823,380

	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
1991	0%	0	0	0%	0	0	41	0.02	0.008
1992	0%	0	0	0%	0	0	36	0.02	0.007
1993	0%	0	0	0%	0	0	37	0.02	0.007
1994	0%	0	0	0%	0	0	42	0.02	0.008
1995	0%	0	0	0%	0	0	55	0.03	0.01
1996	0%	0	0	0%	0	0	54	0.04	0.01
1997	0%	0	0	0%	0	0	69	0.04	0.01
1998	0%	0	0	0%	0	0	79	0.03	0.01
1999	0%	0	0	0%	0	0	84	0.03	0.01
2000	0%	0	0	0%	0	0	109	0.02	0.01
2001	0%	0	0	0%	0	0	116	0.02	0.01
2002	0%	0	0	0%	0	0	129	0.02	0.02
2003	0%	0	0	0%	0	0	153	0.02	0.02
2004	0%	0	0	0%	0	0	172	0.01	0.006
2005	0%	0	0	0%	0	0	222	0.01	0.007
2006	0%	0	0	0%	0	0	265	0.01	0.008
2007	0%	0	0	0%	0	0	323	0.02	0.01
2008	0%	0	0	0%	0	0	322	0.02	0.01
2009	0%	0	0	0%	0	0	293	0.01	0.010
2010	0%	0	0	0%	0	0	381	0.02	0.01
2011	0%	0	0	0%	0	0	475	0.02	0.02
2012	0%	0	0	0%	0	0	804	0.04	0.03
2013	0%	0	0	0%	0	0	1,164	0.05	0.04
2014	0%	0	0	0%	0	0	1,409	0.06	0.05
2015	0%	0	0	0%	0	0	1,991	0.08	0.07
2016	0%	0	0	0%	0	0	2,353	0.11	0.08
2017	0%	0	0	0%	0	0	2,931	0.12	0.10
2018	0%	0	0	0%	0	0	3,022	0.12	0.10
2019	0%	0	0	0%	0	0	2,984	0.11	0.10
2020	0%	0	0	0%	0	0	2,726	0.10	0.09
2021	0%	0	0	0%	0	0	3,621	0.12	0.12
2022	0%	0	0	0%	0	0	4,642	0.14	0.15
2023	0%	0	0	0%	0	0	5,064	0.14	0.16
2024	0%	0	0	0%	0	0	5,543	0.14	0.16
2025	0%	0	0	0%	0	0	5,997	0.13	0.17
2026	20%	144,305	7,475,083	0%	0	0	5,115	0.10	0.14
2027	28%	210,352	11,333,465	0%	0	0	4,922	0.10	0.13
2028	36%	283,299	15,872,743	0%	0	0	4,660	0.09	0.12
2029	43%	358,704	20,891,081	0%	0	0	4,238	0.08	0.10
2030	52%	448,985	27,159,173	0%	0	0	3,630	0.06	0.08
2031	60%	534,022	33,533,743	0%	0	0	2,970	0.05	0.06
2032	66%	602,224	39,225,755	0%	0	0	2,429	0.04	0.05
2033	72%	676,837	45,645,106	0%	0	0	1,813	0.03	0.03
2034	78%	744,711	51,815,687	0%	0	0	1,085	0.02	0.02
2035	84%	727,792	52,087,406	0%	0	0	252	0.007	0.004

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-14) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-16. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fuel Consumption[3] (MJ of electricity/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of electricity/day)
1996	100%	13,224	407,390	0%	0	0	0	0%	0	0
1997	100%	15,957	507,603	0%	0	0	0	0%	2	27
1998	100%	17,428	573,388	0%	0	0	0	0%	2	23
1999	100%	17,981	612,358	0%	0	0	0	0%	2	19
2000	100%	21,212	772,196	0%	0	0	0	0%	0	5
2001	100%	20,869	808,569	0%	0	0	0	0%	1	19
2002	100%	20,957	866,980	0%	0	0	0	0%	8	114
2003	100%	22,226	985,080	0%	0	0	0	0%	1	18
2004	100%	21,228	1,041,890	0%	0	0	0	0%	1	12
2005	100%	24,808	1,278,892	0%	0	0	0	0%	1	16
2006	100%	25,795	1,417,856	0%	0	0	0	0%	1	22
2007	100%	28,657	1,630,516	0%	0	0	0	0%	2	44
2008	100%	24,894	1,513,071	0%	0	0	0	0%	12	206
2009	100%	20,958	1,283,229	0%	0	0	0	0%	3	64
2010	100%	26,447	1,559,497	0%	1	7	31	0%	15	295
2011	99%	28,341	1,849,619	0%	51	367	1,752	1%	172	3,720
2012	98%	44,963	2,967,860	1%	539	4,153	19,596	1%	240	5,433
2013	97%	60,869	4,125,844	2%	1,150	9,385	43,891	1%	858	20,372
2014	96%	67,874	4,888,299	3%	1,863	16,131	74,982	1%	1,028	25,649
2015	97%	93,376	6,979,373	2%	1,592	14,608	67,463	2%	1,750	45,992
2016	95%	109,366	8,447,742	2%	1,998	19,377	88,913	3%	3,230	88,645
2017	91%	132,055	10,809,831	4%	5,994	61,088	279,650	5%	7,052	203,451
2018	87%	137,285	11,794,487	4%	6,483	69,602	317,087	9%	14,800	449,301
2019	88%	141,083	12,595,274	3%	5,505	64,430	274,520	8%	13,018	416,452
2020	86%	135,652	12,343,563	4%	6,558	82,023	336,557	9%	14,744	498,290
2021	85%	189,590	17,659,856	4%	9,979	135,046	521,355	10%	22,644	801,678
2022	84%	253,809	24,240,958	5%	14,007	218,733	693,952	11%	32,657	1,210,322
2023	84%	291,017	28,467,215	5%	16,137	271,680	807,271	11%	39,377	1,526,695
2024	83%	329,600	32,998,938	5%	18,166	329,087	916,198	12%	47,021	1,906,128
2025	83%	371,783	38,066,268	5%	20,520	399,967	1,039,937	12%	54,873	2,325,226
2026	65%	324,168	33,911,685	4%	20,675	421,047	1,090,413	11%	53,811	2,380,112
2027	57%	314,930	34,373,272	4%	22,823	485,341	1,253,824	11%	60,947	2,812,115
2028	49%	294,302	33,491,115	4%	24,583	545,508	1,406,015	11%	67,997	3,270,853
2029	41%	267,079	31,668,216	4%	26,362	610,009	1,568,829	12%	75,286	3,773,157
2030	32%	222,088	27,421,128	4%	27,764	669,514	1,718,317	12%	82,893	4,325,829
2031	24%	177,426	22,797,903	4%	29,575	742,704	1,902,479	12%	88,297	4,795,314
2032	18%	139,693	18,670,261	4%	31,047	811,564	2,074,749	12%	92,692	5,235,411
2033	12%	98,033	13,625,389	4%	32,682	888,696	2,267,776	12%	97,574	5,728,006
2034	6%	50,852	7,346,988	4%	33,905	958,694	2,441,908	12%	101,227	6,173,591
2035	0%	0	0	4%	35,347	1,038,360	2,640,531	12%	105,530	6,681,472
2036	0%	0	0	4%	36,408	1,110,551	2,819,782	12%	108,697	7,140,339
2037	0%	0	0	4%	37,287	1,179,840	2,992,407	12%	111,321	7,581,528
2038	0%	0	0	4%	38,359	1,256,478	3,185,885	12%	114,524	8,075,024
2039	0%	0	0	4%	38,889	1,313,727	3,332,835	12%	116,107	8,451,703
2040	0%	0	0	4%	35,217	1,222,994	3,106,042	12%	105,142	7,882,098

Table A-53. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenarios 1d and 1d-1 in Calendar Year 2040
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
1996	0%	0	0	0%	0	0	33	0.02	0.007
1997	0%	0	0	0%	0	0	42	0.03	0.009
1998	0%	0	0	0%	0	0	47	0.02	0.009
1999	0%	0	0	0%	0	0	50	0.02	0.008
2000	0%	0	0	0%	0	0	63	0.01	0.009
2001	0%	0	0	0%	0	0	66	0.01	0.009
2002	0%	0	0	0%	0	0	71	0.01	0.009
2003	0%	0	0	0%	0	0	81	0.01	0.010
2004	0%	0	0	0%	0	0	85	0.007	0.003
2005	0%	0	0	0%	0	0	105	0.008	0.004
2006	0%	0	0	0%	0	0	116	0.007	0.004
2007	0%	0	0	0%	0	0	133	0.008	0.005
2008	0%	0	0	0%	0	0	124	0.007	0.004
2009	0%	0	0	0%	0	0	105	0.006	0.004
2010	0%	0	0	0%	0	0	128	0.007	0.005
2011	0%	0	0	0%	0	0	152	0.008	0.006
2012	0%	0	0	0%	0	0	245	0.01	0.009
2013	0%	0	0	0%	0	0	341	0.02	0.01
2014	0%	0	0	0%	0	0	406	0.02	0.02
2015	0%	0	0	0%	0	0	577	0.03	0.02
2016	0%	0	0	0%	0	0	699	0.04	0.03
2017	0%	0	0	0%	0	0	908	0.04	0.03
2018	0%	0	0	0%	0	0	992	0.05	0.04
2019	0%	0	0	0%	0	0	1,054	0.05	0.04
2020	0%	0	0	0%	0	0	1,038	0.04	0.04
2021	0%	0	0	0%	0	0	1,489	0.06	0.05
2022	0%	0	0	0%	0	0	2,041	0.07	0.07
2023	0%	0	0	0%	0	0	2,397	0.08	0.08
2024	0%	0	0	0%	0	0	2,777	0.08	0.10
2025	0%	0	0	0%	0	0	3,202	0.08	0.10
2026	20%	100,066	4,187,223	0%	0	0	2,866	0.07	0.09
2027	28%	153,809	6,715,034	0%	0	0	2,917	0.07	0.09
2028	36%	213,735	9,729,071	0%	0	0	2,857	0.07	0.09
2029	43%	282,685	13,407,489	0%	0	0	2,721	0.06	0.08
2030	52%	361,281	17,842,846	0%	0	0	2,386	0.05	0.07
2031	60%	443,977	22,819,090	0%	0	0	2,022	0.04	0.05
2032	66%	512,639	27,406,185	0%	0	0	1,698	0.04	0.04
2033	72%	588,656	32,726,258	0%	0	0	1,301	0.03	0.03
2034	78%	661,545	38,231,651	0%	0	0	801	0.02	0.02
2035	84%	742,681	44,579,105	0%	0	0	216	0.007	0.004
2036	84%	764,974	47,666,794	0%	0	0	231	0.007	0.004
2037	84%	783,440	50,635,276	0%	0	0	245	0.008	0.004
2038	84%	805,975	53,929,091	0%	0	0	261	0.008	0.005
2039	84%	817,118	56,397,065	0%	0	0	273	0.008	0.005
2040	84%	739,955	52,515,117	0%	0	0	254	0.007	0.004

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-17) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-19. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

Table A-54. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenarios 1d and 1d-1 in Calendar Year 2045
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Model Year	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fuel Consumption[3] (MJ of electricity/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of electricity/day)
2001	100%	17,581	492,838	0%	0	0	0	0%	1	13
2002	100%	17,396	519,815	0%	0	0	0	0%	7	79
2003	100%	18,261	584,063	0%	0	0	0	0%	1	12
2004	100%	17,485	620,429	0%	0	0	0	0%	1	8
2005	100%	19,931	744,101	0%	0	0	0	0%	1	11
2006	100%	20,294	810,536	0%	0	0	0	0%	1	13
2007	100%	21,610	895,705	0%	0	0	0	0%	2	26
2008	100%	17,913	797,202	0%	0	0	0	0%	8	112
2009	100%	14,142	635,358	0%	0	0	0	0%	2	35
2010	100%	16,923	735,246	0%	1	3	15	0%	9	147
2011	99%	16,799	809,857	0%	30	158	790	1%	101	1,691
2012	98%	25,037	1,225,371	1%	300	1,692	8,301	1%	133	2,322
2013	97%	31,446	1,584,333	2%	594	3,560	17,255	1%	442	8,105
2014	96%	32,442	1,745,658	3%	890	5,695	27,363	1%	489	9,437
2015	97%	41,547	2,333,580	2%	708	4,833	22,999	2%	777	15,810
2016	95%	46,072	2,687,564	2%	841	6,105	28,783	3%	1,354	28,787
2017	91%	52,700	3,274,039	4%	2,391	18,339	86,121	5%	2,789	62,457
2018	87%	52,549	3,444,774	4%	2,479	20,175	94,087	9%	5,607	132,466
2019	88%	52,919	3,622,227	3%	2,063	18,391	80,115	8%	4,832	120,601
2020	86%	51,080	3,577,777	4%	2,469	23,635	98,982	9%	5,552	146,669
2021	85%	72,808	5,249,034	4%	3,832	39,919	157,067	10%	8,696	241,288
2022	84%	101,322	7,527,271	5%	5,592	67,570	218,488	11%	13,037	379,660
2023	84%	122,476	9,364,450	5%	6,792	88,932	269,022	11%	16,572	506,226
2024	83%	148,333	11,660,897	5%	8,175	115,750	327,717	12%	21,161	677,755
2025	83%	179,162	14,468,745	5%	9,889	151,350	399,826	12%	26,443	887,822
2026	65%	167,925	13,913,800	4%	10,710	171,981	451,908	11%	27,875	979,732
2027	57%	173,839	15,087,722	4%	12,598	212,114	555,489	11%	33,642	1,237,162
2028	49%	174,181	15,820,703	4%	14,549	256,617	669,890	11%	40,244	1,547,489
2029	41%	166,713	15,834,899	4%	16,455	303,793	790,664	12%	46,994	1,888,561
2030	32%	147,252	14,612,516	4%	18,409	355,407	922,379	12%	54,961	2,306,853
2031	24%	123,062	12,750,639	4%	20,513	413,850	1,071,177	12%	61,243	2,683,184
2032	18%	102,163	11,044,387	4%	22,706	478,352	1,235,027	12%	67,790	3,098,236
2033	12%	73,974	8,338,115	4%	24,661	542,144	1,396,451	12%	73,628	3,508,235
2034	6%	40,081	4,707,395	4%	26,724	612,627	1,574,494	12%	79,786	3,960,912
2035	0%	0	0	4%	28,447	679,589	1,742,931	12%	84,931	4,390,345
2036	0%	0	0	4%	30,274	753,214	1,927,965	12%	90,386	4,862,426
2037	0%	0	0	4%	31,753	822,345	2,100,691	12%	94,802	5,304,019
2038	0%	0	0	4%	33,394	899,667	2,293,959	12%	99,700	5,797,554
2039	0%	0	0	4%	34,612	969,669	2,467,860	12%	103,338	6,242,847
2040	0%	0	0	4%	36,047	1,049,189	2,665,871	12%	107,620	6,749,460
2041	0%	0	0	4%	37,091	1,121,019	2,843,979	12%	110,738	7,205,621
2042	0%	0	0	4%	37,942	1,189,565	3,014,512	12%	113,278	7,641,631
2043	0%	0	0	4%	38,974	1,264,855	3,204,367	12%	116,360	8,126,069
2044	0%	0	0	4%	39,438	1,319,800	3,345,305	12%	117,745	8,487,539
2045	0%	0	0	4%	35,636	1,225,722	3,110,204	12%	106,395	7,896,358

Table A-54. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenarios 1d and 1d-1 in Calendar Year 2045

Model Year	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
2001	0%	0	0	0%	0	0	40	0.01	0.006
2002	0%	0	0	0%	0	0	43	0.01	0.006
2003	0%	0	0	0%	0	0	48	0.01	0.006
2004	0%	0	0	0%	0	0	51	0.005	0.002
2005	0%	0	0	0%	0	0	61	0.005	0.002
2006	0%	0	0	0%	0	0	66	0.005	0.002
2007	0%	0	0	0%	0	0	73	0.005	0.003
2008	0%	0	0	0%	0	0	65	0.005	0.003
2009	0%	0	0	0%	0	0	52	0.003	0.002
2010	0%	0	0	0%	0	0	60	0.004	0.003
2011	0%	0	0	0%	0	0	66	0.004	0.003
2012	0%	0	0	0%	0	0	101	0.006	0.004
2013	0%	0	0	0%	0	0	131	0.008	0.006
2014	0%	0	0	0%	0	0	145	0.009	0.006
2015	0%	0	0	0%	0	0	193	0.01	0.008
2016	0%	0	0	0%	0	0	222	0.01	0.009
2017	0%	0	0	0%	0	0	275	0.02	0.01
2018	0%	0	0	0%	0	0	290	0.02	0.01
2019	0%	0	0	0%	0	0	303	0.02	0.01
2020	0%	0	0	0%	0	0	301	0.01	0.01
2021	0%	0	0	0%	0	0	443	0.02	0.02
2022	0%	0	0	0%	0	0	634	0.03	0.03
2023	0%	0	0	0%	0	0	789	0.03	0.03
2024	0%	0	0	0%	0	0	982	0.03	0.04
2025	0%	0	0	0%	0	0	1,217	0.04	0.04
2026	20%	51,836	1,717,997	0%	0	0	1,176	0.03	0.04
2027	28%	84,901	2,947,481	0%	0	0	1,281	0.04	0.05
2028	36%	126,498	4,595,868	0%	0	0	1,350	0.04	0.05
2029	43%	176,455	6,704,079	0%	0	0	1,361	0.04	0.05
2030	52%	239,541	9,508,321	0%	0	0	1,272	0.03	0.04
2031	60%	307,941	12,762,489	0%	0	0	1,132	0.03	0.04
2032	66%	374,915	16,212,119	0%	0	0	1,005	0.03	0.03
2033	72%	444,190	20,026,975	0%	0	0	797	0.02	0.02
2034	78%	521,423	24,495,954	0%	0	0	514	0.01	0.01
2035	84%	597,713	29,240,461	0%	0	0	143	0.006	0.003
2036	84%	636,105	32,385,067	0%	0	0	158	0.006	0.003
2037	84%	667,180	35,331,680	0%	0	0	172	0.006	0.003
2038	84%	701,654	38,641,177	0%	0	0	188	0.007	0.004
2039	84%	727,252	41,634,573	0%	0	0	202	0.007	0.004
2040	84%	757,391	45,036,251	0%	0	0	218	0.007	0.004
2041	84%	779,333	48,107,775	0%	0	0	233	0.008	0.004
2042	84%	797,208	51,043,944	0%	0	0	247	0.008	0.004
2043	84%	818,902	54,279,621	0%	0	0	262	0.008	0.005
2044	84%	828,649	56,648,596	0%	0	0	274	0.008	0.005
2045	84%	748,769	52,624,174	0%	0	0	255	0.007	0.004

Notes:

1 Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

2 Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

3 Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-20) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

4 Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-22. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

5 Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

Table A-55. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenarios 1d and 1d-1 in Calendar Year 2050
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Model Year	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fuel Consumption[3] (MJ of electricity/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of electricity/day)
2006	100%	17,095	495,171	0%	0	0	0	0%	1	9
2007	100%	17,938	537,342	0%	0	0	0	0%	2	18
2008	100%	14,711	473,301	0%	0	0	0	0%	6	73
2009	100%	11,643	378,435	0%	0	0	0	0%	2	24
2010	100%	13,584	427,686	0%	0	2	9	0%	8	94
2011	99%	13,206	463,001	0%	24	89	472	1%	79	1,039
2012	98%	18,883	674,484	1%	226	915	4,745	1%	100	1,368
2013	97%	22,656	836,306	2%	428	1,850	9,427	1%	314	4,504
2014	96%	21,908	865,904	3%	601	2,783	14,018	1%	326	4,894
2015	97%	26,586	1,101,721	2%	453	2,250	11,180	2%	491	7,761
2016	95%	27,295	1,177,776	2%	498	2,640	12,955	3%	790	13,009
2017	91%	29,325	1,351,831	4%	1,329	7,482	36,484	5%	1,525	26,393
2018	87%	27,113	1,322,228	4%	1,278	7,675	37,071	9%	2,868	52,384
2019	89%	25,304	1,294,975	3%	986	6,516	29,339	8%	2,292	44,244
2020	86%	22,760	1,198,129	4%	1,100	7,856	33,925	9%	2,474	50,596
2021	85%	30,740	1,673,570	4%	1,618	12,642	51,178	10%	3,671	78,995
2022	84%	40,577	2,287,454	5%	2,239	20,404	67,892	11%	5,221	118,112
2023	84%	47,100	2,747,369	5%	2,612	25,936	80,590	11%	6,373	151,554
2024	83%	55,817	3,364,077	5%	3,076	33,204	96,428	12%	7,963	198,997
2025	83%	67,473	4,197,128	5%	3,724	43,672	118,177	12%	9,959	261,533
2026	65%	64,497	4,139,198	4%	4,114	50,877	136,660	11%	10,706	295,109
2027	57%	69,408	4,689,197	4%	5,030	65,571	175,255	11%	13,432	388,383
2028	49%	73,318	5,209,164	4%	6,124	84,058	223,637	11%	16,940	513,531
2029	41%	75,042	5,600,876	4%	7,407	106,921	283,234	12%	21,153	672,043
2030	32%	70,975	5,559,659	4%	8,873	134,574	355,060	12%	26,491	881,507
2031	24%	63,763	5,236,564	4%	10,628	169,173	444,687	12%	31,732	1,105,371
2032	18%	56,405	4,852,327	4%	12,536	209,209	548,060	12%	37,427	1,364,096
2033	12%	43,791	3,942,469	4%	14,599	255,208	666,413	12%	43,586	1,661,080
2034	6%	25,024	2,355,959	4%	16,685	305,290	794,782	12%	49,813	1,984,022
2035	0%	0	0	4%	18,865	360,976	937,068	12%	56,324	2,343,007
2036	0%	0	0	4%	21,003	419,968	1,087,267	12%	62,706	2,722,815
2037	0%	0	0	4%	23,227	484,984	1,252,421	12%	69,345	3,141,091
2038	0%	0	0	4%	25,203	549,142	1,414,757	12%	75,245	3,553,333
2039	0%	0	0	4%	27,285	619,964	1,593,644	12%	81,462	4,008,057
2040	0%	0	0	4%	29,016	687,067	1,762,410	12%	86,629	4,438,238
2041	0%	0	0	4%	30,849	760,761	1,947,591	12%	92,102	4,910,573
2042	0%	0	0	4%	32,326	829,839	2,120,143	12%	96,511	5,351,582
2043	0%	0	0	4%	33,964	907,037	2,313,062	12%	101,402	5,844,049
2044	0%	0	0	4%	35,170	976,725	2,486,125	12%	105,002	6,287,030
2045	0%	0	0	4%	36,591	1,055,810	2,682,995	12%	109,246	6,790,499
2046	0%	0	0	4%	37,615	1,127,036	2,859,529	12%	112,302	7,242,409
2047	0%	0	0	4%	38,433	1,194,575	3,027,460	12%	114,744	7,671,556
2048	0%	0	0	4%	39,420	1,268,267	3,213,196	12%	117,693	8,145,301
2049	0%	0	0	4%	39,817	1,320,843	3,348,041	12%	118,877	8,491,081
2050	0%	0	0	4%	35,902	1,223,884	3,105,533	12%	107,188	7,881,262

Table A-55. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenarios 1d and 1d-1 in Calendar Year 2050

	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
2006	0%	0	0	0%	0	0	41	0.004	0.002
2007	0%	0	0	0%	0	0	44	0.004	0.002
2008	0%	0	0	0%	0	0	39	0.003	0.002
2009	0%	0	0	0%	0	0	31	0.002	0.001
2010	0%	0	0	0%	0	0	35	0.003	0.002
2011	0%	0	0	0%	0	0	38	0.003	0.002
2012	0%	0	0	0%	0	0	56	0.004	0.003
2013	0%	0	0	0%	0	0	69	0.005	0.003
2014	0%	0	0	0%	0	0	72	0.005	0.003
2015	0%	0	0	0%	0	0	91	0.006	0.004
2016	0%	0	0	0%	0	0	97	0.007	0.005
2017	0%	0	0	0%	0	0	114	0.008	0.005
2018	0%	0	0	0%	0	0	111	0.007	0.005
2019	0%	0	0	0%	0	0	108	0.006	0.005
2020	0%	0	0	0%	0	0	101	0.006	0.004
2021	0%	0	0	0%	0	0	141	0.008	0.006
2022	0%	0	0	0%	0	0	193	0.009	0.009
2023	0%	0	0	0%	0	0	232	0.01	0.01
2024	0%	0	0	0%	0	0	283	0.01	0.01
2025	0%	0	0	0%	0	0	353	0.01	0.01
2026	20%	19,909	511,085	0%	0	0	350	0.01	0.01
2027	28%	33,898	916,064	0%	0	0	398	0.01	0.02
2028	36%	53,247	1,513,247	0%	0	0	445	0.01	0.02
2029	43%	79,427	2,371,263	0%	0	0	482	0.01	0.02
2030	52%	115,458	3,617,654	0%	0	0	484	0.01	0.02
2031	60%	159,555	5,241,430	0%	0	0	465	0.01	0.02
2032	66%	206,994	7,122,759	0%	0	0	442	0.01	0.02
2033	72%	262,949	9,469,254	0%	0	0	377	0.01	0.01
2034	78%	325,544	12,259,745	0%	0	0	258	0.008	0.008
2035	84%	396,387	15,596,251	0%	0	0	77	0.004	0.002
2036	84%	441,302	18,129,484	0%	0	0	89	0.004	0.002
2037	84%	488,028	20,918,848	0%	0	0	103	0.004	0.002
2038	84%	529,547	23,667,001	0%	0	0	116	0.005	0.003
2039	84%	573,298	26,698,382	0%	0	0	130	0.005	0.003
2040	84%	609,667	29,566,053	0%	0	0	144	0.006	0.003
2041	84%	648,178	32,713,752	0%	0	0	159	0.006	0.003
2042	84%	679,210	35,658,179	0%	0	0	174	0.006	0.003
2043	84%	713,632	38,962,677	0%	0	0	189	0.007	0.004
2044	84%	738,970	41,942,891	0%	0	0	204	0.007	0.004
2045	84%	768,833	45,326,292	0%	0	0	220	0.007	0.004
2046	84%	790,339	48,372,330	0%	0	0	234	0.008	0.004
2047	84%	807,527	51,265,670	0%	0	0	248	0.008	0.004
2048	84%	828,277	54,433,171	0%	0	0	263	0.008	0.005
2049	84%	836,615	56,700,766	0%	0	0	274	0.008	0.005
2050	84%	754,352	52,552,223	0%	0	0	254	0.008	0.004

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-23) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-25. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

Table A-56. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenarios 2a and 2b in Calendar Year 2026
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fuel Consumption[3] (MJ of electricity/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of electricity/day)
1982	100%	4,657	174,227	0%	0	0	0	0%	1	9
1983	100%	5,273	206,541	0%	0	0	0	0%	1	9
1984	100%	7,858	329,345	0%	0	0	0	0%	1	13
1985	100%	10,024	435,286	0%	0	0	0	0%	0	0
1986	100%	10,647	463,741	0%	0	0	0	0%	0	0
1987	100%	12,832	586,622	0%	0	0	0	0%	1	18
1988	100%	12,139	592,716	0%	0	0	0	0%	0	0
1989	100%	14,970	774,940	0%	0	0	0	0%	1	14
1990	100%	18,044	991,990	0%	0	0	0	0%	0	0
1991	100%	21,281	1,234,023	0%	0	0	0	0%	0	0
1992	100%	18,332	1,127,213	0%	0	0	0	0%	0	0
1993	100%	20,138	1,231,512	0%	0	0	0	0%	3	46
1994	100%	22,840	1,473,479	0%	0	0	0	0%	0	7
1995	100%	29,675	2,022,331	0%	0	0	0	0%	2	31
1996	100%	29,436	2,128,971	0%	0	0	0	0%	0	0
1997	100%	39,761	2,978,637	0%	0	0	0	0%	4	95
1998	100%	48,817	3,777,000	0%	0	0	0	0%	5	107
1999	100%	56,921	4,546,344	0%	0	0	0	0%	4	98
2000	100%	76,964	6,529,441	0%	0	0	0	0%	1	31
2001	100%	87,221	7,793,387	0%	0	0	0	0%	6	155
2002	100%	102,135	9,644,077	0%	0	0	0	0%	37	1,030
2003	100%	127,287	12,720,322	0%	0	0	0	0%	7	196
2004	100%	143,690	15,732,253	0%	0	0	0	0%	5	155
2005	100%	191,623	21,752,720	0%	0	0	0	0%	7	213
2006	100%	225,488	26,980,154	0%	0	0	0	0%	11	389
2007	100%	275,180	33,665,694	0%	0	0	0	0%	23	834
2008	100%	258,265	33,318,492	0%	0	0	0	0%	126	4,586
2009	100%	229,086	29,357,696	0%	0	0	0	0%	34	1,333
2010	100%	292,924	35,681,010	0%	11	154	687	0%	161	6,445
2011	99%	307,002	40,824,099	0%	548	8,280	37,013	1%	1,890	79,947
2012	98%	465,759	61,806,971	1%	5,585	88,399	392,722	1%	2,528	111,558
2013	97%	592,447	79,686,217	2%	11,199	185,018	819,056	1%	8,583	395,185
2014	96%	599,553	84,574,041	3%	16,462	284,537	1,256,341	1%	9,356	449,554
2015	96%	738,821	106,767,996	2%	12,602	227,577	1,002,629	2%	14,202	712,794
2016	95%	754,102	111,262,248	2%	13,790	259,774	1,141,452	3%	23,130	1,205,441
2017	91%	794,462	122,943,456	4%	36,125	706,874	3,105,093	5%	43,901	2,385,744
2018	86%	705,513	113,371,002	4%	33,412	680,299	2,980,537	10%	78,294	4,428,841
2019	88%	622,322	102,867,416	3%	24,317	533,860	2,191,127	8%	58,438	3,447,620
2020	86%	508,892	85,019,301	4%	24,600	571,597	2,264,467	9%	55,310	3,416,834
2021	85%	619,444	104,948,162	4%	32,604	811,289	3,029,262	10%	73,983	4,748,184
2022	84%	724,703	124,757,619	5%	39,994	1,137,171	3,486,691	11%	93,245	6,212,763
2023	84%	731,635	127,883,688	5%	40,571	1,231,754	3,543,090	11%	98,996	6,843,258
2024	83%	747,543	132,487,563	5%	41,200	1,332,140	3,598,733	12%	106,645	7,641,910
2025	83%	758,530	135,969,595	5%	41,866	1,438,799	3,640,575	12%	111,956	8,303,968
2026	65%	540,131	97,639,769	24%	201,179	7,122,038	18,026,732	11%	89,660	6,866,855

Table A-56. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenarios 2a and 2b in Calendar Year 2026
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
1982	0%	0	0	0%	0	0	14	0.008	0.003
1983	0%	0	0	0%	0	0	17	0.009	0.003
1984	0%	0	0	0%	0	0	27	0.01	0.005
1985	0%	0	0	0%	0	0	36	0.02	0.006
1986	0%	0	0	0%	0	0	38	0.02	0.007
1987	0%	0	0	0%	0	0	48	0.02	0.009
1988	0%	0	0	0%	0	0	49	0.02	0.009
1989	0%	0	0	0%	0	0	63	0.03	0.01
1990	0%	0	0	0%	0	0	81	0.04	0.01
1991	0%	0	0	0%	0	0	101	0.05	0.02
1992	0%	0	0	0%	0	0	92	0.04	0.02
1993	0%	0	0	0%	0	0	101	0.05	0.02
1994	0%	0	0	0%	0	0	121	0.06	0.02
1995	0%	0	0	0%	0	0	166	0.08	0.03
1996	0%	0	0	0%	0	0	174	0.09	0.04
1997	0%	0	0	0%	0	0	244	0.11	0.05
1998	0%	0	0	0%	0	0	309	0.11	0.05
1999	0%	0	0	0%	0	0	372	0.09	0.06
2000	0%	0	0	0%	0	0	535	0.08	0.07
2001	0%	0	0	0%	0	0	638	0.09	0.07
2002	0%	0	0	0%	0	0	790	0.11	0.09
2003	0%	0	0	0%	0	0	1,041	0.13	0.11
2004	0%	0	0	0%	0	0	1,288	0.07	0.04
2005	0%	0	0	0%	0	0	1,781	0.08	0.05
2006	0%	0	0	0%	0	0	2,209	0.09	0.06
2007	0%	0	0	0%	0	0	2,756	0.11	0.08
2008	0%	0	0	0%	0	0	2,728	0.10	0.08
2009	0%	0	0	0%	0	0	2,404	0.09	0.07
2010	0%	0	0	0%	0	0	2,921	0.11	0.09
2011	0%	0	0	0%	0	0	3,345	0.12	0.10
2012	0%	0	0	0%	0	0	5,092	0.18	0.15
2013	0%	0	0	0%	0	0	6,591	0.22	0.19
2014	0%	0	0	0%	0	0	7,027	0.23	0.20
2015	0%	0	0	0%	0	0	8,823	0.28	0.24
2016	0%	0	0	0%	0	0	9,203	0.32	0.26
2017	0%	0	0	0%	0	0	10,320	0.32	0.27
2018	0%	0	0	0%	0	0	9,526	0.28	0.24
2019	0%	0	0	0%	0	0	8,601	0.23	0.21
2020	0%	0	0	0%	0	0	7,146	0.19	0.17
2021	0%	0	0	0%	0	0	8,840	0.21	0.21
2022	0%	0	0	0%	0	0	10,500	0.23	0.24
2023	0%	0	0	0%	0	0	10,760	0.21	0.23
2024	0%	0	0	0%	0	0	11,142	0.20	0.22
2025	0%	0	0	0%	0	0	11,430	0.16	0.20
2026	0%	0	0	0%	0	0	9,470	0.15	0.16

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-8) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-10. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

Table A-57. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenarios 2a and 2b in Calendar Year 2030

Model Year	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fuel Consumption[3] (MJ of electricity/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of electricity/day)
1986	100%	9,277	319,606	0%	0	0	0	0%	0	0
1987	100%	11,036	395,358	0%	0	0	0	0%	1	13
1988	100%	10,287	394,106	0%	0	0	0	0%	0	0
1989	100%	12,682	513,141	0%	0	0	0	0%	1	10
1990	100%	15,335	660,988	0%	0	0	0	0%	0	0
1991	100%	17,755	806,207	0%	0	0	0	0%	0	0
1992	100%	14,968	722,403	0%	0	0	0	0%	0	0
1993	100%	15,722	757,504	0%	0	0	0	0%	2	30
1994	100%	16,938	862,749	0%	0	0	0	0%	0	4
1995	100%	21,266	1,147,175	0%	0	0	0	0%	1	18
1996	100%	20,041	1,148,835	0%	0	0	0	0%	0	0
1997	100%	25,571	1,519,989	0%	0	0	0	0%	3	55
1998	100%	29,544	1,816,366	0%	0	0	0	0%	3	55
1999	100%	32,392	2,061,329	0%	0	0	0	0%	2	47
2000	100%	41,346	2,802,701	0%	0	0	0	0%	1	14
2001	100%	44,766	3,209,806	0%	0	0	0	0%	3	65
2002	100%	49,911	3,795,455	0%	0	0	0	0%	18	424
2003	100%	59,781	4,832,777	0%	0	0	0	0%	3	76
2004	100%	65,751	5,844,031	0%	0	0	0	0%	2	59
2005	100%	86,903	8,039,211	0%	0	0	0	0%	3	81
2006	100%	103,055	10,092,547	0%	0	0	0	0%	5	144
2007	100%	128,610	12,929,139	0%	0	0	0	0%	11	328
2008	100%	125,543	13,361,675	0%	0	0	0	0%	60	1,794
2009	100%	116,809	12,395,606	0%	0	0	0	0%	18	572
2010	100%	158,274	16,020,574	0%	6	69	311	0%	86	2,863
2011	99%	175,648	19,479,572	0%	313	3,932	17,791	1%	1,076	37,957
2012	98%	282,481	31,367,919	1%	3,387	44,658	200,590	1%	1,526	56,296
2013	97%	378,095	42,683,040	2%	7,146	98,660	441,197	1%	5,433	209,483
2014	96%	402,992	47,862,257	3%	11,064	160,332	714,692	1%	6,227	251,167
2015	97%	518,113	63,218,662	2%	8,836	134,191	596,394	2%	9,879	417,410
2016	95%	553,278	69,108,331	2%	10,115	160,689	711,773	3%	16,817	738,736
2017	91%	604,853	79,402,357	4%	27,493	454,641	2,012,619	5%	33,194	1,524,212
2018	86%	555,971	75,960,952	4%	26,314	453,896	2,003,609	10%	61,332	2,941,765
2019	88%	505,059	71,135,364	3%	19,734	368,011	1,521,560	8%	47,387	2,378,873
2020	86%	424,894	60,588,792	4%	20,540	406,324	1,621,195	9%	46,181	2,435,627
2021	85%	528,088	76,514,975	4%	27,796	590,252	2,219,126	10%	63,072	3,464,139
2022	84%	629,123	92,802,888	5%	34,719	844,508	2,607,459	11%	80,947	4,626,137
2023	84%	652,013	97,885,688	5%	36,155	941,473	2,725,229	11%	88,223	5,242,684
2024	83%	670,253	102,369,934	5%	36,940	1,028,217	2,790,931	12%	95,619	5,905,793
2025	83%	697,118	108,259,056	5%	38,476	1,144,799	2,904,428	12%	102,891	6,603,088
2026	65%	562,392	88,712,763	24%	209,471	6,470,997	16,377,775	11%	93,356	6,216,252
2027	57%	506,170	82,823,038	32%	283,891	9,098,918	23,004,500	11%	97,957	6,763,472
2028	49%	448,945	76,077,298	40%	363,543	12,066,027	30,499,462	11%	103,726	7,417,910
2029	41%	382,216	66,862,077	47%	442,277	15,149,570	38,314,540	12%	107,741	7,961,945
2030	32%	271,278	48,854,015	56%	475,213	16,751,030	42,410,446	12%	101,252	7,716,317

Table A-57. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenarios 2a and 2b in Calendar Year 2030

	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
1986	0%	0	0	0%	0	0	26	0.01	0.005
1987	0%	0	0	0%	0	0	32	0.02	0.006
1988	0%	0	0	0%	0	0	32	0.02	0.006
1989	0%	0	0	0%	0	0	42	0.02	0.008
1990	0%	0	0	0%	0	0	54	0.03	0.010
1991	0%	0	0	0%	0	0	66	0.03	0.01
1992	0%	0	0	0%	0	0	59	0.03	0.01
1993	0%	0	0	0%	0	0	62	0.03	0.01
1994	0%	0	0	0%	0	0	71	0.04	0.01
1995	0%	0	0	0%	0	0	94	0.05	0.02
1996	0%	0	0	0%	0	0	94	0.05	0.02
1997	0%	0	0	0%	0	0	124	0.06	0.02
1998	0%	0	0	0%	0	0	149	0.06	0.03
1999	0%	0	0	0%	0	0	169	0.05	0.03
2000	0%	0	0	0%	0	0	229	0.04	0.03
2001	0%	0	0	0%	0	0	263	0.04	0.03
2002	0%	0	0	0%	0	0	311	0.05	0.04
2003	0%	0	0	0%	0	0	396	0.05	0.04
2004	0%	0	0	0%	0	0	478	0.03	0.01
2005	0%	0	0	0%	0	0	658	0.03	0.02
2006	0%	0	0	0%	0	0	826	0.04	0.02
2007	0%	0	0	0%	0	0	1,059	0.05	0.03
2008	0%	0	0	0%	0	0	1,094	0.05	0.03
2009	0%	0	0	0%	0	0	1,015	0.04	0.03
2010	0%	0	0	0%	0	0	1,312	0.06	0.04
2011	0%	0	0	0%	0	0	1,596	0.06	0.05
2012	0%	0	0	0%	0	0	2,585	0.10	0.08
2013	0%	0	0	0%	0	0	3,531	0.13	0.11
2014	0%	0	0	0%	0	0	3,977	0.15	0.12
2015	0%	0	0	0%	0	0	5,225	0.19	0.16
2016	0%	0	0	0%	0	0	5,716	0.22	0.18
2017	0%	0	0	0%	0	0	6,666	0.24	0.20
2018	0%	0	0	0%	0	0	6,383	0.22	0.18
2019	0%	0	0	0%	0	0	5,949	0.19	0.17
2020	0%	0	0	0%	0	0	5,093	0.15	0.14
2021	0%	0	0	0%	0	0	6,446	0.18	0.18
2022	0%	0	0	0%	0	0	7,811	0.20	0.21
2023	0%	0	0	0%	0	0	8,237	0.19	0.21
2024	0%	0	0	0%	0	0	8,610	0.18	0.21
2025	0%	0	0	0%	0	0	9,101	0.16	0.20
2026	0%	0	0	0%	0	0	8,604	0.16	0.18
2027	0%	0	0	0%	0	0	8,664	0.16	0.17
2028	0%	0	0	0%	0	0	8,726	0.17	0.16
2029	0%	0	0	0%	0	0	8,611	0.17	0.15
2030	0%	0	0	0%	0	0	7,472	0.15	0.12

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-11) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-13. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

Table A-58. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenarios 2a and 2b in Calendar Year 2035
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fuel Consumption[3] (MJ of electricity/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of electricity/day)
1991	100%	14,887	496,519	0%	0	0	0	0%	0	0
1992	100%	12,386	437,879	0%	0	0	0	0%	0	0
1993	100%	12,876	454,610	0%	0	0	0	0%	2	20
1994	100%	13,908	519,028	0%	0	0	0	0%	0	3
1995	100%	17,011	673,579	0%	0	0	0	0%	1	11
1996	100%	15,726	662,566	0%	0	0	0	0%	0	0
1997	100%	19,249	841,793	0%	0	0	0	0%	3	36
1998	100%	21,231	962,917	0%	0	0	0	0%	2	32
1999	100%	21,841	1,026,080	0%	0	0	0	0%	2	27
2000	100%	26,428	1,326,406	0%	0	0	0	0%	0	7
2001	100%	26,524	1,412,096	0%	0	0	0	0%	2	30
2002	100%	27,790	1,574,561	0%	0	0	0	0%	11	189
2003	100%	30,887	1,866,413	0%	0	0	0	0%	2	31
2004	100%	31,459	2,100,346	0%	0	0	0	0%	1	22
2005	100%	38,743	2,705,815	0%	0	0	0	0%	1	29
2006	100%	43,503	3,231,279	0%	0	0	0	0%	2	47
2007	100%	51,445	3,941,697	0%	0	0	0	0%	4	103
2008	100%	48,196	3,931,397	0%	0	0	0	0%	23	522
2009	100%	43,832	3,583,029	0%	0	0	0	0%	7	170
2010	100%	59,373	4,651,159	0%	2	20	92	0%	32	847
2011	99%	67,186	5,797,667	0%	120	1,161	5,375	1%	409	11,360
2012	98%	112,410	9,761,699	1%	1,348	13,798	63,245	1%	603	17,549
2013	97%	158,581	14,066,520	2%	2,997	32,296	147,122	1%	2,255	68,707
2014	96%	180,829	16,955,018	3%	4,964	56,441	255,982	1%	2,764	88,302
2015	97%	248,911	24,094,495	2%	4,244	50,842	229,574	2%	4,701	157,841
2016	95%	285,862	28,441,636	2%	5,224	65,752	295,555	3%	8,578	300,098
2017	91%	332,615	34,903,768	4%	15,110	198,715	892,263	5%	18,042	661,811
2018	86%	327,985	35,952,376	4%	15,507	213,599	955,739	9%	35,779	1,376,403
2019	88%	314,542	35,673,840	3%	12,281	183,606	769,058	8%	29,273	1,183,116
2020	86%	281,575	32,424,569	4%	13,612	216,540	874,542	9%	30,604	1,303,564
2021	85%	366,087	42,975,928	4%	19,269	330,198	1,255,839	10%	43,723	1,945,314
2022	84%	459,912	55,139,274	5%	25,381	499,808	1,561,702	11%	59,175	2,747,832
2023	84%	491,823	60,167,945	5%	27,272	576,729	1,688,911	11%	66,548	3,223,016
2024	83%	528,134	65,889,598	5%	29,108	659,860	1,811,619	12%	75,344	3,803,598
2025	83%	560,849	71,323,875	5%	30,955	752,392	1,930,200	12%	82,779	4,355,000
2026	65%	467,482	60,539,560	24%	174,121	4,405,065	11,267,062	11%	77,601	4,248,646
2027	57%	430,704	58,014,343	32%	241,564	6,361,596	16,239,550	11%	83,353	4,746,114
2028	49%	390,089	54,639,940	40%	315,883	8,654,239	22,052,020	11%	90,128	5,333,845
2029	41%	338,901	49,344,310	47%	392,155	11,172,708	28,417,556	12%	95,531	5,873,508
2030	32%	276,003	41,738,586	56%	483,490	14,312,319	36,344,465	12%	103,016	6,575,282
2031	24%	213,410	33,502,607	64%	569,594	17,509,546	44,395,455	12%	106,205	7,033,396
2032	18%	164,104	26,722,257	70%	638,697	20,369,220	51,588,926	12%	108,890	7,476,741
2033	12%	112,719	19,004,076	76%	714,415	23,588,087	59,723,539	12%	112,190	7,976,623
2034	6%	57,245	9,957,437	82%	782,879	26,661,420	67,539,241	12%	113,952	8,366,832
2035	0%	0	0	88%	762,430	26,697,090	67,700,364	12%	103,414	7,823,380

	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
1991	0%	0	0	0%	0	0	41	0.02	0.008
1992	0%	0	0	0%	0	0	36	0.02	0.007
1993	0%	0	0	0%	0	0	37	0.02	0.007
1994	0%	0	0	0%	0	0	42	0.02	0.008
1995	0%	0	0	0%	0	0	55	0.03	0.01
1996	0%	0	0	0%	0	0	54	0.04	0.01
1997	0%	0	0	0%	0	0	69	0.04	0.01
1998	0%	0	0	0%	0	0	79	0.03	0.01
1999	0%	0	0	0%	0	0	84	0.03	0.01
2000	0%	0	0	0%	0	0	109	0.02	0.01
2001	0%	0	0	0%	0	0	116	0.02	0.01
2002	0%	0	0	0%	0	0	129	0.02	0.02
2003	0%	0	0	0%	0	0	153	0.02	0.02
2004	0%	0	0	0%	0	0	172	0.01	0.006
2005	0%	0	0	0%	0	0	222	0.01	0.007
2006	0%	0	0	0%	0	0	265	0.01	0.008
2007	0%	0	0	0%	0	0	323	0.02	0.01
2008	0%	0	0	0%	0	0	322	0.02	0.01
2009	0%	0	0	0%	0	0	293	0.01	0.010
2010	0%	0	0	0%	0	0	381	0.02	0.01
2011	0%	0	0	0%	0	0	475	0.02	0.02
2012	0%	0	0	0%	0	0	804	0.04	0.03
2013	0%	0	0	0%	0	0	1,164	0.05	0.04
2014	0%	0	0	0%	0	0	1,409	0.06	0.05
2015	0%	0	0	0%	0	0	1,991	0.08	0.07
2016	0%	0	0	0%	0	0	2,353	0.11	0.08
2017	0%	0	0	0%	0	0	2,931	0.12	0.10
2018	0%	0	0	0%	0	0	3,022	0.12	0.10
2019	0%	0	0	0%	0	0	2,984	0.11	0.10
2020	0%	0	0	0%	0	0	2,726	0.10	0.09
2021	0%	0	0	0%	0	0	3,621	0.12	0.12
2022	0%	0	0	0%	0	0	4,642	0.14	0.15
2023	0%	0	0	0%	0	0	5,064	0.14	0.16
2024	0%	0	0	0%	0	0	5,543	0.14	0.16
2025	0%	0	0	0%	0	0	5,997	0.13	0.17
2026	0%	0	0	0%	0	0	5,879	0.13	0.15
2027	0%	0	0	0%	0	0	6,079	0.14	0.15
2028	0%	0	0	0%	0	0	6,279	0.15	0.15
2029	0%	0	0	0%	0	0	6,367	0.15	0.14
2030	0%	0	0	0%	0	0	6,393	0.16	0.13
2031	0%	0	0	0%	0	0	6,378	0.16	0.13
2032	0%	0	0	0%	0	0	6,412	0.17	0.12
2033	0%	0	0	0%	0	0	6,446	0.17	0.12
2034	0%	0	0	0%	0	0	6,345	0.18	0.11
2035	0%	0	0	0%	0	0	5,543	0.16	0.09

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-14) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-16. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

Table A-59. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenarios 2a and 2b in Calendar Year 2040
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fuel Consumption[3] (MJ of electricity/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of electricity/day)
1996	100%	13,224	407,390	0%	0	0	0	0%	0	0
1997	100%	15,957	507,603	0%	0	0	0	0%	2	27
1998	100%	17,428	573,388	0%	0	0	0	0%	2	23
1999	100%	17,981	612,358	0%	0	0	0	0%	2	19
2000	100%	21,212	772,196	0%	0	0	0	0%	0	5
2001	100%	20,869	808,569	0%	0	0	0	0%	1	19
2002	100%	20,957	866,980	0%	0	0	0	0%	8	114
2003	100%	22,226	985,080	0%	0	0	0	0%	1	18
2004	100%	21,228	1,041,890	0%	0	0	0	0%	1	12
2005	100%	24,808	1,278,892	0%	0	0	0	0%	1	16
2006	100%	25,795	1,417,856	0%	0	0	0	0%	1	22
2007	100%	28,657	1,630,516	0%	0	0	0	0%	2	44
2008	100%	24,894	1,513,071	0%	0	0	0	0%	12	206
2009	100%	20,958	1,283,229	0%	0	0	0	0%	3	64
2010	100%	26,447	1,559,497	0%	1	7	31	0%	15	295
2011	99%	28,341	1,849,619	0%	51	367	1,752	1%	172	3,720
2012	98%	44,963	2,967,860	1%	539	4,153	19,596	1%	240	5,433
2013	97%	60,869	4,125,844	2%	1,150	9,385	43,891	1%	858	20,372
2014	96%	67,874	4,888,299	3%	1,863	16,131	74,982	1%	1,028	25,649
2015	97%	93,376	6,979,373	2%	1,592	14,608	67,463	2%	1,750	45,992
2016	95%	109,366	8,447,742	2%	1,998	19,377	88,913	3%	3,230	88,645
2017	91%	132,055	10,809,831	4%	5,994	61,088	279,650	5%	7,052	203,451
2018	87%	137,285	11,794,487	4%	6,483	69,602	317,087	9%	14,800	449,301
2019	88%	141,083	12,595,274	3%	5,505	64,430	274,520	8%	13,018	416,452
2020	86%	135,652	12,343,563	4%	6,558	82,023	336,557	9%	14,744	498,290
2021	85%	189,590	17,659,856	4%	9,979	135,046	521,355	10%	22,644	801,678
2022	84%	253,809	24,240,958	5%	14,007	218,733	693,952	11%	32,657	1,210,322
2023	84%	291,017	28,467,215	5%	16,137	271,680	807,271	11%	39,377	1,526,695
2024	83%	329,600	32,998,938	5%	18,166	329,087	916,198	12%	47,021	1,906,128
2025	83%	371,783	38,066,268	5%	20,520	399,967	1,039,937	12%	54,873	2,325,226
2026	65%	324,168	33,911,685	24%	120,741	2,456,781	6,362,489	11%	53,811	2,380,112
2027	57%	314,930	34,373,272	32%	176,632	3,753,160	9,695,864	11%	60,947	2,812,115
2028	49%	294,302	33,491,115	40%	238,318	5,284,446	13,620,346	11%	67,997	3,270,853
2029	41%	267,079	31,668,216	47%	309,047	7,146,500	18,379,446	12%	75,286	3,773,157
2030	32%	222,088	27,421,128	56%	389,045	9,375,775	24,063,052	12%	82,893	4,325,829
2031	24%	177,426	22,797,903	64%	473,551	11,886,096	30,446,929	12%	88,297	4,795,314
2032	18%	139,693	18,670,261	70%	543,686	14,206,290	36,318,127	12%	92,692	5,235,411
2033	12%	98,033	13,625,389	76%	621,338	16,890,765	43,101,880	12%	97,574	5,728,006
2034	6%	50,852	7,346,988	82%	695,450	19,661,005	50,078,899	12%	101,227	6,173,591
2035	0%	0	0	88%	778,027	22,854,249	58,117,967	12%	105,530	6,681,472
2036	0%	0	0	88%	801,381	24,445,808	62,069,943	12%	108,697	7,140,339
2037	0%	0	0	88%	820,727	25,973,021	65,874,884	12%	111,321	7,581,528
2038	0%	0	0	88%	844,334	27,659,635	70,132,899	12%	114,524	8,075,024
2039	0%	0	0	88%	856,007	28,915,842	73,357,488	12%	116,107	8,451,703
2040	0%	0	0	88%	775,172	26,912,195	68,349,021	12%	105,142	7,882,098

Table A-59. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenarios 2a and 2b in Calendar Year 2040

Model Year	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
1996	0%	0	0	0%	0	0	33	0.02	0.007
1997	0%	0	0	0%	0	0	42	0.03	0.009
1998	0%	0	0	0%	0	0	47	0.02	0.009
1999	0%	0	0	0%	0	0	50	0.02	0.008
2000	0%	0	0	0%	0	0	63	0.01	0.009
2001	0%	0	0	0%	0	0	66	0.01	0.009
2002	0%	0	0	0%	0	0	71	0.01	0.009
2003	0%	0	0	0%	0	0	81	0.01	0.010
2004	0%	0	0	0%	0	0	85	0.007	0.003
2005	0%	0	0	0%	0	0	105	0.008	0.004
2006	0%	0	0	0%	0	0	116	0.007	0.004
2007	0%	0	0	0%	0	0	133	0.008	0.005
2008	0%	0	0	0%	0	0	124	0.007	0.004
2009	0%	0	0	0%	0	0	105	0.006	0.004
2010	0%	0	0	0%	0	0	128	0.007	0.005
2011	0%	0	0	0%	0	0	152	0.008	0.006
2012	0%	0	0	0%	0	0	245	0.01	0.009
2013	0%	0	0	0%	0	0	341	0.02	0.01
2014	0%	0	0	0%	0	0	406	0.02	0.02
2015	0%	0	0	0%	0	0	577	0.03	0.02
2016	0%	0	0	0%	0	0	699	0.04	0.03
2017	0%	0	0	0%	0	0	908	0.04	0.03
2018	0%	0	0	0%	0	0	992	0.05	0.04
2019	0%	0	0	0%	0	0	1,054	0.05	0.04
2020	0%	0	0	0%	0	0	1,038	0.04	0.04
2021	0%	0	0	0%	0	0	1,489	0.06	0.05
2022	0%	0	0	0%	0	0	2,041	0.07	0.07
2023	0%	0	0	0%	0	0	2,397	0.08	0.08
2024	0%	0	0	0%	0	0	2,777	0.08	0.10
2025	0%	0	0	0%	0	0	3,202	0.08	0.10
2026	0%	0	0	0%	0	0	3,297	0.09	0.10
2027	0%	0	0	0%	0	0	3,608	0.10	0.11
2028	0%	0	0	0%	0	0	3,857	0.11	0.11
2029	0%	0	0	0%	0	0	4,098	0.12	0.11
2030	0%	0	0	0%	0	0	4,215	0.12	0.10
2031	0%	0	0	0%	0	0	4,359	0.13	0.10
2032	0%	0	0	0%	0	0	4,502	0.14	0.10
2033	0%	0	0	0%	0	0	4,644	0.14	0.10
2034	0%	0	0	0%	0	0	4,702	0.15	0.09
2035	0%	0	0	0%	0	0	4,758	0.16	0.09
2036	0%	0	0	0%	0	0	5,082	0.16	0.09
2037	0%	0	0	0%	0	0	5,393	0.17	0.10
2038	0%	0	0	0%	0	0	5,742	0.18	0.10
2039	0%	0	0	0%	0	0	6,006	0.18	0.10
2040	0%	0	0	0%	0	0	5,596	0.16	0.09

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-17) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-19. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

Table A-60. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenarios 2a and 2b in Calendar Year 2045
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Model Year	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fuel Consumption[3] (MJ of electricity/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of electricity/day)
2001	100%	17,581	492,838	0%	0	0	0	0%	1	13
2002	100%	17,396	519,815	0%	0	0	0	0%	7	79
2003	100%	18,261	584,063	0%	0	0	0	0%	1	12
2004	100%	17,485	620,429	0%	0	0	0	0%	1	8
2005	100%	19,931	744,101	0%	0	0	0	0%	1	11
2006	100%	20,294	810,536	0%	0	0	0	0%	1	13
2007	100%	21,610	895,705	0%	0	0	0	0%	2	26
2008	100%	17,913	797,202	0%	0	0	0	0%	8	112
2009	100%	14,142	635,358	0%	0	0	0	0%	2	35
2010	100%	16,923	735,246	0%	1	3	15	0%	9	147
2011	99%	16,799	809,857	0%	30	158	790	1%	101	1,691
2012	98%	25,037	1,225,371	1%	300	1,692	8,301	1%	133	2,322
2013	97%	31,446	1,584,333	2%	594	3,560	17,255	1%	442	8,105
2014	96%	32,442	1,745,658	3%	890	5,695	27,363	1%	489	9,437
2015	97%	41,547	2,333,580	2%	708	4,833	22,999	2%	777	15,810
2016	95%	46,072	2,687,564	2%	841	6,105	28,783	3%	1,354	28,787
2017	91%	52,700	3,274,039	4%	2,391	18,339	86,121	5%	2,789	62,457
2018	87%	52,549	3,444,774	4%	2,479	20,175	94,087	9%	5,607	132,466
2019	88%	52,919	3,622,227	3%	2,063	18,391	80,115	8%	4,832	120,601
2020	86%	51,080	3,577,777	4%	2,469	23,635	98,982	9%	5,552	146,669
2021	85%	72,808	5,249,034	4%	3,832	39,919	157,067	10%	8,696	241,288
2022	84%	101,322	7,527,271	5%	5,592	67,570	218,488	11%	13,037	379,660
2023	84%	122,476	9,364,450	5%	6,792	88,932	269,022	11%	16,572	506,226
2024	83%	148,333	11,660,897	5%	8,175	115,750	327,717	12%	21,161	677,755
2025	83%	179,162	14,468,745	5%	9,889	151,350	399,826	12%	26,443	887,822
2026	65%	167,925	13,913,800	24%	62,546	1,002,674	2,634,686	11%	27,875	979,732
2027	57%	173,839	15,087,722	32%	97,499	1,639,041	4,292,360	11%	33,642	1,237,162
2028	49%	174,181	15,820,703	40%	141,047	2,484,175	6,484,862	11%	40,244	1,547,489
2029	41%	166,713	15,834,899	47%	192,910	3,556,786	9,257,046	12%	46,994	1,888,561
2030	32%	147,252	14,612,516	56%	257,950	4,974,048	12,909,018	12%	54,961	2,306,853
2031	24%	123,062	12,750,639	64%	328,454	6,619,481	17,133,367	12%	61,243	2,683,184
2032	18%	102,163	11,044,387	70%	397,621	8,368,951	21,607,289	12%	67,790	3,098,236
2033	12%	73,974	8,338,115	76%	468,852	10,298,591	26,527,044	12%	73,628	3,508,235
2034	6%	40,081	4,707,395	82%	548,147	12,556,980	32,272,327	12%	79,786	3,960,912
2035	0%	0	0	88%	626,161	14,949,637	38,341,070	12%	84,931	4,390,345
2036	0%	0	0	88%	666,380	16,570,887	42,415,687	12%	90,386	4,862,426
2037	0%	0	0	88%	698,933	18,093,950	46,221,243	12%	94,802	5,304,019
2038	0%	0	0	88%	735,048	19,797,683	50,479,837	12%	99,700	5,797,554
2039	0%	0	0	88%	761,864	21,340,809	54,313,494	12%	103,338	6,242,847
2040	0%	0	0	88%	793,438	23,093,397	58,677,697	12%	107,620	6,749,460
2041	0%	0	0	88%	816,424	24,677,159	62,604,937	12%	110,738	7,205,621
2042	0%	0	0	88%	835,150	26,188,211	66,364,303	12%	113,278	7,641,631
2043	0%	0	0	88%	857,877	27,845,352	70,543,046	12%	116,360	8,126,069
2044	0%	0	0	88%	868,087	29,051,020	73,635,778	12%	117,745	8,487,539
2045	0%	0	0	88%	784,405	26,973,776	68,444,515	12%	106,395	7,896,358

Table A-60. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenarios 2a and 2b in Calendar Year 2045
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Model Year	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
2001	0%	0	0	0%	0	0	40	0.01	0.006
2002	0%	0	0	0%	0	0	43	0.01	0.006
2003	0%	0	0	0%	0	0	48	0.01	0.006
2004	0%	0	0	0%	0	0	51	0.005	0.002
2005	0%	0	0	0%	0	0	61	0.005	0.002
2006	0%	0	0	0%	0	0	66	0.005	0.002
2007	0%	0	0	0%	0	0	73	0.005	0.003
2008	0%	0	0	0%	0	0	65	0.005	0.003
2009	0%	0	0	0%	0	0	52	0.003	0.002
2010	0%	0	0	0%	0	0	60	0.004	0.003
2011	0%	0	0	0%	0	0	66	0.004	0.003
2012	0%	0	0	0%	0	0	101	0.006	0.004
2013	0%	0	0	0%	0	0	131	0.008	0.006
2014	0%	0	0	0%	0	0	145	0.009	0.006
2015	0%	0	0	0%	0	0	193	0.01	0.008
2016	0%	0	0	0%	0	0	222	0.01	0.009
2017	0%	0	0	0%	0	0	275	0.02	0.01
2018	0%	0	0	0%	0	0	290	0.02	0.01
2019	0%	0	0	0%	0	0	303	0.02	0.01
2020	0%	0	0	0%	0	0	301	0.01	0.01
2021	0%	0	0	0%	0	0	443	0.02	0.02
2022	0%	0	0	0%	0	0	634	0.03	0.03
2023	0%	0	0	0%	0	0	789	0.03	0.03
2024	0%	0	0	0%	0	0	982	0.03	0.04
2025	0%	0	0	0%	0	0	1,217	0.04	0.04
2026	0%	0	0	0%	0	0	1,355	0.04	0.05
2027	0%	0	0	0%	0	0	1,587	0.05	0.05
2028	0%	0	0	0%	0	0	1,826	0.06	0.06
2029	0%	0	0	0%	0	0	2,054	0.07	0.06
2030	0%	0	0	0%	0	0	2,253	0.08	0.06
2031	0%	0	0	0%	0	0	2,447	0.09	0.07
2032	0%	0	0	0%	0	0	2,673	0.10	0.07
2033	0%	0	0	0%	0	0	2,854	0.11	0.07
2034	0%	0	0	0%	0	0	3,028	0.11	0.07
2035	0%	0	0	0%	0	0	3,139	0.12	0.06
2036	0%	0	0	0%	0	0	3,473	0.13	0.07
2037	0%	0	0	0%	0	0	3,784	0.14	0.07
2038	0%	0	0	0%	0	0	4,133	0.15	0.08
2039	0%	0	0	0%	0	0	4,447	0.15	0.08
2040	0%	0	0	0%	0	0	4,804	0.16	0.09
2041	0%	0	0	0%	0	0	5,126	0.17	0.09
2042	0%	0	0	0%	0	0	5,433	0.17	0.10
2043	0%	0	0	0%	0	0	5,776	0.18	0.10
2044	0%	0	0	0%	0	0	6,029	0.18	0.10
2045	0%	0	0	0%	0	0	5,604	0.16	0.10

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-20) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-22. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

Table A-61. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenarios 2a and 2b in Calendar Year 2050
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
Model Year	**Fleet Mix[1] (%)**	**Population[2] (vehicles)**	**Fuel Consumption[3] (MJ of gasoline/day)**	**Fleet Mix[1] (%)**	**Population[2] (vehicles)**	**Fuel Consumption[3] (MJ of gasoline/day)**	**Fuel Consumption[3] (MJ of electricity/day)**	**Fleet Mix[1] (%)**	**Population[2] (vehicles)**	**Fuel Consumption[3] (MJ of electricity/day)**
2006	100%	17,095	495,171	0%	0	0	0	0%	1	9
2007	100%	17,938	537,342	0%	0	0	0	0%	2	18
2008	100%	14,711	473,301	0%	0	0	0	0%	6	73
2009	100%	11,643	378,435	0%	0	0	0	0%	2	24
2010	100%	13,584	427,686	0%	0	2	9	0%	8	94
2011	99%	13,206	463,001	0%	24	89	472	1%	79	1,039
2012	98%	18,883	674,484	1%	226	915	4,745	1%	100	1,368
2013	97%	22,656	836,306	2%	428	1,850	9,427	1%	314	4,504
2014	96%	21,908	865,904	3%	601	2,783	14,018	1%	326	4,894
2015	97%	26,586	1,101,721	2%	453	2,250	11,180	2%	491	7,761
2016	95%	27,295	1,177,776	2%	498	2,640	12,955	3%	790	13,009
2017	91%	29,325	1,351,831	4%	1,329	7,482	36,484	5%	1,525	26,393
2018	87%	27,113	1,322,228	4%	1,278	7,675	37,071	9%	2,868	52,384
2019	89%	25,304	1,294,975	3%	986	6,516	29,339	8%	2,292	44,244
2020	86%	22,760	1,198,129	4%	1,100	7,856	33,925	9%	2,474	50,596
2021	85%	30,740	1,673,570	4%	1,618	12,642	51,178	10%	3,671	78,995
2022	84%	40,577	2,287,454	5%	2,239	20,404	67,892	11%	5,221	118,112
2023	84%	47,100	2,747,369	5%	2,612	25,936	80,590	11%	6,373	151,554
2024	83%	55,817	3,364,077	5%	3,076	33,204	96,428	12%	7,963	198,997
2025	83%	67,473	4,197,128	5%	3,724	43,672	118,177	12%	9,959	261,533
2026	65%	64,497	4,139,198	24%	24,023	296,043	795,196	11%	10,706	295,109
2027	57%	69,408	4,689,197	32%	38,928	505,776	1,351,812	11%	13,432	388,383
2028	49%	73,318	5,209,164	40%	59,371	812,427	2,161,469	11%	16,940	513,531
2029	41%	75,042	5,600,876	47%	86,834	1,250,068	3,311,433	12%	21,153	672,043
2030	32%	70,975	5,559,659	56%	124,331	1,881,108	4,963,106	12%	26,491	881,507
2031	24%	63,763	5,236,564	64%	170,183	2,703,072	7,105,273	12%	31,732	1,105,371
2032	18%	56,405	4,852,327	70%	219,530	3,656,882	9,579,853	12%	37,427	1,364,096
2033	12%	43,791	3,942,469	76%	277,548	4,844,114	12,649,212	12%	43,586	1,661,080
2034	6%	25,024	2,355,959	82%	342,228	6,253,137	16,279,177	12%	49,813	1,984,022
2035	0%	0	0	88%	415,252	7,935,655	20,600,419	12%	56,324	2,343,007
2036	0%	0	0	88%	462,305	9,233,976	23,906,101	12%	62,706	2,722,815
2037	0%	0	0	88%	511,255	10,665,010	27,541,275	12%	69,345	3,141,091
2038	0%	0	0	88%	554,750	12,077,399	31,115,059	12%	75,245	3,553,333
2039	0%	0	0	88%	600,583	13,636,644	35,053,579	12%	81,462	4,008,057
2040	0%	0	0	88%	638,683	15,114,332	38,770,069	12%	86,629	4,438,238
2041	0%	0	0	88%	679,027	16,737,200	42,848,155	12%	92,102	4,910,573
2042	0%	0	0	88%	711,536	18,259,200	46,650,176	12%	96,511	5,351,582
2043	0%	0	0	88%	747,596	19,960,328	50,901,391	12%	101,402	5,844,049
2044	0%	0	0	88%	774,140	21,496,670	54,716,951	12%	105,002	6,287,030
2045	0%	0	0	88%	805,424	23,239,836	59,056,434	12%	109,246	6,790,499
2046	0%	0	0	88%	827,953	24,810,504	62,949,469	12%	112,302	7,242,409
2047	0%	0	0	88%	845,960	26,299,555	66,652,019	12%	114,744	7,671,556
2048	0%	0	0	88%	867,698	27,921,700	70,740,561	12%	117,693	8,145,301
2049	0%	0	0	88%	876,432	29,075,425	73,699,707	12%	118,877	8,491,081
2050	0%	0	0	88%	790,255	26,934,839	68,345,548	12%	107,188	7,881,262

Table A-61. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenarios 2a and 2b in Calendar Year 2050
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
2006	0%	0	0	0%	0	0	41	0.004	0.002
2007	0%	0	0	0%	0	0	44	0.004	0.002
2008	0%	0	0	0%	0	0	39	0.003	0.002
2009	0%	0	0	0%	0	0	31	0.002	0.001
2010	0%	0	0	0%	0	0	35	0.003	0.002
2011	0%	0	0	0%	0	0	38	0.003	0.002
2012	0%	0	0	0%	0	0	56	0.004	0.003
2013	0%	0	0	0%	0	0	69	0.005	0.003
2014	0%	0	0	0%	0	0	72	0.005	0.003
2015	0%	0	0	0%	0	0	91	0.006	0.004
2016	0%	0	0	0%	0	0	97	0.007	0.005
2017	0%	0	0	0%	0	0	114	0.008	0.005
2018	0%	0	0	0%	0	0	111	0.007	0.005
2019	0%	0	0	0%	0	0	108	0.006	0.005
2020	0%	0	0	0%	0	0	101	0.006	0.004
2021	0%	0	0	0%	0	0	141	0.008	0.006
2022	0%	0	0	0%	0	0	193	0.009	0.009
2023	0%	0	0	0%	0	0	232	0.01	0.01
2024	0%	0	0	0%	0	0	283	0.01	0.01
2025	0%	0	0	0%	0	0	353	0.01	0.01
2026	0%	0	0	0%	0	0	404	0.02	0.02
2027	0%	0	0	0%	0	0	495	0.02	0.02
2028	0%	0	0	0%	0	0	603	0.02	0.02
2029	0%	0	0	0%	0	0	730	0.03	0.02
2030	0%	0	0	0%	0	0	862	0.04	0.03
2031	0%	0	0	0%	0	0	1,010	0.04	0.03
2032	0%	0	0	0%	0	0	1,182	0.05	0.03
2033	0%	0	0	0%	0	0	1,358	0.06	0.04
2034	0%	0	0	0%	0	0	1,526	0.07	0.04
2035	0%	0	0	0%	0	0	1,687	0.08	0.04
2036	0%	0	0	0%	0	0	1,957	0.09	0.04
2037	0%	0	0	0%	0	0	2,255	0.10	0.05
2038	0%	0	0	0%	0	0	2,547	0.11	0.06
2039	0%	0	0	0%	0	0	2,870	0.12	0.06
2040	0%	0	0	0%	0	0	3,174	0.12	0.07
2041	0%	0	0	0%	0	0	3,508	0.13	0.07
2042	0%	0	0	0%	0	0	3,819	0.14	0.08
2043	0%	0	0	0%	0	0	4,167	0.15	0.08
2044	0%	0	0	0%	0	0	4,480	0.16	0.09
2045	0%	0	0	0%	0	0	4,835	0.16	0.09
2046	0%	0	0	0%	0	0	5,154	0.17	0.09
2047	0%	0	0	0%	0	0	5,457	0.17	0.10
2048	0%	0	0	0%	0	0	5,792	0.18	0.10
2049	0%	0	0	0%	0	0	6,034	0.18	0.10
2050	0%	0	0	0%	0	0	5,596	0.17	0.10

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-23) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-25. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

Table A-62. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 2c in Calendar Year 2026
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Model Year	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fuel Consumption[3] (MJ of electricity/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of electricity/day)
1982	100%	4,657	174,227	0%	0	0	0	0%	1	9
1983	100%	5,273	206,541	0%	0	0	0	0%	1	9
1984	100%	7,858	329,345	0%	0	0	0	0%	1	13
1985	100%	10,024	435,286	0%	0	0	0	0%	0	0
1986	100%	10,647	463,741	0%	0	0	0	0%	0	0
1987	100%	12,832	586,622	0%	0	0	0	0%	1	18
1988	100%	12,139	592,716	0%	0	0	0	0%	0	0
1989	100%	14,970	774,940	0%	0	0	0	0%	1	14
1990	100%	18,044	991,990	0%	0	0	0	0%	0	0
1991	100%	21,281	1,234,023	0%	0	0	0	0%	0	0
1992	100%	18,332	1,127,213	0%	0	0	0	0%	0	0
1993	100%	20,138	1,231,512	0%	0	0	0	0%	3	46
1994	100%	22,840	1,473,479	0%	0	0	0	0%	0	7
1995	100%	29,675	2,022,331	0%	0	0	0	0%	2	31
1996	100%	29,436	2,128,971	0%	0	0	0	0%	0	0
1997	100%	39,761	2,978,637	0%	0	0	0	0%	4	95
1998	100%	48,817	3,777,000	0%	0	0	0	0%	5	107
1999	100%	56,921	4,546,344	0%	0	0	0	0%	4	98
2000	100%	76,964	6,529,441	0%	0	0	0	0%	1	31
2001	100%	87,221	7,793,387	0%	0	0	0	0%	6	155
2002	100%	102,135	9,644,077	0%	0	0	0	0%	37	1,030
2003	100%	127,287	12,720,322	0%	0	0	0	0%	7	196
2004	100%	143,690	15,732,253	0%	0	0	0	0%	5	155
2005	100%	191,623	21,752,720	0%	0	0	0	0%	7	213
2006	100%	225,488	26,980,154	0%	0	0	0	0%	11	389
2007	100%	275,180	33,665,694	0%	0	0	0	0%	23	834
2008	100%	258,265	33,318,492	0%	0	0	0	0%	126	4,586
2009	100%	229,086	29,357,696	0%	0	0	0	0%	34	1,333
2010	100%	292,924	35,681,010	0%	11	154	687	0%	161	6,445
2011	99%	307,002	40,824,099	0%	548	8,280	37,013	1%	1,890	79,947
2012	98%	465,759	61,806,971	1%	5,585	88,399	392,722	1%	2,528	111,558
2013	97%	592,447	79,686,217	2%	11,199	185,018	819,056	1%	8,583	395,185
2014	96%	599,553	84,574,041	3%	16,462	284,537	1,256,341	1%	9,356	449,554
2015	96%	738,821	106,767,996	2%	12,602	227,577	1,002,629	2%	14,202	712,794
2016	95%	754,102	111,262,248	2%	13,790	259,774	1,141,452	3%	23,130	1,205,441
2017	91%	794,462	122,943,456	4%	36,125	706,874	3,105,093	5%	43,901	2,385,744
2018	86%	705,513	113,371,002	4%	33,412	680,299	2,980,537	10%	78,294	4,428,841
2019	88%	622,322	102,867,416	3%	24,317	533,860	2,191,127	8%	58,438	3,447,620
2020	86%	508,892	85,019,301	4%	24,600	571,597	2,264,467	9%	55,310	3,416,834
2021	85%	619,444	104,948,162	4%	32,604	811,289	3,029,262	10%	73,983	4,748,184
2022	84%	724,703	124,757,619	5%	39,994	1,137,171	3,486,691	11%	93,245	6,212,763
2023	84%	731,635	127,883,688	5%	40,571	1,231,754	3,543,090	11%	98,996	6,843,258
2024	83%	747,543	132,487,563	5%	41,200	1,332,140	3,598,733	12%	106,645	7,641,910
2025	83%	758,530	135,969,595	5%	41,866	1,438,799	3,640,575	12%	111,956	8,303,968
2026	65%	540,131	97,639,769	4%	34,449	1,220,027	3,088,034	11%	89,660	6,866,855

Table A-62. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 2c in Calendar Year 2026

Model Year	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
1982	0%	0	0	0%	0	0	14	0.008	0.003
1983	0%	0	0	0%	0	0	17	0.009	0.003
1984	0%	0	0	0%	0	0	27	0.01	0.005
1985	0%	0	0	0%	0	0	36	0.02	0.006
1986	0%	0	0	0%	0	0	38	0.02	0.007
1987	0%	0	0	0%	0	0	48	0.02	0.009
1988	0%	0	0	0%	0	0	49	0.02	0.009
1989	0%	0	0	0%	0	0	63	0.03	0.01
1990	0%	0	0	0%	0	0	81	0.04	0.01
1991	0%	0	0	0%	0	0	101	0.05	0.02
1992	0%	0	0	0%	0	0	92	0.04	0.02
1993	0%	0	0	0%	0	0	101	0.05	0.02
1994	0%	0	0	0%	0	0	121	0.06	0.02
1995	0%	0	0	0%	0	0	166	0.08	0.03
1996	0%	0	0	0%	0	0	174	0.09	0.04
1997	0%	0	0	0%	0	0	244	0.11	0.05
1998	0%	0	0	0%	0	0	309	0.11	0.05
1999	0%	0	0	0%	0	0	372	0.09	0.06
2000	0%	0	0	0%	0	0	535	0.08	0.07
2001	0%	0	0	0%	0	0	638	0.09	0.07
2002	0%	0	0	0%	0	0	790	0.11	0.09
2003	0%	0	0	0%	0	0	1,041	0.13	0.11
2004	0%	0	0	0%	0	0	1,288	0.07	0.04
2005	0%	0	0	0%	0	0	1,781	0.08	0.05
2006	0%	0	0	0%	0	0	2,209	0.09	0.06
2007	0%	0	0	0%	0	0	2,756	0.11	0.08
2008	0%	0	0	0%	0	0	2,728	0.10	0.08
2009	0%	0	0	0%	0	0	2,404	0.09	0.07
2010	0%	0	0	0%	0	0	2,921	0.11	0.09
2011	0%	0	0	0%	0	0	3,345	0.12	0.10
2012	0%	0	0	0%	0	0	5,092	0.18	0.15
2013	0%	0	0	0%	0	0	6,591	0.22	0.19
2014	0%	0	0	0%	0	0	7,027	0.23	0.20
2015	0%	0	0	0%	0	0	8,823	0.28	0.24
2016	0%	0	0	0%	0	0	9,203	0.32	0.26
2017	0%	0	0	0%	0	0	10,320	0.32	0.27
2018	0%	0	0	0%	0	0	9,526	0.28	0.24
2019	0%	0	0	0%	0	0	8,601	0.23	0.21
2020	0%	0	0	0%	0	0	7,146	0.19	0.17
2021	0%	0	0	0%	0	0	8,840	0.21	0.21
2022	0%	0	0	0%	0	0	10,500	0.23	0.24
2023	0%	0	0	0%	0	0	10,760	0.21	0.23
2024	0%	0	0	0%	0	0	11,142	0.20	0.22
2025	0%	0	0	0%	0	0	11,430	0.16	0.20
2026	0%	0	0	20%	166,731	21,378,386	9,997	0.14	0.17

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-8) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-10. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

Table A-63. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 2c in Calendar Year 2030
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fuel Consumption[3] (MJ of electricity/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of electricity/day)
1986	100%	9,277	319,606	0%	0	0	0	0%	0	0
1987	100%	11,036	395,358	0%	0	0	0	0%	1	13
1988	100%	10,287	394,106	0%	0	0	0	0%	0	0
1989	100%	12,682	513,141	0%	0	0	0	0%	1	10
1990	100%	15,335	660,988	0%	0	0	0	0%	0	0
1991	100%	17,755	806,207	0%	0	0	0	0%	0	0
1992	100%	14,968	722,403	0%	0	0	0	0%	0	0
1993	100%	15,722	757,504	0%	0	0	0	0%	2	30
1994	100%	16,938	862,749	0%	0	0	0	0%	0	4
1995	100%	21,266	1,147,175	0%	0	0	0	0%	1	18
1996	100%	20,041	1,148,835	0%	0	0	0	0%	0	0
1997	100%	25,571	1,519,989	0%	0	0	0	0%	3	55
1998	100%	29,544	1,816,366	0%	0	0	0	0%	3	55
1999	100%	32,392	2,061,329	0%	0	0	0	0%	2	47
2000	100%	41,346	2,802,701	0%	0	0	0	0%	1	14
2001	100%	44,766	3,209,806	0%	0	0	0	0%	3	65
2002	100%	49,911	3,795,455	0%	0	0	0	0%	18	424
2003	100%	59,781	4,832,777	0%	0	0	0	0%	3	76
2004	100%	65,751	5,844,031	0%	0	0	0	0%	2	59
2005	100%	86,903	8,039,211	0%	0	0	0	0%	3	81
2006	100%	103,055	10,092,547	0%	0	0	0	0%	5	144
2007	100%	128,610	12,929,139	0%	0	0	0	0%	11	328
2008	100%	125,543	13,361,675	0%	0	0	0	0%	60	1,794
2009	100%	116,809	12,395,606	0%	0	0	0	0%	18	572
2010	100%	158,274	16,020,574	0%	6	69	311	0%	86	2,863
2011	99%	175,648	19,479,572	0%	313	3,932	17,791	1%	1,076	37,957
2012	98%	282,481	31,367,919	1%	3,387	44,658	200,590	1%	1,526	56,296
2013	97%	378,095	42,683,040	2%	7,146	98,660	441,197	1%	5,433	209,483
2014	96%	402,992	47,862,257	3%	11,064	160,332	714,692	1%	6,227	251,167
2015	97%	518,113	63,218,662	2%	8,836	134,191	596,394	2%	9,879	417,410
2016	95%	553,278	69,108,331	2%	10,115	160,689	711,773	3%	16,817	738,736
2017	91%	604,853	79,402,357	4%	27,493	454,641	2,012,619	5%	33,194	1,524,212
2018	86%	555,971	75,960,952	4%	26,314	453,896	2,003,609	10%	61,332	2,941,765
2019	88%	505,059	71,135,364	3%	19,734	368,011	1,521,560	8%	47,387	2,378,873
2020	86%	424,894	60,588,792	4%	20,540	406,324	1,621,195	9%	46,181	2,435,627
2021	85%	528,088	76,514,975	4%	27,796	590,252	2,219,126	10%	63,072	3,464,139
2022	84%	629,123	92,802,888	5%	34,719	844,508	2,607,459	11%	80,947	4,626,137
2023	84%	652,013	97,885,688	5%	36,155	941,473	2,725,229	11%	88,223	5,242,684
2024	83%	670,253	102,369,934	5%	36,940	1,028,217	2,790,931	12%	95,619	5,905,793
2025	83%	697,118	108,259,056	5%	38,476	1,144,799	2,904,428	12%	102,891	6,603,088
2026	65%	562,392	88,712,763	4%	35,869	1,108,113	2,804,580	11%	93,356	6,216,252
2027	57%	506,170	82,823,038	4%	36,682	1,175,675	2,972,420	11%	97,957	6,763,472
2028	49%	448,945	76,077,298	4%	37,500	1,244,657	3,146,136	11%	103,726	7,417,910
2029	41%	382,216	66,862,077	4%	37,726	1,292,471	3,268,769	12%	107,741	7,961,945
2030	32%	271,278	48,854,015	4%	33,914	1,195,950	3,027,919	12%	101,252	7,716,317

Table A-63. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 2c in Calendar Year 2030

Model Year	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
1986	0%	0	0	0%	0	0	26	0.01	0.005
1987	0%	0	0	0%	0	0	32	0.02	0.006
1988	0%	0	0	0%	0	0	32	0.02	0.006
1989	0%	0	0	0%	0	0	42	0.02	0.008
1990	0%	0	0	0%	0	0	54	0.03	0.010
1991	0%	0	0	0%	0	0	66	0.03	0.01
1992	0%	0	0	0%	0	0	59	0.03	0.01
1993	0%	0	0	0%	0	0	62	0.03	0.01
1994	0%	0	0	0%	0	0	71	0.04	0.01
1995	0%	0	0	0%	0	0	94	0.05	0.02
1996	0%	0	0	0%	0	0	94	0.05	0.02
1997	0%	0	0	0%	0	0	124	0.06	0.02
1998	0%	0	0	0%	0	0	149	0.06	0.03
1999	0%	0	0	0%	0	0	169	0.05	0.03
2000	0%	0	0	0%	0	0	229	0.04	0.03
2001	0%	0	0	0%	0	0	263	0.04	0.03
2002	0%	0	0	0%	0	0	311	0.05	0.04
2003	0%	0	0	0%	0	0	396	0.05	0.04
2004	0%	0	0	0%	0	0	478	0.03	0.01
2005	0%	0	0	0%	0	0	658	0.03	0.02
2006	0%	0	0	0%	0	0	826	0.04	0.02
2007	0%	0	0	0%	0	0	1,059	0.05	0.03
2008	0%	0	0	0%	0	0	1,094	0.05	0.03
2009	0%	0	0	0%	0	0	1,015	0.04	0.03
2010	0%	0	0	0%	0	0	1,312	0.06	0.04
2011	0%	0	0	0%	0	0	1,596	0.06	0.05
2012	0%	0	0	0%	0	0	2,585	0.10	0.08
2013	0%	0	0	0%	0	0	3,531	0.13	0.11
2014	0%	0	0	0%	0	0	3,977	0.15	0.12
2015	0%	0	0	0%	0	0	5,225	0.19	0.16
2016	0%	0	0	0%	0	0	5,716	0.22	0.18
2017	0%	0	0	0%	0	0	6,666	0.24	0.20
2018	0%	0	0	0%	0	0	6,383	0.22	0.18
2019	0%	0	0	0%	0	0	5,949	0.19	0.17
2020	0%	0	0	0%	0	0	5,093	0.15	0.14
2021	0%	0	0	0%	0	0	6,446	0.18	0.18
2022	0%	0	0	0%	0	0	7,811	0.20	0.21
2023	0%	0	0	0%	0	0	8,237	0.19	0.21
2024	0%	0	0	0%	0	0	8,610	0.18	0.21
2025	0%	0	0	0%	0	0	9,101	0.16	0.20
2026	0%	0	0	20%	173,603	19,423,803	9,083	0.15	0.20
2027	0%	0	0	28%	247,209	28,691,278	9,373	0.15	0.19
2028	0%	0	0	36%	326,043	39,189,369	9,695	0.15	0.19
2029	0%	0	0	43%	404,551	50,196,693	9,852	0.14	0.18
2030	0%	0	0	52%	441,299	56,370,317	8,863	0.12	0.15

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-11) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-13. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

Table A-64. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 2c in Calendar Year 2035

	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fuel Consumption[3] (MJ of electricity/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of electricity/day)
1991	100%	14,887	496,519	0%	0	0	0	0%	0	0
1992	100%	12,386	437,879	0%	0	0	0	0%	0	0
1993	100%	12,876	454,610	0%	0	0	0	0%	2	20
1994	100%	13,908	519,028	0%	0	0	0	0%	0	3
1995	100%	17,011	673,579	0%	0	0	0	0%	1	11
1996	100%	15,726	662,566	0%	0	0	0	0%	0	0
1997	100%	19,249	841,793	0%	0	0	0	0%	3	36
1998	100%	21,231	962,917	0%	0	0	0	0%	2	32
1999	100%	21,841	1,026,080	0%	0	0	0	0%	2	27
2000	100%	26,428	1,326,406	0%	0	0	0	0%	0	7
2001	100%	26,524	1,412,096	0%	0	0	0	0%	2	30
2002	100%	27,790	1,574,561	0%	0	0	0	0%	11	189
2003	100%	30,887	1,866,413	0%	0	0	0	0%	2	31
2004	100%	31,459	2,100,346	0%	0	0	0	0%	1	22
2005	100%	38,743	2,705,815	0%	0	0	0	0%	1	29
2006	100%	43,503	3,231,279	0%	0	0	0	0%	2	47
2007	100%	51,445	3,941,697	0%	0	0	0	0%	4	103
2008	100%	48,196	3,931,397	0%	0	0	0	0%	23	522
2009	100%	43,832	3,583,029	0%	0	0	0	0%	7	170
2010	100%	59,373	4,651,159	0%	2	20	92	0%	32	847
2011	99%	67,186	5,797,667	0%	120	1,161	5,375	1%	409	11,360
2012	98%	112,410	9,761,699	1%	1,348	13,798	63,245	1%	603	17,549
2013	97%	158,581	14,066,520	2%	2,997	32,296	147,122	1%	2,255	68,707
2014	96%	180,829	16,955,018	3%	4,964	56,441	255,982	1%	2,764	88,302
2015	97%	248,911	24,094,495	2%	4,244	50,842	229,574	2%	4,701	157,841
2016	95%	285,862	28,441,636	2%	5,224	65,752	295,555	3%	8,578	300,098
2017	91%	332,615	34,903,768	4%	15,110	198,715	892,263	5%	18,042	661,811
2018	86%	327,985	35,952,376	4%	15,507	213,599	955,739	9%	35,779	1,376,403
2019	88%	314,542	35,673,840	3%	12,281	183,606	769,058	8%	29,273	1,183,116
2020	86%	281,575	32,424,569	4%	13,612	216,540	874,542	9%	30,604	1,303,564
2021	85%	366,087	42,975,928	4%	19,269	330,198	1,255,839	10%	43,723	1,945,314
2022	84%	459,912	55,139,274	5%	25,381	499,808	1,561,702	11%	59,175	2,747,832
2023	84%	491,823	60,167,945	5%	27,272	576,729	1,688,911	11%	66,548	3,223,016
2024	83%	528,134	65,889,598	5%	29,108	659,860	1,811,619	12%	75,344	3,803,598
2025	83%	560,849	71,323,875	5%	30,955	752,392	1,930,200	12%	82,779	4,355,000
2026	65%	467,482	60,539,560	4%	29,815	754,625	1,930,143	11%	77,601	4,248,646
2027	57%	430,704	58,014,343	4%	31,213	822,291	2,099,102	11%	83,353	4,746,114
2028	49%	390,089	54,639,940	4%	32,584	892,959	2,275,365	11%	90,128	5,333,845
2029	41%	338,901	49,344,310	4%	33,451	953,218	2,424,492	12%	95,531	5,873,508
2030	32%	276,003	41,738,586	4%	34,505	1,021,517	2,594,022	12%	103,016	6,575,282
2031	24%	213,410	33,502,607	4%	35,573	1,093,525	2,772,634	12%	106,205	7,033,396
2032	18%	164,104	26,722,257	4%	36,472	1,163,085	2,945,735	12%	108,890	7,476,741
2033	12%	112,719	19,004,076	4%	37,578	1,240,654	3,141,258	12%	112,190	7,976,623
2034	6%	57,245	9,957,437	4%	38,168	1,299,952	3,293,065	12%	113,952	8,366,832
2035	0%	0	0	4%	34,638	1,213,298	3,076,767	12%	103,414	7,823,380

Table A-64. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 2c in Calendar Year 2035

	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
1991	0%	0	0	0%	0	0	41	0.02	0.008
1992	0%	0	0	0%	0	0	36	0.02	0.007
1993	0%	0	0	0%	0	0	37	0.02	0.007
1994	0%	0	0	0%	0	0	42	0.02	0.008
1995	0%	0	0	0%	0	0	55	0.03	0.01
1996	0%	0	0	0%	0	0	54	0.04	0.01
1997	0%	0	0	0%	0	0	69	0.04	0.01
1998	0%	0	0	0%	0	0	79	0.03	0.01
1999	0%	0	0	0%	0	0	84	0.03	0.01
2000	0%	0	0	0%	0	0	109	0.02	0.01
2001	0%	0	0	0%	0	0	116	0.02	0.01
2002	0%	0	0	0%	0	0	129	0.02	0.02
2003	0%	0	0	0%	0	0	153	0.02	0.02
2004	0%	0	0	0%	0	0	172	0.01	0.006
2005	0%	0	0	0%	0	0	222	0.01	0.007
2006	0%	0	0	0%	0	0	265	0.01	0.008
2007	0%	0	0	0%	0	0	323	0.02	0.01
2008	0%	0	0	0%	0	0	322	0.02	0.01
2009	0%	0	0	0%	0	0	293	0.01	0.010
2010	0%	0	0	0%	0	0	381	0.02	0.01
2011	0%	0	0	0%	0	0	475	0.02	0.02
2012	0%	0	0	0%	0	0	804	0.04	0.03
2013	0%	0	0	0%	0	0	1,164	0.05	0.04
2014	0%	0	0	0%	0	0	1,409	0.06	0.05
2015	0%	0	0	0%	0	0	1,991	0.08	0.07
2016	0%	0	0	0%	0	0	2,353	0.11	0.08
2017	0%	0	0	0%	0	0	2,931	0.12	0.10
2018	0%	0	0	0%	0	0	3,022	0.12	0.10
2019	0%	0	0	0%	0	0	2,984	0.11	0.10
2020	0%	0	0	0%	0	0	2,726	0.10	0.09
2021	0%	0	0	0%	0	0	3,621	0.12	0.12
2022	0%	0	0	0%	0	0	4,642	0.14	0.15
2023	0%	0	0	0%	0	0	5,064	0.14	0.16
2024	0%	0	0	0%	0	0	5,543	0.14	0.16
2025	0%	0	0	0%	0	0	5,997	0.13	0.17
2026	0%	0	0	20%	144,305	13,255,235	6,200	0.13	0.17
2027	0%	0	0	28%	210,352	20,097,133	6,567	0.13	0.17
2028	0%	0	0	36%	283,299	28,146,436	6,964	0.13	0.17
2029	0%	0	0	43%	358,704	37,045,232	7,271	0.13	0.17
2030	0%	0	0	52%	448,985	48,160,163	7,573	0.13	0.17
2031	0%	0	0	60%	534,022	59,463,907	7,838	0.13	0.17
2032	0%	0	0	66%	602,224	69,557,302	8,124	0.13	0.17
2033	0%	0	0	72%	676,837	80,940,453	8,440	0.13	0.16
2034	0%	0	0	78%	744,711	91,882,472	8,607	0.12	0.15
2035	0%	0	0	84%	727,792	92,364,300	7,814	0.11	0.13

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-14) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-16. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fuel Consumption[3] (MJ of electricity/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of electricity/day)
1996	100%	13,224	407,390	0%	0	0	0	0%	0	0
1997	100%	15,957	507,603	0%	0	0	0	0%	2	27
1998	100%	17,428	573,388	0%	0	0	0	0%	2	23
1999	100%	17,981	612,358	0%	0	0	0	0%	2	19
2000	100%	21,212	772,196	0%	0	0	0	0%	0	5
2001	100%	20,869	808,569	0%	0	0	0	0%	1	19
2002	100%	20,957	866,980	0%	0	0	0	0%	8	114
2003	100%	22,226	985,080	0%	0	0	0	0%	1	18
2004	100%	21,228	1,041,890	0%	0	0	0	0%	1	12
2005	100%	24,808	1,278,892	0%	0	0	0	0%	1	16
2006	100%	25,795	1,417,856	0%	0	0	0	0%	1	22
2007	100%	28,657	1,630,516	0%	0	0	0	0%	2	44
2008	100%	24,894	1,513,071	0%	0	0	0	0%	12	206
2009	100%	20,958	1,283,229	0%	0	0	0	0%	3	64
2010	100%	26,447	1,559,497	0%	1	7	31	0%	15	295
2011	99%	28,341	1,849,619	0%	51	367	1,752	1%	172	3,720
2012	98%	44,963	2,967,860	1%	539	4,153	19,596	1%	240	5,433
2013	97%	60,869	4,125,844	2%	1,150	9,385	43,891	1%	858	20,372
2014	96%	67,874	4,888,299	3%	1,863	16,131	74,982	1%	1,028	25,649
2015	97%	93,376	6,979,373	2%	1,592	14,608	67,463	2%	1,750	45,992
2016	95%	109,366	8,447,742	2%	1,998	19,377	88,913	3%	3,230	88,645
2017	91%	132,055	10,809,831	4%	5,994	61,088	279,650	5%	7,052	203,451
2018	87%	137,285	11,794,487	4%	6,483	69,602	317,087	9%	14,800	449,301
2019	88%	141,083	12,595,274	3%	5,505	64,430	274,520	8%	13,018	416,452
2020	86%	135,652	12,343,563	4%	6,558	82,023	336,557	9%	14,744	498,290
2021	85%	189,590	17,659,856	4%	9,979	135,046	521,355	10%	22,644	801,678
2022	84%	253,809	24,240,958	5%	14,007	218,733	693,952	11%	32,657	1,210,322
2023	84%	291,017	28,467,215	5%	16,137	271,680	807,271	11%	39,377	1,526,695
2024	83%	329,600	32,998,938	5%	18,166	329,087	916,198	12%	47,021	1,906,128
2025	83%	371,783	38,066,268	5%	20,520	399,967	1,039,937	12%	54,873	2,325,226
2026	65%	324,168	33,911,685	4%	20,675	421,047	1,090,413	11%	53,811	2,380,112
2027	57%	314,930	34,373,272	4%	22,823	485,341	1,253,824	11%	60,947	2,812,115
2028	49%	294,302	33,491,115	4%	24,583	545,508	1,406,015	11%	67,997	3,270,853
2029	41%	267,079	31,668,216	4%	26,362	610,009	1,568,829	12%	75,286	3,773,157
2030	32%	222,088	27,421,128	4%	27,764	669,514	1,718,317	12%	82,893	4,325,829
2031	24%	177,426	22,797,903	4%	29,575	742,704	1,902,479	12%	88,297	4,795,314
2032	18%	139,693	18,670,261	4%	31,047	811,564	2,074,749	12%	92,692	5,235,411
2033	12%	98,033	13,625,389	4%	32,682	888,696	2,267,776	12%	97,574	5,728,006
2034	6%	50,852	7,346,988	4%	33,905	958,694	2,441,908	12%	101,227	6,173,591
2035	0%	0	0	4%	35,347	1,038,360	2,640,531	12%	105,530	6,681,472
2036	0%	0	0	4%	36,408	1,110,551	2,819,782	12%	108,697	7,140,339
2037	0%	0	0	4%	37,287	1,179,840	2,992,407	12%	111,321	7,581,528
2038	0%	0	0	4%	38,359	1,256,478	3,185,885	12%	114,524	8,075,024
2039	0%	0	0	4%	38,889	1,313,727	3,332,835	12%	116,107	8,451,703
2040	0%	0	0	4%	35,217	1,222,994	3,106,042	12%	105,142	7,882,098

Table A-65. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 2c in Calendar Year 2040
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Model Year	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
1996	0%	0	0	0%	0	0	33	0.02	0.007
1997	0%	0	0	0%	0	0	42	0.03	0.009
1998	0%	0	0	0%	0	0	47	0.02	0.009
1999	0%	0	0	0%	0	0	50	0.02	0.008
2000	0%	0	0	0%	0	0	63	0.01	0.009
2001	0%	0	0	0%	0	0	66	0.01	0.009
2002	0%	0	0	0%	0	0	71	0.01	0.009
2003	0%	0	0	0%	0	0	81	0.01	0.010
2004	0%	0	0	0%	0	0	85	0.007	0.003
2005	0%	0	0	0%	0	0	105	0.008	0.004
2006	0%	0	0	0%	0	0	116	0.007	0.004
2007	0%	0	0	0%	0	0	133	0.008	0.005
2008	0%	0	0	0%	0	0	124	0.007	0.004
2009	0%	0	0	0%	0	0	105	0.006	0.004
2010	0%	0	0	0%	0	0	128	0.007	0.005
2011	0%	0	0	0%	0	0	152	0.008	0.006
2012	0%	0	0	0%	0	0	245	0.01	0.009
2013	0%	0	0	0%	0	0	341	0.02	0.01
2014	0%	0	0	0%	0	0	406	0.02	0.02
2015	0%	0	0	0%	0	0	577	0.03	0.02
2016	0%	0	0	0%	0	0	699	0.04	0.03
2017	0%	0	0	0%	0	0	908	0.04	0.03
2018	0%	0	0	0%	0	0	992	0.05	0.04
2019	0%	0	0	0%	0	0	1,054	0.05	0.04
2020	0%	0	0	0%	0	0	1,038	0.04	0.04
2021	0%	0	0	0%	0	0	1,489	0.06	0.05
2022	0%	0	0	0%	0	0	2,041	0.07	0.07
2023	0%	0	0	0%	0	0	2,397	0.08	0.08
2024	0%	0	0	0%	0	0	2,777	0.08	0.10
2025	0%	0	0	0%	0	0	3,202	0.08	0.10
2026	0%	0	0	20%	100,066	7,425,018	3,474	0.08	0.11
2027	0%	0	0	28%	153,809	11,907,473	3,892	0.09	0.12
2028	0%	0	0	36%	213,735	17,252,133	4,270	0.10	0.13
2029	0%	0	0	43%	282,685	23,774,908	4,668	0.10	0.14
2030	0%	0	0	52%	361,281	31,639,931	4,976	0.10	0.14
2031	0%	0	0	60%	443,977	40,464,086	5,335	0.11	0.14
2032	0%	0	0	66%	512,639	48,598,179	5,677	0.11	0.15
2033	0%	0	0	72%	588,656	58,032,030	6,052	0.11	0.15
2034	0%	0	0	78%	661,545	67,794,501	6,352	0.12	0.15
2035	0%	0	0	84%	742,681	79,050,161	6,688	0.12	0.15
2036	0%	0	0	84%	764,974	84,525,424	7,151	0.12	0.15
2037	0%	0	0	84%	783,440	89,789,302	7,596	0.12	0.16
2038	0%	0	0	84%	805,975	95,630,079	8,090	0.12	0.16
2039	0%	0	0	84%	817,118	100,006,428	8,461	0.12	0.15
2040	0%	0	0	84%	739,955	93,122,741	7,878	0.11	0.13

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-17) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-19. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

Table A-66. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 2c in Calendar Year 2045

	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fuel Consumption[3] (MJ of electricity/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of electricity/day)
2001	100%	17,581	492,838	0%	0	0	0	0%	1	13
2002	100%	17,396	519,815	0%	0	0	0	0%	7	79
2003	100%	18,261	584,063	0%	0	0	0	0%	1	12
2004	100%	17,485	620,429	0%	0	0	0	0%	1	8
2005	100%	19,931	744,101	0%	0	0	0	0%	1	11
2006	100%	20,294	810,536	0%	0	0	0	0%	1	13
2007	100%	21,610	895,705	0%	0	0	0	0%	2	26
2008	100%	17,913	797,202	0%	0	0	0	0%	8	112
2009	100%	14,142	635,358	0%	0	0	0	0%	2	35
2010	100%	16,923	735,246	0%	1	3	15	0%	9	147
2011	99%	16,799	809,857	0%	30	158	790	1%	101	1,691
2012	98%	25,037	1,225,371	1%	300	1,692	8,301	1%	133	2,322
2013	97%	31,446	1,584,333	2%	594	3,560	17,255	1%	442	8,105
2014	96%	32,442	1,745,658	3%	890	5,695	27,363	1%	489	9,437
2015	97%	41,547	2,333,580	2%	708	4,833	22,999	2%	777	15,810
2016	95%	46,072	2,687,564	2%	841	6,105	28,783	3%	1,354	28,787
2017	91%	52,700	3,274,039	4%	2,391	18,339	86,121	5%	2,789	62,457
2018	87%	52,549	3,444,774	4%	2,479	20,175	94,087	9%	5,607	132,466
2019	88%	52,919	3,622,227	3%	2,063	18,391	80,115	8%	4,832	120,601
2020	86%	51,080	3,577,777	4%	2,469	23,635	98,982	9%	5,552	146,669
2021	85%	72,808	5,249,034	4%	3,832	39,919	157,067	10%	8,696	241,288
2022	84%	101,322	7,527,271	5%	5,592	67,570	218,488	11%	13,037	379,660
2023	84%	122,476	9,364,450	5%	6,792	88,932	269,022	11%	16,572	506,226
2024	83%	148,333	11,660,897	5%	8,175	115,750	327,717	12%	21,161	677,755
2025	83%	179,162	14,468,745	5%	9,889	151,350	399,826	12%	26,443	887,822
2026	65%	167,925	13,913,800	4%	10,710	171,981	451,908	11%	27,875	979,732
2027	57%	173,839	15,087,722	4%	12,598	212,114	555,489	11%	33,642	1,237,162
2028	49%	174,181	15,820,703	4%	14,549	256,617	669,890	11%	40,244	1,547,489
2029	41%	166,713	15,834,899	4%	16,455	303,793	790,664	12%	46,994	1,888,561
2030	32%	147,252	14,612,516	4%	18,409	355,407	922,379	12%	54,961	2,306,853
2031	24%	123,062	12,750,639	4%	20,513	413,850	1,071,177	12%	61,243	2,683,184
2032	18%	102,163	11,044,387	4%	22,706	478,352	1,235,027	12%	67,790	3,098,236
2033	12%	73,974	8,338,115	4%	24,661	542,144	1,396,451	12%	73,628	3,508,235
2034	6%	40,081	4,707,395	4%	26,724	612,627	1,574,494	12%	79,786	3,960,912
2035	0%	0	0	4%	28,447	679,589	1,742,931	12%	84,931	4,390,345
2036	0%	0	0	4%	30,274	753,214	1,927,965	12%	90,386	4,862,426
2037	0%	0	0	4%	31,753	822,345	2,100,691	12%	94,802	5,304,019
2038	0%	0	0	4%	33,394	899,667	2,293,959	12%	99,700	5,797,554
2039	0%	0	0	4%	34,612	969,669	2,467,860	12%	103,338	6,242,847
2040	0%	0	0	4%	36,047	1,049,189	2,665,871	12%	107,620	6,749,460
2041	0%	0	0	4%	37,091	1,121,019	2,843,979	12%	110,738	7,205,621
2042	0%	0	0	4%	37,942	1,189,565	3,014,512	12%	113,278	7,641,631
2043	0%	0	0	4%	38,974	1,264,855	3,204,367	12%	116,360	8,126,069
2044	0%	0	0	4%	39,438	1,319,800	3,345,305	12%	117,745	8,487,539
2045	0%	0	0	4%	35,636	1,225,722	3,110,204	12%	106,395	7,896,358

Table A-66. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 2c in Calendar Year 2045

Model Year	Fuel Cell Electric Vehicle Fleet Mix[1] (%)	Fuel Cell Electric Vehicle Population[2] (vehicles)	Fuel Cell Electric Vehicle Fuel Consumption[3] (MJ of hydrogen/day)	Hybrid Electric Vehicle Fleet Mix[1] (%)	Hybrid Electric Vehicle Population[2] (vehicles)	Hybrid Electric Vehicle Fuel Consumption[3] (MJ of gasoline/day)	Tailpipe Emission Estimates[4] (tons/day) CO_2	CH_4	N_2O
2001	0%	0	0	0%	0	0	40	0.01	0.006
2002	0%	0	0	0%	0	0	43	0.01	0.006
2003	0%	0	0	0%	0	0	48	0.01	0.006
2004	0%	0	0	0%	0	0	51	0.005	0.002
2005	0%	0	0	0%	0	0	61	0.005	0.002
2006	0%	0	0	0%	0	0	66	0.005	0.002
2007	0%	0	0	0%	0	0	73	0.005	0.003
2008	0%	0	0	0%	0	0	65	0.005	0.003
2009	0%	0	0	0%	0	0	52	0.003	0.002
2010	0%	0	0	0%	0	0	60	0.004	0.003
2011	0%	0	0	0%	0	0	66	0.004	0.003
2012	0%	0	0	0%	0	0	101	0.006	0.004
2013	0%	0	0	0%	0	0	131	0.008	0.006
2014	0%	0	0	0%	0	0	145	0.009	0.006
2015	0%	0	0	0%	0	0	193	0.01	0.008
2016	0%	0	0	0%	0	0	222	0.01	0.009
2017	0%	0	0	0%	0	0	275	0.02	0.01
2018	0%	0	0	0%	0	0	290	0.02	0.01
2019	0%	0	0	0%	0	0	303	0.02	0.01
2020	0%	0	0	0%	0	0	301	0.01	0.01
2021	0%	0	0	0%	0	0	443	0.02	0.02
2022	0%	0	0	0%	0	0	634	0.03	0.03
2023	0%	0	0	0%	0	0	789	0.03	0.03
2024	0%	0	0	0%	0	0	982	0.03	0.04
2025	0%	0	0	0%	0	0	1,217	0.04	0.04
2026	0%	0	0	20%	51,836	3,046,449	1,426	0.04	0.05
2027	0%	0	0	28%	84,901	5,226,638	1,709	0.05	0.06
2028	0%	0	0	36%	126,498	8,149,650	2,017	0.05	0.07
2029	0%	0	0	43%	176,455	11,888,048	2,334	0.06	0.08
2030	0%	0	0	52%	239,541	16,860,685	2,652	0.07	0.09
2031	0%	0	0	60%	307,941	22,631,158	2,984	0.07	0.10
2032	0%	0	0	66%	374,915	28,748,236	3,359	0.08	0.10
2033	0%	0	0	72%	444,190	35,512,951	3,705	0.08	0.11
2034	0%	0	0	78%	521,423	43,437,595	4,071	0.09	0.12
2035	0%	0	0	84%	597,713	51,850,819	4,388	0.09	0.12
2036	0%	0	0	84%	636,105	57,427,010	4,860	0.10	0.13
2037	0%	0	0	84%	667,180	62,652,109	5,301	0.10	0.14
2038	0%	0	0	84%	701,654	68,520,696	5,798	0.11	0.15
2039	0%	0	0	84%	727,252	73,828,753	6,247	0.11	0.15
2040	0%	0	0	84%	757,391	79,860,798	6,757	0.12	0.15
2041	0%	0	0	84%	779,333	85,307,396	7,217	0.12	0.16
2042	0%	0	0	84%	797,208	90,513,974	7,657	0.12	0.16
2043	0%	0	0	84%	818,902	96,251,657	8,143	0.12	0.16
2044	0%	0	0	84%	828,649	100,452,456	8,498	0.12	0.15
2045	0%	0	0	84%	748,769	93,316,127	7,895	0.11	0.13

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-20) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-22. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

Table A-67. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 2c in Calendar Year 2050
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Model Year	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fuel Consumption[3] (MJ of electricity/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of electricity/day)
2006	100%	17,095	495,171	0%	0	0	0	0%	1	9
2007	100%	17,938	537,342	0%	0	0	0	0%	2	18
2008	100%	14,711	473,301	0%	0	0	0	0%	6	73
2009	100%	11,643	378,435	0%	0	0	0	0%	2	24
2010	100%	13,584	427,686	0%	0	2	9	0%	8	94
2011	99%	13,206	463,001	0%	24	89	472	1%	79	1,039
2012	98%	18,883	674,484	1%	226	915	4,745	1%	100	1,368
2013	97%	22,656	836,306	2%	428	1,850	9,427	1%	314	4,504
2014	96%	21,908	865,904	3%	601	2,783	14,018	1%	326	4,894
2015	97%	26,586	1,101,721	2%	453	2,250	11,180	2%	491	7,761
2016	95%	27,295	1,177,776	2%	498	2,640	12,955	3%	790	13,009
2017	91%	29,325	1,351,831	4%	1,329	7,482	36,484	5%	1,525	26,393
2018	87%	27,113	1,322,228	4%	1,278	7,675	37,071	9%	2,868	52,384
2019	89%	25,304	1,294,975	3%	986	6,516	29,339	8%	2,292	44,244
2020	86%	22,760	1,198,129	4%	1,100	7,856	33,925	9%	2,474	50,596
2021	85%	30,740	1,673,570	4%	1,618	12,642	51,178	10%	3,671	78,995
2022	84%	40,577	2,287,454	5%	2,239	20,404	67,892	11%	5,221	118,112
2023	84%	47,100	2,747,369	5%	2,612	25,936	80,590	11%	6,373	151,554
2024	83%	55,817	3,364,077	5%	3,076	33,204	96,428	12%	7,963	198,997
2025	83%	67,473	4,197,128	5%	3,724	43,672	118,177	12%	9,959	261,533
2026	65%	64,497	4,139,198	4%	4,114	50,877	136,660	11%	10,706	295,109
2027	57%	69,408	4,689,197	4%	5,030	65,571	175,255	11%	13,432	388,383
2028	49%	73,318	5,209,164	4%	6,124	84,058	223,637	11%	16,940	513,531
2029	41%	75,042	5,600,876	4%	7,407	106,921	283,234	12%	21,153	672,043
2030	32%	70,975	5,559,659	4%	8,873	134,574	355,060	12%	26,491	881,507
2031	24%	63,763	5,236,564	4%	10,628	169,173	444,687	12%	31,732	1,105,371
2032	18%	56,405	4,852,327	4%	12,536	209,209	548,060	12%	37,427	1,364,096
2033	12%	43,791	3,942,469	4%	14,599	255,208	666,413	12%	43,586	1,661,080
2034	6%	25,024	2,355,959	4%	16,685	305,290	794,782	12%	49,813	1,984,022
2035	0%	0	0	4%	18,865	360,976	937,068	12%	56,324	2,343,007
2036	0%	0	0	4%	21,003	419,968	1,087,267	12%	62,706	2,722,815
2037	0%	0	0	4%	23,227	484,984	1,252,421	12%	69,345	3,141,091
2038	0%	0	0	4%	25,203	549,142	1,414,757	12%	75,245	3,553,333
2039	0%	0	0	4%	27,285	619,964	1,593,644	12%	81,462	4,008,057
2040	0%	0	0	4%	29,016	687,067	1,762,410	12%	86,629	4,438,238
2041	0%	0	0	4%	30,849	760,761	1,947,591	12%	92,102	4,910,573
2042	0%	0	0	4%	32,326	829,839	2,120,143	12%	96,511	5,351,582
2043	0%	0	0	4%	33,964	907,037	2,313,062	12%	101,402	5,844,049
2044	0%	0	0	4%	35,170	976,725	2,486,125	12%	105,002	6,287,030
2045	0%	0	0	4%	36,591	1,055,810	2,682,995	12%	109,246	6,790,499
2046	0%	0	0	4%	37,615	1,127,036	2,859,529	12%	112,302	7,242,409
2047	0%	0	0	4%	38,433	1,194,575	3,027,460	12%	114,744	7,671,556
2048	0%	0	0	4%	39,420	1,268,267	3,213,196	12%	117,693	8,145,301
2049	0%	0	0	4%	39,817	1,320,843	3,348,041	12%	118,877	8,491,081
2050	0%	0	0	4%	35,902	1,223,884	3,105,533	12%	107,188	7,881,262

Table A-67. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 2c in Calendar Year 2050

	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
2006	0%	0	0	0%	0	0	41	0.004	0.002
2007	0%	0	0	0%	0	0	44	0.004	0.002
2008	0%	0	0	0%	0	0	39	0.003	0.002
2009	0%	0	0	0%	0	0	31	0.002	0.001
2010	0%	0	0	0%	0	0	35	0.003	0.002
2011	0%	0	0	0%	0	0	38	0.003	0.002
2012	0%	0	0	0%	0	0	56	0.004	0.003
2013	0%	0	0	0%	0	0	69	0.005	0.003
2014	0%	0	0	0%	0	0	72	0.005	0.003
2015	0%	0	0	0%	0	0	91	0.006	0.004
2016	0%	0	0	0%	0	0	97	0.007	0.005
2017	0%	0	0	0%	0	0	114	0.008	0.005
2018	0%	0	0	0%	0	0	111	0.007	0.005
2019	0%	0	0	0%	0	0	108	0.006	0.005
2020	0%	0	0	0%	0	0	101	0.006	0.004
2021	0%	0	0	0%	0	0	141	0.008	0.006
2022	0%	0	0	0%	0	0	193	0.009	0.009
2023	0%	0	0	0%	0	0	232	0.01	0.01
2024	0%	0	0	0%	0	0	283	0.01	0.01
2025	0%	0	0	0%	0	0	353	0.01	0.01
2026	0%	0	0	20%	19,909	906,284	424	0.01	0.02
2027	0%	0	0	28%	33,898	1,624,416	531	0.02	0.02
2028	0%	0	0	36%	53,247	2,683,374	664	0.02	0.03
2029	0%	0	0	43%	79,427	4,204,857	826	0.02	0.03
2030	0%	0	0	52%	115,458	6,415,025	1,009	0.03	0.04
2031	0%	0	0	60%	159,555	9,294,397	1,226	0.03	0.04
2032	0%	0	0	66%	206,994	12,630,474	1,476	0.04	0.05
2033	0%	0	0	72%	262,949	16,791,411	1,752	0.05	0.06
2034	0%	0	0	78%	325,544	21,739,666	2,038	0.05	0.07
2035	0%	0	0	84%	396,387	27,656,145	2,341	0.06	0.08
2036	0%	0	0	84%	441,302	32,148,214	2,721	0.07	0.09
2037	0%	0	0	84%	488,028	37,094,470	3,140	0.07	0.10
2038	0%	0	0	84%	529,547	41,967,649	3,552	0.08	0.11
2039	0%	0	0	84%	573,298	47,343,063	4,007	0.09	0.12
2040	0%	0	0	84%	609,667	52,428,177	4,437	0.09	0.13
2041	0%	0	0	84%	648,178	58,009,853	4,909	0.10	0.13
2042	0%	0	0	84%	679,210	63,231,075	5,350	0.11	0.14
2043	0%	0	0	84%	713,632	69,090,797	5,846	0.11	0.15
2044	0%	0	0	84%	738,970	74,375,479	6,293	0.12	0.15
2045	0%	0	0	84%	768,833	80,375,114	6,800	0.12	0.16
2046	0%	0	0	84%	790,339	85,776,520	7,257	0.12	0.16
2047	0%	0	0	84%	807,527	90,907,152	7,691	0.12	0.16
2048	0%	0	0	84%	828,277	96,523,942	8,166	0.13	0.16
2049	0%	0	0	84%	836,615	100,544,967	8,506	0.12	0.15
2050	0%	0	0	84%	754,352	93,188,539	7,884	0.11	0.13

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-23) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-25. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

Table A-68. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenarios 3a, 3a-1, 3a-2 and 3b in Calendar Year 2026

	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fuel Consumption[3] (MJ of electricity/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of electricity/day)
1982	100%	4,657	174,227	0%	0	0	0	0%	1	9
1983	100%	5,273	206,541	0%	0	0	0	0%	1	9
1984	100%	7,858	329,345	0%	0	0	0	0%	1	13
1985	100%	10,024	435,286	0%	0	0	0	0%	0	0
1986	100%	10,647	463,741	0%	0	0	0	0%	0	0
1987	100%	12,832	586,622	0%	0	0	0	0%	1	18
1988	100%	12,139	592,716	0%	0	0	0	0%	0	0
1989	100%	14,970	774,940	0%	0	0	0	0%	1	14
1990	100%	18,044	991,990	0%	0	0	0	0%	0	0
1991	100%	21,281	1,234,023	0%	0	0	0	0%	0	0
1992	100%	18,332	1,127,213	0%	0	0	0	0%	0	0
1993	100%	20,138	1,231,512	0%	0	0	0	0%	3	46
1994	100%	22,840	1,473,479	0%	0	0	0	0%	0	7
1995	100%	29,675	2,022,331	0%	0	0	0	0%	2	31
1996	100%	29,436	2,128,971	0%	0	0	0	0%	0	0
1997	100%	39,761	2,978,637	0%	0	0	0	0%	4	95
1998	100%	48,817	3,777,000	0%	0	0	0	0%	5	107
1999	100%	56,921	4,546,344	0%	0	0	0	0%	4	98
2000	100%	76,964	6,529,441	0%	0	0	0	0%	1	31
2001	100%	87,221	7,793,387	0%	0	0	0	0%	6	155
2002	100%	102,135	9,644,077	0%	0	0	0	0%	37	1,030
2003	100%	127,287	12,720,322	0%	0	0	0	0%	7	196
2004	100%	143,690	15,732,253	0%	0	0	0	0%	5	155
2005	100%	191,623	21,752,720	0%	0	0	0	0%	7	213
2006	100%	225,488	26,980,154	0%	0	0	0	0%	11	389
2007	100%	275,180	33,665,694	0%	0	0	0	0%	23	834
2008	100%	258,265	33,318,492	0%	0	0	0	0%	126	4,586
2009	100%	229,086	29,357,696	0%	0	0	0	0%	34	1,333
2010	100%	292,924	35,681,010	0%	11	154	687	0%	161	6,445
2011	99%	307,002	40,824,099	0%	548	8,280	37,013	1%	1,890	79,947
2012	98%	465,759	61,806,971	1%	5,585	88,399	392,722	1%	2,528	111,558
2013	97%	592,447	79,686,217	2%	11,199	185,018	819,056	1%	8,583	395,185
2014	96%	599,553	84,574,041	3%	16,462	284,537	1,256,341	1%	9,356	449,554
2015	96%	738,821	106,767,996	2%	12,602	227,577	1,002,629	2%	14,202	712,794
2016	95%	754,102	111,262,248	2%	13,790	259,774	1,141,452	3%	23,130	1,205,441
2017	91%	794,462	122,943,456	4%	36,125	706,874	3,105,093	5%	43,901	2,385,744
2018	86%	705,513	113,371,002	4%	33,412	680,299	2,980,537	10%	78,294	4,428,841
2019	88%	622,322	102,867,416	3%	24,317	533,860	2,191,127	8%	58,438	3,447,620
2020	86%	508,892	85,019,301	4%	24,600	571,597	2,264,467	9%	55,310	3,416,834
2021	85%	619,444	104,948,162	4%	32,604	811,289	3,029,262	10%	73,983	4,748,184
2022	84%	724,703	124,757,619	5%	39,994	1,137,171	3,486,691	11%	93,245	6,212,763
2023	84%	731,635	127,883,688	5%	40,571	1,231,754	3,543,090	11%	98,996	6,843,258
2024	83%	747,543	132,487,563	5%	41,200	1,332,140	3,598,733	12%	106,645	7,641,910
2025	83%	758,530	135,969,595	5%	41,866	1,438,799	3,640,575	12%	111,956	8,303,968
2026	85%	706,862	127,779,786	4%	34,449	1,220,027	3,088,034	11%	89,660	6,866,855

Table A-68. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenarios 3a, 3a-1, 3a-2 and 3b in Calendar Year 2026
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Model Year	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
1982	0%	0	0	0%	0	0	14	0.008	0.003
1983	0%	0	0	0%	0	0	17	0.009	0.003
1984	0%	0	0	0%	0	0	27	0.01	0.005
1985	0%	0	0	0%	0	0	36	0.02	0.006
1986	0%	0	0	0%	0	0	38	0.02	0.007
1987	0%	0	0	0%	0	0	48	0.02	0.009
1988	0%	0	0	0%	0	0	49	0.02	0.009
1989	0%	0	0	0%	0	0	63	0.03	0.01
1990	0%	0	0	0%	0	0	81	0.04	0.01
1991	0%	0	0	0%	0	0	101	0.05	0.02
1992	0%	0	0	0%	0	0	92	0.04	0.02
1993	0%	0	0	0%	0	0	101	0.05	0.02
1994	0%	0	0	0%	0	0	121	0.06	0.02
1995	0%	0	0	0%	0	0	166	0.08	0.03
1996	0%	0	0	0%	0	0	174	0.09	0.04
1997	0%	0	0	0%	0	0	244	0.11	0.05
1998	0%	0	0	0%	0	0	309	0.11	0.05
1999	0%	0	0	0%	0	0	372	0.09	0.06
2000	0%	0	0	0%	0	0	535	0.08	0.07
2001	0%	0	0	0%	0	0	638	0.09	0.07
2002	0%	0	0	0%	0	0	790	0.11	0.09
2003	0%	0	0	0%	0	0	1,041	0.13	0.11
2004	0%	0	0	0%	0	0	1,288	0.07	0.04
2005	0%	0	0	0%	0	0	1,781	0.08	0.05
2006	0%	0	0	0%	0	0	2,209	0.09	0.06
2007	0%	0	0	0%	0	0	2,756	0.11	0.08
2008	0%	0	0	0%	0	0	2,728	0.10	0.08
2009	0%	0	0	0%	0	0	2,404	0.09	0.07
2010	0%	0	0	0%	0	0	2,921	0.11	0.09
2011	0%	0	0	0%	0	0	3,345	0.12	0.10
2012	0%	0	0	0%	0	0	5,092	0.18	0.15
2013	0%	0	0	0%	0	0	6,591	0.22	0.19
2014	0%	0	0	0%	0	0	7,027	0.23	0.20
2015	0%	0	0	0%	0	0	8,823	0.28	0.24
2016	0%	0	0	0%	0	0	9,203	0.32	0.26
2017	0%	0	0	0%	0	0	10,320	0.32	0.27
2018	0%	0	0	0%	0	0	9,526	0.28	0.24
2019	0%	0	0	0%	0	0	8,601	0.23	0.21
2020	0%	0	0	0%	0	0	7,146	0.19	0.17
2021	0%	0	0	0%	0	0	8,840	0.21	0.21
2022	0%	0	0	0%	0	0	10,500	0.23	0.24
2023	0%	0	0	0%	0	0	10,760	0.21	0.23
2024	0%	0	0	0%	0	0	11,142	0.20	0.22
2025	0%	0	0	0%	0	0	11,430	0.16	0.20
2026	0%	0	0	0%	0	0	10,714	0.15	0.18

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-8) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-10. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

Table A-69. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenarios 3a, 3a-1, 3a-2 and 3b in Calendar Year 2030

	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fuel Consumption[3] (MJ of electricity/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of electricity/day)
1986	100%	9,277	319,606	0%	0	0	0	0%	0	0
1987	100%	11,036	395,358	0%	0	0	0	0%	1	13
1988	100%	10,287	394,106	0%	0	0	0	0%	0	0
1989	100%	12,682	513,141	0%	0	0	0	0%	1	10
1990	100%	15,335	660,988	0%	0	0	0	0%	0	0
1991	100%	17,755	806,207	0%	0	0	0	0%	0	0
1992	100%	14,968	722,403	0%	0	0	0	0%	0	0
1993	100%	15,722	757,504	0%	0	0	0	0%	2	30
1994	100%	16,938	862,749	0%	0	0	0	0%	0	4
1995	100%	21,266	1,147,175	0%	0	0	0	0%	1	18
1996	100%	20,041	1,148,835	0%	0	0	0	0%	0	0
1997	100%	25,571	1,519,989	0%	0	0	0	0%	3	55
1998	100%	29,544	1,816,366	0%	0	0	0	0%	3	55
1999	100%	32,392	2,061,329	0%	0	0	0	0%	2	47
2000	100%	41,346	2,802,701	0%	0	0	0	0%	1	14
2001	100%	44,766	3,209,806	0%	0	0	0	0%	3	65
2002	100%	49,911	3,795,455	0%	0	0	0	0%	18	424
2003	100%	59,781	4,832,777	0%	0	0	0	0%	3	76
2004	100%	65,751	5,844,031	0%	0	0	0	0%	2	59
2005	100%	86,903	8,039,211	0%	0	0	0	0%	3	81
2006	100%	103,055	10,092,547	0%	0	0	0	0%	5	144
2007	100%	128,610	12,929,139	0%	0	0	0	0%	11	328
2008	100%	125,543	13,361,675	0%	0	0	0	0%	60	1,794
2009	100%	116,809	12,395,606	0%	0	0	0	0%	18	572
2010	100%	158,274	16,020,574	0%	6	69	311	0%	86	2,863
2011	99%	175,648	19,479,572	0%	313	3,932	17,791	1%	1,076	37,957
2012	98%	282,481	31,367,919	1%	3,387	44,658	200,590	1%	1,526	56,296
2013	97%	378,095	42,683,040	2%	7,146	98,660	441,197	1%	5,433	209,483
2014	96%	402,992	47,862,257	3%	11,064	160,332	714,692	1%	6,227	251,167
2015	97%	518,113	63,218,662	2%	8,836	134,191	596,394	2%	9,879	417,410
2016	95%	553,278	69,108,331	2%	10,115	160,689	711,773	3%	16,817	738,736
2017	91%	604,853	79,402,357	4%	27,493	454,641	2,012,619	5%	33,194	1,524,212
2018	86%	555,971	75,960,952	4%	26,314	453,896	2,003,609	10%	61,332	2,941,765
2019	88%	505,059	71,135,364	3%	19,734	368,011	1,521,560	8%	47,387	2,378,873
2020	86%	424,894	60,588,792	4%	20,540	406,324	1,621,195	9%	46,181	2,435,627
2021	85%	528,088	76,514,975	4%	27,796	590,252	2,219,126	10%	63,072	3,464,139
2022	84%	629,123	92,802,888	5%	34,719	844,508	2,607,459	11%	80,947	4,626,137
2023	84%	652,013	97,885,688	5%	36,155	941,473	2,725,229	11%	88,223	5,242,684
2024	83%	670,253	102,369,934	5%	36,940	1,028,217	2,790,931	12%	95,619	5,905,793
2025	83%	697,118	108,259,056	5%	38,476	1,144,799	2,904,428	12%	102,891	6,603,088
2026	85%	735,995	116,097,140	4%	35,869	1,108,113	2,804,580	11%	93,356	6,216,252
2027	85%	753,379	123,273,035	4%	36,682	1,175,675	2,972,420	11%	97,957	6,763,472
2028	85%	774,987	131,327,881	4%	37,500	1,244,657	3,146,136	11%	103,726	7,417,910
2029	84%	786,767	137,631,182	4%	37,726	1,292,471	3,268,769	12%	107,741	7,961,945
2030	84%	712,577	128,326,917	4%	33,914	1,195,950	3,027,919	12%	101,252	7,716,317

Table A-69. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenarios 3a, 3a-1, 3a-2 and 3b in Calendar Year 2030

Model Year	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
1986	0%	0	0	0%	0	0	26	0.01	0.005
1987	0%	0	0	0%	0	0	32	0.02	0.006
1988	0%	0	0	0%	0	0	32	0.02	0.006
1989	0%	0	0	0%	0	0	42	0.02	0.008
1990	0%	0	0	0%	0	0	54	0.03	0.010
1991	0%	0	0	0%	0	0	66	0.03	0.01
1992	0%	0	0	0%	0	0	59	0.03	0.01
1993	0%	0	0	0%	0	0	62	0.03	0.01
1994	0%	0	0	0%	0	0	71	0.04	0.01
1995	0%	0	0	0%	0	0	94	0.05	0.02
1996	0%	0	0	0%	0	0	94	0.05	0.02
1997	0%	0	0	0%	0	0	124	0.06	0.02
1998	0%	0	0	0%	0	0	149	0.06	0.03
1999	0%	0	0	0%	0	0	169	0.05	0.03
2000	0%	0	0	0%	0	0	229	0.04	0.03
2001	0%	0	0	0%	0	0	263	0.04	0.03
2002	0%	0	0	0%	0	0	311	0.05	0.04
2003	0%	0	0	0%	0	0	396	0.05	0.04
2004	0%	0	0	0%	0	0	478	0.03	0.01
2005	0%	0	0	0%	0	0	658	0.03	0.02
2006	0%	0	0	0%	0	0	826	0.04	0.02
2007	0%	0	0	0%	0	0	1,059	0.05	0.03
2008	0%	0	0	0%	0	0	1,094	0.05	0.03
2009	0%	0	0	0%	0	0	1,015	0.04	0.03
2010	0%	0	0	0%	0	0	1,312	0.06	0.04
2011	0%	0	0	0%	0	0	1,596	0.06	0.05
2012	0%	0	0	0%	0	0	2,585	0.10	0.08
2013	0%	0	0	0%	0	0	3,531	0.13	0.11
2014	0%	0	0	0%	0	0	3,977	0.15	0.12
2015	0%	0	0	0%	0	0	5,225	0.19	0.16
2016	0%	0	0	0%	0	0	5,716	0.22	0.18
2017	0%	0	0	0%	0	0	6,666	0.24	0.20
2018	0%	0	0	0%	0	0	6,383	0.22	0.18
2019	0%	0	0	0%	0	0	5,949	0.19	0.17
2020	0%	0	0	0%	0	0	5,093	0.15	0.14
2021	0%	0	0	0%	0	0	6,446	0.18	0.18
2022	0%	0	0	0%	0	0	7,811	0.20	0.21
2023	0%	0	0	0%	0	0	8,237	0.19	0.21
2024	0%	0	0	0%	0	0	8,610	0.18	0.21
2025	0%	0	0	0%	0	0	9,101	0.16	0.20
2026	0%	0	0	0%	0	0	9,735	0.16	0.21
2027	0%	0	0	0%	0	0	10,336	0.16	0.21
2028	0%	0	0	0%	0	0	11,010	0.16	0.21
2029	0%	0	0	0%	0	0	11,536	0.16	0.21
2030	0%	0	0	0%	0	0	10,754	0.15	0.18

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-11) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-13. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

Table A-70. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenarios 3a, 3a-1, 3a-2 and 3b in Calendar Year 2035

	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fuel Consumption[3] (MJ of electricity/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of electricity/day)
1991	100%	14,887	496,519	0%	0	0	0	0%	0	0
1992	100%	12,386	437,879	0%	0	0	0	0%	0	0
1993	100%	12,876	454,610	0%	0	0	0	0%	2	20
1994	100%	13,908	519,028	0%	0	0	0	0%	0	3
1995	100%	17,011	673,579	0%	0	0	0	0%	1	11
1996	100%	15,726	662,566	0%	0	0	0	0%	0	0
1997	100%	19,249	841,793	0%	0	0	0	0%	3	36
1998	100%	21,231	962,917	0%	0	0	0	0%	2	32
1999	100%	21,841	1,026,080	0%	0	0	0	0%	2	27
2000	100%	26,428	1,326,406	0%	0	0	0	0%	0	7
2001	100%	26,524	1,412,096	0%	0	0	0	0%	2	30
2002	100%	27,790	1,574,561	0%	0	0	0	0%	11	189
2003	100%	30,887	1,866,413	0%	0	0	0	0%	2	31
2004	100%	31,459	2,100,346	0%	0	0	0	0%	1	22
2005	100%	38,743	2,705,815	0%	0	0	0	0%	1	29
2006	100%	43,503	3,231,279	0%	0	0	0	0%	2	47
2007	100%	51,445	3,941,697	0%	0	0	0	0%	4	103
2008	100%	48,196	3,931,397	0%	0	0	0	0%	23	522
2009	100%	43,832	3,583,029	0%	0	0	0	0%	7	170
2010	100%	59,373	4,651,159	0%	2	20	92	0%	32	847
2011	99%	67,186	5,797,667	0%	120	1,161	5,375	1%	409	11,360
2012	98%	112,410	9,761,699	1%	1,348	13,798	63,245	1%	603	17,549
2013	97%	158,581	14,066,520	2%	2,997	32,296	147,122	1%	2,255	68,707
2014	96%	180,829	16,955,018	3%	4,964	56,441	255,982	1%	2,764	88,302
2015	97%	248,911	24,094,495	2%	4,244	50,842	229,574	2%	4,701	157,841
2016	95%	285,862	28,441,636	2%	5,224	65,752	295,555	3%	8,578	300,098
2017	91%	332,615	34,903,768	4%	15,110	198,715	892,263	5%	18,042	661,811
2018	86%	327,985	35,952,376	4%	15,507	213,599	955,739	9%	35,779	1,376,403
2019	88%	314,542	35,673,840	3%	12,281	183,606	769,058	8%	29,273	1,183,116
2020	86%	281,575	32,424,569	4%	13,612	216,540	874,542	9%	30,604	1,303,564
2021	85%	366,087	42,975,928	4%	19,269	330,198	1,255,839	10%	43,723	1,945,314
2022	84%	459,912	55,139,274	5%	25,381	499,808	1,561,702	11%	59,175	2,747,832
2023	84%	491,823	60,167,945	5%	27,272	576,729	1,688,911	11%	66,548	3,223,016
2024	83%	528,134	65,889,598	5%	29,108	659,860	1,811,619	12%	75,344	3,803,598
2025	83%	560,849	71,323,875	5%	30,955	752,392	1,930,200	12%	82,779	4,355,000
2026	85%	611,788	79,227,267	4%	29,815	754,625	1,930,143	11%	77,601	4,248,646
2027	85%	641,056	86,348,005	4%	31,213	822,291	2,099,102	11%	83,353	4,746,114
2028	85%	673,388	94,321,799	4%	32,584	892,959	2,275,365	11%	90,128	5,333,845
2029	84%	697,604	101,572,012	4%	33,451	953,218	2,424,492	12%	95,531	5,873,508
2030	84%	724,988	109,636,518	4%	34,505	1,021,517	2,594,022	12%	103,016	6,575,282
2031	84%	747,432	117,336,964	4%	35,573	1,093,525	2,772,634	12%	106,205	7,033,396
2032	84%	766,329	124,786,645	4%	36,472	1,163,085	2,945,735	12%	108,890	7,476,741
2033	84%	789,556	133,116,841	4%	37,578	1,240,654	3,141,258	12%	112,190	7,976,623
2034	84%	801,955	139,496,654	4%	38,168	1,299,952	3,293,065	12%	113,952	8,366,832
2035	84%	727,792	130,218,515	4%	34,638	1,213,298	3,076,767	12%	103,414	7,823,380

Table A-70. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenarios 3a, 3a-1, 3a-2 and 3b in Calendar Year 2035

Model Year	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
1991	0%	0	0	0%	0	0	41	0.02	0.008
1992	0%	0	0	0%	0	0	36	0.02	0.007
1993	0%	0	0	0%	0	0	37	0.02	0.007
1994	0%	0	0	0%	0	0	42	0.02	0.008
1995	0%	0	0	0%	0	0	55	0.03	0.01
1996	0%	0	0	0%	0	0	54	0.04	0.01
1997	0%	0	0	0%	0	0	69	0.04	0.01
1998	0%	0	0	0%	0	0	79	0.03	0.01
1999	0%	0	0	0%	0	0	84	0.03	0.01
2000	0%	0	0	0%	0	0	109	0.02	0.01
2001	0%	0	0	0%	0	0	116	0.02	0.01
2002	0%	0	0	0%	0	0	129	0.02	0.02
2003	0%	0	0	0%	0	0	153	0.02	0.02
2004	0%	0	0	0%	0	0	172	0.01	0.006
2005	0%	0	0	0%	0	0	222	0.01	0.007
2006	0%	0	0	0%	0	0	265	0.01	0.008
2007	0%	0	0	0%	0	0	323	0.02	0.01
2008	0%	0	0	0%	0	0	322	0.02	0.01
2009	0%	0	0	0%	0	0	293	0.01	0.010
2010	0%	0	0	0%	0	0	381	0.02	0.01
2011	0%	0	0	0%	0	0	475	0.02	0.02
2012	0%	0	0	0%	0	0	804	0.04	0.03
2013	0%	0	0	0%	0	0	1,164	0.05	0.04
2014	0%	0	0	0%	0	0	1,409	0.06	0.05
2015	0%	0	0	0%	0	0	1,991	0.08	0.07
2016	0%	0	0	0%	0	0	2,353	0.11	0.08
2017	0%	0	0	0%	0	0	2,931	0.12	0.10
2018	0%	0	0	0%	0	0	3,022	0.12	0.10
2019	0%	0	0	0%	0	0	2,984	0.11	0.10
2020	0%	0	0	0%	0	0	2,726	0.10	0.09
2021	0%	0	0	0%	0	0	3,621	0.12	0.12
2022	0%	0	0	0%	0	0	4,642	0.14	0.15
2023	0%	0	0	0%	0	0	5,064	0.14	0.16
2024	0%	0	0	0%	0	0	5,543	0.14	0.16
2025	0%	0	0	0%	0	0	5,997	0.13	0.17
2026	0%	0	0	0%	0	0	6,645	0.14	0.18
2027	0%	0	0	0%	0	0	7,241	0.14	0.19
2028	0%	0	0	0%	0	0	7,909	0.15	0.20
2029	0%	0	0	0%	0	0	8,514	0.15	0.20
2030	0%	0	0	0%	0	0	9,189	0.16	0.21
2031	0%	0	0	0%	0	0	9,834	0.16	0.21
2032	0%	0	0	0%	0	0	10,458	0.16	0.21
2033	0%	0	0	0%	0	0	11,156	0.17	0.21
2034	0%	0	0	0%	0	0	11,691	0.17	0.21
2035	0%	0	0	0%	0	0	10,913	0.15	0.18

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-14) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-16. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fuel Consumption[3] (MJ of electricity/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of electricity/day)
1996	100%	13,224	407,390	0%	0	0	0	0%	0	0
1997	100%	15,957	507,603	0%	0	0	0	0%	2	27
1998	100%	17,428	573,388	0%	0	0	0	0%	2	23
1999	100%	17,981	612,358	0%	0	0	0	0%	2	19
2000	100%	21,212	772,196	0%	0	0	0	0%	0	5
2001	100%	20,869	808,569	0%	0	0	0	0%	1	19
2002	100%	20,957	866,980	0%	0	0	0	0%	8	114
2003	100%	22,226	985,080	0%	0	0	0	0%	1	18
2004	100%	21,228	1,041,890	0%	0	0	0	0%	1	12
2005	100%	24,808	1,278,892	0%	0	0	0	0%	1	16
2006	100%	25,795	1,417,856	0%	0	0	0	0%	1	22
2007	100%	28,657	1,630,516	0%	0	0	0	0%	2	44
2008	100%	24,894	1,513,071	0%	0	0	0	0%	12	206
2009	100%	20,958	1,283,229	0%	0	0	0	0%	3	64
2010	100%	26,447	1,559,497	0%	1	7	31	0%	15	295
2011	99%	28,341	1,849,619	0%	51	367	1,752	1%	172	3,720
2012	98%	44,963	2,967,860	1%	539	4,153	19,596	1%	240	5,433
2013	97%	60,869	4,125,844	2%	1,150	9,385	43,891	1%	858	20,372
2014	96%	67,874	4,888,299	3%	1,863	16,131	74,982	1%	1,028	25,649
2015	97%	93,376	6,979,373	2%	1,592	14,608	67,463	2%	1,750	45,992
2016	95%	109,366	8,447,742	2%	1,998	19,377	88,913	3%	3,230	88,645
2017	91%	132,055	10,809,831	4%	5,994	61,088	279,650	5%	7,052	203,451
2018	87%	137,285	11,794,487	4%	6,483	69,602	317,087	9%	14,800	449,301
2019	88%	141,083	12,595,274	3%	5,505	64,430	274,520	8%	13,018	416,452
2020	86%	135,652	12,343,563	4%	6,558	82,023	336,557	9%	14,744	498,290
2021	85%	189,590	17,659,856	4%	9,979	135,046	521,355	10%	22,644	801,678
2022	84%	253,809	24,240,958	5%	14,007	218,733	693,952	11%	32,657	1,210,322
2023	84%	291,017	28,467,215	5%	16,137	271,680	807,271	11%	39,377	1,526,695
2024	83%	329,600	32,998,938	5%	18,166	329,087	916,198	12%	47,021	1,906,128
2025	83%	371,783	38,066,268	5%	20,520	399,967	1,039,937	12%	54,873	2,325,226
2026	85%	424,233	44,379,743	4%	20,675	421,047	1,090,413	11%	53,811	2,380,112
2027	85%	468,739	51,160,857	4%	22,823	485,341	1,253,824	11%	60,947	2,812,115
2028	85%	508,037	57,813,793	4%	24,583	545,508	1,406,015	11%	67,997	3,270,853
2029	84%	549,764	65,186,938	4%	26,362	610,009	1,568,829	12%	75,286	3,773,157
2030	84%	583,369	72,028,242	4%	27,764	669,514	1,718,317	12%	82,893	4,325,829
2031	84%	621,402	79,845,628	4%	29,575	742,704	1,902,479	12%	88,297	4,795,314
2032	84%	652,332	87,185,723	4%	31,047	811,564	2,074,749	12%	92,692	5,235,411
2033	84%	686,690	95,441,034	4%	32,682	888,696	2,267,776	12%	97,574	5,728,006
2034	84%	712,396	102,926,116	4%	33,905	958,694	2,441,908	12%	101,227	6,173,591
2035	84%	742,681	111,447,763	4%	35,347	1,038,360	2,640,531	12%	105,530	6,681,472
2036	84%	764,974	119,166,985	4%	36,408	1,110,551	2,819,782	12%	108,697	7,140,339
2037	84%	783,440	126,588,190	4%	37,287	1,179,840	2,992,407	12%	111,321	7,581,528
2038	84%	805,975	134,822,728	4%	38,359	1,256,478	3,185,885	12%	114,524	8,075,024
2039	84%	817,118	140,992,663	4%	38,889	1,313,727	3,332,835	12%	116,107	8,451,703
2040	84%	739,955	131,287,793	4%	35,217	1,222,994	3,106,042	12%	105,142	7,882,098

Table A-71. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenarios 3a, 3a-1, 3a-2 and 3b in Calendar Year 2040
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
1996	0%	0	0	0%	0	0	33	0.02	0.007
1997	0%	0	0	0%	0	0	42	0.03	0.009
1998	0%	0	0	0%	0	0	47	0.02	0.009
1999	0%	0	0	0%	0	0	50	0.02	0.008
2000	0%	0	0	0%	0	0	63	0.01	0.009
2001	0%	0	0	0%	0	0	66	0.01	0.009
2002	0%	0	0	0%	0	0	71	0.01	0.009
2003	0%	0	0	0%	0	0	81	0.01	0.010
2004	0%	0	0	0%	0	0	85	0.007	0.003
2005	0%	0	0	0%	0	0	105	0.008	0.004
2006	0%	0	0	0%	0	0	116	0.007	0.004
2007	0%	0	0	0%	0	0	133	0.008	0.005
2008	0%	0	0	0%	0	0	124	0.007	0.004
2009	0%	0	0	0%	0	0	105	0.006	0.004
2010	0%	0	0	0%	0	0	128	0.007	0.005
2011	0%	0	0	0%	0	0	152	0.008	0.006
2012	0%	0	0	0%	0	0	245	0.01	0.009
2013	0%	0	0	0%	0	0	341	0.02	0.01
2014	0%	0	0	0%	0	0	406	0.02	0.02
2015	0%	0	0	0%	0	0	577	0.03	0.02
2016	0%	0	0	0%	0	0	699	0.04	0.03
2017	0%	0	0	0%	0	0	908	0.04	0.03
2018	0%	0	0	0%	0	0	992	0.05	0.04
2019	0%	0	0	0%	0	0	1,054	0.05	0.04
2020	0%	0	0	0%	0	0	1,038	0.04	0.04
2021	0%	0	0	0%	0	0	1,489	0.06	0.05
2022	0%	0	0	0%	0	0	2,041	0.07	0.07
2023	0%	0	0	0%	0	0	2,397	0.08	0.08
2024	0%	0	0	0%	0	0	2,777	0.08	0.10
2025	0%	0	0	0%	0	0	3,202	0.08	0.10
2026	0%	0	0	0%	0	0	3,723	0.09	0.12
2027	0%	0	0	0%	0	0	4,291	0.10	0.13
2028	0%	0	0	0%	0	0	4,848	0.11	0.15
2029	0%	0	0	0%	0	0	5,465	0.12	0.16
2030	0%	0	0	0%	0	0	6,038	0.13	0.17
2031	0%	0	0	0%	0	0	6,693	0.14	0.18
2032	0%	0	0	0%	0	0	7,308	0.14	0.19
2033	0%	0	0	0%	0	0	8,000	0.15	0.20
2034	0%	0	0	0%	0	0	8,627	0.16	0.21
2035	0%	0	0	0%	0	0	9,341	0.16	0.21
2036	0%	0	0	0%	0	0	9,987	0.16	0.22
2037	0%	0	0	0%	0	0	10,609	0.17	0.22
2038	0%	0	0	0%	0	0	11,299	0.17	0.22
2039	0%	0	0	0%	0	0	11,816	0.17	0.21
2040	0%	0	0	0%	0	0	11,003	0.15	0.18

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-17) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-19. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

Table A-72. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenarios 3a, 3a-1, 3a-2 and 3b in Calendar Year 2045

	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fuel Consumption[3] (MJ of electricity/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of electricity/day)
2001	100%	17,581	492,838	0%	0	0	0	0%	1	13
2002	100%	17,396	519,815	0%	0	0	0	0%	7	79
2003	100%	18,261	584,063	0%	0	0	0	0%	1	12
2004	100%	17,485	620,429	0%	0	0	0	0%	1	8
2005	100%	19,931	744,101	0%	0	0	0	0%	1	11
2006	100%	20,294	810,536	0%	0	0	0	0%	1	13
2007	100%	21,610	895,705	0%	0	0	0	0%	2	26
2008	100%	17,913	797,202	0%	0	0	0	0%	8	112
2009	100%	14,142	635,358	0%	0	0	0	0%	2	35
2010	100%	16,923	735,246	0%	1	3	15	0%	9	147
2011	99%	16,799	809,857	0%	30	158	790	1%	101	1,691
2012	98%	25,037	1,225,371	1%	300	1,692	8,301	1%	133	2,322
2013	97%	31,446	1,584,333	2%	594	3,560	17,255	1%	442	8,105
2014	96%	32,442	1,745,658	3%	890	5,695	27,363	1%	489	9,437
2015	97%	41,547	2,333,580	2%	708	4,833	22,999	2%	777	15,810
2016	95%	46,072	2,687,564	2%	841	6,105	28,783	3%	1,354	28,787
2017	91%	52,700	3,274,039	4%	2,391	18,339	86,121	5%	2,789	62,457
2018	87%	52,549	3,444,774	4%	2,479	20,175	94,087	9%	5,607	132,466
2019	88%	52,919	3,622,227	3%	2,063	18,391	80,115	8%	4,832	120,601
2020	86%	51,080	3,577,777	4%	2,469	23,635	98,982	9%	5,552	146,669
2021	85%	72,808	5,249,034	4%	3,832	39,919	157,067	10%	8,696	241,288
2022	84%	101,322	7,527,271	5%	5,592	67,570	218,488	11%	13,037	379,660
2023	84%	122,476	9,364,450	5%	6,792	88,932	269,022	11%	16,572	506,226
2024	83%	148,333	11,660,897	5%	8,175	115,750	327,717	12%	21,161	677,755
2025	83%	179,162	14,468,745	5%	9,889	151,350	399,826	12%	26,443	887,822
2026	85%	219,761	18,208,793	4%	10,710	171,981	451,908	11%	27,875	979,732
2027	85%	258,741	22,456,424	4%	12,598	212,114	555,489	11%	33,642	1,237,162
2028	85%	300,679	27,310,373	4%	14,549	256,617	669,890	11%	40,244	1,547,489
2029	84%	343,168	32,595,097	4%	16,455	303,793	790,664	12%	46,994	1,888,561
2030	84%	386,794	38,383,317	4%	18,409	355,407	922,379	12%	54,961	2,306,853
2031	84%	431,003	44,656,861	4%	20,513	413,850	1,071,177	12%	61,243	2,683,184
2032	84%	477,078	51,574,684	4%	22,706	478,352	1,235,027	12%	67,790	3,098,236
2033	84%	518,165	58,405,552	4%	24,661	542,144	1,396,451	12%	73,628	3,508,235
2034	84%	561,504	65,947,281	4%	26,724	612,627	1,574,494	12%	79,786	3,960,912
2035	84%	597,713	73,101,152	4%	28,447	679,589	1,742,931	12%	84,931	4,390,345
2036	84%	636,105	80,962,667	4%	30,274	753,214	1,927,965	12%	90,386	4,862,426
2037	84%	667,180	88,329,199	4%	31,753	822,345	2,100,691	12%	94,802	5,304,019
2038	84%	701,654	96,602,944	4%	33,394	899,667	2,293,959	12%	99,700	5,797,554
2039	84%	727,252	104,086,433	4%	34,612	969,669	2,467,860	12%	103,338	6,242,847
2040	84%	757,391	112,590,629	4%	36,047	1,049,189	2,665,871	12%	107,620	6,749,460
2041	84%	779,333	120,269,438	4%	37,091	1,121,019	2,843,979	12%	110,738	7,205,621
2042	84%	797,208	127,609,859	4%	37,942	1,189,565	3,014,512	12%	113,278	7,641,631
2043	84%	818,902	135,699,051	4%	38,974	1,264,855	3,204,367	12%	116,360	8,126,069
2044	84%	828,649	141,621,489	4%	39,438	1,319,800	3,345,305	12%	117,745	8,487,539
2045	84%	748,769	131,560,435	4%	35,636	1,225,722	3,110,204	12%	106,395	7,896,358

	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
2001	0%	0	0	0%	0	0	40	0.01	0.006
2002	0%	0	0	0%	0	0	43	0.01	0.006
2003	0%	0	0	0%	0	0	48	0.01	0.006
2004	0%	0	0	0%	0	0	51	0.005	0.002
2005	0%	0	0	0%	0	0	61	0.005	0.002
2006	0%	0	0	0%	0	0	66	0.005	0.002
2007	0%	0	0	0%	0	0	73	0.005	0.003
2008	0%	0	0	0%	0	0	65	0.005	0.003
2009	0%	0	0	0%	0	0	52	0.003	0.002
2010	0%	0	0	0%	0	0	60	0.004	0.003
2011	0%	0	0	0%	0	0	66	0.004	0.003
2012	0%	0	0	0%	0	0	101	0.006	0.004
2013	0%	0	0	0%	0	0	131	0.008	0.006
2014	0%	0	0	0%	0	0	145	0.009	0.006
2015	0%	0	0	0%	0	0	193	0.01	0.008
2016	0%	0	0	0%	0	0	222	0.01	0.009
2017	0%	0	0	0%	0	0	275	0.02	0.01
2018	0%	0	0	0%	0	0	290	0.02	0.01
2019	0%	0	0	0%	0	0	303	0.02	0.01
2020	0%	0	0	0%	0	0	301	0.01	0.01
2021	0%	0	0	0%	0	0	443	0.02	0.02
2022	0%	0	0	0%	0	0	634	0.03	0.03
2023	0%	0	0	0%	0	0	789	0.03	0.03
2024	0%	0	0	0%	0	0	982	0.03	0.04
2025	0%	0	0	0%	0	0	1,217	0.04	0.04
2026	0%	0	0	0%	0	0	1,528	0.04	0.06
2027	0%	0	0	0%	0	0	1,884	0.05	0.07
2028	0%	0	0	0%	0	0	2,291	0.06	0.08
2029	0%	0	0	0%	0	0	2,733	0.07	0.09
2030	0%	0	0	0%	0	0	3,218	0.08	0.11
2031	0%	0	0	0%	0	0	3,744	0.09	0.12
2032	0%	0	0	0%	0	0	4,324	0.10	0.13
2033	0%	0	0	0%	0	0	4,896	0.11	0.15
2034	0%	0	0	0%	0	0	5,528	0.12	0.16
2035	0%	0	0	0%	0	0	6,128	0.13	0.17
2036	0%	0	0	0%	0	0	6,786	0.14	0.18
2037	0%	0	0	0%	0	0	7,404	0.15	0.19
2038	0%	0	0	0%	0	0	8,097	0.15	0.20
2039	0%	0	0	0%	0	0	8,724	0.16	0.21
2040	0%	0	0	0%	0	0	9,436	0.16	0.22
2041	0%	0	0	0%	0	0	10,080	0.17	0.22
2042	0%	0	0	0%	0	0	10,695	0.17	0.22
2043	0%	0	0	0%	0	0	11,372	0.17	0.22
2044	0%	0	0	0%	0	0	11,869	0.17	0.21
2045	0%	0	0	0%	0	0	11,026	0.15	0.18

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-20) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-22. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

Table A-73. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenarios 3a, 3a-1, 3a-2 and 3b in Calendar Year 2050
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fuel Consumption[3] (MJ of electricity/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of electricity/day)
2006	100%	17,095	495,171	0%	0	0	0	0%	1	9
2007	100%	17,938	537,342	0%	0	0	0	0%	2	18
2008	100%	14,711	473,301	0%	0	0	0	0%	6	73
2009	100%	11,643	378,435	0%	0	0	0	0%	2	24
2010	100%	13,584	427,686	0%	0	2	9	0%	8	94
2011	99%	13,206	463,001	0%	24	89	472	1%	79	1,039
2012	98%	18,883	674,484	1%	226	915	4,745	1%	100	1,368
2013	97%	22,656	836,306	2%	428	1,850	9,427	1%	314	4,504
2014	96%	21,908	865,904	3%	601	2,783	14,018	1%	326	4,894
2015	97%	26,586	1,101,721	2%	453	2,250	11,180	2%	491	7,761
2016	95%	27,295	1,177,776	2%	498	2,640	12,955	3%	790	13,009
2017	91%	29,325	1,351,831	4%	1,329	7,482	36,484	5%	1,525	26,393
2018	87%	27,113	1,322,228	4%	1,278	7,675	37,071	9%	2,868	52,384
2019	89%	25,304	1,294,975	3%	986	6,516	29,339	8%	2,292	44,244
2020	86%	22,760	1,198,129	4%	1,100	7,856	33,925	9%	2,474	50,596
2021	85%	30,740	1,673,570	4%	1,618	12,642	51,178	10%	3,671	78,995
2022	84%	40,577	2,287,454	5%	2,239	20,404	67,892	11%	5,221	118,112
2023	84%	47,100	2,747,369	5%	2,612	25,936	80,590	11%	6,373	151,554
2024	83%	55,817	3,364,077	5%	3,076	33,204	96,428	12%	7,963	198,997
2025	83%	67,473	4,197,128	5%	3,724	43,672	118,177	12%	9,959	261,533
2026	85%	84,407	5,416,910	4%	4,114	50,877	136,660	11%	10,706	295,109
2027	85%	103,307	6,979,357	4%	5,030	65,571	175,255	11%	13,432	388,383
2028	85%	126,564	8,992,281	4%	6,124	84,058	223,637	11%	16,940	513,531
2029	84%	154,469	11,529,035	4%	7,407	106,921	283,234	12%	21,153	672,043
2030	84%	186,433	14,603,793	4%	8,873	134,574	355,060	12%	26,491	881,507
2031	84%	223,318	18,340,139	4%	10,628	169,173	444,687	12%	31,732	1,105,371
2032	84%	263,400	22,659,223	4%	12,536	209,209	548,060	12%	37,427	1,364,096
2033	84%	306,740	27,615,605	4%	14,599	255,208	666,413	12%	43,586	1,661,080
2034	84%	350,568	33,005,323	4%	16,685	305,290	794,782	12%	49,813	1,984,022
2035	84%	396,387	38,990,628	4%	18,865	360,976	937,068	12%	56,324	2,343,007
2036	84%	441,302	45,323,709	4%	21,003	419,968	1,087,267	12%	62,706	2,722,815
2037	84%	488,028	52,297,119	4%	23,227	484,984	1,252,421	12%	69,345	3,141,091
2038	84%	529,547	59,167,502	4%	25,203	549,142	1,414,757	12%	75,245	3,553,333
2039	84%	573,298	66,745,954	4%	27,285	619,964	1,593,644	12%	81,462	4,008,057
2040	84%	609,667	73,915,132	4%	29,016	687,067	1,762,410	12%	86,629	4,438,238
2041	84%	648,178	81,784,379	4%	30,849	760,761	1,947,591	12%	92,102	4,910,573
2042	84%	679,210	89,145,447	4%	32,326	829,839	2,120,143	12%	96,511	5,351,582
2043	84%	713,632	97,406,694	4%	33,964	907,037	2,313,062	12%	101,402	5,844,049
2044	84%	738,970	104,857,227	4%	35,170	976,725	2,486,125	12%	105,002	6,287,030
2045	84%	768,833	113,315,730	4%	36,591	1,055,810	2,682,995	12%	109,246	6,790,499
2046	84%	790,339	120,930,825	4%	37,615	1,127,036	2,859,529	12%	112,302	7,242,409
2047	84%	807,527	128,164,176	4%	38,433	1,194,575	3,027,460	12%	114,744	7,671,556
2048	84%	828,277	136,082,929	4%	39,420	1,268,267	3,213,196	12%	117,693	8,145,301
2049	84%	836,615	141,751,914	4%	39,817	1,320,843	3,348,041	12%	118,877	8,491,081
2050	84%	754,352	131,380,558	4%	35,902	1,223,884	3,105,533	12%	107,188	7,881,262

Table A-73. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenarios 3a, 3a-1, 3a-2 and 3b in Calendar Year 2050

	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
2006	0%	0	0	0%	0	0	41	0.004	0.002
2007	0%	0	0	0%	0	0	44	0.004	0.002
2008	0%	0	0	0%	0	0	39	0.003	0.002
2009	0%	0	0	0%	0	0	31	0.002	0.001
2010	0%	0	0	0%	0	0	35	0.003	0.002
2011	0%	0	0	0%	0	0	38	0.003	0.002
2012	0%	0	0	0%	0	0	56	0.004	0.003
2013	0%	0	0	0%	0	0	69	0.005	0.003
2014	0%	0	0	0%	0	0	72	0.005	0.003
2015	0%	0	0	0%	0	0	91	0.006	0.004
2016	0%	0	0	0%	0	0	97	0.007	0.005
2017	0%	0	0	0%	0	0	114	0.008	0.005
2018	0%	0	0	0%	0	0	111	0.007	0.005
2019	0%	0	0	0%	0	0	108	0.006	0.005
2020	0%	0	0	0%	0	0	101	0.006	0.004
2021	0%	0	0	0%	0	0	141	0.008	0.006
2022	0%	0	0	0%	0	0	193	0.009	0.009
2023	0%	0	0	0%	0	0	232	0.01	0.01
2024	0%	0	0	0%	0	0	283	0.01	0.01
2025	0%	0	0	0%	0	0	353	0.01	0.01
2026	0%	0	0	0%	0	0	455	0.02	0.02
2027	0%	0	0	0%	0	0	586	0.02	0.02
2028	0%	0	0	0%	0	0	755	0.02	0.03
2029	0%	0	0	0%	0	0	967	0.03	0.04
2030	0%	0	0	0%	0	0	1,225	0.04	0.05
2031	0%	0	0	0%	0	0	1,538	0.04	0.06
2032	0%	0	0	0%	0	0	1,900	0.05	0.07
2033	0%	0	0	0%	0	0	2,316	0.06	0.08
2034	0%	0	0	0%	0	0	2,767	0.07	0.09
2035	0%	0	0	0%	0	0	3,269	0.08	0.11
2036	0%	0	0	0%	0	0	3,800	0.09	0.12
2037	0%	0	0	0%	0	0	4,384	0.10	0.14
2038	0%	0	0	0%	0	0	4,960	0.11	0.15
2039	0%	0	0	0%	0	0	5,595	0.12	0.16
2040	0%	0	0	0%	0	0	6,196	0.13	0.18
2041	0%	0	0	0%	0	0	6,855	0.14	0.19
2042	0%	0	0	0%	0	0	7,472	0.15	0.20
2043	0%	0	0	0%	0	0	8,164	0.15	0.21
2044	0%	0	0	0%	0	0	8,788	0.16	0.21
2045	0%	0	0	0%	0	0	9,497	0.17	0.22
2046	0%	0	0	0%	0	0	10,135	0.17	0.22
2047	0%	0	0	0%	0	0	10,741	0.17	0.22
2048	0%	0	0	0%	0	0	11,405	0.17	0.22
2049	0%	0	0	0%	0	0	11,880	0.17	0.21
2050	0%	0	0	0%	0	0	11,011	0.15	0.18

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-23) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-25. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

Table A-74. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 4a in Calendar Year 2026
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fuel Consumption[3] (MJ of electricity/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of electricity/day)
1982	100%	4,657	174,227	0%	0	0	0	0%	1	9
1983	100%	5,273	206,541	0%	0	0	0	0%	1	9
1984	100%	7,858	329,345	0%	0	0	0	0%	1	13
1985	100%	10,024	435,286	0%	0	0	0	0%	0	0
1986	100%	10,647	463,741	0%	0	0	0	0%	0	0
1987	100%	12,832	586,622	0%	0	0	0	0%	1	18
1988	100%	12,139	592,716	0%	0	0	0	0%	0	0
1989	100%	14,970	774,940	0%	0	0	0	0%	1	14
1990	100%	18,044	991,990	0%	0	0	0	0%	0	0
1991	100%	21,281	1,234,023	0%	0	0	0	0%	0	0
1992	100%	18,332	1,127,213	0%	0	0	0	0%	0	0
1993	100%	20,138	1,231,512	0%	0	0	0	0%	3	46
1994	100%	22,840	1,473,479	0%	0	0	0	0%	0	7
1995	100%	29,675	2,022,331	0%	0	0	0	0%	2	31
1996	100%	29,436	2,128,971	0%	0	0	0	0%	0	0
1997	100%	39,761	2,978,637	0%	0	0	0	0%	4	95
1998	100%	48,817	3,777,000	0%	0	0	0	0%	5	107
1999	100%	56,921	4,546,344	0%	0	0	0	0%	4	98
2000	100%	76,964	6,529,441	0%	0	0	0	0%	1	31
2001	100%	87,221	7,793,387	0%	0	0	0	0%	6	155
2002	100%	102,135	9,644,077	0%	0	0	0	0%	37	1,030
2003	100%	127,287	12,720,322	0%	0	0	0	0%	7	196
2004	100%	143,690	15,732,253	0%	0	0	0	0%	5	155
2005	100%	191,623	21,752,720	0%	0	0	0	0%	7	213
2006	100%	225,488	26,980,154	0%	0	0	0	0%	11	389
2007	100%	275,180	33,665,694	0%	0	0	0	0%	23	834
2008	100%	258,265	33,318,492	0%	0	0	0	0%	126	4,586
2009	100%	229,086	29,357,696	0%	0	0	0	0%	34	1,333
2010	100%	292,924	35,681,010	0%	11	154	687	0%	161	6,445
2011	99%	307,002	40,824,099	0%	548	8,280	37,013	1%	1,890	79,947
2012	98%	465,759	61,806,971	1%	5,585	88,399	392,722	1%	2,528	111,558
2013	97%	592,447	79,686,217	2%	11,199	185,018	819,056	1%	8,583	395,185
2014	96%	599,553	84,574,041	3%	16,462	284,537	1,256,341	1%	9,356	449,554
2015	96%	738,821	106,767,996	2%	12,602	227,577	1,002,629	2%	14,202	712,794
2016	95%	754,102	111,262,248	2%	13,790	259,774	1,141,452	3%	23,130	1,205,441
2017	91%	794,462	122,943,456	4%	36,125	706,874	3,105,093	5%	43,901	2,385,744
2018	86%	705,513	113,371,002	4%	33,412	680,299	2,980,537	10%	78,294	4,428,841
2019	88%	622,322	102,867,416	3%	24,317	533,860	2,191,127	8%	58,438	3,447,620
2020	86%	508,892	85,019,301	4%	24,600	571,597	2,264,467	9%	55,310	3,416,834
2021	85%	619,444	104,948,162	4%	32,604	811,289	3,029,262	10%	73,983	4,748,184
2022	84%	724,703	124,757,619	5%	39,994	1,137,171	3,486,691	11%	93,245	6,212,763
2023	84%	731,635	127,883,688	5%	40,571	1,231,754	3,543,090	11%	98,996	6,843,258
2024	83%	747,543	132,487,563	5%	41,200	1,332,140	3,598,733	12%	106,645	7,641,910
2025	83%	758,530	135,969,595	5%	41,866	1,438,799	3,640,575	12%	111,956	8,303,968
2026	73%	606,608	109,656,971	5%	42,758	1,514,177	3,832,564	11%	89,660	6,866,855

Table A-74. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 4a in Calendar Year 2026

Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
1982	0%	0	0	0%	0	0	14	0.008	0.003
1983	0%	0	0	0%	0	0	17	0.009	0.003
1984	0%	0	0	0%	0	0	27	0.01	0.005
1985	0%	0	0	0%	0	0	36	0.02	0.006
1986	0%	0	0	0%	0	0	38	0.02	0.007
1987	0%	0	0	0%	0	0	48	0.02	0.009
1988	0%	0	0	0%	0	0	49	0.02	0.009
1989	0%	0	0	0%	0	0	63	0.03	0.01
1990	0%	0	0	0%	0	0	81	0.04	0.01
1991	0%	0	0	0%	0	0	101	0.05	0.02
1992	0%	0	0	0%	0	0	92	0.04	0.02
1993	0%	0	0	0%	0	0	101	0.05	0.02
1994	0%	0	0	0%	0	0	121	0.06	0.02
1995	0%	0	0	0%	0	0	166	0.08	0.03
1996	0%	0	0	0%	0	0	174	0.09	0.04
1997	0%	0	0	0%	0	0	244	0.11	0.05
1998	0%	0	0	0%	0	0	309	0.11	0.05
1999	0%	0	0	0%	0	0	372	0.09	0.06
2000	0%	0	0	0%	0	0	535	0.08	0.07
2001	0%	0	0	0%	0	0	638	0.09	0.07
2002	0%	0	0	0%	0	0	790	0.11	0.09
2003	0%	0	0	0%	0	0	1,041	0.13	0.11
2004	0%	0	0	0%	0	0	1,288	0.07	0.04
2005	0%	0	0	0%	0	0	1,781	0.08	0.05
2006	0%	0	0	0%	0	0	2,209	0.09	0.06
2007	0%	0	0	0%	0	0	2,756	0.11	0.08
2008	0%	0	0	0%	0	0	2,728	0.10	0.08
2009	0%	0	0	0%	0	0	2,404	0.09	0.07
2010	0%	0	0	0%	0	0	2,921	0.11	0.09
2011	0%	0	0	0%	0	0	3,345	0.12	0.10
2012	0%	0	0	0%	0	0	5,092	0.18	0.15
2013	0%	0	0	0%	0	0	6,591	0.22	0.19
2014	0%	0	0	0%	0	0	7,027	0.23	0.20
2015	0%	0	0	0%	0	0	8,823	0.28	0.24
2016	0%	0	0	0%	0	0	9,203	0.32	0.26
2017	0%	0	0	0%	0	0	10,320	0.32	0.27
2018	0%	0	0	0%	0	0	9,526	0.28	0.24
2019	0%	0	0	0%	0	0	8,601	0.23	0.21
2020	0%	0	0	0%	0	0	7,146	0.19	0.17
2021	0%	0	0	0%	0	0	8,840	0.21	0.21
2022	0%	0	0	0%	0	0	10,500	0.23	0.24
2023	0%	0	0	0%	0	0	10,760	0.21	0.23
2024	0%	0	0	0%	0	0	11,142	0.20	0.22
2025	0%	0	0	0%	0	0	11,430	0.16	0.20
2026	0%	0	0	11%	91,943	11,789,077	10,257	0.14	0.17

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-8) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-10. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle

CH_4 - methane

CO_2 - carbon dioxide

EMFAC - EMission FACtor Model

ICEV - internal combustion engine vehicle

MJ - megajoule

N_2O - nitrous oxide

PHEV - plug-in hybrid electric vehicle

Table A-75. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 4a in Calendar Year 2030

	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fuel Consumption[3] (MJ of electricity/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of electricity/day)
1986	100%	9,277	319,606	0%	0	0	0	0%	0	0
1987	100%	11,036	395,358	0%	0	0	0	0%	1	13
1988	100%	10,287	394,106	0%	0	0	0	0%	0	0
1989	100%	12,682	513,141	0%	0	0	0	0%	1	10
1990	100%	15,335	660,988	0%	0	0	0	0%	0	0
1991	100%	17,755	806,207	0%	0	0	0	0%	0	0
1992	100%	14,968	722,403	0%	0	0	0	0%	0	0
1993	100%	15,722	757,504	0%	0	0	0	0%	2	30
1994	100%	16,938	862,749	0%	0	0	0	0%	0	4
1995	100%	21,266	1,147,175	0%	0	0	0	0%	1	18
1996	100%	20,041	1,148,835	0%	0	0	0	0%	0	0
1997	100%	25,571	1,519,989	0%	0	0	0	0%	3	55
1998	100%	29,544	1,816,366	0%	0	0	0	0%	3	55
1999	100%	32,392	2,061,329	0%	0	0	0	0%	2	47
2000	100%	41,346	2,802,701	0%	0	0	0	0%	1	14
2001	100%	44,766	3,209,806	0%	0	0	0	0%	3	65
2002	100%	49,911	3,795,455	0%	0	0	0	0%	18	424
2003	100%	59,781	4,832,777	0%	0	0	0	0%	3	76
2004	100%	65,751	5,844,031	0%	0	0	0	0%	2	59
2005	100%	86,903	8,039,211	0%	0	0	0	0%	3	81
2006	100%	103,055	10,092,547	0%	0	0	0	0%	5	144
2007	100%	128,610	12,929,139	0%	0	0	0	0%	11	328
2008	100%	125,543	13,361,675	0%	0	0	0	0%	60	1,794
2009	100%	116,809	12,395,606	0%	0	0	0	0%	18	572
2010	100%	158,274	16,020,574	0%	6	69	311	0%	86	2,863
2011	99%	175,648	19,479,572	0%	313	3,932	17,791	1%	1,076	37,957
2012	98%	282,481	31,367,919	1%	3,387	44,658	200,590	1%	1,526	56,296
2013	97%	378,095	42,683,040	2%	7,146	98,660	441,197	1%	5,433	209,483
2014	96%	402,992	47,862,257	3%	11,064	160,332	714,692	1%	6,227	251,167
2015	97%	518,113	63,218,662	2%	8,836	134,191	596,394	2%	9,879	417,410
2016	95%	553,278	69,108,331	2%	10,115	160,689	711,773	3%	16,817	738,736
2017	91%	604,853	79,402,357	4%	27,493	454,641	2,012,619	5%	33,194	1,524,212
2018	86%	555,971	75,960,952	4%	26,314	453,896	2,003,609	10%	61,332	2,941,765
2019	88%	505,059	71,135,364	3%	19,734	368,011	1,521,560	8%	47,387	2,378,873
2020	86%	424,894	60,588,792	4%	20,540	406,324	1,621,195	9%	46,181	2,435,627
2021	85%	528,088	76,514,975	4%	27,796	590,252	2,219,126	10%	63,072	3,464,139
2022	84%	629,123	92,802,888	5%	34,719	844,508	2,607,459	11%	80,947	4,626,137
2023	84%	652,013	97,885,688	5%	36,155	941,473	2,725,229	11%	88,223	5,242,684
2024	83%	670,253	102,369,934	5%	36,940	1,028,217	2,790,931	12%	95,619	5,905,793
2025	83%	697,118	108,259,056	5%	38,476	1,144,799	2,904,428	12%	102,891	6,603,088
2026	73%	631,610	99,631,257	5%	44,521	1,375,394	3,481,055	11%	93,356	6,216,252
2027	64%	568,332	92,994,289	6%	54,442	1,744,909	4,411,596	11%	97,957	6,763,472
2028	54%	494,755	83,840,288	7%	64,986	2,156,932	5,452,106	11%	103,726	7,417,910
2029	45%	419,506	73,385,206	8%	75,016	2,569,747	6,499,106	12%	107,741	7,961,945
2030	33%	279,755	50,380,703	9%	76,301	2,690,028	6,810,644	13%	109,730	8,360,042

Model Year	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
1986	0%	0	0	0%	0	0	26	0.01	0.005
1987	0%	0	0	0%	0	0	32	0.02	0.006
1988	0%	0	0	0%	0	0	32	0.02	0.006
1989	0%	0	0	0%	0	0	42	0.02	0.008
1990	0%	0	0	0%	0	0	54	0.03	0.010
1991	0%	0	0	0%	0	0	66	0.03	0.01
1992	0%	0	0	0%	0	0	59	0.03	0.01
1993	0%	0	0	0%	0	0	62	0.03	0.01
1994	0%	0	0	0%	0	0	71	0.04	0.01
1995	0%	0	0	0%	0	0	94	0.05	0.02
1996	0%	0	0	0%	0	0	94	0.05	0.02
1997	0%	0	0	0%	0	0	124	0.06	0.02
1998	0%	0	0	0%	0	0	149	0.06	0.03
1999	0%	0	0	0%	0	0	169	0.05	0.03
2000	0%	0	0	0%	0	0	229	0.04	0.03
2001	0%	0	0	0%	0	0	263	0.04	0.03
2002	0%	0	0	0%	0	0	311	0.05	0.04
2003	0%	0	0	0%	0	0	396	0.05	0.04
2004	0%	0	0	0%	0	0	478	0.03	0.01
2005	0%	0	0	0%	0	0	658	0.03	0.02
2006	0%	0	0	0%	0	0	826	0.04	0.02
2007	0%	0	0	0%	0	0	1,059	0.05	0.03
2008	0%	0	0	0%	0	0	1,094	0.05	0.03
2009	0%	0	0	0%	0	0	1,015	0.04	0.03
2010	0%	0	0	0%	0	0	1,312	0.06	0.04
2011	0%	0	0	0%	0	0	1,596	0.06	0.05
2012	0%	0	0	0%	0	0	2,585	0.10	0.08
2013	0%	0	0	0%	0	0	3,531	0.13	0.11
2014	0%	0	0	0%	0	0	3,977	0.15	0.12
2015	0%	0	0	0%	0	0	5,225	0.19	0.16
2016	0%	0	0	0%	0	0	5,716	0.22	0.18
2017	0%	0	0	0%	0	0	6,666	0.24	0.20
2018	0%	0	0	0%	0	0	6,383	0.22	0.18
2019	0%	0	0	0%	0	0	5,949	0.19	0.17
2020	0%	0	0	0%	0	0	5,093	0.15	0.14
2021	0%	0	0	0%	0	0	6,446	0.18	0.18
2022	0%	0	0	0%	0	0	7,811	0.20	0.21
2023	0%	0	0	0%	0	0	8,237	0.19	0.21
2024	0%	0	0	0%	0	0	8,610	0.18	0.21
2025	0%	0	0	0%	0	0	9,101	0.16	0.20
2026	0%	0	0	11%	95,733	10,711,226	9,319	0.16	0.20
2027	0%	0	0	19%	167,287	19,415,503	9,564	0.15	0.19
2028	0%	0	0	28%	252,746	30,379,278	9,798	0.15	0.19
2029	0%	0	0	35%	329,972	40,942,951	9,892	0.15	0.18
2030	0%	0	0	45%	381,957	48,790,134	8,677	0.12	0.14

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-11) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-13. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

Table A-76. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 4a in Calendar Year 2035
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Model Year	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fuel Consumption[3] (MJ of electricity/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of electricity/day)
1991	100%	14,887	496,519	0%	0	0	0	0%	0	0
1992	100%	12,386	437,879	0%	0	0	0	0%	0	0
1993	100%	12,876	454,610	0%	0	0	0	0%	2	20
1994	100%	13,908	519,028	0%	0	0	0	0%	0	3
1995	100%	17,011	673,579	0%	0	0	0	0%	1	11
1996	100%	15,726	662,566	0%	0	0	0	0%	0	0
1997	100%	19,249	841,793	0%	0	0	0	0%	3	36
1998	100%	21,231	962,917	0%	0	0	0	0%	2	32
1999	100%	21,841	1,026,080	0%	0	0	0	0%	2	27
2000	100%	26,428	1,326,406	0%	0	0	0	0%	0	7
2001	100%	26,524	1,412,096	0%	0	0	0	0%	2	30
2002	100%	27,790	1,574,561	0%	0	0	0	0%	11	189
2003	100%	30,887	1,866,413	0%	0	0	0	0%	2	31
2004	100%	31,459	2,100,346	0%	0	0	0	0%	1	22
2005	100%	38,743	2,705,815	0%	0	0	0	0%	1	29
2006	100%	43,503	3,231,279	0%	0	0	0	0%	2	47
2007	100%	51,445	3,941,697	0%	0	0	0	0%	4	103
2008	100%	48,196	3,931,397	0%	0	0	0	0%	23	522
2009	100%	43,832	3,583,029	0%	0	0	0	0%	7	170
2010	100%	59,373	4,651,159	0%	2	20	92	0%	32	847
2011	99%	67,186	5,797,667	0%	120	1,161	5,375	1%	409	11,360
2012	98%	112,410	9,761,699	1%	1,348	13,798	63,245	1%	603	17,549
2013	97%	158,581	14,066,520	2%	2,997	32,296	147,122	1%	2,255	68,707
2014	96%	180,829	16,955,018	3%	4,964	56,441	255,982	1%	2,764	88,302
2015	97%	248,911	24,094,495	2%	4,244	50,842	229,574	2%	4,701	157,841
2016	95%	285,862	28,441,636	2%	5,224	65,752	295,555	3%	8,578	300,098
2017	91%	332,615	34,903,768	4%	15,110	198,715	892,263	5%	18,042	661,811
2018	86%	327,985	35,952,376	4%	15,507	213,599	955,739	9%	35,779	1,376,403
2019	88%	314,542	35,673,840	3%	12,281	183,606	769,058	8%	29,273	1,183,116
2020	86%	281,575	32,424,569	4%	13,612	216,540	874,542	9%	30,604	1,303,564
2021	85%	366,087	42,975,928	4%	19,269	330,198	1,255,839	10%	43,723	1,945,314
2022	84%	459,912	55,139,274	5%	25,381	499,808	1,561,702	11%	59,175	2,747,832
2023	84%	491,823	60,167,945	5%	27,272	576,729	1,688,911	11%	66,548	3,223,016
2024	83%	528,134	65,889,598	5%	29,108	659,860	1,811,619	12%	75,344	3,803,598
2025	83%	560,849	71,323,875	5%	30,955	752,392	1,930,200	12%	82,779	4,355,000
2026	73%	525,019	67,990,583	5%	37,007	936,560	2,395,486	11%	77,601	4,248,646
2027	64%	483,597	65,138,911	6%	46,325	1,220,255	3,115,002	11%	83,353	4,746,114
2028	54%	429,894	60,215,445	7%	56,467	1,547,259	3,942,598	11%	90,128	5,333,845
2029	45%	371,964	54,158,389	8%	66,514	1,895,198	4,820,398	12%	95,531	5,873,508
2030	33%	284,628	43,042,917	9%	77,630	2,298,109	5,835,781	13%	111,641	7,125,303
2031	16%	142,274	22,335,072	10%	88,925	2,733,603	6,931,051	14%	123,989	8,211,111
2032	8%	72,935	11,876,559	11%	100,291	3,198,380	8,100,506	15%	136,241	9,355,831
2033	0%	0	0	12%	112,724	3,721,781	9,423,313	16%	149,763	10,649,111
2034	0%	0	0	13%	124,035	4,224,185	10,700,790	17%	161,656	11,866,577
2035	0%	0	0	14%	121,222	4,245,070	10,764,948	18%	155,365	11,742,105

Table A-76. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 4a in Calendar Year 2035

Model Year	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
1991	0%	0	0	0%	0	0	41	0.02	0.008
1992	0%	0	0	0%	0	0	36	0.02	0.007
1993	0%	0	0	0%	0	0	37	0.02	0.007
1994	0%	0	0	0%	0	0	42	0.02	0.008
1995	0%	0	0	0%	0	0	55	0.03	0.01
1996	0%	0	0	0%	0	0	54	0.04	0.01
1997	0%	0	0	0%	0	0	69	0.04	0.01
1998	0%	0	0	0%	0	0	79	0.03	0.01
1999	0%	0	0	0%	0	0	84	0.03	0.01
2000	0%	0	0	0%	0	0	109	0.02	0.01
2001	0%	0	0	0%	0	0	116	0.02	0.01
2002	0%	0	0	0%	0	0	129	0.02	0.02
2003	0%	0	0	0%	0	0	153	0.02	0.02
2004	0%	0	0	0%	0	0	172	0.01	0.006
2005	0%	0	0	0%	0	0	222	0.01	0.007
2006	0%	0	0	0%	0	0	265	0.01	0.008
2007	0%	0	0	0%	0	0	323	0.02	0.01
2008	0%	0	0	0%	0	0	322	0.02	0.01
2009	0%	0	0	0%	0	0	293	0.01	0.010
2010	0%	0	0	0%	0	0	381	0.02	0.01
2011	0%	0	0	0%	0	0	475	0.02	0.02
2012	0%	0	0	0%	0	0	804	0.04	0.03
2013	0%	0	0	0%	0	0	1,164	0.05	0.04
2014	0%	0	0	0%	0	0	1,409	0.06	0.05
2015	0%	0	0	0%	0	0	1,991	0.08	0.07
2016	0%	0	0	0%	0	0	2,353	0.11	0.08
2017	0%	0	0	0%	0	0	2,931	0.12	0.10
2018	0%	0	0	0%	0	0	3,022	0.12	0.10
2019	0%	0	0	0%	0	0	2,984	0.11	0.10
2020	0%	0	0	0%	0	0	2,726	0.10	0.09
2021	0%	0	0	0%	0	0	3,621	0.12	0.12
2022	0%	0	0	0%	0	0	4,642	0.14	0.15
2023	0%	0	0	0%	0	0	5,064	0.14	0.16
2024	0%	0	0	0%	0	0	5,543	0.14	0.16
2025	0%	0	0	0%	0	0	5,997	0.13	0.17
2026	0%	0	0	11%	79,577	7,309,578	6,361	0.13	0.17
2027	0%	0	0	19%	142,346	13,599,811	6,702	0.13	0.17
2028	0%	0	0	28%	219,611	21,818,886	7,039	0.13	0.17
2029	0%	0	0	35%	292,577	30,215,957	7,303	0.13	0.17
2030	0%	0	0	45%	388,610	41,684,009	7,415	0.13	0.17
2031	0%	0	0	60%	534,022	59,463,907	7,265	0.13	0.16
2032	0%	0	0	66%	602,224	69,557,302	7,330	0.12	0.15
2033	0%	0	0	72%	676,837	80,940,453	7,398	0.12	0.14
2034	0%	0	0	70%	668,385	82,465,361	7,628	0.12	0.14
2035	0%	0	0	68%	589,257	74,782,771	7,004	0.11	0.12

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-14) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-16. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

Table A-77. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 4a in Calendar Year 2040

Model Year	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fuel Consumption[3] (MJ of electricity/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of electricity/day)
1996	100%	13,224	407,390	0%	0	0	0	0%	0	0
1997	100%	15,957	507,603	0%	0	0	0	0%	2	27
1998	100%	17,428	573,388	0%	0	0	0	0%	2	23
1999	100%	17,981	612,358	0%	0	0	0	0%	2	19
2000	100%	21,212	772,196	0%	0	0	0	0%	0	5
2001	100%	20,869	808,569	0%	0	0	0	0%	1	19
2002	100%	20,957	866,980	0%	0	0	0	0%	8	114
2003	100%	22,226	985,080	0%	0	0	0	0%	1	18
2004	100%	21,228	1,041,890	0%	0	0	0	0%	1	12
2005	100%	24,808	1,278,892	0%	0	0	0	0%	1	16
2006	100%	25,795	1,417,856	0%	0	0	0	0%	1	22
2007	100%	28,657	1,630,516	0%	0	0	0	0%	2	44
2008	100%	24,894	1,513,071	0%	0	0	0	0%	12	206
2009	100%	20,958	1,283,229	0%	0	0	0	0%	3	64
2010	100%	26,447	1,559,497	0%	1	7	31	0%	15	295
2011	99%	28,341	1,849,619	0%	51	367	1,752	1%	172	3,720
2012	98%	44,963	2,967,860	1%	539	4,153	19,596	1%	240	5,433
2013	97%	60,869	4,125,844	2%	1,150	9,385	43,891	1%	858	20,372
2014	96%	67,874	4,888,299	3%	1,863	16,131	74,982	1%	1,028	25,649
2015	97%	93,376	6,979,373	2%	1,592	14,608	67,463	2%	1,750	45,992
2016	95%	109,366	8,447,742	2%	1,998	19,377	88,913	3%	3,230	88,645
2017	91%	132,055	10,809,831	4%	5,994	61,088	279,650	5%	7,052	203,451
2018	87%	137,285	11,794,487	4%	6,483	69,602	317,087	9%	14,800	449,301
2019	88%	141,083	12,595,274	3%	5,505	64,430	274,520	8%	13,018	416,452
2020	86%	135,652	12,343,563	4%	6,558	82,023	336,557	9%	14,744	498,290
2021	85%	189,590	17,659,856	4%	9,979	135,046	521,355	10%	22,644	801,678
2022	84%	253,809	24,240,958	5%	14,007	218,733	693,952	11%	32,657	1,210,322
2023	84%	291,017	28,467,215	5%	16,137	271,680	807,271	11%	39,377	1,526,695
2024	83%	329,600	32,998,938	5%	18,166	329,087	916,198	12%	47,021	1,906,128
2025	83%	371,783	38,066,268	5%	20,520	399,967	1,039,937	12%	54,873	2,325,226
2026	73%	364,065	38,085,431	5%	25,662	522,506	1,353,168	11%	53,811	2,380,112
2027	64%	353,606	38,594,551	6%	33,873	720,113	1,860,331	11%	60,947	2,812,115
2028	54%	324,333	36,908,576	7%	42,601	945,015	2,435,721	11%	67,997	3,270,853
2029	45%	293,135	34,757,798	8%	52,418	1,212,509	3,118,344	12%	75,286	3,773,157
2030	33%	229,029	28,278,038	9%	62,466	1,505,758	3,864,548	13%	89,833	4,686,126
2031	16%	118,284	15,198,602	10%	73,931	1,856,008	4,754,274	14%	103,082	5,594,761
2032	8%	62,086	8,297,894	11%	85,372	2,231,017	5,703,556	15%	115,974	6,545,924
2033	0%	0	0	12%	98,038	2,665,328	6,801,387	16%	130,252	7,641,664
2034	0%	0	0	13%	110,183	3,115,112	7,934,557	17%	143,603	8,754,408
2035	0%	0	0	14%	123,702	3,633,767	9,240,607	18%	158,543	10,036,171
2036	0%	0	0	15%	136,516	4,164,332	10,573,585	19%	172,403	11,326,732
2037	0%	0	0	16%	149,132	4,719,374	11,969,659	20%	185,885	12,664,897
2038	0%	0	0	17%	163,011	5,339,970	13,539,859	21%	200,821	14,165,172
2039	0%	0	0	18%	174,985	5,911,028	14,995,868	22%	213,318	15,525,813
2040	0%	0	0	19%	167,264	5,807,308	14,748,846	23%	201,977	15,124,334

Table A-77. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 4a in Calendar Year 2040

	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
1996	0%	0	0	0%	0	0	33	0.02	0.007
1997	0%	0	0	0%	0	0	42	0.03	0.009
1998	0%	0	0	0%	0	0	47	0.02	0.009
1999	0%	0	0	0%	0	0	50	0.02	0.008
2000	0%	0	0	0%	0	0	63	0.01	0.009
2001	0%	0	0	0%	0	0	66	0.01	0.009
2002	0%	0	0	0%	0	0	71	0.01	0.009
2003	0%	0	0	0%	0	0	81	0.01	0.010
2004	0%	0	0	0%	0	0	85	0.007	0.003
2005	0%	0	0	0%	0	0	105	0.008	0.004
2006	0%	0	0	0%	0	0	116	0.007	0.004
2007	0%	0	0	0%	0	0	133	0.008	0.005
2008	0%	0	0	0%	0	0	124	0.007	0.004
2009	0%	0	0	0%	0	0	105	0.006	0.004
2010	0%	0	0	0%	0	0	128	0.007	0.005
2011	0%	0	0	0%	0	0	152	0.008	0.006
2012	0%	0	0	0%	0	0	245	0.01	0.009
2013	0%	0	0	0%	0	0	341	0.02	0.01
2014	0%	0	0	0%	0	0	406	0.02	0.02
2015	0%	0	0	0%	0	0	577	0.03	0.02
2016	0%	0	0	0%	0	0	699	0.04	0.03
2017	0%	0	0	0%	0	0	908	0.04	0.03
2018	0%	0	0	0%	0	0	992	0.05	0.04
2019	0%	0	0	0%	0	0	1,054	0.05	0.04
2020	0%	0	0	0%	0	0	1,038	0.04	0.04
2021	0%	0	0	0%	0	0	1,489	0.06	0.05
2022	0%	0	0	0%	0	0	2,041	0.07	0.07
2023	0%	0	0	0%	0	0	2,397	0.08	0.08
2024	0%	0	0	0%	0	0	2,777	0.08	0.10
2025	0%	0	0	0%	0	0	3,202	0.08	0.10
2026	0%	0	0	11%	55,181	4,094,515	3,564	0.09	0.11
2027	0%	0	0	19%	104,083	8,057,835	3,972	0.09	0.12
2028	0%	0	0	28%	165,686	13,373,712	4,316	0.10	0.13
2029	0%	0	0	35%	230,572	19,392,012	4,689	0.10	0.14
2030	0%	0	0	45%	312,699	27,385,272	4,874	0.11	0.14
2031	0%	0	0	60%	443,977	40,464,086	4,946	0.10	0.13
2032	0%	0	0	66%	512,639	48,598,179	5,125	0.11	0.13
2033	0%	0	0	72%	588,656	58,032,030	5,308	0.11	0.13
2034	0%	0	0	70%	593,742	60,846,186	5,631	0.11	0.13
2035	0%	0	0	68%	601,311	64,002,976	5,997	0.11	0.13
2036	0%	0	0	66%	601,159	66,424,848	6,304	0.12	0.13
2037	0%	0	0	64%	597,030	68,425,079	6,582	0.12	0.13
2038	0%	0	0	62%	595,027	70,600,721	6,889	0.12	0.13
2039	0%	0	0	60%	583,811	71,452,118	7,078	0.12	0.13
2040	0%	0	0	58%	511,073	64,318,157	6,473	0.11	0.11

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-17) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-19. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

Model Year	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fuel Consumption[3] (MJ of electricity/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of electricity/day)
2001	100%	17,581	492,838	0%	0	0	0	0%	1	13
2002	100%	17,396	519,815	0%	0	0	0	0%	7	79
2003	100%	18,261	584,063	0%	0	0	0	0%	1	12
2004	100%	17,485	620,429	0%	0	0	0	0%	1	8
2005	100%	19,931	744,101	0%	0	0	0	0%	1	11
2006	100%	20,294	810,536	0%	0	0	0	0%	1	13
2007	100%	21,610	895,705	0%	0	0	0	0%	2	26
2008	100%	17,913	797,202	0%	0	0	0	0%	8	112
2009	100%	14,142	635,358	0%	0	0	0	0%	2	35
2010	100%	16,923	735,246	0%	1	3	15	0%	9	147
2011	99%	16,799	809,857	0%	30	158	790	1%	101	1,691
2012	98%	25,037	1,225,371	1%	300	1,692	8,301	1%	133	2,322
2013	97%	31,446	1,584,333	2%	594	3,560	17,255	1%	442	8,105
2014	96%	32,442	1,745,658	3%	890	5,695	27,363	1%	489	9,437
2015	97%	41,547	2,333,580	2%	708	4,833	22,999	2%	777	15,810
2016	95%	46,072	2,687,564	2%	841	6,105	28,783	3%	1,354	28,787
2017	91%	52,700	3,274,039	4%	2,391	18,339	86,121	5%	2,789	62,457
2018	87%	52,549	3,444,774	4%	2,479	20,175	94,087	9%	5,607	132,466
2019	88%	52,919	3,622,227	3%	2,063	18,391	80,115	8%	4,832	120,601
2020	86%	51,080	3,577,777	4%	2,469	23,635	98,982	9%	5,552	146,669
2021	85%	72,808	5,249,034	4%	3,832	39,919	157,067	10%	8,696	241,288
2022	84%	101,322	7,527,271	5%	5,592	67,570	218,488	11%	13,037	379,660
2023	84%	122,476	9,364,450	5%	6,792	88,932	269,022	11%	16,572	506,226
2024	83%	148,333	11,660,897	5%	8,175	115,750	327,717	12%	21,161	677,755
2025	83%	179,162	14,468,745	5%	9,889	151,350	399,826	12%	26,443	887,822
2026	73%	188,593	15,626,267	5%	13,293	213,382	560,696	11%	27,875	979,732
2027	64%	195,188	16,940,600	6%	18,698	314,629	823,959	11%	33,642	1,237,162
2028	54%	191,955	17,435,060	7%	25,213	444,407	1,160,110	11%	40,244	1,547,489
2029	45%	182,978	17,379,767	8%	32,720	603,637	1,571,051	12%	46,994	1,888,561
2030	33%	151,854	15,069,157	9%	41,417	799,032	2,073,706	13%	59,562	2,497,989
2031	16%	82,041	8,500,426	10%	51,278	1,033,837	2,675,905	14%	71,498	3,128,387
2032	8%	45,406	4,908,616	11%	62,436	1,314,527	3,393,898	15%	84,817	3,870,236
2033	0%	0	0	12%	73,977	1,625,355	4,186,579	16%	98,286	4,674,991
2034	0%	0	0	13%	86,845	1,989,837	5,114,021	17%	113,186	5,609,168
2035	0%	0	0	14%	99,556	2,377,278	6,096,962	18%	127,596	6,584,696
2036	0%	0	0	15%	113,519	2,823,202	7,226,411	19%	143,360	7,700,149
2037	0%	0	0	16%	127,002	3,288,080	8,399,445	20%	158,300	8,845,232
2038	0%	0	0	17%	141,911	3,822,420	9,746,350	21%	174,828	10,156,567
2039	0%	0	0	18%	155,741	4,362,607	11,103,067	22%	189,858	11,463,740
2040	0%	0	0	19%	171,206	4,983,044	12,661,348	23%	206,737	12,964,109
2041	0%	0	0	21%	194,709	5,885,170	14,930,435	24%	221,997	14,450,228
2042	0%	0	0	23%	218,143	6,840,270	17,334,125	25%	236,573	15,970,562
2043	0%	0	0	25%	243,564	7,905,571	20,027,869	26%	252,754	17,663,262
2044	0%	0	0	27%	266,180	8,907,835	22,578,739	27%	265,620	19,148,336
2045	0%	0	0	29%	258,336	8,883,750	22,542,040	29%	257,831	19,114,547

Table A-78. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 4a in Calendar Year 2045

	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
2001	0%	0	0	0%	0	0	40	0.01	0.006
2002	0%	0	0	0%	0	0	43	0.01	0.006
2003	0%	0	0	0%	0	0	48	0.01	0.006
2004	0%	0	0	0%	0	0	51	0.005	0.002
2005	0%	0	0	0%	0	0	61	0.005	0.002
2006	0%	0	0	0%	0	0	66	0.005	0.002
2007	0%	0	0	0%	0	0	73	0.005	0.003
2008	0%	0	0	0%	0	0	65	0.005	0.003
2009	0%	0	0	0%	0	0	52	0.003	0.002
2010	0%	0	0	0%	0	0	60	0.004	0.003
2011	0%	0	0	0%	0	0	66	0.004	0.003
2012	0%	0	0	0%	0	0	101	0.006	0.004
2013	0%	0	0	0%	0	0	131	0.008	0.006
2014	0%	0	0	0%	0	0	145	0.009	0.006
2015	0%	0	0	0%	0	0	193	0.01	0.008
2016	0%	0	0	0%	0	0	222	0.01	0.009
2017	0%	0	0	0%	0	0	275	0.02	0.01
2018	0%	0	0	0%	0	0	290	0.02	0.01
2019	0%	0	0	0%	0	0	303	0.02	0.01
2020	0%	0	0	0%	0	0	301	0.01	0.01
2021	0%	0	0	0%	0	0	443	0.02	0.02
2022	0%	0	0	0%	0	0	634	0.03	0.03
2023	0%	0	0	0%	0	0	789	0.03	0.03
2024	0%	0	0	0%	0	0	982	0.03	0.04
2025	0%	0	0	0%	0	0	1,217	0.04	0.04
2026	0%	0	0	11%	28,585	1,679,959	1,463	0.04	0.05
2027	0%	0	0	19%	57,453	3,536,887	1,744	0.05	0.06
2028	0%	0	0	28%	98,060	6,317,542	2,040	0.06	0.07
2029	0%	0	0	35%	143,926	9,696,491	2,345	0.06	0.08
2030	0%	0	0	45%	207,330	14,593,409	2,598	0.07	0.08
2031	0%	0	0	60%	307,941	22,631,158	2,768	0.07	0.09
2032	0%	0	0	66%	374,915	28,748,236	3,033	0.08	0.09
2033	0%	0	0	72%	444,190	35,512,951	3,250	0.08	0.10
2034	0%	0	0	70%	467,982	38,985,640	3,611	0.09	0.10
2035	0%	0	0	68%	483,939	41,981,025	3,936	0.09	0.11
2036	0%	0	0	66%	499,887	45,129,386	4,286	0.10	0.11
2037	0%	0	0	64%	508,433	47,744,836	4,597	0.10	0.12
2038	0%	0	0	62%	518,010	50,586,704	4,940	0.10	0.12
2039	0%	0	0	60%	519,604	52,748,816	5,228	0.11	0.12
2040	0%	0	0	58%	523,116	55,158,378	5,553	0.11	0.12
2041	0%	0	0	55%	510,456	55,875,571	5,797	0.11	0.12
2042	0%	0	0	52%	493,711	56,055,334	6,009	0.12	0.12
2043	0%	0	0	49%	477,919	56,173,405	6,239	0.12	0.12
2044	0%	0	0	46%	454,032	55,039,824	6,355	0.12	0.11
2045	0%	0	0	42%	374,633	46,689,015	5,668	0.11	0.10

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-20) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-22. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

Table A-79. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 4a in Calendar Year 2050

	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fuel Consumption[3] (MJ of electricity/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of electricity/day)
2006	100%	17,095	495,171	0%	0	0	0	0%	1	9
2007	100%	17,938	537,342	0%	0	0	0	0%	2	18
2008	100%	14,711	473,301	0%	0	0	0	0%	6	73
2009	100%	11,643	378,435	0%	0	0	0	0%	2	24
2010	100%	13,584	427,686	0%	0	2	9	0%	8	94
2011	99%	13,206	463,001	0%	24	89	472	1%	79	1,039
2012	98%	18,883	674,484	1%	226	915	4,745	1%	100	1,368
2013	97%	22,656	836,306	2%	428	1,850	9,427	1%	314	4,504
2014	96%	21,908	865,904	3%	601	2,783	14,018	1%	326	4,894
2015	97%	26,586	1,101,721	2%	453	2,250	11,180	2%	491	7,761
2016	95%	27,295	1,177,776	2%	498	2,640	12,955	3%	790	13,009
2017	91%	29,325	1,351,831	4%	1,329	7,482	36,484	5%	1,525	26,393
2018	87%	27,113	1,322,228	4%	1,278	7,675	37,071	9%	2,868	52,384
2019	89%	25,304	1,294,975	3%	986	6,516	29,339	8%	2,292	44,244
2020	86%	22,760	1,198,129	4%	1,100	7,856	33,925	9%	2,474	50,596
2021	85%	30,740	1,673,570	4%	1,618	12,642	51,178	10%	3,671	78,995
2022	84%	40,577	2,287,454	5%	2,239	20,404	67,892	11%	5,221	118,112
2023	84%	47,100	2,747,369	5%	2,612	25,936	80,590	11%	6,373	151,554
2024	83%	55,817	3,364,077	5%	3,076	33,204	96,428	12%	7,963	198,997
2025	83%	67,473	4,197,128	5%	3,724	43,672	118,177	12%	9,959	261,533
2026	73%	72,435	4,648,637	5%	5,106	63,096	169,481	11%	10,706	295,109
2027	64%	77,932	5,265,063	6%	7,465	97,197	259,783	11%	13,432	388,383
2028	54%	80,799	5,740,711	7%	10,613	145,462	387,002	11%	16,940	513,531
2029	45%	82,363	6,147,303	8%	14,728	212,290	562,357	12%	21,153	672,043
2030	33%	73,193	5,733,398	9%	19,963	302,330	797,667	13%	28,709	953,785
2031	16%	42,508	3,491,042	10%	26,569	422,328	1,110,127	14%	37,045	1,287,157
2032	8%	25,069	2,156,590	11%	34,471	574,562	1,505,169	15%	46,828	1,701,409
2033	0%	0	0	12%	43,793	764,692	1,996,805	16%	58,183	2,209,858
2034	0%	0	0	13%	54,221	991,090	2,580,166	17%	70,667	2,804,792
2035	0%	0	0	14%	66,023	1,262,125	3,276,391	18%	84,618	3,507,790
2036	0%	0	0	15%	78,754	1,573,418	4,073,466	19%	99,457	4,304,066
2037	0%	0	0	16%	92,899	1,938,309	5,005,480	20%	115,793	5,228,312
2038	0%	0	0	17%	107,102	2,332,093	6,008,183	21%	131,944	6,212,439
2039	0%	0	0	18%	122,771	2,787,972	7,166,600	22%	149,666	7,344,085
2040	0%	0	0	19%	137,813	3,261,655	8,366,537	23%	166,414	8,505,538
2041	0%	0	0	21%	161,941	3,991,943	10,219,595	24%	184,637	9,824,069
2042	0%	0	0	23%	185,855	4,769,579	12,185,731	25%	201,557	11,158,614
2043	0%	0	0	25%	212,254	5,667,200	14,452,086	26%	220,262	12,680,449
2044	0%	0	0	27%	237,373	6,591,554	16,777,936	27%	236,874	14,175,574
2045	0%	0	0	29%	265,259	7,653,819	19,449,674	29%	264,740	16,455,874
2046	0%	0	0	31%	291,484	8,734,530	22,161,339	31%	290,950	18,775,038
2047	0%	0	0	33%	317,037	9,856,021	24,978,510	33%	316,492	21,183,213
2048	0%	0	0	35%	344,892	11,098,127	28,117,477	35%	344,332	23,856,539
2049	0%	0	0	37%	368,269	12,217,195	30,967,861	37%	367,704	26,274,045
2050	0%	0	0	39%	350,007	11,929,675	30,270,840	39%	349,498	25,672,714

Table A-79. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 4a in Calendar Year 2050

Model Year	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
2006	0%	0	0	0%	0	0	41	0.004	0.002
2007	0%	0	0	0%	0	0	44	0.004	0.002
2008	0%	0	0	0%	0	0	39	0.003	0.002
2009	0%	0	0	0%	0	0	31	0.002	0.001
2010	0%	0	0	0%	0	0	35	0.003	0.002
2011	0%	0	0	0%	0	0	38	0.003	0.002
2012	0%	0	0	0%	0	0	56	0.004	0.003
2013	0%	0	0	0%	0	0	69	0.005	0.003
2014	0%	0	0	0%	0	0	72	0.005	0.003
2015	0%	0	0	0%	0	0	91	0.006	0.004
2016	0%	0	0	0%	0	0	97	0.007	0.005
2017	0%	0	0	0%	0	0	114	0.008	0.005
2018	0%	0	0	0%	0	0	111	0.007	0.005
2019	0%	0	0	0%	0	0	108	0.006	0.005
2020	0%	0	0	0%	0	0	101	0.006	0.004
2021	0%	0	0	0%	0	0	141	0.008	0.006
2022	0%	0	0	0%	0	0	193	0.009	0.009
2023	0%	0	0	0%	0	0	232	0.01	0.01
2024	0%	0	0	0%	0	0	283	0.01	0.01
2025	0%	0	0	0%	0	0	353	0.01	0.01
2026	0%	0	0	11%	10,979	499,769	435	0.01	0.02
2027	0%	0	0	19%	22,939	1,099,249	542	0.02	0.02
2028	0%	0	0	28%	41,276	2,080,130	672	0.02	0.03
2029	0%	0	0	35%	64,784	3,429,693	830	0.03	0.03
2030	0%	0	0	45%	99,932	5,552,389	989	0.03	0.04
2031	0%	0	0	60%	159,555	9,294,397	1,138	0.03	0.04
2032	0%	0	0	66%	206,994	12,630,474	1,334	0.04	0.05
2033	0%	0	0	72%	262,949	16,791,411	1,538	0.04	0.05
2034	0%	0	0	70%	292,179	19,511,549	1,809	0.05	0.06
2035	0%	0	0	68%	320,935	22,391,802	2,102	0.06	0.07
2036	0%	0	0	66%	346,800	25,263,881	2,402	0.06	0.07
2037	0%	0	0	64%	371,908	28,268,312	2,724	0.07	0.08
2038	0%	0	0	62%	390,948	30,983,413	3,029	0.08	0.09
2039	0%	0	0	60%	409,607	33,825,447	3,356	0.08	0.09
2040	0%	0	0	58%	421,086	36,211,173	3,650	0.09	0.10
2041	0%	0	0	55%	424,551	37,995,927	3,948	0.09	0.10
2042	0%	0	0	52%	420,635	39,159,026	4,204	0.10	0.10
2043	0%	0	0	49%	416,483	40,322,062	4,484	0.10	0.11
2044	0%	0	0	46%	404,896	40,751,749	4,710	0.11	0.11
2045	0%	0	0	42%	384,672	40,214,217	4,885	0.11	0.11
2046	0%	0	0	38%	357,821	38,834,824	4,994	0.11	0.10
2047	0%	0	0	34%	327,175	36,831,648	5,061	0.11	0.10
2048	0%	0	0	30%	296,167	34,514,000	5,128	0.11	0.10
2049	0%	0	0	26%	259,335	31,167,115	5,087	0.11	0.09
2050	0%	0	0	22%	197,938	24,452,151	4,480	0.10	0.08

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-23) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-25. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fuel Consumption[3] (MJ of electricity/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of electricity/day)
1982	100%	4,657	174,227	0%	0	0	0	0%	1	9
1983	100%	5,273	206,541	0%	0	0	0	0%	1	9
1984	100%	7,858	329,345	0%	0	0	0	0%	1	13
1985	100%	10,024	435,286	0%	0	0	0	0%	0	0
1986	100%	10,647	463,741	0%	0	0	0	0%	0	0
1987	100%	12,832	586,622	0%	0	0	0	0%	1	18
1988	100%	12,139	592,716	0%	0	0	0	0%	0	0
1989	100%	14,970	774,940	0%	0	0	0	0%	1	14
1990	100%	18,044	991,990	0%	0	0	0	0%	0	0
1991	100%	21,281	1,234,023	0%	0	0	0	0%	0	0
1992	100%	18,332	1,127,213	0%	0	0	0	0%	0	0
1993	100%	20,138	1,231,512	0%	0	0	0	0%	3	46
1994	100%	22,840	1,473,479	0%	0	0	0	0%	0	7
1995	100%	29,675	2,022,331	0%	0	0	0	0%	2	31
1996	100%	29,436	2,128,971	0%	0	0	0	0%	0	0
1997	100%	39,761	2,978,637	0%	0	0	0	0%	4	95
1998	100%	48,817	3,777,000	0%	0	0	0	0%	5	107
1999	100%	56,921	4,546,344	0%	0	0	0	0%	4	98
2000	100%	76,964	6,529,441	0%	0	0	0	0%	1	31
2001	100%	87,221	7,793,387	0%	0	0	0	0%	6	155
2002	100%	102,135	9,644,077	0%	0	0	0	0%	37	1,030
2003	100%	127,287	12,720,322	0%	0	0	0	0%	7	196
2004	100%	143,690	15,732,253	0%	0	0	0	0%	5	155
2005	100%	191,623	21,752,720	0%	0	0	0	0%	7	213
2006	100%	225,488	26,980,154	0%	0	0	0	0%	11	389
2007	100%	275,180	33,665,694	0%	0	0	0	0%	23	834
2008	100%	258,265	33,318,492	0%	0	0	0	0%	126	4,586
2009	100%	229,086	29,357,696	0%	0	0	0	0%	34	1,333
2010	100%	292,924	35,681,010	0%	11	154	687	0%	161	6,445
2011	99%	307,002	40,824,099	0%	548	8,280	37,013	1%	1,890	79,947
2012	98%	465,759	61,806,971	1%	5,585	88,399	392,722	1%	2,528	111,558
2013	97%	592,447	79,686,217	2%	11,199	185,018	819,056	1%	8,583	395,185
2014	96%	599,553	84,574,041	3%	16,462	284,537	1,256,341	1%	9,356	449,554
2015	96%	738,821	106,767,996	2%	12,602	227,577	1,002,629	2%	14,202	712,794
2016	95%	754,102	111,262,248	2%	13,790	259,774	1,141,452	3%	23,130	1,205,441
2017	91%	794,462	122,943,456	4%	36,125	706,874	3,105,093	5%	43,901	2,385,744
2018	86%	705,513	113,371,002	4%	33,412	680,299	2,980,537	10%	78,294	4,428,841
2019	88%	622,322	102,867,416	3%	24,317	533,860	2,191,127	8%	58,438	3,447,620
2020	86%	508,892	85,019,301	4%	24,600	571,597	2,264,467	9%	55,310	3,416,834
2021	85%	619,444	104,948,162	4%	32,604	811,289	3,029,262	10%	73,983	4,748,184
2022	84%	724,703	124,757,619	5%	39,994	1,137,171	3,486,691	11%	93,245	6,212,763
2023	84%	731,635	127,883,688	5%	40,571	1,231,754	3,543,090	11%	98,996	6,843,258
2024	83%	747,543	132,487,563	5%	41,200	1,332,140	3,598,733	12%	106,645	7,641,910
2025	83%	758,530	135,969,595	5%	41,866	1,438,799	3,640,575	12%	111,956	8,303,968
2026	65%	540,667	97,736,781	4%	34,449	1,220,027	3,088,034	11%	89,660	6,866,855

Table A-80. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 4b in Calendar Year 2026
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
1982	0%	0	0	0%	0	0	14	0.008	0.003
1983	0%	0	0	0%	0	0	17	0.009	0.003
1984	0%	0	0	0%	0	0	27	0.01	0.005
1985	0%	0	0	0%	0	0	36	0.02	0.006
1986	0%	0	0	0%	0	0	38	0.02	0.007
1987	0%	0	0	0%	0	0	48	0.02	0.009
1988	0%	0	0	0%	0	0	49	0.02	0.009
1989	0%	0	0	0%	0	0	63	0.03	0.01
1990	0%	0	0	0%	0	0	81	0.04	0.01
1991	0%	0	0	0%	0	0	101	0.05	0.02
1992	0%	0	0	0%	0	0	92	0.04	0.02
1993	0%	0	0	0%	0	0	101	0.05	0.02
1994	0%	0	0	0%	0	0	121	0.06	0.02
1995	0%	0	0	0%	0	0	166	0.08	0.03
1996	0%	0	0	0%	0	0	174	0.09	0.04
1997	0%	0	0	0%	0	0	244	0.11	0.05
1998	0%	0	0	0%	0	0	309	0.11	0.05
1999	0%	0	0	0%	0	0	372	0.09	0.06
2000	0%	0	0	0%	0	0	535	0.08	0.07
2001	0%	0	0	0%	0	0	638	0.09	0.07
2002	0%	0	0	0%	0	0	790	0.11	0.09
2003	0%	0	0	0%	0	0	1,041	0.13	0.11
2004	0%	0	0	0%	0	0	1,288	0.07	0.04
2005	0%	0	0	0%	0	0	1,781	0.08	0.05
2006	0%	0	0	0%	0	0	2,209	0.09	0.06
2007	0%	0	0	0%	0	0	2,756	0.11	0.08
2008	0%	0	0	0%	0	0	2,728	0.10	0.08
2009	0%	0	0	0%	0	0	2,404	0.09	0.07
2010	0%	0	0	0%	0	0	2,921	0.11	0.09
2011	0%	0	0	0%	0	0	3,345	0.12	0.10
2012	0%	0	0	0%	0	0	5,092	0.18	0.15
2013	0%	0	0	0%	0	0	6,591	0.22	0.19
2014	0%	0	0	0%	0	0	7,027	0.23	0.20
2015	0%	0	0	0%	0	0	8,823	0.28	0.24
2016	0%	0	0	0%	0	0	9,203	0.32	0.26
2017	0%	0	0	0%	0	0	10,320	0.32	0.27
2018	0%	0	0	0%	0	0	9,526	0.28	0.24
2019	0%	0	0	0%	0	0	8,601	0.23	0.21
2020	0%	0	0	0%	0	0	7,146	0.19	0.17
2021	0%	0	0	0%	0	0	8,840	0.21	0.21
2022	0%	0	0	0%	0	0	10,500	0.23	0.24
2023	0%	0	0	0%	0	0	10,760	0.21	0.23
2024	0%	0	0	0%	0	0	11,142	0.20	0.22
2025	0%	0	0	0%	0	0	11,430	0.16	0.20
2026	0%	0	0	20%	166,194	21,309,575	9,999	0.14	0.17

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-8) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-10. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

Table A-81. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 4b in Calendar Year 2030

Model Year	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fuel Consumption[3] (MJ of electricity/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of electricity/day)
1986	100%	9,277	319,606	0%	0	0	0	0%	0	0
1987	100%	11,036	395,358	0%	0	0	0	0%	1	13
1988	100%	10,287	394,106	0%	0	0	0	0%	0	0
1989	100%	12,682	513,141	0%	0	0	0	0%	1	10
1990	100%	15,335	660,988	0%	0	0	0	0%	0	0
1991	100%	17,755	806,207	0%	0	0	0	0%	0	0
1992	100%	14,968	722,403	0%	0	0	0	0%	0	0
1993	100%	15,722	757,504	0%	0	0	0	0%	2	30
1994	100%	16,938	862,749	0%	0	0	0	0%	0	4
1995	100%	21,266	1,147,175	0%	0	0	0	0%	1	18
1996	100%	20,041	1,148,835	0%	0	0	0	0%	0	0
1997	100%	25,571	1,519,989	0%	0	0	0	0%	3	55
1998	100%	29,544	1,816,366	0%	0	0	0	0%	3	55
1999	100%	32,392	2,061,329	0%	0	0	0	0%	2	47
2000	100%	41,346	2,802,701	0%	0	0	0	0%	1	14
2001	100%	44,766	3,209,806	0%	0	0	0	0%	3	65
2002	100%	49,911	3,795,455	0%	0	0	0	0%	18	424
2003	100%	59,781	4,832,777	0%	0	0	0	0%	3	76
2004	100%	65,751	5,844,031	0%	0	0	0	0%	2	59
2005	100%	86,903	8,039,211	0%	0	0	0	0%	3	81
2006	100%	103,055	10,092,547	0%	0	0	0	0%	5	144
2007	100%	128,610	12,929,139	0%	0	0	0	0%	11	328
2008	100%	125,543	13,361,675	0%	0	0	0	0%	60	1,794
2009	100%	116,809	12,395,606	0%	0	0	0	0%	18	572
2010	100%	158,274	16,020,574	0%	6	69	311	0%	86	2,863
2011	99%	175,648	19,479,572	0%	313	3,932	17,791	1%	1,076	37,957
2012	98%	282,481	31,367,919	1%	3,387	44,658	200,590	1%	1,526	56,296
2013	97%	378,095	42,683,040	2%	7,146	98,660	441,197	1%	5,433	209,483
2014	96%	402,992	47,862,257	3%	11,064	160,332	714,692	1%	6,227	251,167
2015	97%	518,113	63,218,662	2%	8,836	134,191	596,394	2%	9,879	417,410
2016	95%	553,278	69,108,331	2%	10,115	160,689	711,773	3%	16,817	738,736
2017	91%	604,853	79,402,357	4%	27,493	454,641	2,012,619	5%	33,194	1,524,212
2018	86%	555,971	75,960,952	4%	26,314	453,896	2,003,609	10%	61,332	2,941,765
2019	88%	505,059	71,135,364	3%	19,734	368,011	1,521,560	8%	47,387	2,378,873
2020	86%	424,894	60,588,792	4%	20,540	406,324	1,621,195	9%	46,181	2,435,627
2021	85%	528,088	76,514,975	4%	27,796	590,252	2,219,126	10%	63,072	3,464,139
2022	84%	629,123	92,802,888	5%	34,719	844,508	2,607,459	11%	80,947	4,626,137
2023	84%	652,013	97,885,688	5%	36,155	941,473	2,725,229	11%	88,223	5,242,684
2024	83%	670,253	102,369,934	5%	36,940	1,028,217	2,790,931	12%	95,619	5,905,793
2025	83%	697,118	108,259,056	5%	38,476	1,144,799	2,904,428	12%	102,891	6,603,088
2026	65%	562,951	88,800,905	4%	35,869	1,108,113	2,804,580	11%	93,356	6,216,252
2027	60%	531,375	86,947,141	4%	36,682	1,175,675	2,972,420	11%	97,957	6,763,472
2028	54%	490,961	83,197,345	5%	46,662	1,548,748	3,914,793	11%	103,726	7,417,910
2029	47%	438,150	76,646,771	6%	56,371	1,931,109	4,883,937	12%	107,741	7,961,945
2030	31%	263,273	47,412,456	7%	59,346	2,092,397	5,297,554	12%	101,252	7,716,317

Table A-81. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 4b in Calendar Year 2030
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Model Year	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
1986	0%	0	0	0%	0	0	26	0.01	0.005
1987	0%	0	0	0%	0	0	32	0.02	0.006
1988	0%	0	0	0%	0	0	32	0.02	0.006
1989	0%	0	0	0%	0	0	42	0.02	0.008
1990	0%	0	0	0%	0	0	54	0.03	0.010
1991	0%	0	0	0%	0	0	66	0.03	0.01
1992	0%	0	0	0%	0	0	59	0.03	0.01
1993	0%	0	0	0%	0	0	62	0.03	0.01
1994	0%	0	0	0%	0	0	71	0.04	0.01
1995	0%	0	0	0%	0	0	94	0.05	0.02
1996	0%	0	0	0%	0	0	94	0.05	0.02
1997	0%	0	0	0%	0	0	124	0.06	0.02
1998	0%	0	0	0%	0	0	149	0.06	0.03
1999	0%	0	0	0%	0	0	169	0.05	0.03
2000	0%	0	0	0%	0	0	229	0.04	0.03
2001	0%	0	0	0%	0	0	263	0.04	0.03
2002	0%	0	0	0%	0	0	311	0.05	0.04
2003	0%	0	0	0%	0	0	396	0.05	0.04
2004	0%	0	0	0%	0	0	478	0.03	0.01
2005	0%	0	0	0%	0	0	658	0.03	0.02
2006	0%	0	0	0%	0	0	826	0.04	0.02
2007	0%	0	0	0%	0	0	1,059	0.05	0.03
2008	0%	0	0	0%	0	0	1,094	0.05	0.03
2009	0%	0	0	0%	0	0	1,015	0.04	0.03
2010	0%	0	0	0%	0	0	1,312	0.06	0.04
2011	0%	0	0	0%	0	0	1,596	0.06	0.05
2012	0%	0	0	0%	0	0	2,585	0.10	0.08
2013	0%	0	0	0%	0	0	3,531	0.13	0.11
2014	0%	0	0	0%	0	0	3,977	0.15	0.12
2015	0%	0	0	0%	0	0	5,225	0.19	0.16
2016	0%	0	0	0%	0	0	5,716	0.22	0.18
2017	0%	0	0	0%	0	0	6,666	0.24	0.20
2018	0%	0	0	0%	0	0	6,383	0.22	0.18
2019	0%	0	0	0%	0	0	5,949	0.19	0.17
2020	0%	0	0	0%	0	0	5,093	0.15	0.14
2021	0%	0	0	0%	0	0	6,446	0.18	0.18
2022	0%	0	0	0%	0	0	7,811	0.20	0.21
2023	0%	0	0	0%	0	0	8,237	0.19	0.21
2024	0%	0	0	0%	0	0	8,610	0.18	0.21
2025	0%	0	0	0%	0	0	9,101	0.16	0.20
2026	0%	0	0	20%	173,044	19,361,284	9,085	0.15	0.20
2027	0%	0	0	25%	222,005	25,766,042	9,471	0.15	0.19
2028	0%	0	0	30%	274,864	33,037,841	9,837	0.15	0.19
2029	0%	0	0	35%	329,972	40,942,951	10,027	0.15	0.18
2030	0%	0	0	50%	423,871	54,144,169	8,748	0.12	0.15

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-11) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-13. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

Table A-82. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 4b in Calendar Year 2035
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
Model Year	**Fleet Mix[1] (%)**	**Population[2] (vehicles)**	**Fuel Consumption[3] (MJ of gasoline/day)**	**Fleet Mix[1] (%)**	**Population[2] (vehicles)**	**Fuel Consumption[3] (MJ of gasoline/day)**	**Fuel Consumption[3] (MJ of electricity/day)**	**Fleet Mix[1] (%)**	**Population[2] (vehicles)**	**Fuel Consumption[3] (MJ of electricity/day)**
1991	100%	14,887	496,519	0%	0	0	0	0%	0	0
1992	100%	12,386	437,879	0%	0	0	0	0%	0	0
1993	100%	12,876	454,610	0%	0	0	0	0%	2	20
1994	100%	13,908	519,028	0%	0	0	0	0%	0	3
1995	100%	17,011	673,579	0%	0	0	0	0%	1	11
1996	100%	15,726	662,566	0%	0	0	0	0%	0	0
1997	100%	19,249	841,793	0%	0	0	0	0%	3	36
1998	100%	21,231	962,917	0%	0	0	0	0%	2	32
1999	100%	21,841	1,026,080	0%	0	0	0	0%	2	27
2000	100%	26,428	1,326,406	0%	0	0	0	0%	0	7
2001	100%	26,524	1,412,096	0%	0	0	0	0%	2	30
2002	100%	27,790	1,574,561	0%	0	0	0	0%	11	189
2003	100%	30,887	1,866,413	0%	0	0	0	0%	2	31
2004	100%	31,459	2,100,346	0%	0	0	0	0%	1	22
2005	100%	38,743	2,705,815	0%	0	0	0	0%	1	29
2006	100%	43,503	3,231,279	0%	0	0	0	0%	2	47
2007	100%	51,445	3,941,697	0%	0	0	0	0%	4	103
2008	100%	48,196	3,931,397	0%	0	0	0	0%	23	522
2009	100%	43,832	3,583,029	0%	0	0	0	0%	7	170
2010	100%	59,373	4,651,159	0%	2	20	92	0%	32	847
2011	99%	67,186	5,797,667	0%	120	1,161	5,375	1%	409	11,360
2012	98%	112,410	9,761,699	1%	1,348	13,798	63,245	1%	603	17,549
2013	97%	158,581	14,066,520	2%	2,997	32,296	147,122	1%	2,255	68,707
2014	96%	180,829	16,955,018	3%	4,964	56,441	255,982	1%	2,764	88,302
2015	97%	248,911	24,094,495	2%	4,244	50,842	229,574	2%	4,701	157,841
2016	95%	285,862	28,441,636	2%	5,224	65,752	295,555	3%	8,578	300,098
2017	91%	332,615	34,903,768	4%	15,110	198,715	892,263	5%	18,042	661,811
2018	86%	327,985	35,952,376	4%	15,507	213,599	955,739	9%	35,779	1,376,403
2019	88%	314,542	35,673,840	3%	12,281	183,606	769,058	8%	29,273	1,183,116
2020	86%	281,575	32,424,569	4%	13,612	216,540	874,542	9%	30,604	1,303,564
2021	85%	366,087	42,975,928	4%	19,269	330,198	1,255,839	10%	43,723	1,945,314
2022	84%	459,912	55,139,274	5%	25,381	499,808	1,561,702	11%	59,175	2,747,832
2023	84%	491,823	60,167,945	5%	27,272	576,729	1,688,911	11%	66,548	3,223,016
2024	83%	528,134	65,889,598	5%	29,108	659,860	1,811,619	12%	75,344	3,803,598
2025	83%	560,849	71,323,875	5%	30,955	752,392	1,930,200	12%	82,779	4,355,000
2026	65%	467,947	60,599,710	4%	29,815	754,625	1,930,143	11%	77,601	4,248,646
2027	60%	452,150	60,903,118	4%	31,213	822,291	2,099,102	11%	83,353	4,746,114
2028	54%	426,597	59,753,673	5%	40,545	1,111,059	2,831,110	11%	90,128	5,333,845
2029	47%	388,496	56,565,428	6%	49,983	1,424,208	3,622,445	12%	95,531	5,873,508
2030	31%	267,859	40,506,985	7%	60,380	1,787,472	4,539,077	12%	103,016	6,575,282
2031	5%	44,956	7,057,548	8%	71,141	2,186,911	5,544,912	12%	106,205	7,033,396
2032	0%	508	82,780	8%	72,940	2,326,111	5,891,318	12%	108,890	7,476,741
2033	0%	524	88,306	8%	75,151	2,481,218	6,282,285	12%	112,190	7,976,623
2034	0%	532	92,539	8%	76,331	2,599,611	6,585,387	12%	113,952	8,366,832
2035	0%	483	86,384	8%	69,272	2,426,007	6,152,039	12%	103,414	7,823,380

Table A-82. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 4b in Calendar Year 2035

	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
1991	0%	0	0	0%	0	0	41	0.02	0.008
1992	0%	0	0	0%	0	0	36	0.02	0.007
1993	0%	0	0	0%	0	0	37	0.02	0.007
1994	0%	0	0	0%	0	0	42	0.02	0.008
1995	0%	0	0	0%	0	0	55	0.03	0.01
1996	0%	0	0	0%	0	0	54	0.04	0.01
1997	0%	0	0	0%	0	0	69	0.04	0.01
1998	0%	0	0	0%	0	0	79	0.03	0.01
1999	0%	0	0	0%	0	0	84	0.03	0.01
2000	0%	0	0	0%	0	0	109	0.02	0.01
2001	0%	0	0	0%	0	0	116	0.02	0.01
2002	0%	0	0	0%	0	0	129	0.02	0.02
2003	0%	0	0	0%	0	0	153	0.02	0.02
2004	0%	0	0	0%	0	0	172	0.01	0.006
2005	0%	0	0	0%	0	0	222	0.01	0.007
2006	0%	0	0	0%	0	0	265	0.01	0.008
2007	0%	0	0	0%	0	0	323	0.02	0.01
2008	0%	0	0	0%	0	0	322	0.02	0.01
2009	0%	0	0	0%	0	0	293	0.01	0.010
2010	0%	0	0	0%	0	0	381	0.02	0.01
2011	0%	0	0	0%	0	0	475	0.02	0.02
2012	0%	0	0	0%	0	0	804	0.04	0.03
2013	0%	0	0	0%	0	0	1,164	0.05	0.04
2014	0%	0	0	0%	0	0	1,409	0.06	0.05
2015	0%	0	0	0%	0	0	1,991	0.08	0.07
2016	0%	0	0	0%	0	0	2,353	0.11	0.08
2017	0%	0	0	0%	0	0	2,931	0.12	0.10
2018	0%	0	0	0%	0	0	3,022	0.12	0.10
2019	0%	0	0	0%	0	0	2,984	0.11	0.10
2020	0%	0	0	0%	0	0	2,726	0.10	0.09
2021	0%	0	0	0%	0	0	3,621	0.12	0.12
2022	0%	0	0	0%	0	0	4,642	0.14	0.15
2023	0%	0	0	0%	0	0	5,064	0.14	0.16
2024	0%	0	0	0%	0	0	5,543	0.14	0.16
2025	0%	0	0	0%	0	0	5,997	0.13	0.17
2026	0%	0	0	20%	143,841	13,212,570	6,201	0.13	0.17
2027	0%	0	0	25%	188,905	18,048,119	6,636	0.13	0.17
2028	0%	0	0	30%	238,830	23,728,309	7,067	0.13	0.18
2029	0%	0	0	35%	292,577	30,215,957	7,402	0.13	0.18
2030	0%	0	0	50%	431,254	46,258,246	7,475	0.13	0.17
2031	0%	0	0	75%	666,907	74,260,870	7,112	0.12	0.15
2032	0%	0	0	80%	729,353	84,240,710	7,386	0.12	0.15
2033	0%	0	0	80%	751,459	89,864,241	7,879	0.12	0.15
2034	0%	0	0	80%	763,260	94,171,112	8,257	0.12	0.15
2035	0%	0	0	80%	692,675	87,907,646	7,708	0.11	0.13

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-14) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-16. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

Table A-83. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 4b in Calendar Year 2040
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fuel Consumption[3] (MJ of electricity/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of electricity/day)
1996	100%	13,224	407,390	0%	0	0	0	0%	0	0
1997	100%	15,957	507,603	0%	0	0	0	0%	2	27
1998	100%	17,428	573,388	0%	0	0	0	0%	2	23
1999	100%	17,981	612,358	0%	0	0	0	0%	2	19
2000	100%	21,212	772,196	0%	0	0	0	0%	0	5
2001	100%	20,869	808,569	0%	0	0	0	0%	1	19
2002	100%	20,957	866,980	0%	0	0	0	0%	8	114
2003	100%	22,226	985,080	0%	0	0	0	0%	1	18
2004	100%	21,228	1,041,890	0%	0	0	0	0%	1	12
2005	100%	24,808	1,278,892	0%	0	0	0	0%	1	16
2006	100%	25,795	1,417,856	0%	0	0	0	0%	1	22
2007	100%	28,657	1,630,516	0%	0	0	0	0%	2	44
2008	100%	24,894	1,513,071	0%	0	0	0	0%	12	206
2009	100%	20,958	1,283,229	0%	0	0	0	0%	3	64
2010	100%	26,447	1,559,497	0%	1	7	31	0%	15	295
2011	99%	28,341	1,849,619	0%	51	367	1,752	1%	172	3,720
2012	98%	44,963	2,967,860	1%	539	4,153	19,596	1%	240	5,433
2013	97%	60,869	4,125,844	2%	1,150	9,385	43,891	1%	858	20,372
2014	96%	67,874	4,888,299	3%	1,863	16,131	74,982	1%	1,028	25,649
2015	97%	93,376	6,979,373	2%	1,592	14,608	67,463	2%	1,750	45,992
2016	95%	109,366	8,447,742	2%	1,998	19,377	88,913	3%	3,230	88,645
2017	91%	132,055	10,809,831	4%	5,994	61,088	279,650	5%	7,052	203,451
2018	87%	137,285	11,794,487	4%	6,483	69,602	317,087	9%	14,800	449,301
2019	88%	141,083	12,595,274	3%	5,505	64,430	274,520	8%	13,018	416,452
2020	86%	135,652	12,343,563	4%	6,558	82,023	336,557	9%	14,744	498,290
2021	85%	189,590	17,659,856	4%	9,979	135,046	521,355	10%	22,644	801,678
2022	84%	253,809	24,240,958	5%	14,007	218,733	693,952	11%	32,657	1,210,322
2023	84%	291,017	28,467,215	5%	16,137	271,680	807,271	11%	39,377	1,526,695
2024	83%	329,600	32,998,938	5%	18,166	329,087	916,198	12%	47,021	1,906,128
2025	83%	371,783	38,066,268	5%	20,520	399,967	1,039,937	12%	54,873	2,325,226
2026	65%	324,490	33,945,378	4%	20,675	421,047	1,090,413	11%	53,811	2,380,112
2027	60%	330,612	36,084,860	4%	22,823	485,341	1,253,824	11%	60,947	2,812,115
2028	54%	321,846	36,625,537	5%	30,589	678,677	1,749,251	11%	67,997	3,270,853
2029	47%	306,163	36,302,589	6%	39,390	911,259	2,343,586	12%	75,286	3,773,157
2030	31%	215,535	26,611,999	7%	48,585	1,171,260	3,006,055	12%	82,893	4,325,829
2031	5%	37,376	4,802,531	8%	59,146	1,484,907	3,803,675	12%	88,297	4,795,314
2032	0%	433	57,837	8%	62,089	1,622,680	4,148,353	12%	92,692	5,235,411
2033	0%	456	63,313	8%	65,360	1,777,012	4,534,581	12%	97,574	5,728,006
2034	0%	473	68,279	8%	67,806	1,917,102	4,883,085	12%	101,227	6,173,591
2035	0%	493	73,932	8%	70,689	2,076,523	5,280,561	12%	105,530	6,681,472
2036	0%	0	0	10%	91,012	2,776,250	7,049,129	19%	172,403	11,326,732
2037	0%	0	0	12%	111,850	3,539,529	8,977,241	20%	185,885	12,664,897
2038	0%	0	0	14%	134,245	4,397,626	11,150,481	21%	200,821	14,165,172
2039	0%	0	0	16%	155,543	5,254,271	13,329,721	22%	213,318	15,525,813
2040	0%	0	0	20%	176,067	6,112,929	15,525,032	23%	201,977	15,124,334

	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
1996	0%	0	0	0%	0	0	33	0.02	0.007
1997	0%	0	0	0%	0	0	42	0.03	0.009
1998	0%	0	0	0%	0	0	47	0.02	0.009
1999	0%	0	0	0%	0	0	50	0.02	0.008
2000	0%	0	0	0%	0	0	63	0.01	0.009
2001	0%	0	0	0%	0	0	66	0.01	0.009
2002	0%	0	0	0%	0	0	71	0.01	0.009
2003	0%	0	0	0%	0	0	81	0.01	0.010
2004	0%	0	0	0%	0	0	85	0.007	0.003
2005	0%	0	0	0%	0	0	105	0.008	0.004
2006	0%	0	0	0%	0	0	116	0.007	0.004
2007	0%	0	0	0%	0	0	133	0.008	0.005
2008	0%	0	0	0%	0	0	124	0.007	0.004
2009	0%	0	0	0%	0	0	105	0.006	0.004
2010	0%	0	0	0%	0	0	128	0.007	0.005
2011	0%	0	0	0%	0	0	152	0.008	0.006
2012	0%	0	0	0%	0	0	245	0.01	0.009
2013	0%	0	0	0%	0	0	341	0.02	0.01
2014	0%	0	0	0%	0	0	406	0.02	0.02
2015	0%	0	0	0%	0	0	577	0.03	0.02
2016	0%	0	0	0%	0	0	699	0.04	0.03
2017	0%	0	0	0%	0	0	908	0.04	0.03
2018	0%	0	0	0%	0	0	992	0.05	0.04
2019	0%	0	0	0%	0	0	1,054	0.05	0.04
2020	0%	0	0	0%	0	0	1,038	0.04	0.04
2021	0%	0	0	0%	0	0	1,489	0.06	0.05
2022	0%	0	0	0%	0	0	2,041	0.07	0.07
2023	0%	0	0	0%	0	0	2,397	0.08	0.08
2024	0%	0	0	0%	0	0	2,777	0.08	0.10
2025	0%	0	0	0%	0	0	3,202	0.08	0.10
2026	0%	0	0	20%	99,744	7,401,119	3,474	0.08	0.11
2027	0%	0	0	25%	138,127	10,693,440	3,933	0.09	0.12
2028	0%	0	0	30%	180,185	14,544,078	4,333	0.10	0.13
2029	0%	0	0	35%	230,572	19,392,012	4,752	0.10	0.14
2030	0%	0	0	50%	347,013	30,390,423	4,913	0.11	0.14
2031	0%	0	0	75%	554,455	50,533,145	4,842	0.10	0.13
2032	0%	0	0	80%	620,857	58,857,157	5,163	0.10	0.13
2033	0%	0	0	80%	653,556	64,430,136	5,651	0.11	0.14
2034	0%	0	0	80%	678,023	69,483,149	6,094	0.11	0.14
2035	0%	0	0	80%	706,846	75,235,925	6,598	0.12	0.15
2036	0%	0	0	71%	646,663	71,452,786	6,427	0.11	0.14
2037	0%	0	0	68%	634,312	72,697,923	6,687	0.11	0.14
2038	0%	0	0	65%	623,792	74,013,815	6,973	0.12	0.13
2039	0%	0	0	62%	603,253	73,831,644	7,136	0.12	0.13
2040	0%	0	0	57%	502,270	63,210,288	6,446	0.11	0.11

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-17) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-19. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

Table A-84. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 4b in Calendar Year 2045
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fuel Consumption[3] (MJ of electricity/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of electricity/day)
2001	100%	17,581	492,838	0%	0	0	0	0%	1	13
2002	100%	17,396	519,815	0%	0	0	0	0%	7	79
2003	100%	18,261	584,063	0%	0	0	0	0%	1	12
2004	100%	17,485	620,429	0%	0	0	0	0%	1	8
2005	100%	19,931	744,101	0%	0	0	0	0%	1	11
2006	100%	20,294	810,536	0%	0	0	0	0%	1	13
2007	100%	21,610	895,705	0%	0	0	0	0%	2	26
2008	100%	17,913	797,202	0%	0	0	0	0%	8	112
2009	100%	14,142	635,358	0%	0	0	0	0%	2	35
2010	100%	16,923	735,246	0%	1	3	15	0%	9	147
2011	99%	16,799	809,857	0%	30	158	790	1%	101	1,691
2012	98%	25,037	1,225,371	1%	300	1,692	8,301	1%	133	2,322
2013	97%	31,446	1,584,333	2%	594	3,560	17,255	1%	442	8,105
2014	96%	32,442	1,745,658	3%	890	5,695	27,363	1%	489	9,437
2015	97%	41,547	2,333,580	2%	708	4,833	22,999	2%	777	15,810
2016	95%	46,072	2,687,564	2%	841	6,105	28,783	3%	1,354	28,787
2017	91%	52,700	3,274,039	4%	2,391	18,339	86,121	5%	2,789	62,457
2018	87%	52,549	3,444,774	4%	2,479	20,175	94,087	9%	5,607	132,466
2019	88%	52,919	3,622,227	3%	2,063	18,391	80,115	8%	4,832	120,601
2020	86%	51,080	3,577,777	4%	2,469	23,635	98,982	9%	5,552	146,669
2021	85%	72,808	5,249,034	4%	3,832	39,919	157,067	10%	8,696	241,288
2022	84%	101,322	7,527,271	5%	5,592	67,570	218,488	11%	13,037	379,660
2023	84%	122,476	9,364,450	5%	6,792	88,932	269,022	11%	16,572	506,226
2024	83%	148,333	11,660,897	5%	8,175	115,750	327,717	12%	21,161	677,755
2025	83%	179,162	14,468,745	5%	9,889	151,350	399,826	12%	26,443	887,822
2026	65%	168,092	13,927,624	4%	10,710	171,981	451,908	11%	27,875	979,732
2027	60%	182,495	15,839,002	4%	12,598	212,114	555,489	11%	33,642	1,237,162
2028	54%	190,483	17,301,357	5%	18,104	319,213	833,297	11%	40,244	1,547,489
2029	47%	191,110	18,152,201	6%	24,588	453,715	1,180,857	12%	46,994	1,888,561
2030	31%	142,907	14,181,338	7%	32,214	621,582	1,613,175	12%	54,961	2,306,853
2031	5%	25,924	2,686,007	8%	41,023	827,174	2,140,996	12%	61,243	2,683,184
2032	0%	316	34,213	8%	45,409	956,166	2,468,668	12%	67,790	3,098,236
2033	0%	344	38,745	8%	49,319	1,083,750	2,791,515	12%	73,628	3,508,235
2034	0%	372	43,748	8%	53,444	1,224,720	3,147,617	12%	79,786	3,960,912
2035	0%	397	48,493	8%	56,891	1,358,665	3,484,543	12%	84,931	4,390,345
2036	0%	0	0	10%	75,680	1,882,298	4,818,027	19%	143,360	7,700,149
2037	0%	0	0	12%	95,252	2,466,168	6,299,860	20%	158,300	8,845,232
2038	0%	0	0	14%	116,869	3,147,939	8,026,567	21%	174,828	10,156,567
2039	0%	0	0	16%	138,437	3,877,902	9,869,466	22%	189,858	11,463,740
2040	0%	0	0	20%	180,216	5,245,301	13,327,713	23%	206,737	12,964,109
2041	0%	0	0	24%	222,523	6,725,903	17,063,339	24%	221,997	14,450,228
2042	0%	0	0	39%	369,891	11,598,758	29,392,748	27%	260,284	17,572,280
2043	0%	0	0	39%	379,957	12,332,715	31,243,537	31%	301,465	21,069,402
2044	0%	0	0	39%	384,479	12,866,810	32,613,574	34%	339,557	24,478,734
2045	0%	0	0	39%	347,416	11,946,961	30,314,775	38%	338,003	25,053,589

Table A-84. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 4b in Calendar Year 2045

Model Year	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
2001	0%	0	0	0%	0	0	40	0.01	0.006
2002	0%	0	0	0%	0	0	43	0.01	0.006
2003	0%	0	0	0%	0	0	48	0.01	0.006
2004	0%	0	0	0%	0	0	51	0.005	0.002
2005	0%	0	0	0%	0	0	61	0.005	0.002
2006	0%	0	0	0%	0	0	66	0.005	0.002
2007	0%	0	0	0%	0	0	73	0.005	0.003
2008	0%	0	0	0%	0	0	65	0.005	0.003
2009	0%	0	0	0%	0	0	52	0.003	0.002
2010	0%	0	0	0%	0	0	60	0.004	0.003
2011	0%	0	0	0%	0	0	66	0.004	0.003
2012	0%	0	0	0%	0	0	101	0.006	0.004
2013	0%	0	0	0%	0	0	131	0.008	0.006
2014	0%	0	0	0%	0	0	145	0.009	0.006
2015	0%	0	0	0%	0	0	193	0.01	0.008
2016	0%	0	0	0%	0	0	222	0.01	0.009
2017	0%	0	0	0%	0	0	275	0.02	0.01
2018	0%	0	0	0%	0	0	290	0.02	0.01
2019	0%	0	0	0%	0	0	303	0.02	0.01
2020	0%	0	0	0%	0	0	301	0.01	0.01
2021	0%	0	0	0%	0	0	443	0.02	0.02
2022	0%	0	0	0%	0	0	634	0.03	0.03
2023	0%	0	0	0%	0	0	789	0.03	0.03
2024	0%	0	0	0%	0	0	982	0.03	0.04
2025	0%	0	0	0%	0	0	1,217	0.04	0.04
2026	0%	0	0	20%	51,669	3,036,643	1,426	0.04	0.05
2027	0%	0	0	25%	76,245	4,693,753	1,727	0.05	0.06
2028	0%	0	0	30%	106,641	6,870,405	2,047	0.05	0.07
2029	0%	0	0	35%	143,926	9,696,491	2,377	0.06	0.08
2030	0%	0	0	50%	230,082	16,194,832	2,619	0.07	0.09
2031	0%	0	0	75%	384,569	28,262,682	2,709	0.07	0.09
2032	0%	0	0	80%	454,059	34,816,931	3,055	0.07	0.09
2033	0%	0	0	80%	493,163	39,428,299	3,460	0.08	0.10
2034	0%	0	0	80%	534,411	44,519,554	3,906	0.09	0.11
2035	0%	0	0	80%	568,873	49,348,974	4,330	0.09	0.12
2036	0%	0	0	71%	537,726	48,545,393	4,369	0.09	0.12
2037	0%	0	0	68%	540,182	50,726,291	4,669	0.10	0.12
2038	0%	0	0	65%	543,052	53,032,248	4,999	0.10	0.12
2039	0%	0	0	62%	536,908	54,505,478	5,271	0.11	0.12
2040	0%	0	0	57%	514,106	54,208,285	5,529	0.11	0.12
2041	0%	0	0	52%	482,641	52,830,899	5,722	0.12	0.12
2042	0%	0	0	34%	318,252	36,133,933	5,365	0.12	0.10
2043	0%	0	0	30%	292,814	34,416,639	5,376	0.12	0.10
2044	0%	0	0	27%	261,795	31,735,973	5,268	0.12	0.09
2045	0%	0	0	23%	205,381	25,595,798	4,578	0.10	0.08

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-20) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-22. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

Table A-85. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 4b in Calendar Year 2050

	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fuel Consumption[3] (MJ of electricity/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of electricity/day)
2006	100%	17,095	495,171	0%	0	0	0	0%	1	9
2007	100%	17,938	537,342	0%	0	0	0	0%	2	18
2008	100%	14,711	473,301	0%	0	0	0	0%	6	73
2009	100%	11,643	378,435	0%	0	0	0	0%	2	24
2010	100%	13,584	427,686	0%	0	2	9	0%	8	94
2011	99%	13,206	463,001	0%	24	89	472	1%	79	1,039
2012	98%	18,883	674,484	1%	226	915	4,745	1%	100	1,368
2013	97%	22,656	836,306	2%	428	1,850	9,427	1%	314	4,504
2014	96%	21,908	865,904	3%	601	2,783	14,018	1%	326	4,894
2015	97%	26,586	1,101,721	2%	453	2,250	11,180	2%	491	7,761
2016	95%	27,295	1,177,776	2%	498	2,640	12,955	3%	790	13,009
2017	91%	29,325	1,351,831	4%	1,329	7,482	36,484	5%	1,525	26,393
2018	87%	27,113	1,322,228	4%	1,278	7,675	37,071	9%	2,868	52,384
2019	89%	25,304	1,294,975	3%	986	6,516	29,339	8%	2,292	44,244
2020	86%	22,760	1,198,129	4%	1,100	7,856	33,925	9%	2,474	50,596
2021	85%	30,740	1,673,570	4%	1,618	12,642	51,178	10%	3,671	78,995
2022	84%	40,577	2,287,454	5%	2,239	20,404	67,892	11%	5,221	118,112
2023	84%	47,100	2,747,369	5%	2,612	25,936	80,590	11%	6,373	151,554
2024	83%	55,817	3,364,077	5%	3,076	33,204	96,428	12%	7,963	198,997
2025	83%	67,473	4,197,128	5%	3,724	43,672	118,177	12%	9,959	261,533
2026	65%	64,561	4,143,310	4%	4,114	50,877	136,660	11%	10,706	295,109
2027	60%	72,864	4,922,692	4%	5,030	65,571	175,255	11%	13,432	388,383
2028	54%	80,180	5,696,688	5%	7,620	104,526	278,092	11%	16,940	513,531
2029	47%	86,024	6,420,517	6%	11,068	159,606	422,796	12%	21,153	672,043
2030	31%	68,881	5,395,608	7%	15,527	235,228	620,624	12%	26,491	881,507
2031	5%	13,432	1,103,117	8%	21,256	337,943	888,314	12%	31,732	1,105,371
2032	0%	175	15,032	8%	25,071	417,982	1,094,979	12%	37,427	1,364,096
2033	0%	203	18,320	8%	29,196	509,950	1,331,609	12%	43,586	1,661,080
2034	0%	233	21,895	8%	33,367	610,090	1,588,286	12%	49,813	1,984,022
2035	0%	263	25,865	8%	37,728	721,435	1,872,797	12%	56,324	2,343,007
2036	0%	0	0	10%	52,504	1,049,122	2,716,103	19%	99,457	4,304,066
2037	0%	0	0	12%	69,675	1,453,867	3,754,460	20%	115,793	5,228,312
2038	0%	0	0	14%	88,202	1,920,643	4,948,162	21%	131,944	6,212,439
2039	0%	0	0	16%	109,131	2,478,256	6,370,464	22%	149,666	7,344,085
2040	0%	0	0	20%	145,066	3,433,295	8,806,812	23%	166,414	8,505,538
2041	0%	0	0	24%	185,075	4,562,152	11,679,361	24%	184,637	9,824,069
2042	0%	0	0	39%	315,142	8,087,255	20,662,015	27%	221,758	12,275,351
2043	0%	0	0	39%	331,114	8,840,642	22,544,769	31%	262,712	15,122,020
2044	0%	0	0	39%	342,870	9,521,030	24,234,533	34%	302,809	18,119,847
2045	0%	0	0	39%	356,726	10,293,022	26,156,346	38%	347,060	21,572,837
2046	0%	0	0	39%	366,704	10,988,602	27,880,394	41%	389,677	25,148,333
2047	0%	0	0	39%	374,679	11,648,044	29,520,107	42%	402,955	26,973,923
2048	0%	0	0	39%	384,307	12,366,497	31,330,933	42%	413,310	28,638,221
2049	0%	0	0	39%	388,175	12,877,580	32,641,789	42%	417,470	29,830,638
2050	0%	0	0	39%	350,007	11,929,675	30,270,840	42%	376,421	27,649,542

Model Year	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
2006	0%	0	0	0%	0	0	41	0.004	0.002
2007	0%	0	0	0%	0	0	44	0.004	0.002
2008	0%	0	0	0%	0	0	39	0.003	0.002
2009	0%	0	0	0%	0	0	31	0.002	0.001
2010	0%	0	0	0%	0	0	35	0.003	0.002
2011	0%	0	0	0%	0	0	38	0.003	0.002
2012	0%	0	0	0%	0	0	56	0.004	0.003
2013	0%	0	0	0%	0	0	69	0.005	0.003
2014	0%	0	0	0%	0	0	72	0.005	0.003
2015	0%	0	0	0%	0	0	91	0.006	0.004
2016	0%	0	0	0%	0	0	97	0.007	0.005
2017	0%	0	0	0%	0	0	114	0.008	0.005
2018	0%	0	0	0%	0	0	111	0.007	0.005
2019	0%	0	0	0%	0	0	108	0.006	0.005
2020	0%	0	0	0%	0	0	101	0.006	0.004
2021	0%	0	0	0%	0	0	141	0.008	0.006
2022	0%	0	0	0%	0	0	193	0.009	0.009
2023	0%	0	0	0%	0	0	232	0.01	0.01
2024	0%	0	0	0%	0	0	283	0.01	0.01
2025	0%	0	0	0%	0	0	353	0.01	0.01
2026	0%	0	0	20%	19,845	903,367	424	0.01	0.02
2027	0%	0	0	25%	30,442	1,458,798	537	0.02	0.02
2028	0%	0	0	30%	44,888	2,262,167	674	0.02	0.03
2029	0%	0	0	35%	64,784	3,429,693	841	0.03	0.03
2030	0%	0	0	50%	110,898	6,161,686	997	0.03	0.04
2031	0%	0	0	75%	199,258	11,607,209	1,113	0.03	0.04
2032	0%	0	0	80%	250,690	15,296,741	1,343	0.04	0.05
2033	0%	0	0	80%	291,939	18,642,686	1,637	0.05	0.06
2034	0%	0	0	80%	333,653	22,281,165	1,956	0.05	0.07
2035	0%	0	0	80%	377,261	26,321,712	2,310	0.06	0.08
2036	0%	0	0	71%	373,051	27,176,196	2,447	0.06	0.08
2037	0%	0	0	68%	395,132	30,033,544	2,766	0.07	0.08
2038	0%	0	0	65%	409,848	32,481,264	3,064	0.08	0.09
2039	0%	0	0	62%	423,248	34,951,915	3,383	0.08	0.10
2040	0%	0	0	57%	413,833	35,587,442	3,635	0.09	0.10
2041	0%	0	0	52%	401,417	35,925,521	3,898	0.10	0.10
2042	0%	0	0	34%	271,146	25,242,373	3,758	0.10	0.09
2043	0%	0	0	30%	255,173	24,704,749	3,868	0.10	0.09
2044	0%	0	0	27%	233,463	23,497,466	3,908	0.10	0.08
2045	0%	0	0	23%	210,884	22,046,191	3,946	0.10	0.08
2046	0%	0	0	20%	183,874	19,956,099	3,916	0.10	0.08
2047	0%	0	0	19%	183,069	20,608,997	4,104	0.10	0.08
2048	0%	0	0	19%	187,774	21,882,345	4,357	0.11	0.08
2049	0%	0	0	19%	189,664	22,793,926	4,539	0.11	0.08
2050	0%	0	0	19%	171,015	21,126,196	4,208	0.10	0.07

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-23) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-25. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

Table A-86. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 4c in Calendar Year 2026
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fuel Consumption[3] (MJ of electricity/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of electricity/day)
1982	100%	4,657	174,227	0%	0	0	0	0%	1	9
1983	100%	5,273	206,541	0%	0	0	0	0%	1	9
1984	100%	7,858	329,345	0%	0	0	0	0%	1	13
1985	100%	10,024	435,286	0%	0	0	0	0%	0	0
1986	100%	10,647	463,741	0%	0	0	0	0%	0	0
1987	100%	12,832	586,622	0%	0	0	0	0%	1	18
1988	100%	12,139	592,716	0%	0	0	0	0%	0	0
1989	100%	14,970	774,940	0%	0	0	0	0%	1	14
1990	100%	18,044	991,990	0%	0	0	0	0%	0	0
1991	100%	21,281	1,234,023	0%	0	0	0	0%	0	0
1992	100%	18,332	1,127,213	0%	0	0	0	0%	0	0
1993	100%	20,138	1,231,512	0%	0	0	0	0%	3	46
1994	100%	22,840	1,473,479	0%	0	0	0	0%	0	7
1995	100%	29,675	2,022,331	0%	0	0	0	0%	2	31
1996	100%	29,436	2,128,971	0%	0	0	0	0%	0	0
1997	100%	39,761	2,978,637	0%	0	0	0	0%	4	95
1998	100%	48,817	3,777,000	0%	0	0	0	0%	5	107
1999	100%	56,921	4,546,344	0%	0	0	0	0%	4	98
2000	100%	76,964	6,529,441	0%	0	0	0	0%	1	31
2001	100%	87,221	7,793,387	0%	0	0	0	0%	6	155
2002	100%	102,135	9,644,077	0%	0	0	0	0%	37	1,030
2003	100%	127,287	12,720,322	0%	0	0	0	0%	7	196
2004	100%	143,690	15,732,253	0%	0	0	0	0%	5	155
2005	100%	191,623	21,752,720	0%	0	0	0	0%	7	213
2006	100%	225,488	26,980,154	0%	0	0	0	0%	11	389
2007	100%	275,180	33,665,694	0%	0	0	0	0%	23	834
2008	100%	258,265	33,318,492	0%	0	0	0	0%	126	4,586
2009	100%	229,086	29,357,696	0%	0	0	0	0%	34	1,333
2010	100%	292,924	35,681,010	0%	11	154	687	0%	161	6,445
2011	99%	307,002	40,824,099	0%	548	8,280	37,013	1%	1,890	79,947
2012	98%	465,759	61,806,971	1%	5,585	88,399	392,722	1%	2,528	111,558
2013	97%	592,447	79,686,217	2%	11,199	185,018	819,056	1%	8,583	395,185
2014	96%	599,553	84,574,041	3%	16,462	284,537	1,256,341	1%	9,356	449,554
2015	96%	738,821	106,767,996	2%	12,602	227,577	1,002,629	2%	14,202	712,794
2016	95%	754,102	111,262,248	2%	13,790	259,774	1,141,452	3%	23,130	1,205,441
2017	91%	794,462	122,943,456	4%	36,125	706,874	3,105,093	5%	43,901	2,385,744
2018	86%	705,513	113,371,002	4%	33,412	680,299	2,980,537	10%	78,294	4,428,841
2019	88%	622,322	102,867,416	3%	24,317	533,860	2,191,127	8%	58,438	3,447,620
2020	86%	508,892	85,019,301	4%	24,600	571,597	2,264,467	9%	55,310	3,416,834
2021	85%	619,444	104,948,162	4%	32,604	811,289	3,029,262	10%	73,983	4,748,184
2022	84%	724,703	124,757,619	5%	39,994	1,137,171	3,486,691	11%	93,245	6,212,763
2023	84%	731,635	127,883,688	5%	40,571	1,231,754	3,543,090	11%	98,996	6,843,258
2024	83%	747,543	132,487,563	5%	41,200	1,332,140	3,598,733	12%	106,645	7,641,910
2025	83%	758,530	135,969,595	5%	41,866	1,438,799	3,640,575	12%	111,956	8,303,968
2026	73%	606,608	109,656,971	5%	42,758	1,514,177	3,832,564	11%	89,660	6,866,855

Table A-86. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 4c in Calendar Year 2026

	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
1982	0%	0	0	0%	0	0	14	0.008	0.003
1983	0%	0	0	0%	0	0	17	0.009	0.003
1984	0%	0	0	0%	0	0	27	0.01	0.005
1985	0%	0	0	0%	0	0	36	0.02	0.006
1986	0%	0	0	0%	0	0	38	0.02	0.007
1987	0%	0	0	0%	0	0	48	0.02	0.009
1988	0%	0	0	0%	0	0	49	0.02	0.009
1989	0%	0	0	0%	0	0	63	0.03	0.01
1990	0%	0	0	0%	0	0	81	0.04	0.01
1991	0%	0	0	0%	0	0	101	0.05	0.02
1992	0%	0	0	0%	0	0	92	0.04	0.02
1993	0%	0	0	0%	0	0	101	0.05	0.02
1994	0%	0	0	0%	0	0	121	0.06	0.02
1995	0%	0	0	0%	0	0	166	0.08	0.03
1996	0%	0	0	0%	0	0	174	0.09	0.04
1997	0%	0	0	0%	0	0	244	0.11	0.05
1998	0%	0	0	0%	0	0	309	0.11	0.05
1999	0%	0	0	0%	0	0	372	0.09	0.06
2000	0%	0	0	0%	0	0	535	0.08	0.07
2001	0%	0	0	0%	0	0	638	0.09	0.07
2002	0%	0	0	0%	0	0	790	0.11	0.09
2003	0%	0	0	0%	0	0	1,041	0.13	0.11
2004	0%	0	0	0%	0	0	1,288	0.07	0.04
2005	0%	0	0	0%	0	0	1,781	0.08	0.05
2006	0%	0	0	0%	0	0	2,209	0.09	0.06
2007	0%	0	0	0%	0	0	2,756	0.11	0.08
2008	0%	0	0	0%	0	0	2,728	0.10	0.08
2009	0%	0	0	0%	0	0	2,404	0.09	0.07
2010	0%	0	0	0%	0	0	2,921	0.11	0.09
2011	0%	0	0	0%	0	0	3,345	0.12	0.10
2012	0%	0	0	0%	0	0	5,092	0.18	0.15
2013	0%	0	0	0%	0	0	6,591	0.22	0.19
2014	0%	0	0	0%	0	0	7,027	0.23	0.20
2015	0%	0	0	0%	0	0	8,823	0.28	0.24
2016	0%	0	0	0%	0	0	9,203	0.32	0.26
2017	0%	0	0	0%	0	0	10,320	0.32	0.27
2018	0%	0	0	0%	0	0	9,526	0.28	0.24
2019	0%	0	0	0%	0	0	8,601	0.23	0.21
2020	0%	0	0	0%	0	0	7,146	0.19	0.17
2021	0%	0	0	0%	0	0	8,840	0.21	0.21
2022	0%	0	0	0%	0	0	10,500	0.23	0.24
2023	0%	0	0	0%	0	0	10,760	0.21	0.23
2024	0%	0	0	0%	0	0	11,142	0.20	0.22
2025	0%	0	0	0%	0	0	11,430	0.16	0.20
2026	0%	0	0	11%	91,943	11,789,077	10,257	0.14	0.17

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-8) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-10. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

Table A-87. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 4c in Calendar Year 2030
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fuel Consumption[3] (MJ of electricity/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of electricity/day)
1986	100%	9,277	319,606	0%	0	0	0	0%	0	0
1987	100%	11,036	395,358	0%	0	0	0	0%	1	13
1988	100%	10,287	394,106	0%	0	0	0	0%	0	0
1989	100%	12,682	513,141	0%	0	0	0	0%	1	10
1990	100%	15,335	660,988	0%	0	0	0	0%	0	0
1991	100%	17,755	806,207	0%	0	0	0	0%	0	0
1992	100%	14,968	722,403	0%	0	0	0	0%	0	0
1993	100%	15,722	757,504	0%	0	0	0	0%	2	30
1994	100%	16,938	862,749	0%	0	0	0	0%	0	4
1995	100%	21,266	1,147,175	0%	0	0	0	0%	1	18
1996	100%	20,041	1,148,835	0%	0	0	0	0%	0	0
1997	100%	25,571	1,519,989	0%	0	0	0	0%	3	55
1998	100%	29,544	1,816,366	0%	0	0	0	0%	3	55
1999	100%	32,392	2,061,329	0%	0	0	0	0%	2	47
2000	100%	41,346	2,802,701	0%	0	0	0	0%	1	14
2001	100%	44,766	3,209,806	0%	0	0	0	0%	3	65
2002	100%	49,911	3,795,455	0%	0	0	0	0%	18	424
2003	100%	59,781	4,832,777	0%	0	0	0	0%	3	76
2004	100%	65,751	5,844,031	0%	0	0	0	0%	2	59
2005	100%	86,903	8,039,211	0%	0	0	0	0%	3	81
2006	100%	103,055	10,092,547	0%	0	0	0	0%	5	144
2007	100%	128,610	12,929,139	0%	0	0	0	0%	11	328
2008	100%	125,543	13,361,675	0%	0	0	0	0%	60	1,794
2009	100%	116,809	12,395,606	0%	0	0	0	0%	18	572
2010	100%	158,274	16,020,574	0%	6	69	311	0%	86	2,863
2011	99%	175,648	19,479,572	0%	313	3,932	17,791	1%	1,076	37,957
2012	98%	282,481	31,367,919	1%	3,387	44,658	200,590	1%	1,526	56,296
2013	97%	378,095	42,683,040	2%	7,146	98,660	441,197	1%	5,433	209,483
2014	96%	402,992	47,862,257	3%	11,064	160,332	714,692	1%	6,227	251,167
2015	97%	518,113	63,218,662	2%	8,836	134,191	596,394	2%	9,879	417,410
2016	95%	553,278	69,108,331	2%	10,115	160,689	711,773	3%	16,817	738,736
2017	91%	604,853	79,402,357	4%	27,493	454,641	2,012,619	5%	33,194	1,524,212
2018	86%	555,971	75,960,952	4%	26,314	453,896	2,003,609	10%	61,332	2,941,765
2019	88%	505,059	71,135,364	3%	19,734	368,011	1,521,560	8%	47,387	2,378,873
2020	86%	424,894	60,588,792	4%	20,540	406,324	1,621,195	9%	46,181	2,435,627
2021	85%	528,088	76,514,975	4%	27,796	590,252	2,219,126	10%	63,072	3,464,139
2022	84%	629,123	92,802,888	5%	34,719	844,508	2,607,459	11%	80,947	4,626,137
2023	84%	652,013	97,885,688	5%	36,155	941,473	2,725,229	11%	88,223	5,242,684
2024	83%	670,253	102,369,934	5%	36,940	1,028,217	2,790,931	12%	95,619	5,905,793
2025	83%	697,118	108,259,056	5%	38,476	1,144,799	2,904,428	12%	102,891	6,603,088
2026	73%	631,610	99,631,257	5%	44,521	1,375,394	3,481,055	11%	93,356	6,216,252
2027	64%	568,332	92,994,289	6%	54,442	1,744,909	4,411,596	11%	97,957	6,763,472
2028	54%	494,755	83,840,288	7%	64,986	2,156,932	5,452,106	11%	103,726	7,417,910
2029	45%	419,506	73,385,206	8%	75,016	2,569,747	6,499,106	12%	107,741	7,961,945
2030	33%	279,755	50,380,703	9%	76,301	2,690,028	6,810,644	12%	101,252	7,716,317

Table A-87. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 4c in Calendar Year 2030

Model Year	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
1986	0%	0	0	0%	0	0	26	0.01	0.005
1987	0%	0	0	0%	0	0	32	0.02	0.006
1988	0%	0	0	0%	0	0	32	0.02	0.006
1989	0%	0	0	0%	0	0	42	0.02	0.008
1990	0%	0	0	0%	0	0	54	0.03	0.010
1991	0%	0	0	0%	0	0	66	0.03	0.01
1992	0%	0	0	0%	0	0	59	0.03	0.01
1993	0%	0	0	0%	0	0	62	0.03	0.01
1994	0%	0	0	0%	0	0	71	0.04	0.01
1995	0%	0	0	0%	0	0	94	0.05	0.02
1996	0%	0	0	0%	0	0	94	0.05	0.02
1997	0%	0	0	0%	0	0	124	0.06	0.02
1998	0%	0	0	0%	0	0	149	0.06	0.03
1999	0%	0	0	0%	0	0	169	0.05	0.03
2000	0%	0	0	0%	0	0	229	0.04	0.03
2001	0%	0	0	0%	0	0	263	0.04	0.03
2002	0%	0	0	0%	0	0	311	0.05	0.04
2003	0%	0	0	0%	0	0	396	0.05	0.04
2004	0%	0	0	0%	0	0	478	0.03	0.01
2005	0%	0	0	0%	0	0	658	0.03	0.02
2006	0%	0	0	0%	0	0	826	0.04	0.02
2007	0%	0	0	0%	0	0	1,059	0.05	0.03
2008	0%	0	0	0%	0	0	1,094	0.05	0.03
2009	0%	0	0	0%	0	0	1,015	0.04	0.03
2010	0%	0	0	0%	0	0	1,312	0.06	0.04
2011	0%	0	0	0%	0	0	1,596	0.06	0.05
2012	0%	0	0	0%	0	0	2,585	0.10	0.08
2013	0%	0	0	0%	0	0	3,531	0.13	0.11
2014	0%	0	0	0%	0	0	3,977	0.15	0.12
2015	0%	0	0	0%	0	0	5,225	0.19	0.16
2016	0%	0	0	0%	0	0	5,716	0.22	0.18
2017	0%	0	0	0%	0	0	6,666	0.24	0.20
2018	0%	0	0	0%	0	0	6,383	0.22	0.18
2019	0%	0	0	0%	0	0	5,949	0.19	0.17
2020	0%	0	0	0%	0	0	5,093	0.15	0.14
2021	0%	0	0	0%	0	0	6,446	0.18	0.18
2022	0%	0	0	0%	0	0	7,811	0.20	0.21
2023	0%	0	0	0%	0	0	8,237	0.19	0.21
2024	0%	0	0	0%	0	0	8,610	0.18	0.21
2025	0%	0	0	0%	0	0	9,101	0.16	0.20
2026	0%	0	0	11%	95,733	10,711,226	9,319	0.16	0.20
2027	0%	0	0	19%	167,287	19,415,503	9,564	0.15	0.19
2028	0%	0	0	28%	252,746	30,379,278	9,798	0.15	0.19
2029	0%	0	0	35%	329,972	40,942,951	9,892	0.15	0.18
2030	1%	8,477	610,675	45%	381,957	48,790,134	8,677	0.12	0.14

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-11) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-13. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fuel Consumption[3] (MJ of electricity/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of electricity/day)
1991	100%	14,887	496,519	0%	0	0	0	0%	0	0
1992	100%	12,386	437,879	0%	0	0	0	0%	0	0
1993	100%	12,876	454,610	0%	0	0	0	0%	2	20
1994	100%	13,908	519,028	0%	0	0	0	0%	0	3
1995	100%	17,011	673,579	0%	0	0	0	0%	1	11
1996	100%	15,726	662,566	0%	0	0	0	0%	0	0
1997	100%	19,249	841,793	0%	0	0	0	0%	3	36
1998	100%	21,231	962,917	0%	0	0	0	0%	2	32
1999	100%	21,841	1,026,080	0%	0	0	0	0%	2	27
2000	100%	26,428	1,326,406	0%	0	0	0	0%	0	7
2001	100%	26,524	1,412,096	0%	0	0	0	0%	2	30
2002	100%	27,790	1,574,561	0%	0	0	0	0%	11	189
2003	100%	30,887	1,866,413	0%	0	0	0	0%	2	31
2004	100%	31,459	2,100,346	0%	0	0	0	0%	1	22
2005	100%	38,743	2,705,815	0%	0	0	0	0%	1	29
2006	100%	43,503	3,231,279	0%	0	0	0	0%	2	47
2007	100%	51,445	3,941,697	0%	0	0	0	0%	4	103
2008	100%	48,196	3,931,397	0%	0	0	0	0%	23	522
2009	100%	43,832	3,583,029	0%	0	0	0	0%	7	170
2010	100%	59,373	4,651,159	0%	2	20	92	0%	32	847
2011	99%	67,186	5,797,667	0%	120	1,161	5,375	1%	409	11,360
2012	98%	112,410	9,761,699	1%	1,348	13,798	63,245	1%	603	17,549
2013	97%	158,581	14,066,520	2%	2,997	32,296	147,122	1%	2,255	68,707
2014	96%	180,829	16,955,018	3%	4,964	56,441	255,982	1%	2,764	88,302
2015	97%	248,911	24,094,495	2%	4,244	50,842	229,574	2%	4,701	157,841
2016	95%	285,862	28,441,636	2%	5,224	65,752	295,555	3%	8,578	300,098
2017	91%	332,615	34,903,768	4%	15,110	198,715	892,263	5%	18,042	661,811
2018	86%	327,985	35,952,376	4%	15,507	213,599	955,739	9%	35,779	1,376,403
2019	88%	314,542	35,673,840	3%	12,281	183,606	769,058	8%	29,273	1,183,116
2020	86%	281,575	32,424,569	4%	13,612	216,540	874,542	9%	30,604	1,303,564
2021	85%	366,087	42,975,928	4%	19,269	330,198	1,255,839	10%	43,723	1,945,314
2022	84%	459,912	55,139,274	5%	25,381	499,808	1,561,702	11%	59,175	2,747,832
2023	84%	491,823	60,167,945	5%	27,272	576,729	1,688,911	11%	66,548	3,223,016
2024	83%	528,134	65,889,598	5%	29,108	659,860	1,811,619	12%	75,344	3,803,598
2025	83%	560,849	71,323,875	5%	30,955	752,392	1,930,200	12%	82,779	4,355,000
2026	73%	525,019	67,990,583	5%	37,007	936,560	2,395,486	11%	77,601	4,248,646
2027	64%	483,597	65,138,911	6%	46,325	1,220,255	3,115,002	11%	83,353	4,746,114
2028	54%	429,894	60,215,445	7%	56,467	1,547,259	3,942,598	11%	90,128	5,333,845
2029	45%	371,964	54,158,389	8%	66,514	1,895,198	4,820,398	12%	95,531	5,873,508
2030	33%	284,628	43,042,917	9%	77,630	2,298,109	5,835,781	12%	103,016	6,575,282
2031	16%	142,274	22,335,072	10%	88,925	2,733,603	6,931,051	12%	110,651	7,327,824
2032	8%	72,935	11,876,559	11%	100,291	3,198,380	8,100,506	13%	118,007	8,103,104
2033	0%	0	0	12%	112,724	3,721,781	9,423,313	13%	126,280	8,978,806
2034	0%	0	0	13%	124,035	4,224,185	10,700,790	14%	133,034	9,766,730
2035	0%	0	0	14%	121,222	4,245,070	10,764,948	14%	125,060	9,456,182

Table A-88. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 4c in Calendar Year 2035
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
1991	0%	0	0	0%	0	0	41	0.02	0.008
1992	0%	0	0	0%	0	0	36	0.02	0.007
1993	0%	0	0	0%	0	0	37	0.02	0.007
1994	0%	0	0	0%	0	0	42	0.02	0.008
1995	0%	0	0	0%	0	0	55	0.03	0.01
1996	0%	0	0	0%	0	0	54	0.04	0.01
1997	0%	0	0	0%	0	0	69	0.04	0.01
1998	0%	0	0	0%	0	0	79	0.03	0.01
1999	0%	0	0	0%	0	0	84	0.03	0.01
2000	0%	0	0	0%	0	0	109	0.02	0.01
2001	0%	0	0	0%	0	0	116	0.02	0.01
2002	0%	0	0	0%	0	0	129	0.02	0.02
2003	0%	0	0	0%	0	0	153	0.02	0.02
2004	0%	0	0	0%	0	0	172	0.01	0.006
2005	0%	0	0	0%	0	0	222	0.01	0.007
2006	0%	0	0	0%	0	0	265	0.01	0.008
2007	0%	0	0	0%	0	0	323	0.02	0.01
2008	0%	0	0	0%	0	0	322	0.02	0.01
2009	0%	0	0	0%	0	0	293	0.01	0.010
2010	0%	0	0	0%	0	0	381	0.02	0.01
2011	0%	0	0	0%	0	0	475	0.02	0.02
2012	0%	0	0	0%	0	0	804	0.04	0.03
2013	0%	0	0	0%	0	0	1,164	0.05	0.04
2014	0%	0	0	0%	0	0	1,409	0.06	0.05
2015	0%	0	0	0%	0	0	1,991	0.08	0.07
2016	0%	0	0	0%	0	0	2,353	0.11	0.08
2017	0%	0	0	0%	0	0	2,931	0.12	0.10
2018	0%	0	0	0%	0	0	3,022	0.12	0.10
2019	0%	0	0	0%	0	0	2,984	0.11	0.10
2020	0%	0	0	0%	0	0	2,726	0.10	0.09
2021	0%	0	0	0%	0	0	3,621	0.12	0.12
2022	0%	0	0	0%	0	0	4,642	0.14	0.15
2023	0%	0	0	0%	0	0	5,064	0.14	0.16
2024	0%	0	0	0%	0	0	5,543	0.14	0.16
2025	0%	0	0	0%	0	0	5,997	0.13	0.17
2026	0%	0	0	11%	79,577	7,309,578	6,361	0.13	0.17
2027	0%	0	0	19%	142,346	13,599,811	6,702	0.13	0.17
2028	0%	0	0	28%	219,611	21,818,886	7,039	0.13	0.17
2029	0%	0	0	35%	292,577	30,215,957	7,303	0.13	0.17
2030	1%	8,625	521,732	45%	388,610	41,684,009	7,415	0.13	0.17
2031	2%	13,338	837,565	60%	534,022	59,463,907	7,265	0.13	0.16
2032	2%	18,234	1,187,656	66%	602,224	69,557,302	7,330	0.12	0.15
2033	3%	23,483	1,583,673	72%	676,837	80,940,453	7,398	0.12	0.14
2034	3%	28,622	1,991,487	70%	668,385	82,465,361	7,628	0.12	0.14
2035	4%	30,305	2,168,869	68%	589,257	74,782,771	7,004	0.11	0.12

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-14) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-16. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

Table A-89. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 4c in Calendar Year 2040
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fuel Consumption[3] (MJ of electricity/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of electricity/day)
1996	100%	13,224	407,390	0%	0	0	0	0%	0	0
1997	100%	15,957	507,603	0%	0	0	0	0%	2	27
1998	100%	17,428	573,388	0%	0	0	0	0%	2	23
1999	100%	17,981	612,358	0%	0	0	0	0%	2	19
2000	100%	21,212	772,196	0%	0	0	0	0%	0	5
2001	100%	20,869	808,569	0%	0	0	0	0%	1	19
2002	100%	20,957	866,980	0%	0	0	0	0%	8	114
2003	100%	22,226	985,080	0%	0	0	0	0%	1	18
2004	100%	21,228	1,041,890	0%	0	0	0	0%	1	12
2005	100%	24,808	1,278,892	0%	0	0	0	0%	1	16
2006	100%	25,795	1,417,856	0%	0	0	0	0%	1	22
2007	100%	28,657	1,630,516	0%	0	0	0	0%	2	44
2008	100%	24,894	1,513,071	0%	0	0	0	0%	12	206
2009	100%	20,958	1,283,229	0%	0	0	0	0%	3	64
2010	100%	26,447	1,559,497	0%	1	7	31	0%	15	295
2011	99%	28,341	1,849,619	0%	51	367	1,752	1%	172	3,720
2012	98%	44,963	2,967,860	1%	539	4,153	19,596	1%	240	5,433
2013	97%	60,869	4,125,844	2%	1,150	9,385	43,891	1%	858	20,372
2014	96%	67,874	4,888,299	3%	1,863	16,131	74,982	1%	1,028	25,649
2015	97%	93,376	6,979,373	2%	1,592	14,608	67,463	2%	1,750	45,992
2016	95%	109,366	8,447,742	2%	1,998	19,377	88,913	3%	3,230	88,645
2017	91%	132,055	10,809,831	4%	5,994	61,088	279,650	5%	7,052	203,451
2018	87%	137,285	11,794,487	4%	6,483	69,602	317,087	9%	14,800	449,301
2019	88%	141,083	12,595,274	3%	5,505	64,430	274,520	8%	13,018	416,452
2020	86%	135,652	12,343,563	4%	6,558	82,023	336,557	9%	14,744	498,290
2021	85%	189,590	17,659,856	4%	9,979	135,046	521,355	10%	22,644	801,678
2022	84%	253,809	24,240,958	5%	14,007	218,733	693,952	11%	32,657	1,210,322
2023	84%	291,017	28,467,215	5%	16,137	271,680	807,271	11%	39,377	1,526,695
2024	83%	329,600	32,998,938	5%	18,166	329,087	916,198	12%	47,021	1,906,128
2025	83%	371,783	38,066,268	5%	20,520	399,967	1,039,937	12%	54,873	2,325,226
2026	73%	364,065	38,085,431	5%	25,662	522,506	1,353,168	11%	53,811	2,380,112
2027	64%	353,606	38,594,551	6%	33,873	720,113	1,860,331	11%	60,947	2,812,115
2028	54%	324,333	36,908,576	7%	42,601	945,015	2,435,721	11%	67,997	3,270,853
2029	45%	293,135	34,757,798	8%	52,418	1,212,509	3,118,344	12%	75,286	3,773,157
2030	33%	229,029	28,278,038	9%	62,466	1,505,758	3,864,548	12%	82,893	4,325,829
2031	16%	118,284	15,198,602	10%	73,931	1,856,008	4,754,274	12%	91,993	4,995,176
2032	8%	62,086	8,297,894	11%	85,372	2,231,017	5,703,556	13%	100,453	5,672,249
2033	0%	0	0	12%	98,038	2,665,328	6,801,387	13%	109,828	6,445,628
2034	0%	0	0	13%	110,183	3,115,112	7,934,557	14%	118,177	7,205,918
2035	0%	0	0	14%	123,702	3,633,767	9,240,607	14%	127,619	8,079,263
2036	0%	0	0	15%	136,516	4,164,332	10,573,585	15%	136,000	8,934,507
2037	0%	0	0	16%	149,132	4,719,374	11,969,659	15%	143,943	9,805,502
2038	0%	0	0	17%	163,011	5,339,970	13,539,859	16%	152,878	10,781,757
2039	0%	0	0	18%	174,985	5,911,028	14,995,868	16%	159,852	11,635,052
2040	0%	0	0	19%	167,264	5,807,308	14,748,846	17%	149,158	11,174,023

Table A-89. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 4c in Calendar Year 2040
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
1996	0%	0	0	0%	0	0	33	0.02	0.007
1997	0%	0	0	0%	0	0	42	0.03	0.009
1998	0%	0	0	0%	0	0	47	0.02	0.009
1999	0%	0	0	0%	0	0	50	0.02	0.008
2000	0%	0	0	0%	0	0	63	0.01	0.009
2001	0%	0	0	0%	0	0	66	0.01	0.009
2002	0%	0	0	0%	0	0	71	0.01	0.009
2003	0%	0	0	0%	0	0	81	0.01	0.010
2004	0%	0	0	0%	0	0	85	0.007	0.003
2005	0%	0	0	0%	0	0	105	0.008	0.004
2006	0%	0	0	0%	0	0	116	0.007	0.004
2007	0%	0	0	0%	0	0	133	0.008	0.005
2008	0%	0	0	0%	0	0	124	0.007	0.004
2009	0%	0	0	0%	0	0	105	0.006	0.004
2010	0%	0	0	0%	0	0	128	0.007	0.005
2011	0%	0	0	0%	0	0	152	0.008	0.006
2012	0%	0	0	0%	0	0	245	0.01	0.009
2013	0%	0	0	0%	0	0	341	0.02	0.01
2014	0%	0	0	0%	0	0	406	0.02	0.02
2015	0%	0	0	0%	0	0	577	0.03	0.02
2016	0%	0	0	0%	0	0	699	0.04	0.03
2017	0%	0	0	0%	0	0	908	0.04	0.03
2018	0%	0	0	0%	0	0	992	0.05	0.04
2019	0%	0	0	0%	0	0	1,054	0.05	0.04
2020	0%	0	0	0%	0	0	1,038	0.04	0.04
2021	0%	0	0	0%	0	0	1,489	0.06	0.05
2022	0%	0	0	0%	0	0	2,041	0.07	0.07
2023	0%	0	0	0%	0	0	2,397	0.08	0.08
2024	0%	0	0	0%	0	0	2,777	0.08	0.10
2025	0%	0	0	0%	0	0	3,202	0.08	0.10
2026	0%	0	0	11%	55,181	4,094,515	3,564	0.09	0.11
2027	0%	0	0	19%	104,083	8,057,835	3,972	0.09	0.12
2028	0%	0	0	28%	165,686	13,373,712	4,316	0.10	0.13
2029	0%	0	0	35%	230,572	19,392,012	4,689	0.10	0.14
2030	1%	6,940	342,764	45%	312,699	27,385,272	4,874	0.11	0.14
2031	2%	11,089	569,948	60%	443,977	40,464,086	4,946	0.10	0.13
2032	2%	15,521	829,789	66%	512,639	48,598,179	5,125	0.11	0.13
2033	3%	20,424	1,135,449	72%	588,656	58,032,030	5,308	0.11	0.13
2034	3%	25,426	1,469,398	70%	593,742	60,846,186	5,631	0.11	0.13
2035	4%	30,924	1,856,231	68%	601,311	64,002,976	5,997	0.11	0.13
2036	4%	36,403	2,268,342	66%	601,159	66,424,848	6,304	0.12	0.13
2037	5%	41,942	2,710,805	64%	597,030	68,425,079	6,582	0.12	0.13
2038	5%	47,943	3,207,935	62%	595,027	70,600,721	6,889	0.12	0.13
2039	6%	53,466	3,690,215	60%	583,811	71,452,118	7,078	0.12	0.13
2040	6%	52,819	3,748,591	58%	511,073	64,318,157	6,473	0.11	0.11

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-17) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-19. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

Table A-90. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 4c in Calendar Year 2045
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Model Year	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fuel Consumption[3] (MJ of electricity/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of electricity/day)
2001	100%	17,581	492,838	0%	0	0	0	0%	1	13
2002	100%	17,396	519,815	0%	0	0	0	0%	7	79
2003	100%	18,261	584,063	0%	0	0	0	0%	1	12
2004	100%	17,485	620,429	0%	0	0	0	0%	1	8
2005	100%	19,931	744,101	0%	0	0	0	0%	1	11
2006	100%	20,294	810,536	0%	0	0	0	0%	1	13
2007	100%	21,610	895,705	0%	0	0	0	0%	2	26
2008	100%	17,913	797,202	0%	0	0	0	0%	8	112
2009	100%	14,142	635,358	0%	0	0	0	0%	2	35
2010	100%	16,923	735,246	0%	1	3	15	0%	9	147
2011	99%	16,799	809,857	0%	30	158	790	1%	101	1,691
2012	98%	25,037	1,225,371	1%	300	1,692	8,301	1%	133	2,322
2013	97%	31,446	1,584,333	2%	594	3,560	17,255	1%	442	8,105
2014	96%	32,442	1,745,658	3%	890	5,695	27,363	1%	489	9,437
2015	97%	41,547	2,333,580	2%	708	4,833	22,999	2%	777	15,810
2016	95%	46,072	2,687,564	2%	841	6,105	28,783	3%	1,354	28,787
2017	91%	52,700	3,274,039	4%	2,391	18,339	86,121	5%	2,789	62,457
2018	87%	52,549	3,444,774	4%	2,479	20,175	94,087	9%	5,607	132,466
2019	88%	52,919	3,622,227	3%	2,063	18,391	80,115	8%	4,832	120,601
2020	86%	51,080	3,577,777	4%	2,469	23,635	98,982	9%	5,552	146,669
2021	85%	72,808	5,249,034	4%	3,832	39,919	157,067	10%	8,696	241,288
2022	84%	101,322	7,527,271	5%	5,592	67,570	218,488	11%	13,037	379,660
2023	84%	122,476	9,364,450	5%	6,792	88,932	269,022	11%	16,572	506,226
2024	83%	148,333	11,660,897	5%	8,175	115,750	327,717	12%	21,161	677,755
2025	83%	179,162	14,468,745	5%	9,889	151,350	399,826	12%	26,443	887,822
2026	73%	188,593	15,626,267	5%	13,293	213,382	560,696	11%	27,875	979,732
2027	64%	195,188	16,940,600	6%	18,698	314,629	823,959	11%	33,642	1,237,162
2028	54%	191,955	17,435,060	7%	25,213	444,407	1,160,110	11%	40,244	1,547,489
2029	45%	182,978	17,379,767	8%	32,720	603,637	1,571,051	12%	46,994	1,888,561
2030	33%	151,854	15,069,157	9%	41,417	799,032	2,073,706	12%	54,961	2,306,853
2031	16%	82,041	8,500,426	10%	51,278	1,033,837	2,675,905	12%	63,806	2,794,484
2032	8%	45,406	4,908,616	11%	62,436	1,314,527	3,393,898	13%	73,465	3,355,569
2033	0%	0	0	12%	73,977	1,625,355	4,186,579	13%	82,874	3,945,769
2034	0%	0	0	13%	86,845	1,989,837	5,114,021	14%	93,146	4,620,214
2035	0%	0	0	14%	99,556	2,377,278	6,096,962	14%	102,708	5,304,658
2036	0%	0	0	15%	113,519	2,823,202	7,226,411	15%	113,089	6,078,593
2037	0%	0	0	16%	127,002	3,288,080	8,399,445	15%	122,582	6,853,300
2038	0%	0	0	17%	141,911	3,822,420	9,746,350	16%	133,090	7,734,893
2039	0%	0	0	18%	155,741	4,362,607	11,103,067	16%	142,272	8,592,249
2040	0%	0	0	19%	171,206	4,983,044	12,661,348	17%	152,673	9,574,300
2041	0%	0	0	21%	194,709	5,885,170	14,930,435	17%	161,732	10,526,066
2042	0%	0	0	23%	218,143	6,840,270	17,334,125	18%	170,183	11,485,753
2043	0%	0	0	25%	243,564	7,905,571	20,027,869	18%	179,686	12,554,052
2044	0%	0	0	27%	266,180	8,907,835	22,578,739	19%	186,753	13,462,578
2045	0%	0	0	29%	258,336	8,883,750	22,542,040	20%	182,113	13,505,452

Table A-90. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 4c in Calendar Year 2045
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Model Year	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
2001	0%	0	0	0%	0	0	40	0.01	0.006
2002	0%	0	0	0%	0	0	43	0.01	0.006
2003	0%	0	0	0%	0	0	48	0.01	0.006
2004	0%	0	0	0%	0	0	51	0.005	0.002
2005	0%	0	0	0%	0	0	61	0.005	0.002
2006	0%	0	0	0%	0	0	66	0.005	0.002
2007	0%	0	0	0%	0	0	73	0.005	0.003
2008	0%	0	0	0%	0	0	65	0.005	0.003
2009	0%	0	0	0%	0	0	52	0.003	0.002
2010	0%	0	0	0%	0	0	60	0.004	0.003
2011	0%	0	0	0%	0	0	66	0.004	0.003
2012	0%	0	0	0%	0	0	101	0.006	0.004
2013	0%	0	0	0%	0	0	131	0.008	0.006
2014	0%	0	0	0%	0	0	145	0.009	0.006
2015	0%	0	0	0%	0	0	193	0.01	0.008
2016	0%	0	0	0%	0	0	222	0.01	0.009
2017	0%	0	0	0%	0	0	275	0.02	0.01
2018	0%	0	0	0%	0	0	290	0.02	0.01
2019	0%	0	0	0%	0	0	303	0.02	0.01
2020	0%	0	0	0%	0	0	301	0.01	0.01
2021	0%	0	0	0%	0	0	443	0.02	0.02
2022	0%	0	0	0%	0	0	634	0.03	0.03
2023	0%	0	0	0%	0	0	789	0.03	0.03
2024	0%	0	0	0%	0	0	982	0.03	0.04
2025	0%	0	0	0%	0	0	1,217	0.04	0.04
2026	0%	0	0	11%	28,585	1,679,959	1,463	0.04	0.05
2027	0%	0	0	19%	57,453	3,536,887	1,744	0.05	0.06
2028	0%	0	0	28%	98,060	6,317,542	2,040	0.06	0.07
2029	0%	0	0	35%	143,926	9,696,491	2,345	0.06	0.08
2030	1%	4,602	182,656	45%	207,330	14,593,409	2,598	0.07	0.08
2031	2%	7,691	318,766	60%	307,941	22,631,158	2,768	0.07	0.09
2032	2%	11,351	490,862	66%	374,915	28,748,236	3,033	0.08	0.09
2033	3%	15,411	694,843	72%	444,190	35,512,951	3,250	0.08	0.10
2034	3%	20,040	941,479	70%	467,982	38,985,640	3,611	0.09	0.10
2035	4%	24,888	1,217,544	68%	483,939	41,981,025	3,936	0.09	0.11
2036	4%	30,271	1,541,123	66%	499,887	45,129,386	4,286	0.10	0.11
2037	5%	35,718	1,891,513	64%	508,433	47,744,836	4,597	0.10	0.12
2038	5%	41,737	2,298,544	62%	518,010	50,586,704	4,940	0.10	0.12
2039	6%	47,586	2,724,265	60%	519,604	52,748,816	5,228	0.11	0.12
2040	6%	54,063	3,214,741	58%	523,116	55,158,378	5,553	0.11	0.12
2041	7%	60,266	3,720,156	55%	510,456	55,875,571	5,797	0.11	0.12
2042	7%	66,390	4,250,840	52%	493,711	56,055,334	6,009	0.12	0.12
2043	8%	73,068	4,843,180	49%	477,919	56,173,405	6,239	0.12	0.12
2044	8%	78,867	5,391,525	46%	454,032	55,039,824	6,355	0.12	0.11
2045	9%	75,718	5,321,533	42%	374,633	46,689,015	5,668	0.11	0.10

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-20) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-22. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

Table A-91. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 4c in Calendar Year 2050
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

	Internal Combustion Engine Vehicle			Plug-in Hybrid Electric Vehicle				Battery Electric Vehicle		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	Fuel Consumption[3] (MJ of electricity/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of electricity/day)
2006	100%	17,095	495,171	0%	0	0	0	0%	1	9
2007	100%	17,938	537,342	0%	0	0	0	0%	2	18
2008	100%	14,711	473,301	0%	0	0	0	0%	6	73
2009	100%	11,643	378,435	0%	0	0	0	0%	2	24
2010	100%	13,584	427,686	0%	0	2	9	0%	8	94
2011	99%	13,206	463,001	0%	24	89	472	1%	79	1,039
2012	98%	18,883	674,484	1%	226	915	4,745	1%	100	1,368
2013	97%	22,656	836,306	2%	428	1,850	9,427	1%	314	4,504
2014	96%	21,908	865,904	3%	601	2,783	14,018	1%	326	4,894
2015	97%	26,586	1,101,721	2%	453	2,250	11,180	2%	491	7,761
2016	95%	27,295	1,177,776	2%	498	2,640	12,955	3%	790	13,009
2017	91%	29,325	1,351,831	4%	1,329	7,482	36,484	5%	1,525	26,393
2018	87%	27,113	1,322,228	4%	1,278	7,675	37,071	9%	2,868	52,384
2019	89%	25,304	1,294,975	3%	986	6,516	29,339	8%	2,292	44,244
2020	86%	22,760	1,198,129	4%	1,100	7,856	33,925	9%	2,474	50,596
2021	85%	30,740	1,673,570	4%	1,618	12,642	51,178	10%	3,671	78,995
2022	84%	40,577	2,287,454	5%	2,239	20,404	67,892	11%	5,221	118,112
2023	84%	47,100	2,747,369	5%	2,612	25,936	80,590	11%	6,373	151,554
2024	83%	55,817	3,364,077	5%	3,076	33,204	96,428	12%	7,963	198,997
2025	83%	67,473	4,197,128	5%	3,724	43,672	118,177	12%	9,959	261,533
2026	73%	72,435	4,648,637	5%	5,106	63,096	169,481	11%	10,706	295,109
2027	64%	77,932	5,265,063	6%	7,465	97,197	259,783	11%	13,432	388,383
2028	54%	80,799	5,740,711	7%	10,613	145,462	387,002	11%	16,940	513,531
2029	45%	82,363	6,147,303	8%	14,728	212,290	562,357	12%	21,153	672,043
2030	33%	73,193	5,733,398	9%	19,963	302,330	797,667	12%	26,491	881,507
2031	16%	42,508	3,491,042	10%	26,569	422,328	1,110,127	12%	33,060	1,150,817
2032	8%	25,069	2,156,590	11%	34,471	574,562	1,505,169	13%	40,561	1,476,533
2033	0%	0	0	12%	43,793	764,692	1,996,805	13%	49,059	1,866,872
2034	0%	0	0	13%	54,221	991,090	2,580,166	14%	58,155	2,312,330
2035	0%	0	0	14%	66,023	1,262,125	3,276,391	14%	68,113	2,828,333
2036	0%	0	0	15%	78,754	1,573,418	4,073,466	15%	78,456	3,400,494
2037	0%	0	0	16%	92,899	1,938,309	5,005,480	15%	89,666	4,054,250
2038	0%	0	0	17%	107,102	2,332,093	6,008,183	16%	100,445	4,735,158
2039	0%	0	0	18%	122,771	2,787,972	7,166,600	16%	112,154	5,509,269
2040	0%	0	0	19%	137,813	3,261,655	8,366,537	17%	122,895	6,287,011
2041	0%	0	0	21%	161,941	3,991,943	10,219,595	17%	134,514	7,162,592
2042	0%	0	0	23%	185,855	4,769,579	12,185,731	18%	144,994	8,031,750
2043	0%	0	0	25%	212,254	5,667,200	14,452,086	18%	156,587	9,018,092
2044	0%	0	0	27%	237,373	6,591,554	16,777,936	19%	166,542	9,968,351
2045	0%	0	0	29%	265,259	7,653,819	19,449,674	20%	186,993	11,623,187
2046	0%	0	0	31%	291,484	8,734,530	22,161,339	22%	206,327	13,312,214
2047	0%	0	0	33%	317,037	9,856,021	24,978,510	23%	225,225	15,070,796
2048	0%	0	0	35%	344,892	11,098,127	28,117,477	25%	245,793	17,025,566
2049	0%	0	0	37%	368,269	12,217,195	30,967,861	26%	263,197	18,805,200
2050	0%	0	0	39%	350,007	11,929,675	30,270,840	28%	250,779	18,424,345

Table A-91. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 4c in Calendar Year 2050

	Fuel Cell Electric Vehicle			Hybrid Electric Vehicle			Tailpipe Emission Estimates[4] (tons/day)		
Model Year	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of hydrogen/day)	Fleet Mix[1] (%)	Population[2] (vehicles)	Fuel Consumption[3] (MJ of gasoline/day)	CO_2	CH_4	N_2O
2006	0%	0	0	0%	0	0	41	0.004	0.002
2007	0%	0	0	0%	0	0	44	0.004	0.002
2008	0%	0	0	0%	0	0	39	0.003	0.002
2009	0%	0	0	0%	0	0	31	0.002	0.001
2010	0%	0	0	0%	0	0	35	0.003	0.002
2011	0%	0	0	0%	0	0	38	0.003	0.002
2012	0%	0	0	0%	0	0	56	0.004	0.003
2013	0%	0	0	0%	0	0	69	0.005	0.003
2014	0%	0	0	0%	0	0	72	0.005	0.003
2015	0%	0	0	0%	0	0	91	0.006	0.004
2016	0%	0	0	0%	0	0	97	0.007	0.005
2017	0%	0	0	0%	0	0	114	0.008	0.005
2018	0%	0	0	0%	0	0	111	0.007	0.005
2019	0%	0	0	0%	0	0	108	0.006	0.005
2020	0%	0	0	0%	0	0	101	0.006	0.004
2021	0%	0	0	0%	0	0	141	0.008	0.006
2022	0%	0	0	0%	0	0	193	0.009	0.009
2023	0%	0	0	0%	0	0	232	0.01	0.01
2024	0%	0	0	0%	0	0	283	0.01	0.01
2025	0%	0	0	0%	0	0	353	0.01	0.01
2026	0%	0	0	11%	10,979	499,769	435	0.01	0.02
2027	0%	0	0	19%	22,939	1,099,249	542	0.02	0.02
2028	0%	0	0	28%	41,276	2,080,130	672	0.02	0.03
2029	0%	0	0	35%	64,784	3,429,693	830	0.03	0.03
2030	1%	2,218	69,496	45%	99,932	5,552,389	989	0.03	0.04
2031	2%	3,985	130,914	60%	159,555	9,294,397	1,138	0.03	0.04
2032	2%	6,267	215,659	66%	206,994	12,630,474	1334	0.039	0.047
2033	3%	9,123	328,539	72%	262,949	16,791,411	1,538	0.04	0.05
2034	3%	12,512	471,192	70%	292,179	19,511,549	1,809	0.05	0.06
2035	4%	16,505	649,413	68%	320,935	22,391,802	2,102	0.06	0.07
2036	4%	21,000	862,736	66%	346,800	25,263,881	2,402	0.06	0.07
2037	5%	26,127	1,119,909	64%	371,908	28,268,312	2,724	0.07	0.08
2038	5%	31,500	1,407,816	62%	390,948	30,983,413	3,029	0.08	0.09
2039	6%	37,512	1,746,949	60%	409,607	33,825,447	3,356	0.08	0.09
2040	6%	43,519	2,110,460	58%	421,086	36,211,173	3,650	0.09	0.10
2041	7%	50,123	2,529,742	55%	424,551	37,995,927	3,948	0.09	0.10
2042	7%	56,563	2,969,544	52%	420,635	39,159,026	4,204	0.10	0.10
2043	8%	63,675	3,476,503	49%	416,483	40,322,062	4,484	0.10	0.11
2044	8%	70,331	3,991,911	46%	404,896	40,751,749	4,710	0.11	0.11
2045	9%	77,747	4,583,546	42%	384,672	40,214,217	4,885	0.11	0.11
2046	9%	84,623	5,179,312	38%	357,821	38,834,824	4,994	0.11	0.10
2047	10%	91,267	5,794,057	34%	327,175	36,831,648	5,061	0.11	0.10
2048	10%	98,539	6,475,841	30%	296,167	34,514,000	5,128	0.11	0.10
2049	11%	104,507	7,082,894	26%	259,335	31,167,115	5,087	0.11	0.09
2050	11%	98,719	6,877,273	22%	197,938	24,452,151	4,480	0.10	0.08

Notes:

[1] Fleet mix percentages for each alternative vehicle technology are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[2] Population in each model year is calculated based on the fleet mix percentages for each vehicle type and the total population in the EMFAC data. As described in Section 2 of the report, only ICEVs in the EMFAC2021 default fleet are replaced with other vehicle types as applicable in each scenario. Therefore, the existing population of PHEVs and BEVs in EMFAC2021 defaults serves as the minimum population of these vehicle technologies in all scenarios.

[3] Fuel consumption values are calculated based on fuel economies for each vehicle technology (obtained from Table A-23) and the daily average VMT per vehicle. Refer to Sections 3.1 and 3.3 of the report for additional details.

[4] Tailpipe emissions from vehicles in each model year shown here are calculated based on fuel consumption and emission factors for each vehicle technology shown in Table A-25. Reductions in tailpipe emission from the use of renewable drop-in fuels are accounted for separately.

[5] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CH_4 - methane
CO_2 - carbon dioxide
EMFAC - EMission FACtor Model
ICEV - internal combustion engine vehicle
MJ - megajoule
N_2O - nitrous oxide
PHEV - plug-in hybrid electric vehicle

Table A-92. GREET 2021 Model U.S. Electricity Grid Mix Inputs for Model Year 2026 Light Duty Autos

Country	Year	Overall Electricity Mix[1,2] (% per Energy Source)						Electricity Mix for the "Others" Energy Source in the Overall Electric Mix[1,3] (% per Energy Source)				
		Residual Oil	Natural Gas	Coal	Nuclear	Biomass	Others	Hydroelectric	Geothermal	Wind	Solar PV	Others
United States	2020	1%	41%	19%	20%	2%	18%	38%	2%	46%	12%	2%

Notes:

[1] Electricity mixes obtained from the USEPA's Emissions & Generation Resource Integrated Database (eGRID) 2020 summary data. Available online at: https://www.epa.gov/system/files/documents/2022-01/egrid2020_summary_tables.pdf. Accessed: May 2022.

[2] Electricity mix columns are based on available input fields in the GREET1 model of GREET2021. See 'Fuel_Prod_TS' tab, section 'Electric Generation Mixes'. Available at: https://greet.es.anl.gov/greet_excel_model.models. Accessed: May 2022.

[3] Renewable electricity mix columns are based on available input fields in the GREET1 model of GREET2021. See 'Fuel_Prod_TS' tab, section 'Shares of Technologies for Other Power Plants'. Available at: https://greet.es.anl.gov/greet_excel_model.models. Accessed: May 2022.

Abbreviations:

% - percentage
eGRID - Emissions & Generation Resource Integrated Database
GREET - Greenhouse Gases, Regulated Emissions, and Energy Use in Technologies Model
PV - photovoltaic
U.S. - United States
USEPA - United States Environmental Protection Agency

Table A-93. GREET 2021 Model International Electricity Grid Mix Inputs for Model Year 2026 Light Duty Autos

Country	Year	Electricity Mix[1,2] (% per Energy Source)						
		Petroleum	Natural Gas	Coal	Biomass	Nuclear	Hydroelectric	Others
Chile	2020	40%	14%	16%	21%	0%	5%	4%
South Africa for PGM Production	2019	16%	3%	72%	6%	2%	0%	1%
Australia	2020	32%	29%	30%	5%	0%	1%	3%
Brazil	2019	36%	11%	5%	32%	1%	12%	2%
Canada	2020	32%	38%	4%	5%	9%	11%	1%
China	2019	19%	7%	61%	4%	3%	3%	3%
Finland	2020	24%	7%	9%	32%	20%	5%	2%
Japan	2020	37%	24%	28%	4%	3%	2%	3%
New Caledonia[3]	2016	58%	0%	39%	0%	0%	2%	1%
Norway	2020	33%	15%	3%	6%	0%	40%	3%
Russia	2019	19%	54%	16%	1%	7%	2%	0%
Alberta[4]	2020	32%	38%	4%	5%	9%	11%	1%
Congo for Cobalt Production	2019	22%	25%	0%	50%	0%	2%	0%
Korea	2020	36%	18%	27%	3%	15%	0%	1%
Europe	2019	32%	26%	14%	9%	12%	3%	4%
Chile Grid for Lithium	2020	40%	14%	16%	21%	0%	5%	4%
Singapore	2019	70%	27%	1%	2%	0%	0%	0%
Indonesia	2019	31%	16%	29%	13%	0%	1%	10%

Notes:

[1] Electricity mixes obtained from most recent International Energy Agency (IEA) energy supply data for each region, unless otherwise noted. Available at: https://www.iea.org/countries. Accessed: May 2022.

[2] Electricity mix columns are based on available input fields in the GREET1 model of GREET2021. See 'Electric' tab. Available at: https://greet.es.anl.gov/greet_excel_model.models. Accessed: May 2022.

[3] New Caledonia electric mix obtained from International Renewable Energy Agency (IRENA) country profile data. Available at: https://islands.irena.org/-/media/Files/IRENA/Sids/CountryProfile/New-Caledonia_Oceania_RE_CP.ashx?la=en&hash=6E9BEE26AA69FD35630BE47B3628F4A780C0DD10. Accessed: May 2022.

[4] Alberta electricity mix is assumed to be equivalent to national Canadian electric grid mix.

Abbreviations:

% - percentage

GREET - Greenhouse Gases, Regulated Emissions, and Energy Use in Technologies Model

IEA - International Energy Agency

IRENA - International Renewable Energy Agency

PGM - platinum group metals

Table A-94. GREET 2021 Model Inputs for Model Year 2026 Light Duty Autos
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

GREET Input Parameter	Input for ICEV[1]	Input for HEV[1]	Input for BEV[1]	Input for PHEV[1]
Battery Chemistry	N/A	Ni-MH	Li-ion	Li-ion
Cathode Material[2]	N/A	N/A	NMC622	NMC111
Percent Recycled Battery Materials in Li-ion Battery (%)	N/A	N/A	0%	0%
Li-ion/Ni-MH Battery Replacement	N/A	0	0	0
Peak Battery Power (kW)	N/A	36	N/A	N/A
Peak Battery Energy[3,4] (kWh)	N/A	N/A	81	14
Battery Specific Power (W/kg)	N/A	800	N/A	N/A
Battery Specific Energy (Wh/kg)	N/A	N/A	241 Wh/kg	174 Wh/kg
Battery Production and Assembly Share by Country[5] (% by Country)	N/A	100% US	77% US 13% Japan 5% Korea 4% Europe 1% Other (China)	77% US 13% Japan 5% Korea 4% Europe 1% Other (China)
Battery Materials Production Share by Country (% by Country)	N/A	N/A	LiOH - 80% Ore-China/ 20% Brine-Chile Li_2CO_3 - 45% Brine-Chile/ 55% Ore-China	LiOH - 80% Ore-China/ 20% Brine-Chile Li_2CO_3 - 45% Brine-Chile/ 55% Ore-China
Energy Input of Battery Assembly	N/A	Ni-MH: 2.3 MMBtu/ton	Li-ion: 0.161 MMBtu/kWh	Li-ion: 0.161 MMBtu/kWh
Energy Use of Vehicle Assembly, Disposal, and Recycling[6]	GREET 2021 default	GREET 2021 default	GREET 2021 default	GREET 2021 default
Transportation Distance for Vehicle Materials[7]	GREET 2021 default	GREET 2021 default	GREET 2021 default	GREET 2021 default

Notes:

[1] GREET 2021 default inputs used unless otherwise noted. Non-default values are indicated by the shaded cells.

[2] For BEVs, a battery cathode material of NMC622 is assumed since this is the NMC ratio most commonly used in BEV batteries as of 2021 (Reference A). For PHEVs, there is no option for NMC622 in the GREET model, and so the GREET 2021 default battery chemistry of NMC111 is used.

[3] Peak battery energy for BEVs is calculated as a function of the minimum range from the draft ACC II regulation (200 miles, Reference B), fuel economy from EMFAC2021 (2.59 miles/kWh, Reference C), and the BEV battery SOC utilization from the October 2021 version of the CARB cost workbook (95%, Reference D). A newer version of the CARB cost workbook was released in late April 2022 (after completion of this analysis), which assumed a lower SOC utilization for BEV batteries of 92.5%. However, this does not change the overall conclusions of the analysis.

[4] Peak battery energy for PHEVs is calculated as a function of the minimum range from the draft ACC II regulation (40 miles for US06 cycle, Reference B), fuel economy from EMFAC2021 for electric vehicle miles travelled (3.31 miles/kWh, Reference C), and the PHEV battery SOC utilization from the October 2021 version of the CARB cost workbook (85%, Reference D). A newer version of the CARB cost workbook was released in late April 2022 (after completion of this analysis), which assumed a lower SOC utilization for PHEV batteries of 80%. However, this does not change the overall conclusions of the analysis.

[5] Li-ion battery production and assembly shares by country are based on BEV sales and production data for 2020 (Reference E, Figure A-60).

[6] Includes energy use for multiple vehicle processes including assembly, disposal, and recycling. Refer to tab "Vehi_Inputs" in the GREET 2021 model for further details.

[7] Includes distances for multiple modes of transport across various countries. Refer to tab "GREET2_Factors_T&D" in the GREET 2021 model for further details.

References:

[A] ICCT. 2021. "A global comparison of the life-cycle greenhouse gas emissions of combustion engine and electric passenger cars". July 20. Available at: https://theicct.org/publication/a-global-comparison-of-the-life-cycle-greenhouse-gas-emissions-of-combustion-engine-and-electric-passenger-cars/. Accessed: May 2022.

[B] CARB. 2022. Appendix A-5: Proposed Regulation Order for Section 1962.4 Zero-Emission Vehicle Standards for 2026 and Subsequent Model Year Passenger Cars and Light-Duty Trucks. April 12. Available at: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/accii/appa5.pdf. Accessed: May 2022.

[C] CARB. 2022. EMFAC2021 v1.0.1 Model. Available at: https://arb.ca.gov/emfac/emissions-inventory/. Accessed: January 2022.

[D] CARB. 2021. "ZEV Cost Modeling Workbook October 2021". Available at: https://ww2.arb.ca.gov/sites/default/files/2021-11/ZEV_Cost_Modeling_Workbook_Update_October2021.xlsx. Accessed: January 2022.

[E] Zhou, Yan, Gohlke, David, Rush, Luke, Kelly, Jarod, and Dai, Qiang. 2021. "Lithium-Ion Battery Supply Chain for E-Drive Vehicles in the United States: 2010–2020". Available at: https://www.osti.gov/biblio/1778934-lithium-ion-battery-supply-chain-drive-vehicles-united-states. Accessed: May 2022.

Abbreviations:

% - percentage
ACC - Advanced Clean Cars
BEV - battery electric vehicle
CARB - California Air Resources Board
EMFAC - EMission FACtors Model
GREET - Greenhouse Gases, Regulated Emissions, and Energy Use in Technologies Model
HEV - hybrid electric vehicle
ICCT - International Council on Clean Transportation
ICEV - internal combustion engine vehicle
kg - kilogram
kW - kilowatts
kWh - kilowatt-hours
LCA - life cycle assessment
Li - lithium
Li-ion - lithium-ion
LiOH - lithium hydroxide
Li_2CO_3 - lithium carbonate
Ni-MH - nickel metal hydride
MMBtu - Million British Thermal Units
MPGe - Miles per Gallon Equivalent
NMC - nickel manganese cobalt
PHEV - plug-in hybrid electric vehicle
SOC - state of charge
US - United States
VMT - Vehicle Miles Travelled
W - watt
Wh - watt-hour
ZEV - zero emission vehicle

Table A-95. Vehicle Cycle Emission Factors for Model Year 2026 Light-Duty Autos

Vehicle Life Cycle Stage	Vehicle Cycle GHG Emissions[1] (MT CO_2e / vehicle)			
	Internal Combustion Engine Vehicle	Hybrid Electric Vehicle	Battery Electric Vehicle	Plug-in Hybrid Electric Vehicle
Vehicle Material Production[2]	4.89	4.73	3.81	5.35
Vehicle Assembly[3]	0.69	0.69	0.69	0.69
Lead Acid Battery Assembly[4,5,6]	0.01	0.01	0.01	0.01
Lead Acid Battery Materials[4,5,6]	0.03	0.02	0.02	0.02
Ni-MH Battery Assembly[5]	N/A	0.01	N/A	N/A
Ni-MH Battery Materials[5]	N/A	0.31	N/A	N/A
Li-ion Battery Assembly[6]	N/A	N/A	1.14	0.20
Li-ion Battery Materials[6]	N/A	N/A	4.25	0.91
End of Life[7]	0.18	0.18	0.18	0.18
Total	**5.8**	**5.9**	**10.1**	**7.4**

Notes:

[1] Emissions are estimated using the Argonne National Laboratory (ANL) 2021 Greenhouse gases, Regulated Emissions, and Energy use in Technologies (GREET) Model. Available online at: https://greet.es.anl.gov/. Accessed: May 2022. Refer to Table A-94 for further details on GREET model inputs.

[2] Vehicle material production incorporates emissions associated with the production of vehicle components, fluids, and paints.

[3] Vehicle assembly incorporates emissions associated with vehicle painting, HVAC & lighting, heating, material handling, welding, and compressed air processes. GREET assumes equivalent emissions for vehicle assembly across all vehicle technologies.

[4] Battery materials and assembly for ICEVs incorporate emissions associated with the production and assembly of lead-acid batteries. The values presented in the table account for two lead-acid battery replacements over the vehicle lifetime, based on GREET default assumptions.

[5] Battery materials and assembly for HEVs are emissions associated with the production and assembly of both lead-acid and Ni-MH batteries. The values presented include two lead-acid battery replacements but no Ni-MH battery replacements over the vehicle lifetime, based on GREET default assumptions.

[6] Battery materials and assembly for BEVs and PHEVs are emissions associated with the production and assembly of both lead-acid and Li-ion batteries. The values presented include two lead-acid battery replacements but no Li-ion battery replacements over the vehicle lifetime, based on GREET default assumptions.

[7] End of life emissions are based on vehicle disposal and recycling, and exclude any emissions associated with lithium-ion battery disposal and recycling.

Abbreviations:

ANL - Argonne National Laboratory
BEV - battery electric vehicle
CO_2e - carbon dioxide equivalent
GHG - greenhouse gas
GREET - Greenhouse gases, Regulated Emissions, and Energy use in Technologies Model
HEV - hybrid electric vehicle
HVAC - heating, ventilation, and cooling
ICEV - internal combustion engine vehicle
Li-ion - lithium ion
MT - metric ton
Ni-MH - Nickel–metal hydride
N/A - not applicable
PHEV - plug-in hybrid electric vehicle

Table A-96. Estimating Vehicle Cycle Emissions for Scenario Analysis
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Scenario	Calendar Year	Model Year	Peak Vehicle Population[1]	Fleet Mix[2]				Vehicle Population for Each Vehicle Technology[3]				Vehicle Cycle Emissions[4] (MT CO_2e)				Total Vehicle Cycle Emissions for Calendar Year[5] (MT CO_2e)
				ICEV	HEV	PHEV	BEV	ICEV	HEV	PHEV	BEV	ICEV	HEV	PHEV	BEV	
S0 - ACC I	2026	2026	917,512	85%	0%	4%	11%	780,478	0	38,036	98,998	4,526,980	0	279,738	999,462	5,806,180
	2030	2030	936,884	84%	0%	4%	12%	787,505	0	37,480	111,899	4,567,739	0	275,646	1,129,709	5,973,094
	2035	2035	958,020	84%	0%	4%	12%	805,271	0	38,326	114,423	4,670,786	0	281,864	1,155,195	6,107,846
	2040	2040	975,203	84%	0%	4%	12%	819,714	0	39,013	116,476	4,754,561	0	286,920	1,175,915	6,217,395
	2045	2045	988,060	84%	0%	4%	12%	830,521	0	39,527	118,011	4,817,244	0	290,702	1,191,418	6,299,364
	2050	2050	996,489	84%	0%	4%	12%	837,607	0	39,865	119,018	4,858,342	0	293,182	1,201,582	6,353,107
S1a – ACC II (BEV)	2026	2026	917,512	65%	0%	4%	31%	596,383	0	38,036	283,093	3,459,180	0	279,738	2,858,047	6,596,964
	2030	2030	936,884	32%	0%	4%	64%	299,803	0	37,480	599,601	1,738,937	0	275,646	6,053,448	8,068,031
	2035	2035	958,020	0%	0%	4%	96%	0	0	38,326	919,694	0	0	281,864	9,285,043	9,566,907
	2040	2040	975,203	0%	0%	4%	96%	0	0	39,013	936,190	0	0	286,920	9,451,579	9,738,498
	2045	2045	988,060	0%	0%	4%	96%	0	0	39,527	948,533	0	0	290,702	9,576,186	9,866,888
	2050	2050	996,489	0%	0%	4%	96%	0	0	39,865	956,625	0	0	293,182	9,657,885	9,951,067
S1b – ACC II (BEV + PHEV)	2026	2026	917,512	65%	0%	7%	28%	596,383	0	64,226	256,903	3,459,180	0	472,347	2,593,643	6,525,171
	2030	2030	936,884	32%	0%	14%	54%	299,803	0	127,416	509,665	1,738,937	0	937,079	5,145,471	7,821,487
	2035	2035	958,020	0%	0%	20%	80%	0	0	191,604	766,416	0	0	1,409,146	7,737,576	9,146,722
	2040	2040	975,203	0%	0%	20%	80%	0	0	195,041	780,162	0	0	1,434,421	7,876,356	9,310,777
	2045	2045	988,060	0%	0%	20%	80%	0	0	197,612	790,448	0	0	1,453,332	7,980,196	9,433,528
	2050	2050	996,489	0%	0%	20%	80%	0	0	199,298	797,192	0	0	1,465,731	8,048,279	9,514,010
S2a – PHEV S2b – PHEV + Low-CI Gas	2026	2026	917,512	65%	0%	24%	11%	596,383	0	222,131	98,998	3,459,180	0	1,633,659	999,462	6,092,301
	2030	2030	936,884	32%	0%	56%	12%	299,803	0	525,182	111,899	1,738,937	0	3,862,438	1,129,709	6,731,084
	2035	2035	958,020	0%	0%	88%	12%	0	0	843,597	114,423	0	0	6,204,207	1,155,195	7,359,403
	2040	2040	975,203	0%	0%	88%	12%	0	0	858,727	116,476	0	0	6,315,485	1,175,915	7,491,400
	2045	2045	988,060	0%	0%	88%	12%	0	0	870,048	118,011	0	0	6,398,747	1,191,418	7,590,165
	2050	2050	996,489	0%	0%	88%	12%	0	0	877,471	119,018	0	0	6,453,338	1,201,582	7,654,920
S2c – HEV + Low-CI Gas	2026	2026	917,512	65%	20%	4%	11%	596,383	184,095	38,036	98,998	3,459,180	1,092,870	279,738	999,462	5,831,249
	2030	2030	936,884	32%	52%	4%	12%	299,803	487,702	37,480	111,899	1,738,937	2,895,216	275,646	1,129,709	6,039,508
	2035	2035	958,020	0%	84%	4%	12%	0	805,271	38,326	114,423	0	4,780,446	281,864	1,155,195	6,217,506
	2040	2040	975,203	0%	84%	4%	12%	0	819,714	39,013	116,476	0	4,866,188	286,920	1,175,915	6,329,022
	2045	2045	988,060	0%	84%	4%	12%	0	830,521	39,527	118,011	0	4,930,342	290,702	1,191,418	6,412,462
	2050	2050	996,489	0%	84%	4%	12%	0	837,607	39,865	119,018	0	4,972,405	293,182	1,201,582	6,467,170
S3a – Low-CI Gas S3a1 – Low-CI Gas (Upper Range) S3a2 – Low-CI Gas (Lower Range) S3b – Low-CI Gas (Delayed)	2026	2026	917,512	85%	0%	4%	11%	780,478	0	38,036	98,998	4,526,980	0	279,738	999,462	5,806,180
	2030	2030	936,884	84%	0%	4%	12%	787,505	0	37,480	111,899	4,567,739	0	275,646	1,129,709	5,973,094
	2035	2035	958,020	84%	0%	4%	12%	805,271	0	38,326	114,423	4,670,786	0	281,864	1,155,195	6,107,846
	2040	2040	975,203	84%	0%	4%	12%	819,714	0	39,013	116,476	4,754,561	0	286,920	1,175,915	6,217,395
	2045	2045	988,060	84%	0%	4%	12%	830,521	0	39,527	118,011	4,817,244	0	290,702	1,191,418	6,299,364
	2050	2050	996,489	84%	0%	4%	12%	837,607	0	39,865	119,018	4,858,342	0	293,182	1,201,582	6,353,107
S4a – Custom Fleet Mix 1	2026	2026	917,512	73%	11%	5%	11%	669,784	101,519	47,212	98,998	3,884,925	602,661	347,216	999,462	5,834,264
	2030	2030	936,884	33%	45%	9%	13%	309,172	422,120	84,324	121,268	1,793,279	2,505,893	620,160	1,224,295	6,143,627
	2035	2035	958,020	0%	68%	14%	18%	0	651,988	134,128	171,905	0	3,870,489	986,437	1,735,514	6,592,440
	2040	2040	975,203	0%	58%	19%	23%	0	566,162	185,293	223,748	0	3,360,986	1,362,735	2,258,914	6,982,635
	2045	2045	988,060	0%	42%	29%	29%	0	415,536	286,542	285,982	0	2,466,806	2,107,367	2,887,209	7,461,383
	2050	2050	996,489	0%	22%	39%	39%	0	219,783	388,636	388,070	0	1,304,731	2,858,211	3,917,876	8,080,819
S4b – Custom Fleet Mix 2	2026	2026	917,512	65%	20%	4%	11%	596,976	183,502	38,036	98,998	3,462,617	1,089,352	279,738	999,462	5,831,169
	2030	2030	936,884	31%	50%	7%	12%	290,956	468,442	65,587	111,899	1,687,625	2,780,880	482,354	1,129,709	6,080,569
	2035	2035	958,020	0%	80%	8%	12%	534	766,416	76,646	114,423	3,098	4,549,786	563,693	1,155,195	6,271,773
	2040	2040	975,203	0%	57%	20%	23%	0	556,409	195,045	223,748	0	3,303,094	1,434,456	2,258,914	6,996,463
	2045	2045	988,060	0%	23%	39%	38%	0	227,805	385,348	374,907	0	1,352,350	2,834,033	3,784,982	7,971,364
	2050	2050	996,489	0%	19%	39%	42%	0	189,889	388,636	417,965	0	1,127,263	2,858,211	4,219,687	8,205,161

Notes:

[1] Peak population for model year vehicle occurs in the calendar year subsequent to that model year. Since EMFAC2021 does not output fleet data for CY 2051, Ramboll estimated the peak population of MY 2050 vehicles (which would occur in CY 2051) by applying the percentage increase in MY 2049 vehicles from CY 2049 to CY 2050 to the MY 2050 vehicle population in CY 2050 Please see section 3.2.2 of the report for more details.

[2] Fleet mix for the calendar year and model year for each scenario were obtained from Tables A-26 to A-91.

[3] Estimated as a product of the fleet mix and peak vehicle population.

[4] Calculated as a product of the vehicle population for each vehicle technology type and the vehicle cycle emissions obatained from Table A-95.

[5] Calculated as a sum of the vehicle cycle emissions across all vehicle technology types.

Abbreviations:

ACC - Advanced Clean Cars
BEV - battery electric vehicle
CI - carbon intensity
CO_2e - carbon dioxide equivalent
HEV - hybrid electric vehicle
ICEV - internal combustion engine vehicle
MT - metric ton
PHEV - plug-in hybrid electric vehicle

Table A-97. Vehicle Cycle Emission Factors for Battery Replacement in BEVs

Vehicle Life Cycle Stage	Vehicle Cycle GHG Emissions for BEVs ($MT\ CO_2e$/vehicle)	
	Model Year 2026 to 2050 Vehicles[1]	Pre-2026 Model Year Vehicles[2]
Li-ion Battery Replacement	5.4	4.2

Notes:

[1]Calculated as a sum of Li-ion battery production and Li-ion battery assembly emissions for a model year 2026 BEV with a 81 kWh Li-ion battery, obtained from Table A-95.

[2] Estimated by scaling down the GHG emissions for Li-ion battery replacements in model year 2026-2050 BEVs by the ratio of the Li-ion battery size for MY Pre-2026 vehicles[3] (63 kWh) to the Li-ion battery size for MY 2026-2050 vehicles (81 kWh).

[3] A Li-ion battery size of 63 kWh was used for Pre-2026 model year BEVs. This value is calculated as a weighted average of the battery sizes and cumulative sales of various BEV models from 2010-2020 in the United States, which are detailed in the *Lithium-Ion Battery Supply Chain for E-Drive Vehicles in the United States 2010-2020* (available at: https://www.osti.gov/biblio/1778934-lithium-ion-battery-supply-chain-drive-vehicles-united-states, accessed: May 2022).

Abbreviations:

ANL - Argonne National Laboratory
BEV - battery electric vehicle
CO_2e - carbon dioxide equivalent
EMFAC - EMission FACtor Model
GREET - Greenhouse gases, Regulated Emissions, and Energy use in Technologies Model
GHG - greenhouse gas
kWh - kilowatt-hour
Li-ion - lithium ion
MT - metric ton
MY - model year

Table A-98. Estimating Battery Replacement Emissions for Battery Electric Vehicles in the Scenario Analysis
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Scenario	Calendar Year	Model Year[1]	Battery Electric Vehicle Population[2]	BEV Battery Replacement Emissions for Calendar Year[3] (MT CO_2e)
S0 - ACC I	2026	2017	43,901	183,990
	2030	2021	63,072	264,335
	2035	2026	77,601	418,146
	2040	2031	88,297	475,782
	2045	2036	90,386	487,040
	2050	2041	92,102	496,283
S1a – ACC II (BEV)	2026	2017	43,901	183,990
	2030	2021	63,072	264,335
	2035	2026	221,906	1,195,725
	2040	2031	532,274	2,868,120
	2045	2036	726,491	3,914,650
	2050	2041	740,279	3,988,946
S1b – ACC II (BEV + PHEV)	2026	2017	43,901	183,990
	2030	2021	63,072	264,335
	2035	2026	201,377	1,085,106
	2040	2031	449,479	2,421,985
	2045	2036	605,413	3,262,226
	2050	2041	616,903	3,324,139
S2a – PHEV S2b – PHEV + Low-CI Gas	2026	2017	43,901	183,990
	2030	2021	63,072	264,335
	2035	2026	77,601	418,146
	2040	2031	88,297	475,782
	2045	2036	90,386	487,040
	2050	2041	92,102	496,283
S2c – HEV + Low-CI Gas	2026	2017	43,901	183,990
	2030	2021	63,072	264,335
	2035	2026	77,601	418,146
	2040	2031	88,297	475,782
	2045	2036	90,386	487,040
	2050	2041	92,102	496,283
S3a – Low-CI Gas S3a1 – Low-CI Gas (Upper Range) S3a2 – Low-CI Gas (Lower Range) S3b – Low-CI Gas (Delayed)	2026	2017	43,901	183,990
	2030	2021	63,072	264,335
	2035	2026	77,601	418,146
	2040	2031	88,297	475,782
	2045	2036	90,386	487,040
	2050	2041	92,102	496,283
S4a – Custom Fleet Mix 1	2026	2017	43,901	183,990
	2030	2021	63,072	264,335
	2035	2026	77,601	418,146
	2040	2031	103,082	555,453
	2045	2036	143,360	772,485
	2050	2041	184,637	994,904
S4b – Custom Fleet Mix 2	2026	2017	43,901	183,990
	2030	2021	63,072	264,335
	2035	2026	77,601	418,146
	2040	2031	88,297	475,782
	2045	2036	143,360	772,485
	2050	2041	184,637	994,904

Notes:

[1] Battery replacement emissions are assumed to occur in the ninth year of the battery electric vehicle lifetime. See section 3.3.3 in the report for more details.

[2] Population of BEV for each respective model year that are still in the overall fleet in the respective calendar year. Please see Tables A-26 to A-91.

[3] Battery replacement emissions are estimated based on the GHG emission factor calculated in Table A-97.

Abbreviations:

ACC - Advanced Clean Cars
BEV - battery electric vehicle
CI - carbon intensity
CO_2e - carbon dioxide equivalent
FCEV - fuel cell electric vehicle
GHG - greenhouse gas
HEV - hybrid electric vehicle
ICEV - internal combustion engine vehicle
MT - metric ton
PHEV - plug-in hybrid electric vehicle

ATTACHMENT E

"Impact of the Advanced Clean Cars II (Internal Combustion Engine Ban) Regulation on California Businesses" by Capitol Matrix Consulting dated May 17, 2022

Date: May 17, 2022

To: Western States Petroleum Association

From: Brad Williams
Chief Economist
Capitol Matrix Consulting

Subject: Impact of the Advanced Clean Cars II (Internal Combustion Engine Ban) Regulation on California Businesses

This memo is in response to your request that we identify and discuss the impacts of the *Advanced Clean Cars II* (ACC II) regulatory proposal on California businesses**.** ACC II implements Governor Newsom's executive order N-79-20 with respect to the light-duty vehicle segment of the transportation market by curtailing and eventually banning sales of internal combustion engine powered passenger vehicles and trucks in California. As shown in Figure 1, the proposed regulation requires the zero-emission vehicles' (ZEV) share of new light-duty vehicle sales to rise from about 12 percent today to 26 percent by 2026, 61 percent by 2030, and 100 percent by 2035. A second set of provisions require more rigid emissions standards for new gasoline and diesel-powered internal combustion engine (ICE) vehicles sold during this transition period.

Figure 1
Key Provisions of the Advanced Clean Cars II (Internal Combustion Engine Ban) Proposed Regulation

Provision	Main Features
ZEV & PHEV Provisions	
Zero emission vehicle ("ZEV") and plug-in hybrid electric vehicle ("PHEV") percent sales requirement for light duty vehicles.	➢ Starts at 26% in 2026, rising to 61% by 2030 and 100% by 2035. ➢ Covers all major manufacturers (small manufacturers of custom cars subject to different rules).
Minimum technical requirements and assurance standards for vehicles to count toward standard.	➢ Includes minimum range, direct current (DC) charging capability, durability, and warranty requirements.
Environmental justice flexibilities.	➢ Provides enhanced ZEV sales credits for cars sold at discount or placed (after lease) with households in economically disadvantage communities.

Provision	Main Features
Provisions Affecting Internal Combustion Engine (ICE) Vehicles	
Prevent emission "backsliding" of remaining fleet.	➢ Requires that emissions standards apply to remaining ICE vehicles sold rather than whole fleet. (Otherwise, increased ZEV sales would allow for higher emissions in remaining ICE fleet.)
Reduce cold-start emissions from light-duty vehicles.	➢ Requires emissions tests and standards to be based on "real-world" laboratory conditions. ➢ This includes shorter warm-up period between start and initiation of driving.
Reduce emissions from driving.	➢ Lower the evaporative emissions cap. ➢ Control in-use emissions for medium-duty vehicles while towing. ➢ Lower fleet average caps for medium-duty fleets. ➢ Limit emissions from medium-duty vehicles under aggressive driving conditions.

Key Impacts of the ACC II Regulatory Proposal on Businesses

There are approximately 790,000 businesses operating in California, employing about 15.5 million workers. The ACC II regulation would have multiple effects on most of these businesses, as highlighted in Figure 2.

Figure 2
Key Effects of the ACC II (Internal Combustion Engine Ban) on California Businesses

Type of impact	Businesses Affected	Consequences
Higher ZEV prices	Those opting to purchase ZEVs.	➢ \$5,000 to \$8,000 price increase for small car in 2026. ➢ \$12,000 to \$16,000 price increase for pickup with towing capability in 2026. ➢ Offsetting future operational and fueling related savings are highly uncertain. ACC II SRIA estimates do not take into productivity losses.
Higher costs for ICE vehicles and petroleum-based fuels	Those continuing to purchase and use ICE vehicles	➢ Compliance with new emissions provisions – (\$80 to \$660 depending on type of vehicle). ➢ Fewer suppliers of replacement parts, potentially leading to higher prices. ➢ Phaseout of petroleum-based fuel supplies and retail outlets, leading to higher gasoline and diesel costs and fewer retail fueling options.

Type of impact	Businesses Affected	Consequences
Reduction in fuel tax revenues to state and local governments	All businesses	➢ $31 billion reduction in excise taxes between 2026 and 2040, resulting in: • Less maintenance and fewer road improvements. • More traffic. • Deterioration of roads. • Faster depreciation of vehicles. • Longer travel times and lost productivity.
Increase in utility rates to cover costs of electrification of transportation system.	All businesses	➢ Higher costs for heating, cooling, lighting, cooking, industrial boilers, and other equipment.
Greater exposure to electrical power disruptions	All businesses, but especially those converting to ZEVs	➢ Widespread loss of charging capabilities. ➢ Major disruptions to vehicle transportation.
Customer-related impacts	All businesses	➢ Loss of customer discretionary income tied to higher ZEV purchase prices, and lower demand in regions affected by phase-out of Oil & Gas (O&G) industry. ➢ Pressure for business-financed installation of charging outlets in parking facilities.

ACC II will have disparate impacts on small businesses. The impacts shown in Figure 2 will have different effects on small businesses throughout the state. Clearly, businesses with large vehicle fleets and significant travel requirements will be hit hard by the regulation. But other businesses will also bear disproportionate impacts. For example, businesses located in hot inland regions will be hit harder by rising electricity rates stemming from the regulation because of their higher electricity requirements for air conditioning and refrigeration as compared to their counterparts located on the coast. Also, contractors located in rural areas that purchase ZEVs – especially those needing to travel long distances – will face greater challenges than their urban counterparts in finding shared charging stations, especially during the transition period when the charging network has yet to be built out. Similarly, rural businesses that retain ICE vehicles and need to travel long distances will be hit particularly hard by rising gasoline costs and fewer fueling stations as petroleum supplies phase out.

In the following sections, we discuss each of the impacts identified in Figure 2 in greater detail.

Higher ZEV prices

Businesses purchasing ZEVs will face significantly higher purchase costs. Today, the incremental cost for a ZEV compared to an ICE vehicle with similar features, capabilities, and range is well over $10,000 for small vehicles, and well over $20,000 for high-end sedans, SUVs, and pickup trucks. [1]

[1] For example, a Hyundai Kona gasoline-powered vehicle has a base MSRP of approximately $22,500, compared to $34,000 for the EV version. The range for the EV is 258 miles, and the gasoline-powered vehicle is 462 miles. As another example, the Lariat extended range EV version of 2023 Ford F-150 pickup will have an MSRP of $79,000

The California Air Resources Board (CARB)-issued Standard Regulatory Impact Report (SRIA) for the ACC II proposed regulation assumes that the current price increments will diminish sharply between now and 2035, due to improved and simplified battery cell and pack designs, introduction of new battery chemistries, new manufacturing techniques, and economies of scale from increasing production volumes.

Even if the SRIA's optimistic assumptions are realized, however, price differentials will remain significant through 2035 for larger vehicles used by businesses, such as pickups and vans. For example, CARB estimates that the incremental manufacturing cost for a high-end battery-powered electric vehicle (EV) pickup with towing capacity will be $11,600 in 2026 and remain at $4,000 above a comparable ICE vehicle in 2035. The implication is that it will take many years of operational savings to offset the higher up-front incremental costs resulting from purchases of more expensive ZEVs.

CARB estimates of future ZEV price declines may be overstated. While it is reasonable to assume *some* reduction in ZEV prices as the market achieves scale and technological advances continue, recent trends suggest that the size of the reductions may be significantly less than assumed by CARB in the ACC II SRIA projections. The CARB projections are based on the assumption that battery costs, measured as dollars per kilowatt hours (kWh) of battery capacity, will decline steadily by 7 percent per year between 2020 and 2030, and by 5 percent annually between 2030 and 2035. However, battery prices are rising in 2022 due to sharp price increases for battery-related metals such as cobalt, nickel sulfate and lithium carbonate, and it is probable that these upward pricing pressures will continue for several years. Key factors pushing up battery prices are growing worldwide demand for battery-powered vehicles and supply constraints caused by long lead times needed to open new mines and strong resistance to new mining in the U.S. and other western countries.

As an illustration of the impact of slower price-declines in battery costs on future vehicle price differentials, if we (1) take into account the recent uptick in battery prices and (2) then assume that future price decline in battery costs from 2022 levels are one-half that assumed in the SRIA (i.e., 3.5 percent instead of 7 percent annually through 2030 and 2.5 percent instead of 5 percent annually between 2030 and 2035), the resulting incremental price for the EV pickup would be $16,000 in 2026 and nearly $10,000 in 2035.

It is important to note that these differentials reflect only manufacturing costs. The full price difference is magnified significantly when dealer markup, sales taxes, vehicle license fees, and financing costs are included. Also, the price increment does not consider the additional expense of on-site chargers, which can range from the high hundreds of dollars to several thousands of dollars for level-2 chargers, depending on whether electrical upgrades are needed. For rapid chargers, annual costs can easily exceed $75,000 for the charger and installation costs combined.

Future operational and refueling cost-savings are highly uncertain. According to estimates presented in the ACC II SRIA, higher upfront costs for ZEVs will be offset by lower costs for refueling and maintenance. However, in calculating the offsets, business owners will need to consider that (1) the operational savings will occur over many years, and (2) any prospective savings will be subject to uncertainties regarding both the future costs of electricity versus gasoline and future business conditions (which in turn will impact the usage of the newly purchased vehicle). From a business perspective, future savings related to operation and maintenance costs

---

(https://www.caranddriver.com/ford/f-150). This compares to $56,400 for the 2022 gas-powered version Lariat model with a V-8 engine. (https://www.caranddriver.com/ford/f-150-lightning) need to be discounted to reflect these uncertainties, making it even less likely that total costs of ownership over the lifetime of the ZEV vehicle will be comparable to the ICE vehicle counterpart. We also note that one of the key assumptions in the SRIA is that much charging will be accomplished through overnight charging on level 1 and level 2 chargers, which holds down prices per kilowatt hour.[2] This is a reasonable assumption for businesses that (1) have access to garages or storage facilities for overnight charging; and (2) use their vehicles at predictable times and on local routes. However, the assumption is less applicable to businesses that are reliant on public or private shared chargers, especially those that use vehicles for longer and more variable routes or operate their vehicles on a continuous schedule. These businesses will need to recharge "on the road," using more expensive rapid chargers, and hence will achieve relatively less fueling-related savings over time.

A closely related factor is that "time is money" for businesses. The added costs involved in planning and altering routes to match locations of public chargers, and the additional time spent recharging (up to 45 minutes for rapid charges and up to 8 hours for level 2 chargers, versus less than 5 minutes for gasoline vehicles), translates into lost productivity, higher expenses and lower revenues for these businesses.

Higher costs for ICE vehicles and petroleum-based fuels

Businesses that are unable (or unwilling) to incur the higher costs and lost productivity for ZEVs can purchase ICE vehicles through the 2026-to-2035 transition period, and all car owners can continue to drive light-duty vehicles after 2035, either by holding onto existing vehicles or purchasing ICE vehicles on the used-car market, Businesses that continue to use ICE vehicles will avoid costs associated with purchasing ZEVs. However, they will still face higher costs associated with continued purchases and operation of ICE vehicles under the ACC II regulation.

A relatively small portion of these higher costs are directly related to the ACC II regulatory proposal provisions focused on reducing emissions from ICE vehicles sold during the transition period. According to CARB calculations, these provisions will increase per-vehicle costs by $80 for light duty vehicles, and $660 for medium and heavy-duty vehicles sold in 2026.

However, the much larger impact relates to the phase-out of petroleum fuels and ICE vehicles that will result from the government-mandated shift to an all-ZEV market. According to Stillwater Associates (a transportation fuels consulting firm), the ACC II regulation will reduce gasoline sales by 66 percent by 2035, and by 90 percent by 2050. Stillwater also projects that diesel sales will fall by 34 percent by 2035 and by 60 percent by 2050. Declines of this magnitude will likely result in a major consolidation, and perhaps the entire elimination, of the petroleum refining industry in California, as well as an over 50 percent decline in retail fueling stations by 2035, and an 80 percent decline in fueling stations by 2050. Per-gallon petroleum fuel costs will rise, as the fixed costs related to the distribution and sales of gasoline are spread over fewer and fewer customers.

The CARB SRIA acknowledges the job and income-related impacts of declining O&G production, refining and distribution in California. However, the SRIA does not address the very important impact that the O&G declines will have on businesses that continue to rely on ICE vehicles. These vehicle operators will have to travel further and pay more to cover the increased per-gallon cost of

---

[2] In the ACC II SRIA, CARB specifically estimates that the "all in" cost of charging (including capital recovery of up-front investments) will be 24 cents per kilowatt hour (kWh) for public level 2 (L2) chargers, 25 cents/kWh for home charging, and 40 cents/kWH for direct current (DC) fast chargers.

gasoline and diesel as the oil and gas industry phases out, which will raise expenses and depress bottom-line earnings.

Deteriorating roads and more traffic

The reduction in gasoline and diesel sales will also result in a major decline in excise and sales taxes, which are major funding sources for California's transportation infrastructure. According to the CARB SRIA, total losses in excise and sales tax revenues on gasoline and diesel will be $41 billion over the 2026 through 2040 period, which will be only partially offset by $12 billion in new revenues from the $100 road improvement fee levied on ZEVs.

While the SRIA acknowledges the reduction in excise and sales taxes available for transportation infrastructure, it does not address the consequences of such a reduction, which would be severe. Absent the replacement of the gasoline excise tax with an alternative statewide funding source, the decline in gasoline sales will result in less maintenance, fewer road expansions, and fewer road improvements – all of which will lead to more traffic, longer travel times, faster vehicle depreciation, and, ultimately, reduced business productivity and earnings in the state.

Higher utility rates

Utilities will incur major *up-front* costs associated with installing an adequate-sized ZEV fueling network. According to the California Energy Commission's assessment of charging infrastructure needs outlined in its July 2021 report,[3] 1.2 million public and shared private chargers are needed to support almost 8 million ZEVs in 2030, which is consistent with the number that would be on the road under the Clean Cars II proposal. That is about 1 million more than the 193,000 chargers that are currently online or in planning stages throughout California. Charging needs will continue to expand sharply after 2030 to accommodate the growing fleet of ZEVs mandated by the ACC II proposed regulation.

Utilities will also incur major costs for upgrades to the electric grid needed to accommodate an all-electric transportation system. Based on annual data contained in the CARB 2021 study titled "2021 SB 100 Joint Agency Report" (SB 100 report), we estimate that full electrification of California's economy will require total utility investments of $1.8 trillion during the 30-year period from 2020 to 2050, about 50 percent above that required by a "business as usual" baseline. About 60 percent of the added costs relative to the baseline is directly attributable to upgrades needed to accommodate a fully electrified transportation system, with the balance needed to accommodate electrification of the commercial, industrial, and residential sectors of the economy.

Funding for additional chargers and grid upgrades has traditionally come from utility ratepayers (although in 2021-22 and 2022-23 the state has used surplus General Fund resources to support one-time commitments to charging subsidies). The projected funding needs imply substantial increases in electricity rates paid by businesses, which already pay rates that are among the highest in the U.S.

[3] California Energy Commission. "Assembly Bill 2127 Electric Vehicle Charging Infrastructure Assessment," July 2021. (https://www.energy.ca.gov/programs-and-topics/programs/electric-vehicle-charging-infrastructure-assessment-ab-2127)

This is demonstrated in Figure 3, which shows that the average electricity rate paid by commercial businesses in California was 19.29 cents per Kilowatt hour during February 2022. This was more than double the average paid by commercial businesses in neighboring states (Oregon, Washington, Arizona and Nevada) and about 64 percent above the national average. Rates paid by industrial users were also more than double those in neighboring rates and were about 87 percent above the national average.

Figure 3
Comparison of Electricity Rates
February 2022 (Cents per Kilowatt Hour)

Location	Residential	Commercial	Industrial
California	25.59	19.29	13.93
Neighboring States Average	11.96	9.43	6.26
U.S. Average	13.83	11.78	7.46

Further ratepayer increases will have substantial impacts on all California businesses, irrespective of their usage of electrical vehicles. This is because electricity is a major power source for lighting, heating, cooking, air conditioning, refrigeration, and for a variety of other appliances and machinery used by businesses.

Greater exposure to electrical power disruptions

Full electrification of the transportation system will put all ZEV owners, including businesses, at greater risk of electrical power disruptions. Such disruptions are due to unplanned shortages caused by such factors as (1) high demand and lower-than-expected generation from solar, wind, or hydroelectric power, and (2) planned power outages adopted by utilities in windy, hot and dry weather conditions to preempt the risks of their grids sparking major fires. The frequency of outages will likely rise in the future as the risk of major wildfires grows and the state shuts down natural gas and nuclear power plants over the next several years. Such outages will delay recharging, thereby disrupting travel plans and reducing business productivity.

Customer-related impacts

Finally, California businesses will face indirect customer-related effects from the proposed ACC II regulation. For example, higher costs for ZEVs will leave less room in household's budgets for purchases of other goods and services supplied by businesses. Those businesses operating in the Central Valley, Southern California and other regions significantly impacted by the phase-out of the O&G industry will face reduced demand for their product and services due to higher unemployment and weaker economic conditions. Retail businesses in all regions will face increased pressure to install chargers in parking lots and garages – at a significant cost – to attract and retain customers that are ZEV owners without access to overnight charging at home and thus in need of shared charging. While these costs could presumably be recovered through charging fees, the up-front investments may prove challenging to businesses without access to adequate cash-flows or credit to cover the up-front investment.

Impacts of Other Executive Order N-79-20 Provisions

As noted above, the ACC II regulatory proposal primarily implements the provisions in the Governor's EO N-79-20 relating to the light-duty vehicle segment of the market. However, it is important to note that the other provisions of executive order 79-20 affecting the medium- and heavy-duty vehicle segments will have even more serious impacts on California businesses. These provisions require that all medium- and heavy-duty drayage trucks on the road be ZEVs by 2035, and that all other medium- and heavy-duty vehicles on the road be ZEV by 2045.

The potentially major impacts arise because achieving the Governor's executive order will require large improvements in big-rig battery power and range capabilities relative to today's level – and even than the up-front incremental costs for vehicles and chargers will be substantial.[4] These higher costs will be reflected in higher shipping rates for virtually all major products, which will in turn drive up the wholesale price of goods in the state. Such cost increases will depress profits and put California businesses that sell products on national or regional markets at a competitive disadvantage against businesses operating in other states.

Conclusion

The ACC II regulation will have wide-ranging impacts on California businesses. Those purchasing ZEVs will face higher costs with no assurance that projected savings in future years will fully offset those costs. Those that continue to purchase and use ICE vehicles will face higher costs for fuel and spare parts as the market for ICE vehicles and petroleum-based fuels is phased out. Reductions in excise taxes and local sales taxes on gasoline will impair the ability of state and local governments to maintain and improve roadways, resulting in more traffic congestion, longer travel times, and added depreciation and repair costs. Businesses will also be affected by higher utility rates, and in some cases, falling demand from customers and pressures to make costly installations of charging facilities to attract customers requiring shared charging during the day. Many of these impacts will have disproportionate effects on small businesses located in hotter inland regions and rural regions of the state. While some of the impacts are covered in the ACC II SRIA, many are not, and should be fully vetted before the regulation is finalized.

[4] For example, the estimates made by the energy consulting firm E3 in October 2020 (summarized in a report titled "Achieving Carbon Neutrality in California") assumed that a battery-powered EV version of a Class 8 tractor would be $170,748 and a fuel cell powered version would be $190,155, compared $130,000 for a diesel-powered vehicle. The CARB report issued in 2018 titled "Deep Decarbonization in a Highly Renewables Future," found that incremental costs associated with decarbonizing the medium and heavy-duty transportation were among the highest of all solutions they considered. Finally, in its analysis released in March 2021 titled "Proposed Rule 2305 – Warehouse Indirect Source Rule – Warehouse Actions and Investments to Reduce Emissions (WAIRE) Program and Proposed Rule 316 – Fees for Rule 2305," the South Coast Air Quality Management District estimated that chargers for Class 7 or 8 big-rigs will cost as much as $140,000 to purchase and $80,000 to install.

ATTACHMENT F
"Distributional Impacts of the Advanced Clean Cars II (Internal Combustion Engine Ban) Regulator Proposal" by Capitol Matrix Consulting dated May 26, 2022

Date: May 26, 2022

To: Western States Petroleum Association

From: Brad Williams
Chief Economist
Capitol Matrix Consulting

Subject: Distributional Impacts of the Advanced Clean Cars II (Internal Combustion Engine Ban) Regulatory Proposal

This memo is in response to your request that we evaluate the impact of the proposed Advanced Clean Cars II (ACC II) regulation on lower and moderate-income households. As discussed in my previous memos, the ACC II proposed regulation would phase out sales of internal combustion engine (ICE) vehicle sales in California over the 2026-2025 period, requiring that all passenger vehicles requiring sold in the state be zero emissions vehicles (ZEVs) by 2035.[1] The proposed regulation would also impose more stringent emission standards on ICE vehicles sold during the 2026-2025 transition period.

While California Air Resources Board's (CARB) Standardized Regulatory Impact Assessment (SRIA) addresses many of the aggregate impacts of the proposed regulation, it does not cover distributional impacts in any meaningful way. We believe this is a major omission, especially for a proposal that is as far-reaching as the ACC II regulation. The mandated phase-out and eventual ban of ICE vehicles will have substantial distributional impacts in California, disproportionately affecting those at the lower end of the state's income spectrum. This is significant because income inequality is already a major issue in California, a state that has extreme wealth and income at the top end, but also a large number of families that are struggling to make ends meet due to limited resources and the high cost of living in the state.[2] According to data from the *U.S. Consumer Expenditure Survey* for California, the bottom 60 percent of families in California (approximately 8.6 million) spend virtually all of their income each year.[3] Similarly, data from the Federal Reserve on U.S. consumer finances finds that the bottom 60 percent of the U.S.

---

[1] In this memo, ZEVs refer to battery-powered electric vehicles (BEVs), hydrogen powered fuel cell electric vehicles (FCEVs) and, during the 2026-2035 ramp up period, some plug-in hybrid electric vehicles (PHEVs). Most of the references in this memo refer to BEVs, however, as they are assumed in the CARB SRIA to comprise the great majority of ZEVs during the projection period. This partly reflects their more favorable economics relative to FCEVs and PHEVs.

[2] For example, the Public Policy Institute of California reported that 17.6 percent of Californians were in poverty (as measured by the Supplemental Poverty Measure, which takes into account housing costs), and another 17 percent had incomes that were within 50 percent of the poverty line. See "Poverty in California," Public Policy Institute of California. Accessed May 28, 2021. https://www.ppic.org/publication/poverty-in-California.

[3] U.S. Bureau of Labor Statistics, *Consumer Expenditures Surveys, California: Quintiles of income before taxes, 2018-19.* https://www.bls.gov/cex/tables/geographic/mean/cu-state-ca-income-quintiles-before-taxes-2-year-average-2019.htm.)

income distribution have a median of just $2,400 in their combined checking and savings accounts.[4] Together, these data indicate that over one-half of California's households are living paycheck-to-paycheck and likely have little if any room for unexpected expenses.

Workers in the lower- and middle-income tiers have struggled for decades with lagging wages and job losses in industries such as manufacturing and mining that have historically been the source of good salaries and benefits for workers with high-school degrees and technical skills.[5]

Impacts of Proposal on Low- and Moderate-Income Households

The ACC II regulation would have multiple impacts on low- and moderate-income households. As highlighted in **Figure 1** (next page), those families that purchase new battery-powered electric vehicles (BEVs) would have to pay much more for these vehicles. Lower-income BEV owners would likely pay more for electricity to charge their vehicles than their higher-income counterparts that have access to overnight charging. Those that stay with ICE vehicles will also pay higher prices for gasoline and repairs. Lower- and moderate-income households will be hard-hit by regressive increases in utility rates to cover costs of electrifying the transportation system. And lower- and moderate-income households would be negatively affected by the loss of good-paying job opportunities as a result of the regulation's impact on traditional energy jobs. In the following sections we discuss these impacts in more detail.

Higher Purchase Prices for BEVs

Currently, the incremental cost for a BEV compared to an ICE vehicle with similar features, capabilities, and range is $12,000 or more for small passenger vehicles, and well over $20,000 for high-end sedans, SUVs, and pickup trucks.[6] (The price differences for fuel cell hydrogen vehicles are even greater.) The California Air Resources Board (CARB) Standard Regulatory Impact Report (SRIA) for the ACC II proposed regulation assumes that this difference will fall by over 50 percent between 2020 and 2026 – and further in subsequent years – due to improved and simplified battery cell and pack designs, introduction of new battery chemistries, new manufacturing techniques, and economies of scale.

Unfortunately, recent trends are moving in the opposite direction. Price differentials between BEV and comparable ICE vehicles are expanding rather than contracting for several models in 2022 due to strong demand and soaring costs for battery metals such as cobalt, nickel sulfate and lithium carbonate. These increases are not expected to ease for several years as worldwide demand for battery-powered vehicles grows and battery supplies are constrained by supply shortages, long lead times needed to open new mines, and strong resistance to new mining in the U.S. and other western countries.

---

[4] Board of Governors of the Federal Reserve System, *Survey of Consumer Finances.* https://www.federalreserve.gov/econres/scfindex.htm

[5] Between 1990 and 2019 California lost just under one-third of its manufacturing base. The loss between 1990 and 2021 was 35 percent. See California Employment Development Department, Labor Market Information Division. https://www.labormarketinfo.edd.ca.gov/data/employment-by-industry.html

[6] For example, a Hyundai Kona gasoline-powered vehicle has a base MSRP of approximately $22,500, compared to $34,000 for the EV version. The range for the EV is 258 miles, and the gasoline-powered vehicle is 462 miles. As another example, the Lariat extended range EV version of the 2023 Ford F-150 pickup will have an MSRP of $79,000 (https://www.caranddriver.com/ford/f-150). This compares to $56,400 for the 2022 gas-powered version of the Lariat model with a V-8 engine. (https://www.caranddriver.com/ford/f-150-lightning)

Figure 1
Key Effects of the ACC II (Internal Combustion Engine Ban) on Low- and Moderate-Income Households

Type of Impact	Comments
Higher costs for BEV purchases.	➢ BEV models of small passenger cars are currently at least $12,000 more than comparable ICE models. ➢ CARB assumes price differential will fall by more than one-half by 2026, but current trends are toward a widening, rather than narrowing, gap. ➢ Financing higher-priced cars – if even possible - will have a disproportionate impact on lower-income owners, due to higher credit costs. ➢ Insurance, sales tax, and vehicle fees add to increase.
Higher costs for charging.	➢ CARB asserts that higher up-front costs will be more than offset over time by lower fuel and maintenance costs. ➢ However, the magnitude of fuel-related cost-savings is highly dependent on both the extent of future BEV price declines and the access to home charging. ➢ Low-income BEV owners living in older high-density multi-family dwellings are less likely to have access to home charging. ➢ Therefore, low-income BEV owners will likely have to rely on more-expensive direct charging, making it less likely that their operational savings will be sufficient to offset higher BEV prices.
Higher prices for petroleum-based fuels, and repairs of ICE vehicles.	➢ Will impact lower-income owners that that can't afford EVs and continue to use ICE vehicles. ➢ Causes: ▪ Phase-out of petroleum-based fuel supplies and retail outlets, leading to higher gasoline prices and fewer retail fueling options. ▪ Fewer suppliers of replacement parts, putting upward pressure on prices.
Increase in utility rates to cover costs of electrification of transportation system.	➢ Utility rate increases are regressive, hitting budgets of lower-income households the hardest. ➢ Low-income households also less able to avoid higher utility costs through investments in rooftop solar. ➢ Disproportionate impacts on households in hotter inland regions of the state, which have lower median household incomes and higher energy needs.
Phase-out of petroleum industry.	➢ Will result in major declines in good-paying jobs with benefits that have been available to workers with high-school diplomas. ➢ Industry reductions will also affect workers in building and trades that work on major refinery maintenance projects. ➢ Bottom line – fewer opportunities for good paying jobs and upward mobility.

In short, there is no assurance that price differentials will narrow as much as assumed in the ACC II regulation SRIA, yet there is no provision in the regulation that would alter the phase-out period for ICE vehicles if the economics were less favorable than assumed.

While price differentials of $10,000 (or more) for a small vehicle may be only a moderate inconvenience for those at the top of California's income distribution, the incremental price will have major impacts on lower- and moderate-income households in the state. As noted above, these households are much more likely to have limited or non-existent liquid savings and virtually no room in their budgets to finance more-expensive BEV purchases.

Of particular concern is that low-income owners attempting to cover the higher costs through increased borrowing will face higher financing charges due to poorer loan-to-value and loan-to-income ratios. The impacts will be especially significant for younger households with limited credit histories or those with weaker credit scores. As an indication of how significant additional financing costs can be, financing an additional $10,000 to cover the incremental price of a BEV would cost low-income owners $15,660 over the life of a 7-year loan.[7] Beyond the direct costs, these households also will have to pay more for insurance, sales taxes, and annual vehicle fees.

Higher Costs for Charging

The SRIA asserts that the higher incremental purchase price paid for a BEV will be offset by reductions in fuel and maintenance costs. This is illustrated in **Figure 2**, which is extracted from the SRIA report, and is based on CARB's assumptions of rapidly falling BEV prices.

Figure 2
ACC II SRIA Estimate: Total Cost of Ownership of Small BEV vs. ICE Vehicle (Assumes 10-Year Ownership and 5-Year Financing Period Beginning in 2026)

Cost/Savings	BEV With 300 Mile Range	
	With Home Charger	No Home Charger
Costs		
Incremental vehicle price	$4,936	$4,936
Home Level 2 Charger	$680	--
Incremental Finance Costs (including sales tax)	$1,185	$1,042
Incremental Insurance Costs	$1,003	$1,003
Incremental Registration	$806	$806
Savings		
Incremental fuel savings	-$4,871	-$2,912
Incremental Maintenance Savings	-$4,540	-$4,540
Total Cost of Ownership (10 years)	**-$1,732**	**-$484**

[7] This incremental financing cost is based on the following assumptions: (1) price of EV version is $33,000 versus $23,000 for the ICE version; (2) 10 percent down payment and sales tax are included in the loan, (3) interest rate of 5 percent on the ICE vehicle but 8 percent for the more expensive EV vehicle because of deterioration in various financial metrics, such as debt-service to income ratio.

Figure 2 specifically shows CARB's estimated total cost of ownership over the 10-year life of a small passenger vehicle purchased in 2026. It shows that – for an owner with access to overnight charging – the projected savings from lower fuel and maintenance expenses more than offsets the higher upfront costs for the car and charger, yielding a net savings of $1,732 over the life of the vehicle. For an owner <u>without</u> access to a home charger, there is still a net savings, but it is much less – $484 over the life of the vehicle. The lower net savings occurs because this owner would have to rely on more expensive electricity from shared direct-current chargers.

Again, it is important to note that the net reduction in total ownership costs is highly dependent on CARB's assumption that relative prices of BEVs will fall sharply from today's levels. At current price differentials, total costs of ownership would be several thousand dollars higher for BEV owners with chargers – and even more for BEV owners without home chargers.

Regardless of the bottom-line costs or savings, however, the key takeaway from **Figure 2** is the much lower total cost of ownership for owners having access to chargers as compared to owners that do not. This is important because:

- Lower income households are *more likely* to be renters (according to the 2018-19 Consumer Expenditure Survey for California, about 56 percent of the bottom 60 percent of households are renters, versus 22 percent of the top 20 percent of households); and

- Renters living in older high density multi-family dwellings are *less likely* to have garages or other points of access to inexpensive overnight charging.

Those that have access to overnight charging will pay much less per charge than those that are required rapid chargers during peak hours of the day. The SRIA recognizes a significant difference in charging costs, by assuming average home charging rates of $0.26/kWh versus rapid charging rates of $0.40/kWh. It is because of this difference that CARB shows the lower cost of ownership in **Figure 2** for those with home chargers. We note that the actual difference is likely to be even larger than shown in **Figure 2**, given the recent outsized increases in rapid charging rates. For example, current rates for Tesla superchargers during daytime hours are 0.58/kWh.

Higher Costs for ICE Vehicles and Petroleum-Based Fuels

Low- and moderate-income households that cannot afford the higher upfront costs for BEVs can purchase ICE vehicles during the 2026-to-2035 transition period. And they can avoid BEV purchases beyond 2035 by holding on to their aging ICE vehicle or purchasing ICE vehicles on the used-car market. These individuals will avoid costs associated with purchasing BEVs. However, they will still face higher costs associated with continued maintenance and operation of ICE vehicles under the ACC II regulation. A small portion of these higher costs are directly related to the ACC II regulatory proposal provisions focused on reducing emissions from ICE vehicles sold during the transition period. However, the great majority of the impact is related to the phase-out of the markets for petroleum fuels and ICE vehicles as the government-mandated ban on new ICE vehicle sales takes hold.

CARB estimates that a 2035 ban on ICE vehicle sales will reduce gasoline sales in California by 66 percent by 2035, and by 90 percent by 2050. Declines of this magnitude will likely result in a major consolidation, and perhaps the entire elimination, of the petroleum refining industry in California. Recent estimates made by Stillwater Associates (a transportation consulting firm) indicate that gasoline sales declines of these magnitudes will lead to an over 50 percent drop in retail fueling stations by 2035, and an 80 percent decline in fueling stations by 2050. A key result of this decline is that per-gallon gasoline prices will rise significantly, as the fixed costs related to the distribution and sales of gasoline are spread over fewer and fewer customers. The rise in fixed costs per-gallon sold, combined with higher expenses related to the Low-Carbon-Fuel-Standard and Cap and Trade programs, will add $1.70 to the price per gallon by 2035, and $4.27 to the price per gallon by 2050. All projections as to possible future costs of transportation fuels are only projections, and the actual costs will be determined by fuels market dynamics such as supply and demand.

Any higher costs will have a major impact on lower-income households, which are the most likely to hold onto ICE vehicles in the face of higher costs for BEV's.[8] If we assume (1) the average vehicle is driven 12,500 per year in this state; and (2) the average mileage of California's light passenger fleet will be about 25 miles per gallon by 2030 – the cost per household of a $1.70 per gallon price increase is about **$1,275 per year**. If we further assume that the fleetwide mileage rate increases to 29 miles per gallon by 2050, the $4.27 per gallon increase in that year would translate into **$2,815 per year**. These cost increases are particularly significant in view of the extremely tight budgets and limited liquid savings held by low- and moderate-income households in this state.

Increases in Utility Costs

To accommodate an all-electric transportation system, utilities and state and local governments will need to incur major up-front costs associated with installing a BEV-charging network that has sufficient capacity in all areas of California to avoid fueling bottlenecks and give prospective BEV owners confidence that they will be able to complete longer trips, regardless of destination. According to the California Energy Commission's assessment of charging infrastructure needs released in its July 2021[9] report, 1.2 million public and shared private chargers are needed to support almost 8 million BEVs in 2030, which is consistent with the number that would be on the road under the Clean Cars II proposal. That is about 1 million more than the 193,000 chargers that are online or in planning stages throughout California. We estimate that another 1 million chargers would be needed by 2035 to fully support the number of BEVs on the road under the ACC II regulation. A key finding of the CEC report is that more public funding will be needed, starting immediately, to achieve even the 2030 goals.

Beyond the costs of chargers, the state will incur expenses for developing additional power generation and upgrading its electrical grid. In March 2021, the California Energy Commission (CEC), CARB, and California Public Utilities Commission (CPUC) jointly issued an updated analysis on California's progress toward its zero carbon electricity goals.[10] The report indicated that under a "high electrification scenario," which is consistent with the Governor's ZEV goals, electricity demand from the state's transportation sector will grow from 3,000 Gigawatt-hours in 2020 to an estimated 81,000 Gigawatt-

[8] According to the 2018-19 Consumer Expenditure Survey for California, 70 percent of households in bottom 20 percent of household income own or lease at least one car. The rate for households in the 20-40th percentile is 88 percent, and in the 40-60 percentile its 94 percent.
[9] California Energy Commission. "Assembly Bill 2127 Electric Vehicle Charging Infrastructure Assessment," July 2021. https://www.energy.ca.gov/programs-and-topics/programs/electric-vehicle-charging-infrastructure-assessment-ab-2127
[10] SB 100 Joint Agency Report: Charting a path to a 100% Clean Energy Future. March 15, 2021. https://www.energy.ca.gov/publications/2021/2021-sb-100-joint-agency-report-achieving-100-percent-clean-electricity

hours in 2045. Expanding the grid to accommodate those and related needs will require record build rates for utility-scale solar and other power sources.

Combined costs for light vehicle chargers and upgrades to the grid will be in the multiple tens of billions of dollars. Funding for these types of capital improvements has traditionally come primarily from California utility ratepayers, which already face among the highest and fastest rising rates in the U.S. (see **Figure 3**).

Figure 3
Comparison of Electricity Rates
February 2021 and February 2022 (Cents per Kilowatt Hour)

Location	February 2021	February 2022	% Increase: 2021 to 2022
California	22.53	25.59	13.6%
Neighboring States' Average	11.17	11.96	7.1%
U.S. Average	13.35	13.83	3.6%

Higher utility rates will disproportionately affect lower- and moderate-income households mainly because these households devote a much larger share of their annual income to electricity consumption than do their higher-income counterparts. According to the 2018-19 *Consumer Expenditure*, households in the bottom 20 percent of California's income distribution devoted 7.7 percent of their income to electricity purchases in the 2018-19 period. This percentage is ten times more than the 0.7 percent that their counterparts in the top 20 percent of the income distribution devoted to electricity purchases. This difference occurs because the average income of the top 20 percent of households ($237,713) is 19 times that of the bottom 20 percent of households ($12,460), yet electricity consumption by this top group is less than double the size of the bottom group. The relatively small difference in consumption rates reflects the fact that electricity is a necessity, used by all households regardless of income to keep the lights on and appliances working.

Two other factors are also behind the disproportionate impact. First, lower-income households are less likely to be homeowners, and thus less likely to benefit from rooftop solar systems that would otherwise enable them to avoid higher utility costs, at least partially. Second, lower-income households tend to be located in inland regions of the state, where temperatures are hotter and cooling needs are greater. As shown in **Figure 4** (next page), average per-household consumption of electricity in the state's inland counties is nearly double that of counties in the Bay Area, and about one-third higher than Southern California coastal counties. At the same time, median incomes in these inland counties are about 50 percent lower than the Bay Area counties and about 25 percent lower than the Southern California coastal counties. Similarly, poverty rates in the inland counties are, on average, nearly double that of the Bay Area counties, and about 50 percent higher than the Southern California coastal counties.

In summary, higher utility costs resulting from electrification of the transportation system will disproportionately affect low-income households, especially those in inland regions of the state where electricity consumption is much higher than in coastal counties. Because low- and moderate-income families will likely be later adopters of ZEVs, they will also pay higher utility rates without receiving the benefit of avoided gasoline expenses.

Figure 4
Median Household Income and Electricity Consumption – 2019*

Counties	Median Household Income	Poverty Rate	Average Annual Household Electricity Consumption (kWh)
Bay Area Counties			
Marin	$110,843	6.0%	2,512
San Francisco	$135,968	10.0%	4,077
San Mateo	$138,500	5.5%	5,844
Santa Clara	$133,076	6.6%	6,270
South Coast Counties			
Los Angeles	$72,797	13.2%	6,211
Orange	$107,171	9.0%	6,703
San Diego	$85,507	9.5%	5,813
Inland Counties			
Kern	$53,057	18.3%	8,597
San Bernardino	$67,903	14.3%	8,321
Fresno	$57,518	17.1%	8,929
San Joaquin	$68,997	13.9%	8,099
Stanislaus	$63,057	13.0%	10,286
Sacramento	$82,121	12.5%	8,610

* Sources: U.S. Census Bureau (for median household income) and the California Energy Commission (for residential electricity consumption).

Fewer Job Opportunities

CARB estimates that the ACC II regulatory proposal will reduce employment by 60,084 jobs in 2030, 86,929 in 2034, and 93,117 jobs by 2038. CARB attributes the employment losses to the impact of higher ZEV prices on consumer spending on other goods and services in California's economy, as well as the reduction in state and local revenues on employment in the public sector.

We believe that the job losses, though significant, are understated, in that they fail to consider the likely impact of an ICE ban on California's petroleum industry. CARB's estimate shows only a 1,536 decline in jobs related to the petroleum refining industry by 2040, a reduction of about 15 percent from current levels. Absent a shift in refining activities to hydrogen or biofuels, we would expect a rapid phase-out of gasoline-powered vehicles to due to lower demand, resulting in a rise in unit costs of production and forcing more rapid consolidations and more job losses in the refinery industry. Reductions in this industry would have major consequences for the broader economy due to the hundreds of millions of dollars spent by refineries each year for major maintenance and modernization investments. Consolidations in the refinery industry will affect multiple thousands of workers employed in supplying industries. These include construction workers and electricians, many of them in trade unions, working on refinery turnaround projects.[11] The losses in petroleum and construction industries are of particular importance because of their negative impacts on job opportunities that are so important to upward mobility of workers in this state with high-school diplomas and technical training.

Conclusion

The ACC II regulatory proposal will have a disproportionate impact on low- and moderate- income households, whose budgets are already stretched because of many years of lagging income growth and California's high cost-of-living. The disproportionate impacts are related to higher BEV prices (which are amplified because of financing costs), relatively higher charging costs, higher utility-related electricity costs, and (for those that defer purchases of BEVs) higher costs for petroleum-based fuels. Lower- and moderate-income households will also be disproportionately affected by the reduction in jobs in the construction and petroleum industries, which will mean fewer good-paying jobs opportunities for workers with high school and technical degrees. While the state budgets enacted in 2021-22 and proposed for 2022-23 begin to address some of these issues, the ACC II SRIA is largely silent on the disproportionate impacts that the ACC II regulation would have on millions of lower-income Californians.

[11] Turnaround work includes major maintenance, upgrades, and modernization of refineries.

American
Fuel & Petrochemical
Manufacturers

1800 M Street, NW
Suite 900 North
Washington, DC
20036

202.457.0480 office
202.457.0486 fax
afpm.org

July 5, 2023

Administrator Michael Regan
Environmental Protection Agency
EPA Docket Center, OAR Docket
Mail Code 28221T
1200 Pennsylvania Avenue NW
Washington, DC 20460

Attention: Docket ID No EPA-HQ-OAR-2022-0829
Submitted to the Federal eRulemaking Portal (www.regulations.gov)

Re: EPA-HQ-OAR-2022-0829, Notice of Proposed Rulemaking: Multi-Pollutant Emissions Standards for Model Year 2027 and Later Light-Duty and Medium-Duty Vehicles

Dear Administrator Regan,

On May 5, 2023, the U.S. Environmental Protection Agency ("EPA" or "Agency") proposed multi-pollutant emissions standards for model years ("MY") 2027 and later for light-duty and medium-duty vehicles (the "Proposed Rule" or "Proposal").[1] "Despite the significant emissions reductions achieved by [previous] rulemakings,"[2] EPA is revisiting the existing regulatory regime to mandate unrealistic emissions standards that are only achievable through an exponential growth in sales of zero-emission vehicles ("ZEVs"). The American Fuel & Petrochemical Manufacturers ("AFPM") supports improving motor vehicle efficiency and reducing transportation-related emissions, but we cannot support EPA's unlawful attempt to ban internal combustion engine vehicles ("ICEV") and limit consumer choice. Disturbingly, the Proposal provides little to no discernable regard for alternative technologies, consumer preferences, feasibility, cost, the impact on U.S. energy and national security interests, or the very real environmental trade-offs associated with an effective ban on new ICEVs nor does the Proposed Rule encourage informed input from the public, as evidenced by the arbitrary 60-day comment period spanning two federal holidays for a rule more than 250 pages in length supported by a 280-page Draft Regulatory Impact Analysis ("DRIA").

EPA's Proposed Rule fails to take a comprehensive view of all available technologies and their associated environmental impacts. The proposal conspicuously omits any discussion of technology to reduce the carbon intensity of liquid fuels, and in fact does not even use the words "biofuels" or "renewable fuels" a single time. Instead, the Proposal forces automotive electrification in a manner that both exceeds EPA's statutory authority and employs arbitrary and capricious decision-making. There are better, lawful ways to reduce transportation-related emissions that do not ban entire vehicle powertrains or sacrifice our hard-earned energy independence.

AFPM represents the U.S. refining, petrochemical, and midstream industries. In addition to actively pursuing emissions reductions from their operations, our members are increasingly

[1] 88 Fed. Reg. 29,184 (May 5, 2023).
[2] *Id.* at 29,186.

investing in renewable fuels such as ethanol, renewable gasoline, renewable diesel, and sustainable aviation fuel. We are committed to sustainably manufacturing and delivering affordable and reliable fuels that power our transportation needs and enable our nation to thrive. Importantly, the U.S. refining and petrochemical industries are critical assets for U.S. energy and national security, a fact which EPA insufficiently considers. AFPM does not oppose expanding consumer choice to include electric vehicles ("EVs") as part of a diverse transportation future that will require more energy to sustain a growing global population. What we oppose is limiting consumer choice. The Proposed Rule does so by abandoning technology-neutral standards and intentionally setting tailpipe emissions standards unachievable by well-controlled ICEVs. Consequently, the only choice for consumers in the future will be government-mandated ZEVs. ZEVs are not the only means to reduce carbon and criteria pollutant emissions from the transportation sector, particularly when consumer costs are considered. A cost-effective, technology-neutral approach, built upon a full lifecycle analysis (LCA), would achieve better outcomes for consumers, U.S. energy and national security, and the environment.

EPA's regulatory cost-benefit analysis is grossly deficient, having overstated the environmental benefits by ignoring emissions that this rule will cause and understating known costs where those factors undermined the pre-determined outcome of mandatory electrification. EPA's biased analysis is pervasive throughout the proposal, rising to the level of arbitrary and capricious rulemaking. We discuss this deficiency in greater detail in Section IV, infra.

EXECUTIVE SUMMARY

EPA proposed unachievable standards for light- and medium-duty ICEVs. This attempt to force an unprecedented transformation of the national transportation system to ZEVs goes far beyond the authority delegated to the Agency by Congress. The Proposal—which will likely require hundreds of billions of dollars, dictate what vehicles are permissible for automakers to sell, and has significant ramifications for the U.S. energy sector, national security, and consumers—clearly addresses questions of major economic and political significance that EPA is neither authorized nor equipped to address.

EPA also misinterprets its authority to establish feasible efficiency improvements by proposing standards that cannot be achieved with ICEV technologies. First, EPA is not permitted to rely on averaging, banking, and trading mechanisms as a means to establish the relevant standards. Second, because ZEVs do not have tailpipe emissions, they do not directly "cause or contribute to" air pollution within the construct of a tailpipe emissions standard, and therefore any standard applicable to "any class or classes" of vehicles "which . . . cause, or contribute" to air pollution cannot include ZEVs.

Even if EPA had Congressional authority to promulgate the proposed standards, the proposal is arbitrary and capricious due to the Agency's reliance on incomplete facts, overly optimistic or outright mistaken assumptions, and failure to use reason-based decision-making. The Agency significantly overestimates environmental benefits and feasibility, underestimates costs, and relies on little more than unsupported hope that consumer preferences will change to enable the Agency's intended policy. EPA's decision to not only ignore lifecycle emissions of ZEVs, but to explicitly propose removing the requirement for automakers to account for them, serves neither consumers nor the environment. EPA's reasoning, that its policy of not accounting for these emissions serves its goal of promoting the use of EVs, is the definition of arbitrary and capricious biased decision-making. Unfortunately, the Agency also ignored significant issues related to energy security and U.S. national security.

The Proposed Rule requires increased reliance on imported critical minerals and metals for battery production and grid expansion that could have serious negative consequences for our energy and national security. The supply chain for key minerals needed to produce electric vehicle batteries is not assured and will require dramatic increases to meet expected demand. The extraction and processing of battery critical minerals is concentrated in politically unstable or unfriendly nations. Domestic copper and aluminum smelting capacity is insufficient to meet grid expansion needs, and new mines can take over a decade to increase domestic supply. The deployment timeline necessary to develop new resources for batteries and the grid is impracticable and presents unnecessary risks to our energy and economic security. In contrast, domestically consumed liquid fuels sourced from petroleum and bio feedstocks are largely sourced in North America, and the U.S. benefits from its position as a net exporter of petroleum and refined product exports.

There is significant doubt that the U.S. electric grid can reliably support the proposal. Demand for electric vehicle charging will place significant stress on generation, transmission, distribution, and consumer charging systems, that are unlikely to meet increased demand in such a short timeframe. EPA should better assess grid impacts from a regional basis, particularly in the Southwest where the grid is already under significant stress.

The purported benefits in terms of reductions in cost, greenhouse gas emissions, and environmental impacts are based on flawed analyses and will not be realized by consumers. EPA's tailpipe-only approach is flawed, and the Agency needs to evaluate light- and medium-duty vehicles on a full lifecycle basis, regardless of whether those emissions result from electricity generation, battery production, or the combustion of liquid or gaseous fuels. Consumer benefits from the proposal are exaggerated by assuming an unrealistic baseline rate of ZEV-adoption, and inadequate assessments of ZEV purchase and ownership costs, charging costs, and road infrastructure costs.

EPA also failed to provide a meaningful opportunity for public comment by limiting the comment period to 60 days, denying requests form AFPM and other stakeholders to extend the comment period, and concurrently proposing heavy-duty standards and other significant rulemakings related to vehicle electrification, fuels, and electricity generation. Significant time is required to read and respond to the voluminous material in each rulemaking docket, particularly given EPA's evident lack of rigor in its analysis, and lack of discipline in citing and characterizing underlying sources.

Despite EPA's assertions that the standards are technology-neutral, the reality is the proposed tailpipe-only approach is a *de facto* ban on ICEVs. AFPM does not oppose electric vehicles comprising an increasing share of the transportation mix, but we oppose regulations that are framed to ultimately ban ICEVs. EPA should establish standards, based on the full lifecycle of each vehicle class, that are achievable by each powertrain technology. ICEVs will continue to have a place in a diverse transportation future. This approach was summarized well in a 2021 report from the National Academies of Science:

> Internal combustion engines (ICEs) will continue to play a significant role in the new vehicle fleet in MY 2025–2035 in ICE-only vehicles, as well as in hybrid electric vehicles (HEVs) from mild hybrids to plug-in hybrids but will decrease in number with

> increasing battery electric vehicle (BEV) and fuel cell electric vehicle penetration. In this period, manufacturers will continue to develop and deploy technologies to further improve the efficiency of conventional powertrains, for ICE-only vehicles and as implemented in HEVs. Developments in the ICE for hybrids will advance toward engines optimized for a limited range of engine operating conditions, with associated efficiency benefits. Major automakers are on differing paths, with some focusing their research and development and advanced technology deployment more squarely on BEVs, and others more focused on advanced HEVs to maximize ICE efficiency.[6]

I. EPA's Proposal Does Not Comprehensively Address Cross-Cutting Issues

EPA's desire to remake the automotive sector creates significant energy and national security concerns and stresses an aging electrical grid subject to increasing demand. In glossing over these issues, EPA fails to adequately consider the mineral, metal, electricity generation, transmission, distribution, and charging infrastructure requirements necessary for the Proposed Rule to be feasible. This is alarming and undermines our energy security. We lack the supply of domestically sourced minerals and metals needed to build batteries and transmission lines and, contrary to the legislative intent of U.S. laws such as the Bipartisan Infrastructure Law ("BIL") and Inflation Reduction Act ("IRA"), we will have to rely on foreign countries to fulfill the Proposed Rule's mandate.

Even if we could import vast quantities of mineral resources, EPA's electrification mandate is unobtainable. We face a limited supply of copper, which is a critical mineral needed to build out the transmission grid to supply electricity to charging stations. We also do not have near the vehicle charging infrastructure necessary to power the mandated number of ZEVs. Rather than conducting a clear-eyed assessment of these challenges, EPA erroneously assumes that all the necessary conditions to enable its proposal will happen on its aggressive timeline. This conclusion dismisses or outright ignores a multitude of evidence to the contrary.

A. The Proposal Compromises Energy and National Security

1. Inadequate Minerals for Batteries Will Make Original Equipment Manufacturers ("OEMs") Dependent on Foreign Suppliers and Make it Difficult to Supply Electric Vehicles Required by this Proposal

The Russian invasion of Ukraine highlights the importance of assessing, planning, and mitigating risks to energy supplies. As we have seen with Europe, a strategy of supply diversification (e.g., increasing imports from a diverse pool of suppliers) is an important way to mitigate global supply disruptions.[3] The key tenet of risk mitigation is not about removing the likelihood of a risk but about reducing its impact to an acceptable level—the primary justification for the U.S. holding a Strategic Petroleum Reserve. The U.S. similarly holds a national defense commodity-based stockpile meant to decrease or prevent "dependence upon foreign and single

---

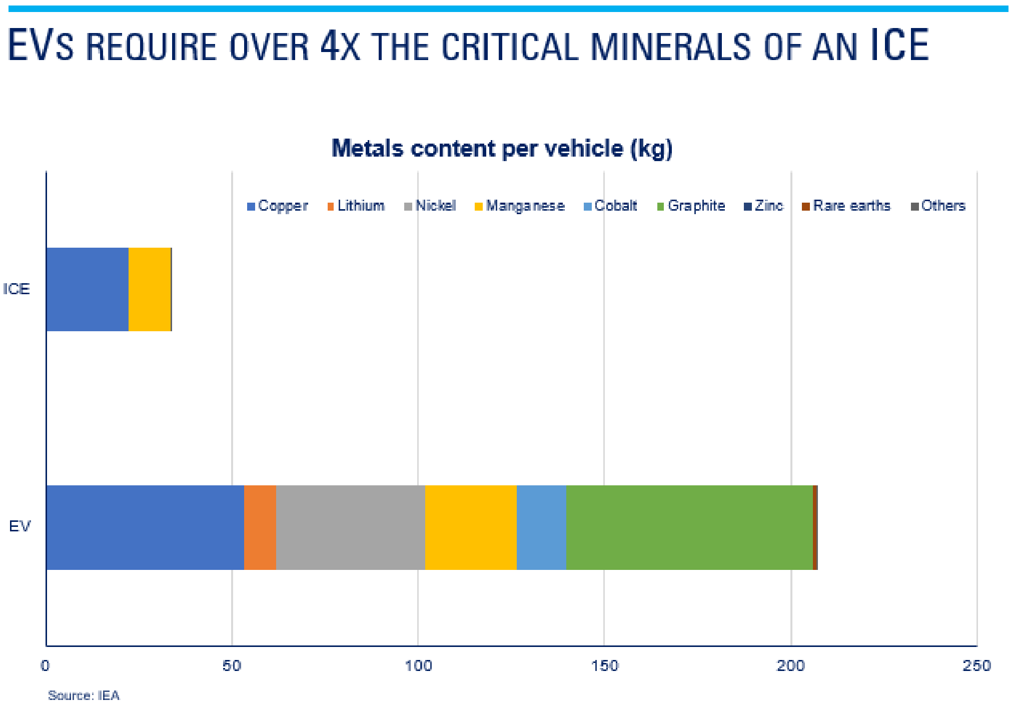
[3] "Europe's Reliance on Diverse Pool of LNG Sources Continues Year after Ukraine Invasion." Natural Gas Intelligence, 22 Feb. 2023, www.naturalgasintel.com/europes-reliance-on-diverse-pool-of-lng-sources-continues-year-after-ukraine-invasion/. Accessed 28 June 2023.

points of supply for strategic and critical materials needed in times of national emergency."[4] Exposing U.S. mobility to the risk of critical mineral supply availability raises an essential energy security question: How best does the U.S. trade risks it can mitigate for risks it cannot? But EPA fails to address this question in its Proposal. Rather, EPA largely limits its analysis to energy security impacts resulting from decreased fuel consumption and ignores the riskier implications of mandating reliance on an unstable, foreign-dominated supply chain, as evidenced by China's announcement this week that it is limiting exports of two rare earth minerals.[5]

The supply chain necessary to support new technologies contemplated by the Proposed Rule is far from assured and is likely to increase dependence on critical minerals from foreign sources. Reliance on a limited number of technologies (e.g., ZEVs) on the timeline required by the Proposed Rule will result in a non-resilient transportation sector that is vulnerable to unexpected disruptions and cost increases. For instance, both the federal government and the private sector recognized critical minerals are essential to the future of ZEVs.[6] Unstable critical mineral supply chains could disrupt this future. ZEVs, as compared to ICEVs, have a much greater reliance on several critical minerals, as seen in **Figure 1** below. There are six minerals critical to the production of ZEVs: cobalt, copper, graphite, lithium, manganese, and nickel.[7]

[4] Congressional Research Service, "National Stockpiles: Background and Issues for Congress" (June 15, 2020) *available at* https://crsreports.congress.gov/product/pdf/IF/IF11574; Congressional Research Service, "The Strategic National Stockpile: Overview Issues for Congress" (Jan. 25, 2023) *available at* https://sgp.fas.org/crs/misc/R47400.pdf.
[5] *See, e.g.*, Proposed Rule at 29,345, 29,388–90; Archie Hunter & Alfred Cang, *China Restricts Export of Chipmaking Metals in Clash with US*, July 3, 2023. Bloomberg. Available at China to Restrict Exports of Metals Critical to Chip Production - Bloomberg.
[6] Note that the term "zero emissions vehicle" ("ZEVs"), and even near-ZEVs as used by EPA, is a misnomer. ZEVs are not actually zero emission when accounting for the vehicle lifecycle, including GHG and criteria pollutant emissions associated with electricity generation required for charging certain ZEVs and production of the ZEV vehicle and battery. We recognize that in the Proposed Rule, EPA uses "ZEV" to refer only to those vehicles with a specific meaning under California's EV program, but for ease of review, "ZEVs" is used throughout these comments and encompasses all of the EV technologies, including plug in electric vehicles ("PEVs") such as plug-in hybrid electric vehicles ("PHEVs") and battery electric vehicles ("BEVs").
[7] International Energy Administration, "The Role of Critical Minerals in Clean Energy Transitions," (revised March 2022) *available at* https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions. [hereinafter IEA Report 2022].

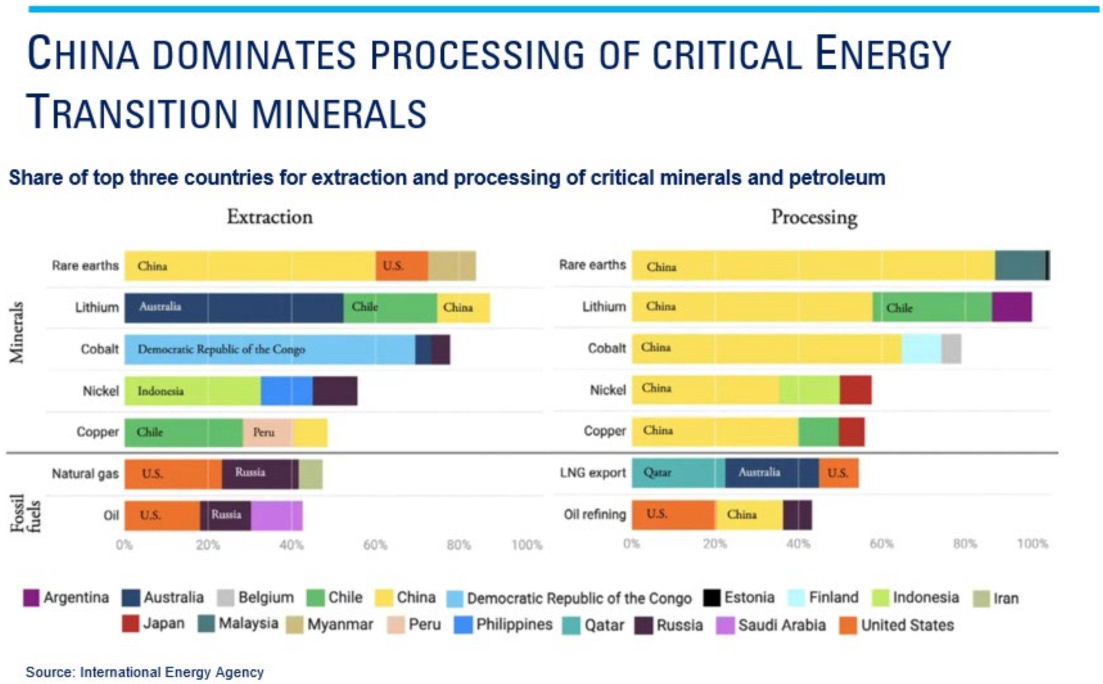
Figure 1: Metal intensity – ICEVs vs. EV[8]



Critical mineral supply, especially those essential to the manufacturing of a lithium-ion (Li-ion) battery, is dominated by three lithium producing countries as summarized in **Figure 2** below. Of the foreign nations that produce cobalt, molybdenum, and other minerals needed to produce ZEVs, China has disproportionate influence. While 70 percent of global cobalt production comes from the Democratic Republic of Congo,[9] most of those mines are owned/operated by China, and more than 60 percent of cobalt processing is in China. Moreover, 67 percent of the world's graphite is also produced in China.[10] The U.S. imports most of its manganese from Gabon, a less politically stable country, providing 65 percent of the United States' supply.[11]

[8] TURNER, MASON & COMPANY. "Evaluation of EPA's Assumptions and Analyses Used in Their Proposed Rule for Multi-Pollutant Emissions Standards" (June 7, 2023) (Research funded by AFPM and available upon request) [hereinafter "Turner Mason Report"].
[9] Id.
[10] G.R. Robinson, et al., U.S. GEOLOGICAL SURVEY, "Professional Paper 1802 Critical mineral resources of the United States—Economic and environmental geology and prospects for future supply" (Dec. 19, 2017) p. J1–J24, *available at* https://doi.org/10.3133/pp1802J.
[11] OEC, "Manganese Ore in the United States" (Mar. 2023) *available at* https://oec.world/en/profile/bilateral-product/manganese-ore/reporter/usa.

Figure 2: U.S. lack of critical mineral extraction or processing capacity[12]



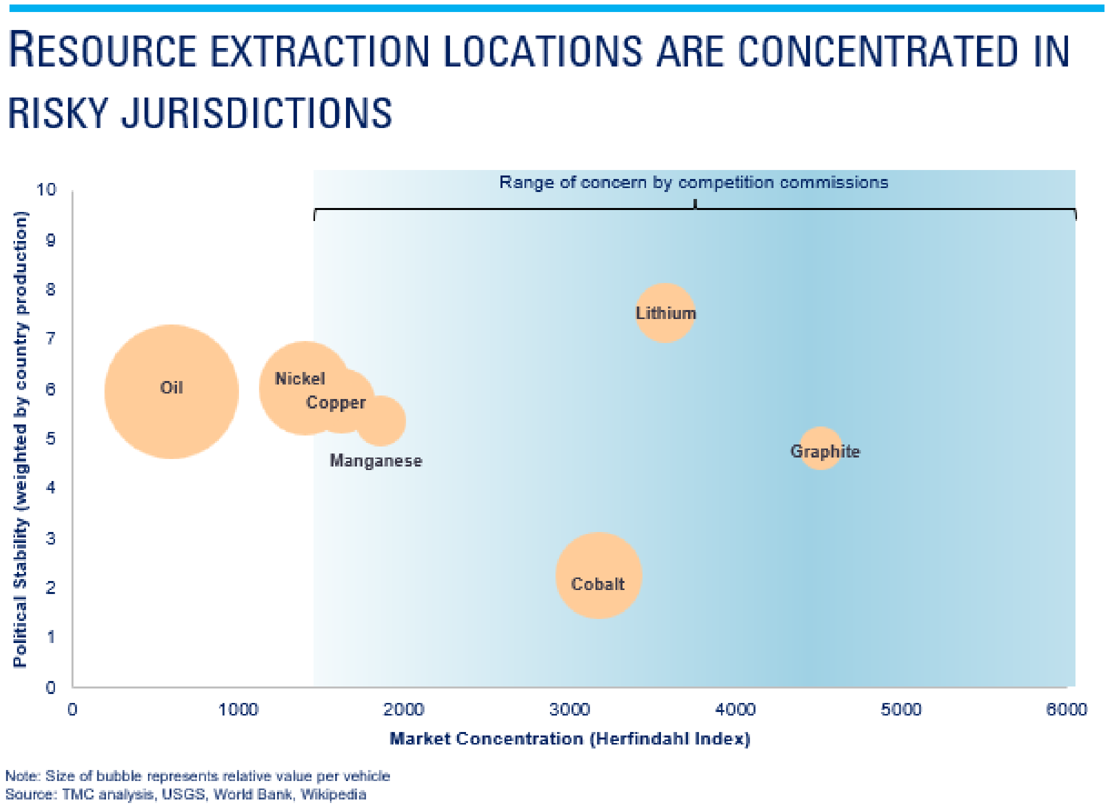
Expected supply from existing mines and projects under construction is estimated to meet only half of projected world demand for lithium and cobalt."[13]

In contrast to oil, which has a lower global market concentration than the critical minerals required for ZEVs, **Figure 3** shows that most critical materials for ZEVs are concentrated in less politically stable countries. Other than lithium production which is dominated by Australia (52 percent), all other critical ZEV minerals have a political stability index less than oil. As demand for these commodities grows, the market concentration (and ability to exert power over pricing) swings toward producers in less politically stable countries. If producer countries have market power, they have the potential to impact not only price, but the ability for consumer countries to influence other issues, such as sanctity of commercial contracts, labor and/or/human rights, and environmental standards in the producing jurisdictions. The significance of this issue is compounded by the fact that multiple critical minerals are needed for ZEV production, so a disruption in the supply of a single mineral can disable the entire supply chain. The operation of ICEVs, to the contrary, relies on a single natural resource for which there is an abundant domestic supply.

---

[12] Turner Mason Report.
[13] Axios Generate, The supply crunch that could slow the climate fight, (May 5, 2021).

Figure 3: U.S. risk exposure to critical energy resources[14]



The supply chain necessary to support new technologies contemplated by the Proposed Rule is far from assured and is likely to increase dependence on critical minerals from foreign sources.[15] In the event of supply disruption or pricing volatility related to geopolitical pressures, the U.S. is highly exposed as it heavily relies on imports to satisfy domestic demand in each of these critical minerals.[16] **Figure 4** puts this import dependence in perspective. By 2032 the Proposed Rule would raise import dependence to 100 percent of U.S. demand for most minerals, and more than 50 percent for nickel and copper. Except for copper, the U.S. does not mine significant quantities of these critical minerals. And, despite the U.S. having substantial domestic copper mining, it still relies on imports to meet 45 percent of U.S. demand.

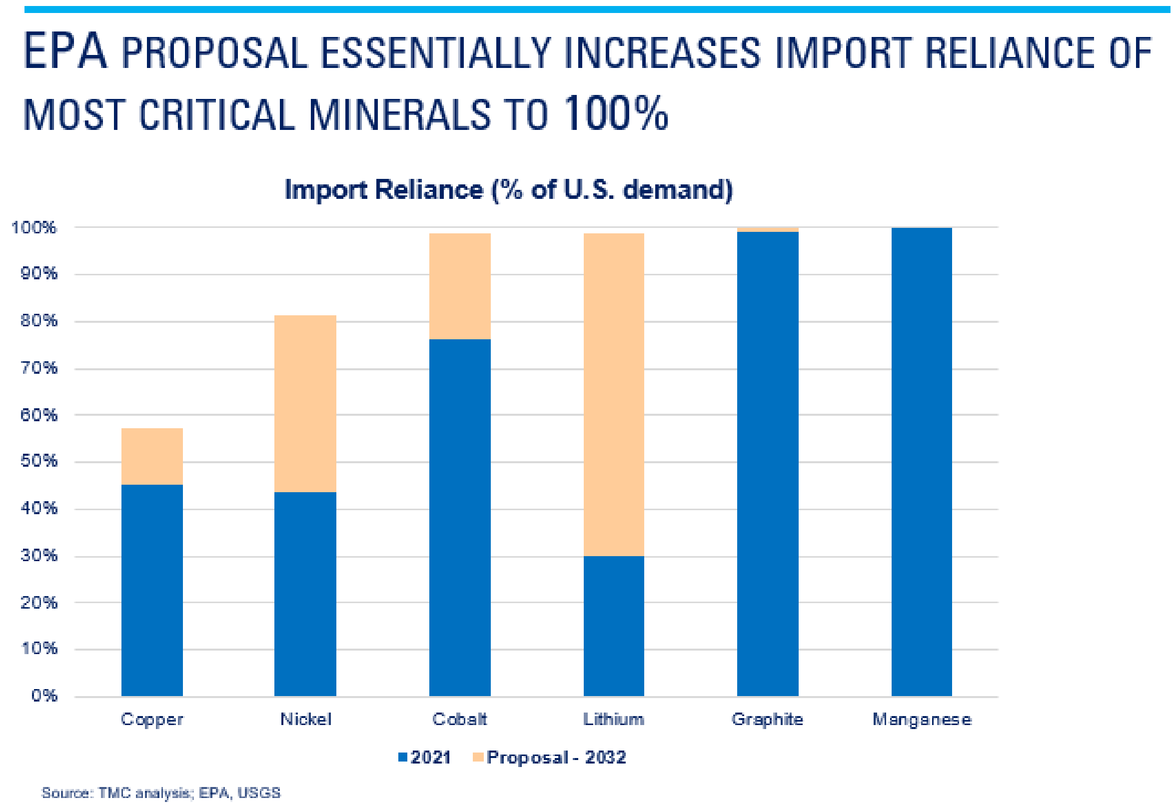
---

[14] Turner Mason Report.

[15] *See, e.g.*, Shelley Challis, POST REGISTER, "Jervois shuts down Idaho Cobalt mine" (Apr. 7, 2023), *available at* https://www.postregister.com/messenger/news/jervois-shuts-down-idaho-cobalt-mine/article_efd97f32-d015-11ed-9424-bfb28220210c.html (describing suspension of construction at Idaho Cobalt Operations due to, in part, low cobalt prices).

[16] China announced it will restrict the export of two metals (gallium and germanium) used in EV production. While these metals are not particularly rare, China could limit export of processed key EV battery minerals to maintain its supply chain dominance. See Archie Hunter & Alfred Cang, *China Restricts Export of Chipmaking Metals in Clash with US*, July 3, 2023. Bloomberg, *available at* https://www.bloomberg.com/news/articles/2023-07-03/china-to-restrict-exports-of-metals-critical-to-chip-production.

Figure 4: U.S. import reliance of several critical minerals[17]



China's dominance does not stop at critical mineral extraction and processing. China produces 75 percent of all Li-ion batteries and houses the production capacity for 70 percent of cathodes and 85 percent of anodes (both key battery components).[18] Conversely, the United States plays a very small role in the global electric vehicle ("EV") supply chain, with only 7 percent of battery production capacity.[19]

This new demand for foreign-sourced materials will upset the decades of progress the U.S. made in energy security, where we are currently a net exporter of crude and refined petroleum products combined, and it will undermine the domestic security provided by our refining industry. Sourcing critical minerals and building a secure, North American supply chain for ZEVs is not guaranteed as foreign production and processing of critical minerals have an established, large market share and competitive advantage today. Because passenger vehicles have domestic manufacturing and sourcing requirements in the IRA to be eligible for the clean vehicle tax credit,

[17] Turner Mason Report.
[18] International Energy Agency, "Global Supply Chains of EV Batteries," (July 2022), https://iea.blob.core.windows.net/assets/961cfc6c-6a8c-42bb-a3ef-57f3657b7aca/GlobalSupplyChainsofEVBatteries.pdf.
[19] *See id*. Regardless of recent funding awarded by the Department of Energy to construct three battery plants, the domestic supply of these critical minerals remains unchanged and, once these manufacturing facilities are permitted, constructed, and operable, they will rely heavily on foreign-sourced materials to maximize capacity and output, if even possible.

compliance will be challenging.[20] Yet the proposal assumes, without basis, that virtually all batteries will qualify for the full tax credits and will achieve cost parity despite a significant increase in demand. In making this assumption, EPA ignores the obvious benefits of a multi-technology approach that would reduce the risks associated with a ZEV-focused approach. For example, Toyota recently noted in a memo to its dealers that "the amount of raw materials in one long-range battery electric vehicle could instead be used to make 6 plug-in hybrid electric vehicles or 90 hybrid electric vehicles . . . the overall carbon reduction of those 90 hybrids over their lifetimes is 37 times as much as a single battery electric vehicle."[21]

2. The Availability of North American Crude, Refining, and Biofuel Capacity Makes the United States Energy Secure

Unlike critical minerals, the U.S. is the largest producer of crude oil and petroleum products in the world. We are also home to the world's largest biofuels industry. Our refineries and petrochemical producers are the most competitive in the world, taking advantage of a sophisticated workforce, low-cost resources, refinery complexity, and scale to compete with even the largest state-owned enterprises in foreign markets. In 2022, the crude oil processed by U.S. refineries was 84 percent sourced from North America. The U.S. produces more crude and refined products than it consumes and became a net exporter of crude and refined petroleum products in late 2019, after being a net exporter of refined products for the past decade.[22] EPA's DRIA undervalues the energy security aspects of the domestic petroleum industry, particularly by failing to distinguish between sources of imported crude oil, ignoring that 70 percent and 84 percent of imported and total crude oil, respectively, is sourced from North America. The proposal also ignores the significant pipeline connectivity between the U.S. and our North American trading partners, as well as the unique configurations of each U.S. refinery. For example, many U.S. refiners require heavier crude oils, which are not produced in the U.S. and must be sourced from Canada or other heavy crude producers. U.S. energy leadership means that the energy security impacts of reduced oil imports are not as significant as they historically had been. It also means that reduced U.S. demand for liquid fuels will impact U.S. oil producers as much, if not more so, than existing trading partners. This employment effect is not contemplated in EPA's analysis.

U.S. refiners are also critical suppliers of fuel to the U.S. military. In the most recent contract year, U.S. refiners provided 750 million gallons of fuel on the West Coast alone, supporting force readiness for conflict in the Pacific. EPA did not assess the impact of likely refinery closures on military operations and readiness. Instead, the DRIA inexplicably focuses on a narrow aspect of energy security, choosing to describe the cost of protecting trade routes.

Shockingly, EPA provides no analysis of the impact of this rule on the U.S. biofuels or agricultural industries. The U.S. is the world's largest biofuels producer, yet a search of the DRIA reveals that the only mention of biofuels comes in a footnote describing the contents of an EIA Annual Energy Outlook table. Considering the implications for the biofuels industry, as well as the

---

[20] IRA, Section 45W(c) (The IRA requires 50% of the value of battery components to be produced or assembled in North America to qualify for a $3,750 credit and 40% of the value of critical minerals sourced from the United States or a free trade partner also for a $3,750 credit).
[21] William Johnson, TESLARATI, "Toyota releases new defense of lagging EV strategy" (May 18, 2023) *available at* https://www.teslarati.com/toyota-defends-ev-strategy/.
[22] EIA, "Oil imports and petroleum product explained" (Jun. 12, 2023) *available at* https://www.eia.gov/energyexplained/oil-and-petroleum-products/imports-and-exports.php.

significant impact it will have on the agricultural producers that supply the industry, this glaring omission underscores the arbitrary nature of this rulemaking.

The DRIA also relies on out-of-date cases from EIA's AEO 2021. In EIA's AEO 2023 released earlier this year, U.S. crude production is higher, as are U.S. net exports of petroleum products, petroleum consumption is lower and U.S. refining capacity is lower. These changes call into question the validity of EPA's estimate of the reduction in U.S. imports of crude oil that result from the proposed rule.

Finally, EPA used a Low Economic Growth case from AEO 2021 to estimate the impact of the proposed rule on oil imports, rather than carrying out an analysis specific to the changes in demand that EPA projects to result from the proposed rule. Although demand in the Low Economic Growth Case is lower than in the Reference Case, the oil demand decreases in the Low Economic Growth case differ from the oil demand decreases EPA projects in Table 9-42 and there is no consideration of how those differences affect the oil security analysis.

B. The United States Lacks Copper and Aluminum Production Required for Grid Expansion

Beyond the ZEV itself, electricity networks need a large amount of copper and aluminum.[23] The need for grid expansion that would result from this rapid increase in electricity demand underpins a doubling of annual demand for copper and aluminum.[24] Most supply of these materials will come from overseas, as the United States lacks current production capacity or the ability to increase such capacity in time to meet the demands of the Proposed Rule.

The United States does not supply much of the world's aluminum. Instead, China, Russia, and India lead global production with an estimated 45 million metric tons per year. China possesses more than half of the entire world's aluminum smelting capacity and produces by far the most aluminum of any country at over 36 million tons per year.[25] The United States, by contrast, produces approximately 1 million tons per year. Similarly, countries supplying the most copper are Chile, Peru, China, and the Democratic Republic of the Congo. These countries supply ten times the amount produced domestically.

Experts predict our demand for these materials will rise dramatically, but we lack the ability to source them domestically. The latest data concludes sourcing copper for electric infrastructure (e.g., charging stations and storage) needed to accommodate increased electrical demand will be challenging.[26] Copper demand is expected to rise by 53 percent, while supply is expected to rise by only 16 percent.[27] U.S. import dependency for copper has grown from 10 percent in 1995 to 40 percent in 2020, with projections of copper import dependency reaching between 55 percent

---

[23] IEA Report 2022.
[24] *Id.*
[25] Andy Home, "Global aluminum production pendulum swings back to China" (June 21, 2022) *available at* https://www.mining.com/web/column-global-aluminum-production-pendulum-swings-back-to-china/.
[26] IEA Report 2022.
[27] BLOOMBERGNEF, "Copper Miners Eye M&A as Clean Energy Drives Supply" (Aug. 30, 2022), *available at* https://about.bnef.com/blog/coppers-miners-eye-ma-as-clean-energy-drives-supply-gap/#:~:text=Copper%20demand%20is%20set%20to,and%20difficulty%20developing%20greenfield%20mines.

and 67 percent between 2020 and 2040.[28] Other estimates predict that by 2030 supply from existing mines and projects under construction is estimated to meet only 80 percent of copper needs by 2030[29]—not considering the anticipated increase in ZEV production anticipated by EPA's Proposed Rule.

Establishing new mines, particularly in the United States, is not a near-term solution. Permitting and authorizing new domestic mining and smelting capacity requires a substantial amount of time and government support. According to the National Mining Association, it can take up to 10 years to obtain a permit to commence mining operations in the U.S., while permitting takes two years in Canada and Australia.[30] "[U]nless the permitting process can be improved, U.S. mining developments will continue to take longer to come online and carry more financial risks compared with the rest of the world, China's domination of battery manufacturing and critical minerals production will continue for a longer period, and the U.S. will find it increasingly difficult to acquire the metals and minerals it needs for its long-term clean-energy goals."[31] Despite this Rule's unlawful push to transition to EVs, the Bureau of Land Management placed a 20-year moratorium on mining rare earth minerals, such as copper, nickel, and cobalt, from almost a quarter of a million acres of Minnesota, effectively killing the proposed Twin Metals copper-nickel mine project.[32]

Globally, regulatory approval for new copper mines is at its lowest level in a decade.[33] As a case in point, the Resolution copper deposit in Arizona was discovered in 1995. This world-class resource has been trying to acquire the necessary regulatory approvals for over 27 years. As recently as May 19, 2023, the U.S. Forest Service told a federal court it was suspending approval of a land swap between the project (owned by Rio Tinto and BHP) and several Native American groups.[34] The land swap was approved by the U.S. Congress in 2014, but the completed environmental report was blocked in March 2021. Other copper mining projects in Alaska and Minnesota have been halted by this administration, resulting in increased import dependence.[35]

---

[28] S&P GLOBAL, "The Future of Copper Will the Looming Supply Gap Short-Circuit the Energy Transition?" (July 2022) *available at* https://cdn.ihsmarkit.com/www/pdf/0722/The-Future-of-Copper_Full-Report_14July2022.pdf.

[29] IEA Report 2022.

[30] National Mining Association, Delays in the U.S. Mine Permitting Process Impair and Discourage Mining at Home, May 31, 2021. Available at https://nma.org/wp-content/uploads/2021/05/Infographic_SNL_minerals_permitting_5.7_updated.pdf.

[31] Jason Lindquist, Don't Pass Me By - With Many Steps Required, Mining Projects Face Trickiest Path To Approval, RBN Energy Blog (June 30, 2023) (Attachment 2).

[32] 88 Fed. Reg. 6308 (Jan. 31, 2023).

[33] Ernest Scheyder, REUTERS, "Copper Industry Warns of Looming Supply Gap without More Mines" (Apr. 21, 2023) *available at* www.reuters.com/markets/commodities/copper-industry-warns-looming-supply-gap-without-more-mines-2023-04-20/.

[34] Ernest Scheyder, REUTERS "U.S. Forest Service Pauses Timeline for Rio Tinto Arizona Copper Mine" (May 19, 2023) *available at* https://www.reuters.com/legal/us-forest-service-pauses-timeline-rio-tinto-arizona-copper-mine-2023-05-19/.

[35] Jim Vinoski, FORBES, "There's Not Enough Copper for Our Electrification Plans–and Biden Is Making It Worse" (Apr. 28, 2023) *available at* www.forbes.com/sites/jimvinoski/2023/04/28/theres-not-enough-copper-for-our-electrification-plansand-biden-is-making-it-worse/?sh=19ca0a5d1fbf.

C. The Proposal's Deployment Timeline is Impracticable

EPA's emissions standards rely on the unsubstantiated assumption that the U.S. electricity and transmission grid and ZEV charging infrastructure will be available to charge the massive numbers of ZEVs that will enter the market. As outlined below, available data supports the Alliance for Automotive Innovation's conclusion that the timeline for EPA's standard is infeasible.[36]

1. There is Significant Doubt that the U.S. Electrical Grid and Transmission Grid Can Reliably Support this Proposal.

The Proposal will further strain our nation's electricity system as global electricity demand could increase 47 percent by 2050 based on 2021 projections of population and economic growth, alone.[37] In the U.S., the estimated increase in energy consumption is 15 percent by 2050, without consideration of EPA's Proposal. Notably, this value is likely much higher considering the anticipated increase of between 900 and 2,000 percent electricity purchased for transportation by 2050 with the increased adoption of EVs.[38] The Department of Energy concluded that transmission systems must expand by 60 percent by 2030 and triple that capacity by 2050 to meet the Administration's emissions goals.[39] An author of the Princeton University's Net-Zero America Project[40] said "The current power grid took 150 years to build. Now, to get to net-zero emissions by 2050, we have to build that amount of transmission again in the next 15 years and then build that much more again in the 15 years after that. It's a huge amount of change."[41]

Yet, our electricity generation and transmission system are increasingly challenged to keep up with current demand. As shown in **Figure 5**, the North American Electric Reliability Corporation's ("NERC") recent summer assessment shows roughly two-thirds of the U.S. faces increased resource adequacy risk in the summer of 2023.[42]

---

[36] Alliance for Automotive Innovation, Comments to the Environmental Protection Agency, Multi-Pollutant Emissions Standards for Model Years 2027 and Later Light-Duty and Medium-Duty Vehicles, Proposed Rule, Docket No. EPA-HQ-OAR-2022-0829 (hereinafter AAI Comments) at iv.

[37] Meghan Gordon and Maya Weber, S&P Global, "Global energy demands to grow 47% by 2050, with oil still top source: US EIA" (Oct. 6, 2021) available at https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/oil/100621-global-energy-demand-to-grow-47-by-2050-with-oil-still-top-source-us-eia#.

[38] EIA, "U.S. energy consumption increases between 0% and 15% by 2050" (Apr. 3, 2023) *available at* https://www.eia.gov/todayinenergy/detail.php?id=56040#:~:text=U.S.%20energy%20consumption%20increases%20between%200%25%20and%2015%25%20by%202050.

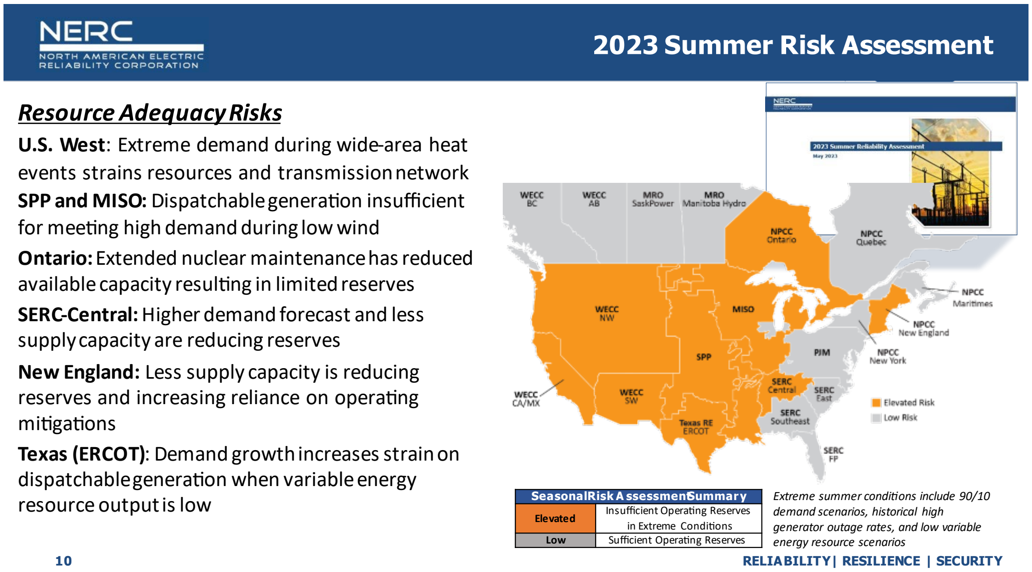
[39] Evan Halper and Timothy Puko, "Biden's Ambitious Climate Plans for EVs Face These Big Hurdles," The Washington Post, April 16, 2023.

[40] E. Larson, et al., Net-Zero America: Potential Pathways, Infrastructure, and Impacts, Final report, Princeton University, (Oct. 29, 2021).

[41] Molly Seltzer, PRINCETON, "Big but Affordable Effort Needed for America to Reach Net-Zero Emissions by 2050, Princeton Study Shows" (Dec. 15, 2020) *available at* www.princeton.edu/news/2020/12/15/big-affordable-effort-needed-america-reach-net-zero-emissions-2050-princeton-study. Accessed 28 June 2023.

[42] NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION, "2023 Summer Reliability Assessment" (May 2023).

Figure 5: NERC 2023 Summer Risk Assessment[43]



Depending on where you are, the long-term reliability assessment is not much better. NERC's 2022 Long-Term Reliability Assessment of the U.S. analyzed the electrical grid and the entities delivering power to the continental United States during 2023-2032.[44] Regional operators of the power grid—Regional Transmission Organizations ("RTOs") or Independent System Operators ("ISO")—are responsible for transmission, but also balancing a regional power system to ensure that supply constantly matches demand. The grids in some RTOs are already under various degrees of stress. Several operating regions are still at-risk during periods of peak demand, including the Midcontinent ISO (which will face challenges in meeting above-normal peak demand), the SERC – Central area (where, compared to the summer of 2022, forecasted peak demand has risen by over 950 MW while growth in anticipated resources has remained flat) and the Southwest Power Pool (where reserve margins have fallen as a result of increasing peak demand and declining anticipated resources).[45]

Future electricity demand is expected to grow due to government policies for EV adoption and energy transition programs. The California Energy Commission staff estimates that by 2030, an additional 5,500 MW of demand at midnight and 4,600 MW of demand at 10:00 a.m. on a typical weekday will be needed for plug-in EV charging.[46] This is an increase of 25 and 20 percent, respectively, at those times. State and local policies for transitioning appliances and heating systems, such as banning natural gas stoves, can also affect projections of electricity demand

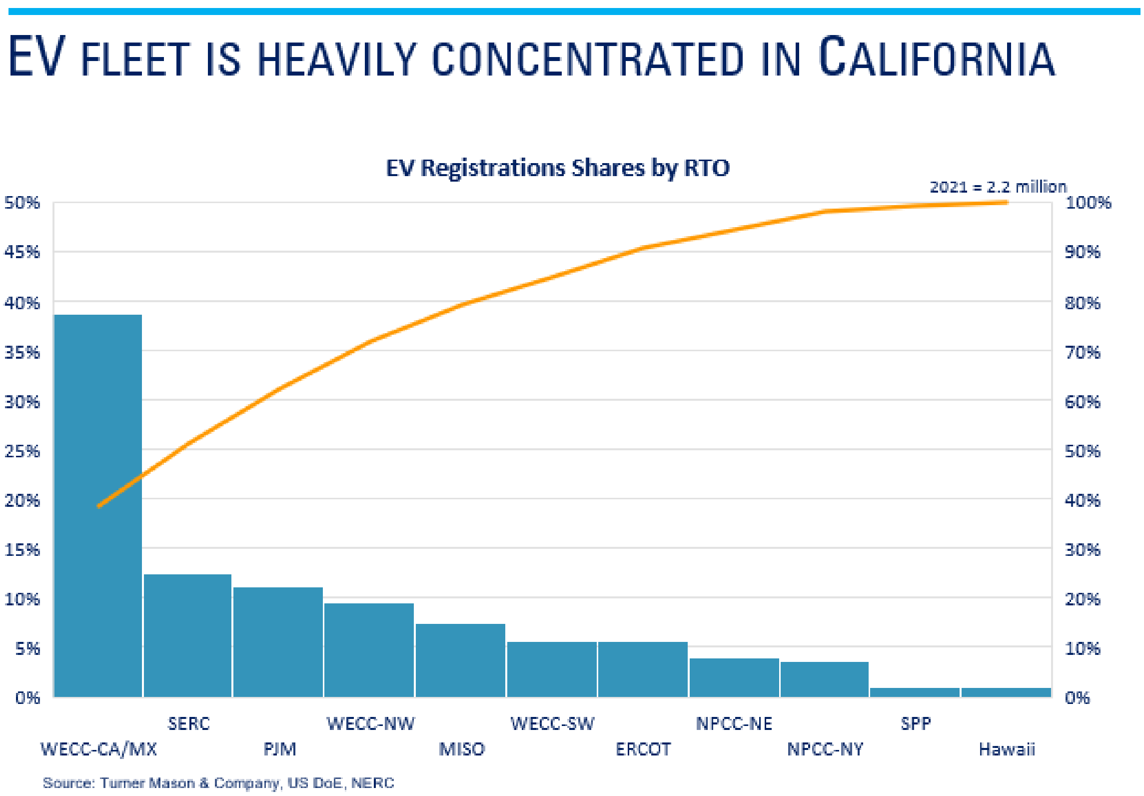
---

[43] NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION, "2023 Summer Energy Market and Electric Reliability Assessment" (May 18, 2023), *available at* https://www.ferc.gov/news-events/news/presentation-report-2023-summer-energy-market-and-electric-reliability-assessment
[44] NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION, "2022 Long Term Reliability Assessment" (December 2022), *available at* https://www.nerc.com/pa/RAPA/ra/Reliability%20Assessments%20DL/NERC_LTRA_2022.pdf.
[45] NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION, "2023 Summer Reliability Assessment" (May 2023) at 23, *available at* https://www.nerc.com/pa/RAPA/ra/Reliability%20Assessments%20DL/NERC_SRA_2023.pdf.
[46] Id.

and daily load shapes.[47] Moreover, as global temperatures rise, increased use of air conditioning will draw a greater load from the grid. As recently reported, “two-thirds of North America is at risk of energy shortfalls this summer during periods of extreme demand.”[48]

Although EPA projects ZEV sales on a national basis, the ability to charge the vehicles is driven by the ability of the RTOs and ISOs to manage regional or local power grids to supply electricity on demand. EPA’s national data thus disguise important problems that increasing ZEV penetration will cause. By 2022, more than 50 percent of ZEVs were concentrated in California (WECC-CA/MX), Florida (SERC), and Texas (ERCOT).[49] The distribution of the ZEV fleet across RTOs can be seen in **Figure 6**, in which state shares of ZEV registrations are allocated across RTOs.[50]

Figure 6: ZEV registrations by RTO[51]

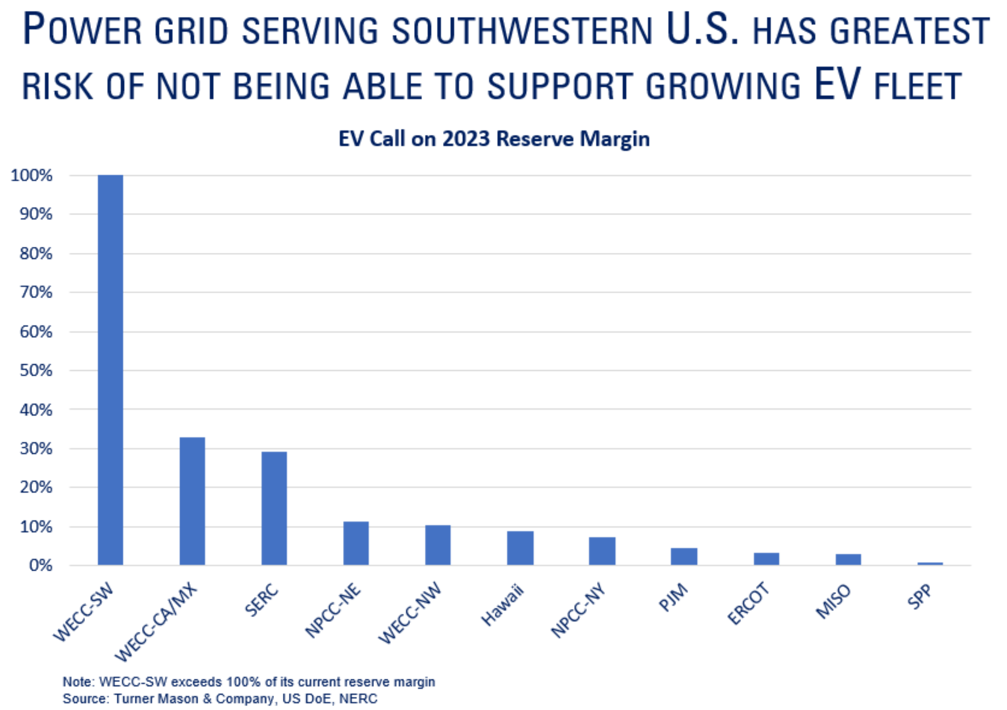


As seen in **Figure 7**, the greatest stress is not in California (although it is significant in California), but rather in the southwestern U.S.

---

[47] Id.
[48] https://www.cnn.com/2023/06/26/business/heat-wave-power-blackout/index.html
[49] S&P GLOBAL MOBILITY, “EV Chargers: How Many Do We Need?” (Jan. 9, 2023), *available at* press.spglobal.com/2023-01-09-EV-Chargers-How-many-do-we-need.
[50] There are several states which are covered by more than one RTO. For this high-level assessment, the Turner Mason Report allocates state EV sales by roughly the geographic footprint of each RTO within the state.
[51] Turner Mason Report.

Figure 7: EV Power Requirement by RTO[52]



In the southwestern U.S., for example, electricity demand from EV charging is expected to completely consume the 2023 reserve margin for the WECC-SW grid, leaving no reserve margin to address emergency conditions. This is based on EPA's estimate of ZEV electricity demand in 2032, allocated to RTOs, assuming no reserve capacity is added over the next eight years. For an RTO to fill incremental ZEV electricity demand and maintain its reserve margin, the required capacity investment will vary depending on the source of generation and that source's availability (*i.e.,* expected load factor) specific to that region. For the U.S. the total investment would be significant; the Brattle Group estimated an additional $75 to $125 billion total investment across the power sector at a ZEV penetration rate lower than EPA proposes.[53]

2. Required battery production is not feasible within the Proposal's time frame.

EPA severely overestimates the availability of minerals and the mining/processing infrastructure and capabilities in the U.S.[54] EPA's position in the DRIA that "PEV production in the U.S. need not be heavily reliant on foreign manufacture of battery cells or packs as PEV penetration increases and domestic mineral and cell production comes online" is unfounded.[55]

The development of natural resources projects, like critical mineral mining and processing, can easily require more than a decade. Increasing supply is not merely a matter of increasing

[53] Michael Hagerty, et al., "Opportunities for the Electricity Industry in Preparing for an EV Future" (June 2020).
[54] AAI Comments at iv.
[55] DRIA at 3-20.

current production. "The ability for the miners to quickly ramp up production of key ores is limited by regulatory hurdles and capital investment." Globally, it takes on average more than 16 years to move mining projects from first discovery to production.[56] The ability to quickly scale minerals production is further affected by ore quality, which in recent years has been declining, and thus requires more material to be mined, more resources such as water in stressed areas for processing, and ultimately greater environmental impacts. Even with the requisite authorizations in hand, mine development and production can take years. For an open pit mine, it takes about 7 to 8 years from discovery to first ore; for a subsurface mine, the time frame is more like 10 to 12 years.

Extracting critical minerals is challenging because most critical mineral ores exist in relatively low concentrations and the quality of the ore grade is declining. For example, the average ore grade for copper discoveries decreased in excess of 25 percent during the last 15 years. In that same period, total energy consumption increased at a higher rate (46 percent) than production (30 percent). Extraction (*i.e.*, mining and processing) of metal content from lower-grade ores requires removing more overburden to access the ore body, which requires more energy, exerting upward pressure on production costs, greenhouse gas and criteria pollutant emissions, and waste volumes. And once the raw material is mined, it must be qualified. This is not a mine-to-producer scenario. It is a specialty chemical that must be tested at different stages for safety, consistency of product output, and performance before it can be qualified for use in battery/ZEV manufacturing. Substantial lead time is needed to qualify battery-grade materials as they go through a very rigorous, staged approach. Careful attention to putting up projects on the scale of raw material resource extraction and gigafactories requires time, careful consideration, and intensive safety precautions. Accelerating the buildup of a domestic battery value chain should not overstep aspects of safe project development.

The required critical minerals are not available at scale today. Mining capacity cannot be increased as quickly as required to meet the production rate required under the Proposed Rule, and at-scale recycling capabilities to remove these materials will not be available soon. EPA's willingness to assume that global supply shortages of critical minerals will resolve themselves without specific analysis of how that problem will be addressed is another example of EPA ignoring an issue of central relevance to this rulemaking. EPA neglects to appreciate these limitations, rendering its Proposed Rule arbitrary and factually unsupported.

II. Banning the Internal Combustion Engine is a "Major Question" that Congress did not Delegate to EPA.

The Proposed Rule goes beyond imposing regulations that represent appropriate and feasible technological improvements in the efficiency of ICEVs; rather, it requires the manufacturing of ZEVs and ultimately phasing out ICEVs. Though EPA contends the proposed standards do not mandate a specific technology (e.g., ZEVs), the proposed standards are a de facto ZEV mandate requiring auto manufacturers to shift production away from ICEV and to ZEVs.[57] Consequently, the Proposed Rule obligates OEMs to increase the percentage of ZEVs they sell well more than market forces. EPA predicts that for MY 2032, the Proposed Rule will result in ZEV adoption rates between 62–78 percent across all body styles (sedans,

[56] IEA Report 2022.
[57] Alliance for Automotive Innovation, Comments to the Environmental Protection Agency, Multi-Pollutant Emissions Standards for Model Years 2027 and Later Light-Duty and Medium-Duty Vehicles, Proposed Rule, Docket No. EPA-HQ-OAR-2022-0829 (hereinafter AAI Comments) at iii.

crossovers/SUVs, and pickups).[58] This is a tremendous jump from the 8.4 percent of LDV production that was plug-in electric in 2022.[59] As a result, implementing this Proposal "requires massive changes from all sectors of the U.S. economy: from automotive suppliers to home builders to utilities, labor to mining to mineral processing."[60]

But the question of whether this shift is necessary and, if so, how to accomplish this shift, is a "major question" reserved for Congress, not EPA.

The "major questions doctrine" holds that Congress must "speak clearly when authorizing an agency to exercise [such] powers" of "vast economic and political significance."[61] And as EPA is aware, this doctrine applies in the context of environmental regulation. Last year, in *West Virginia v. EPA*, the Supreme Court relied on the major questions doctrine in holding that the EPA exceeded its statutory authority in adopting its Clean Power Plan. That regulation sought to impose caps on GHG emissions by requiring utilities and other providers to shift electricity production from coal-fired power to natural gas and then to renewable energy in place of imposing source-specific requirements reflective of the application of state-of-the-art emission reduction technologies.[62]

As noted by the Court, EPA "announc[ed] what the market share of coal, natural gas, wind, and solar must be, and then require[d] plants to reduce operations or subsidize their competitors to get there."[63] EPA's attempt to devise GHG emissions caps based on a generation-shifting approach would have had major economic and political significance impacting vast swaths of American life and substantially restructured the American energy market; however, EPA's purported authority was only based on a "vague statutory grant" within Section 111(d) of the Clean Air Act—far from the "clear authorization required by [Supreme Court] precedents."[64] The need for clear congressional authorization for such sweeping regulatory programs is nothing new – just last week the Supreme Court reaffirmed the major questions doctrine "as an identifiable body of law that has developed over a series of significant cases spanning decades."[65]

EPA's Proposed Rule here presents an analogous situation, albeit one with substantially greater costs. Mandating a rapid shift from ICEV to ZEV will reshape the American automotive

---

[58] Proposed Rule at 29,329; U.S. Environmental Protection Agency, "Multi-Pollutant Emissions Standards for Model Years 2027 and Later Light-Duty and Medium-Duty Vehicles Draft Regulatory Impact Analysis" (April 2023) pg. 13-36, 13-37, *available at* https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P10175J2.pdf [hereinafter, "DRIA"].
[59] Proposed Rule at 29,189 (identifying the percentage that was PEV, which included PHEVs and ZEVs).
[60] AAI Comments at iv.
[61] Nat'l Fed. Of Indep. Bus. v. Dep't of Labor, 142 S. Ct. 661,665 (2022); see also Ala. Assoc. of Realtors v. Dep't of Health & Human Servs., 141 S. Ct. 2485, 2489 (2021); Utility Air Regulatory Group v. EPA, 573 U.S. 302, 324 (2014); U.S. Telecom Assoc. v. FCC, 855 F.3d 381, 419-21 (D.C. Cir. 2017) (Kavanaugh, J., dissenting from denial of rehearing en banc) (explaining provenance of "major rules doctrine").
[62] *West Virginia v. EPA*, 142 S. Ct. 2587 (2022).
[63] *Id.* at 2613, n4.
[64] *Id.* at 2614.
[65] *Biden v. Nebraska*, No. 22-506, slip op. at 23 (June 30, 2023) (internal quotations omitted) (applying major questions doctrine to strike down student loan repayment program that will cost taxpayers approximately $500 billion and affects nearly every student loan borrower). Just as the trade-offs inherent in a mass debt cancelation program are ones that Congress would likely have reserved for itself, *id.,* slip op. at 25, so too are those that must be considered for the mass adoption of electric vehicles.

market with profound collateral effects, making clear that EPA is encroaching upon an issue of "vast economic and political significance." As further discussed herein, the Proposal's direct compliance costs are enormous—even in the face of numerous errors and oversights in its analysis that materially understate these costs. EPA estimates that the cost of vehicle technology (not including the vehicle or battery tax credits) would be approximately $180 billion–$280 billion in addition to greater than $7 billion in electric vehicle supply equipment ("EVSE") costs through 2055. These figures do not include the transformation of the electric power sector and grid updates needed to meet the electricity demand created by the Proposed Rule, which is estimated to cost trillions of dollars.[66] EPA acknowledges that auto manufacturers are spending over a trillion dollars by 2030, mainly for manufacturing facilities. By setting emissions standards requiring production of a different product, the Proposed Rule undoubtedly forces OEMs to meet production deadlines that would not exist but for EPA's new ZEV mandate.

There are several issues included in the Proposal with impacts that go well beyond EPA's expertise, and the Agency is not positioned to fully grapple with the consequences that such a rapid push for ZEVs will have across the nation. Beyond the obvious impacts to consumer automotive markets, the Proposed Rule will also eliminate American jobs in the refining sector that will not be offset by the "projected" job growth in the automotive sector.[67] It will significantly strain the electric grid, requiring utilities to rapidly increase generation, transmission, and distribution capacity to a degree not fully contemplated by EPA. And it will have profound impacts on national security by forcing the American automotive industry and a large share of the domestic transportation market to depend on critical minerals from foreign suppliers—most notably, China—rather than a domestically-abundant and secure resource. The fact that mandating ZEVs forces EPA to wade into all these areas outside of vehicle tailpipe emissions—as EPA must, to appropriately quantify emissions reductions and other impacts of the Proposal—shows that mandating a wholesale switch to vehicles for which the bulk of emissions occur upstream, rather than at the tailpipe, was not contemplated or provided for by Congress. Because the Proposed Rule raises a major question, EPA can only proceed if Congress clearly authorized EPA to do so. But Congress did not.

As with the Clean Power Plan, EPA lacks Congressional authorization in the Clean Air Act to impose a manufacturing-shifting standard to a preferred powertrain and effectively order regulated parties to phase out combustion engine technologies. EPA's standard-setting tools are limited to those which Congress provided in Section 202(a) of the Clean Air Act. Here, EPA is only authorized to set "standards" for "emission[s]" from "any class or classes of new motor vehicles or new motor vehicle engines, which . . . cause, or contribute to," potentially harmful air pollution. EPA has elected to focus solely on tailpipe emissions. But EPA acknowledges that ZEVs do not have tailpipe emissions of carbon dioxide, nitrogen oxides, non-methane organic gases, particulate matter, carbon monoxide, or formaldehyde, the pollutants of concern here, so the operation of such vehicles alone cannot "cause, or contribute to," air pollution within the constructs

[66] Dan Shreve and Wade Schauer, *Deep decarbonization requires deep pockets* (June 2019), https://www.decarbonisation.think.woodmac.com/ (The U.S. needs to invest $4.5 trillion to fully transition the U.S. power grid to renewables during the next 10-20 years, annual investments exceeding the U.S. defense budget).
[67] Proposed Rule at 29,393; DRIA at 4-59 (EPA admits that its proposal may affect employment for firms providing fuels: "Reduced consumption of petroleum represents cost savings for purchasers of fuel, as well as a potential loss in value of output for the petroleum refining industry, fuel distributors, and gasoline stations, which could result in reduced employment in these sectors.").

of a tailpipe emissions regulation, especially when EPA does not require vehicle manufactures to account for the upstream emissions from ZEVs in their compliance calculations.

Far from "clear congressional authorization," Section 202(a) provides EPA no authority to set standards that go beyond that which could be achieved by improvements to ICEVs alone such that OEMs are required to cease producing the underlying technology governed at the time the Clean Air Act was adopted and amended. Nor does it permit EPA to establish a fleet averaging and emission credit trading program as a mechanism to limit ICEV sales.[68] Notably, in its 1990 updates to the Clean Air Act, Congress instituted a clean fuel vehicles program with reference to "clean alternative fuel" vehicles, which includes ZEVs. In doing so, Congress explicitly distinguished such vehicles from "conventional gasoline-fueled or diesel-fueled vehicles of the same category and model year," dispelling the notion that ZEVs and ICEVs can be lumped together to set standards that will enable the former to eventually displace the latter.[69] EPA does not—and cannot—explain how such authority can be read to regulate ZEVs and ICEVs under a common standard, especially in light of the statutory language requiring EPA to set standards for any class or classes of vehicles. It is no surprise then that up until the current Administration, EPA has never claimed the authority to mandate even partial electrification.

Congress clarified that it, not EPA, must make the important policy decisions affecting if, when, and how the American automotive industry will transition from ICEVs to ZEVs. In the 116th Congress, for example, Congress introduced 44 bills seeking to reduce petroleum-based fuel consumption and GHG emissions from the transportation sector through customer rebates, vehicle and fuel producer incentives, local funding, development of standards, and research and development. Congress rejected bills that would have banned the sale of new light duty ICEVs by 2040[70] and it has consistently disapproved of EPA's efforts to hamstring the automotive sector with more stringent air pollution standards than are feasible.[71]

It should be no surprise then that in the wake of the Proposed Rule, members of Congress requested that the Agency rescind the proposals, asserting they "effectively mandate a costly transition to electric cars and trucks in the absence of congressional direction."[72] That Congress

---

[68] *See supra* II.A.
[69] 42 U.S.C. §§ 7581, 7582(b).
[70] *See* Zero-Emission Vehicles Act of 2019, H.R. 2764, 116th Cong. (2019); Zero-Emission Vehicles Act of 2018, S. 3664, 115th Cong. (2018); *see also* 116 Cong. Rec. 19238-40 (1970) (proposed amendment to Title II that would have banned ICEVs by 1978).
[71] *See, e.g.*, S. J. Res. 11, 118th Cong. (2023) (Although passed only by the Senate thus far, the joint resolution calls for disapproval of a similar rule submitted by the Administrator of the Environmental Protection Agency relating to "Control of Air Pollution From New Motor Vehicles: Heavy-Duty Engine and Vehicle Standards," 88 Fed. Reg. 4296 (Jan. 24, 2023)).
[72] Letter from Senator Shelley Capito, et al. to Administrator Michael S. Regan, EPA (May 25, 2023); *see also* Senate Resolution S.J. Res. 11, 118th Congress (Apr. 26, 2023) (Although related to heavy duty vehicles ("HDVs"), Congress has expressed its disapproval of EPA's overreach in this space. For example, in April of this year both houses of Congress passed a Congressional Review Act resolution to rescind EPA's December 2022 heavy duty NOx standards, sending a strong signal that Congress views EPA's efforts in this space as unnecessary, infeasible, and uniformed in light of economic and energy security concerns); House Resolution H2523 (May 23, 2023); *see also* Congressional Record, H2523 (May 23, 2023) at 1444, Statement from Mr. Walberg (R-MI) ("From tailpipe emissions regulations that will force people to buy expensive and less practical EVs to new rules on power plants that will threaten the reliability of our electric grid. It seems like the EPA has not even thought about the economic and energy security of our constituents.").

intended for it, not EPA, to direct these policy decisions is made all the more clear by the passage of the IRA and the BIL whereby Congress identified the policy levers it deemed appropriate. Congress could have, but did not, delegate the authority to (or otherwise direct) EPA to establish a fleet-wide credit trading regime to further drive ZEV development and rapid adoption.

The Proposed Rule stands in direct contrast to other legislation, such as the Renewable Fuel Standard Program ("RFS"), whereby Congress mandated that "gasoline sold or introduced into commerce in the United States" must contain renewable fuels[73] and, in 2022, must include billions of gallons of renewable fuel.[74] In fact, EPA's Proposal directly conflicts with the statutory framework that Congress provided in the RFS for lowering GHG emissions from the transportation sector. In the proposed rule, EPA cites only its authority under section 202(a) of the Clean Air Act and Executive Order 14037 as the basis for requirements that will extend from MY 2027 to 2032.[75] Because Executive Orders have no force of law,[76] EPA at bottom contends that a few general paragraphs of the Clean Air Act, enacted over 50 years ago, provides sufficient legislative authority and direction for the entirety of its proposed rule. But Congress demonstrated in the RFS that when it wants to transform the transportation sector, and specifically, when it desires to address GHGs associated with that sector, it does so with precision and within the context of a prescribed statutory framework.

III. The Proposed Rule Contravenes or is Otherwise Contrary to the Clean Air Act and Energy Policy and Conservation Act

A. EPA Lacks Statutory Authority Under the Clean Air Act.

1. The Clean Air Act Requires Standards With Which All Vehicles In A Class Can Comply

As set forth in detail in the brief appended as Attachment 1, EPA lacks statutory authority under Section 202(a) of the Clean Air Act to set fleetwide emission standards, and even if it had such authority, it could not lawfully use it to force electrification by including vehicles that have no tailpipe emissions in the fleetwide average standard for ICEVs. While EPA purports to rebut arguments that it lacks such statutory authority, EPA's own search for its expansive authority turns into a circular argument. If "Congress's focus was on emissions from classes of motor vehicles and the 'requisite technologies' *that could feasibly reduce those emissions*" as EPA suggests, it follows that those "requisite technologies" must be applied to directly reduce emissions from the vehicles on which they are installed.[77] And those technologies must remain with the vehicle for its useful life.[78]

The Proposed Rule results in fleet-wide standards that cannot be met by ICEVs alone; however, under the Clean Air Act, EPA may only set individual vehicle-level emission standards. Such standards must be for "emission[s]" from "any class or classes of new motor vehicles or new

---

[73] 42 U.S.C. § 7545(o)(2)(A)(i).
[74] *Id.*, § 7545(o)(2)(B); 87 Fed. Reg. 39,600 (July 1, 2022).
[75] 88 Fed. Reg. at 29,186.
[76] Rather, Executive Orders "simply serve as presidential directives to agency officials to consider certain policies when making rulemaking decisions." State of California v. EPA, No. 21-1018 (D.C. Cir. 2023), *Slip Op*. at 17.
[77] Proposed Rule at 29,231 (emphasis added).
[78] 42 U.S.C. § 7521(a)(1).

motor vehicle engines, which . . . cause, or contribute to," potentially harmful air pollution.[79] The plain language of this provision authorizes EPA to set standards for classes of *individual* vehicles or engines that emit air pollutants. As EPA acknowledges, EPA's "rules have historically not required the use of any particular technology, but rather have allowed manufacturers to use any technology that demonstrates the engines or vehicles meet the standards over the applicable test procedures."[80] This precedent is squarely at odds with the Proposed Rule, where "any technology" cannot be used to meet the proposed emission standards, which can only be met by phasing out ICEVs, distorting as well as exceeding EPA's authority to set standards to permit the "development and application of the requisite technology."[81]

EPA both describes ZEVs as having "zero emissions"[82] for purposes of compliance with its standards and is "proposing to make the 0 g/mile treatment of ZEV operation a permanent part of the program."[83] If so, then EPA's proposed standards that apply to ZEVs do not apply "to the emission of any air pollutant from any class or classes vehicles … that cause, or contribute to, air pollution."[84] In other words, EPA cannot have it both ways. It cannot claim to be regulating emissions from ZEVs while at the same time considering such vehicles to have no emissions.

The Clean Air Act does not provide EPA authority to regulate vehicles that have tailpipe emissions by including them within the same standards that apply to vehicles without tailpipe emissions. For LDVs specifically, emission standards must reflect "the greatest degree of emission reduction achievable through the application of technology which the [EPA] determines will be available" during the relevant model year.[85] The Supreme Court noted that similar language in Section 111(d) of the Act generally refers to "measures that would reduce pollution by causing [sources] to operate more cleanly."[86] Congress enabled EPA to increase emission standard stringency through cleaner fuels and improved emissions-related systems to be incorporated into ICEVs such as advances in fuel injection, exhaust gas combustion management, and advances in catalysts to neutralize pollutants of concern.[87] ZEVs are not similarly situated "technology" originally contemplated by Congress. To ensure compliance with emission standards under Section 202(a), Congress required "emissions-related systems" and accompanying "diagnostic systems" on each vehicle, underscoring its view that the vehicles subject to an emission standard emit the relevant pollutant in EPA's judgment.

In addition, by factoring in ZEV performance into standards broadly applicable to both ZEV and non-ZEV, utilizing averaging, EPA is ignoring the technological feasibility of emissions-related

---

[79] 42 U.S.C. § 7521(a)(1).
[80] *Id.* at 29,232. Moreover, while EPA suggests that the Clean Air Act's legislative history shows that Congress contemplated replacing the ICEV with ZEVs, *id.*, such an interpretation is squarely at odds with the text of the statute. If EPA were to replace ICEVs with ZEVs – as the Proposed Rule would put it on track to do – each and every statutory reference to an "engine" would be meaningless as ZEVs do not have engines.
[81] 42 U.S.C. § 7521(a)(2).
[82] "As the term 'zero-emission vehicle' suggests, these cars and trucks have zero GHG and criteria pollutant emissions from their tailpipes." 88 Fed. Reg. at 29,187.
[83] *Id.* at 29,251,
[84] 42 U.S.C. § 7521(a)(1).
[85] 42 U.S.C. § 7521(a)(3)(A)(i).
[86] *West Virginia*, 142 S. Ct. at 2599.
[87] For example, Section 202(m) requires the monitoring of "emission-related systems" such as the "catalytic converter and oxygen sensor." 42 U.S.C. § 7521(m)(l).

systems and simply requiring the production of fewer ICEVs. This approach also ignores the fact that major automakers are on differing technological paths, as noted by the National Academies of Sciences, "with some focusing their research and development and advanced technology deployment more squarely on ZEVs, and others more focused on advanced HEVs to maximize ICE efficiency."[88] During the last two years, 17,000 research articles were published that focus on improving ICEVs or lowering their carbon footprint with liquid fuel technologies, such as lower carbon fuel production technologies, the substitution of lower carbon feedstocks and lower carbon fuels, and by optimizing fuel properties like octane.[89] Instead of focusing on advances to ICEV technologies when setting the standards, the Proposed Rule relies on ZEVs as the only relevant advanced technology, which is arbitrary and capricious given that many ICEV technologies, unlike mass adoption of ZEVs, "permit the development and application of the requisite technology" within the time necessary to comply with the forthcoming standards.[90]

And even for criteria pollutants emitted from ICEVs, the Clean Air Act says nothing about averaging across fleets or banking and trading credits across different model years, different vehicle classes, and OEMs. While EPA previously adopted fleetwide averaging, it has also acknowledged that "Congress did not specifically contemplate an averaging program when it enacted the Clean Air Act."[91] And "[j]ust as the statute does not explicitly address EPA's authority to allow averaging, it does not address the Agency's authority to permit banking and trading."[92] By definition, then, the Act does not address—let alone clearly authorize—the use of averaging, banking, and trading in a manner that mandates electrification of the national vehicle fleet of motor vehicles and motor vehicle engines. Instead, as EPA acknowledges, even if its authority to use averaging, banking, and trading could be inferred, such programs are limited to compliance flexibilities rather than setting the standards with which vehicles must comply or phasing out ICEVs on a national scale.[93]

The structure of the Clean Air Act and its regulatory provisions for standard setting, certification, compliance enforcement, warranties, and penalties also directly conflict with a fleet-wide averaging regulatory regime. Notably, under Section 202(a), EPA "shall test, or require to be tested in such manner as [it] deems appropriate, any new motor vehicle or new motor vehicle engine submitted by a manufacturer" and issue a certificate of conformity "if such vehicle or engine" complies with the standards.[94] And EPA must "test any emission control system incorporated in a motor vehicle or motor vehicle engine . . . to determine whether such a system enables such vehicle or engine to conform to the standards required to be prescribe under [Section 202(b)]" of the Act.[95] EPA's use of a fleetwide averaging regulatory regime directly conflicts with the statutory provisions that Congress already included to provide manufacturers with compliance flexibility. For example, section 202(b)(3) provided compliance flexibilities for

---

[88] National Academies of Sciences, Engineering, and Medicine. 2021. Assessment of Technologies for Improving Light-Duty Vehicle Fuel Economy—2025-2035. Washington, DC: The National Academies Press. p. 369. https://doi.org/10.17226/26092.
[89] Fuels Institute. *Literature Review Summary: Future Capabilities of Combustion Engines and Liquid Fuels*. Nov. 2022.
[90] 42 U.S.C. § 7521(a).
[91] 48 Fed. Reg. 33,456, 33,458 (July 21, 1983)
[92] 54 Fed. Reg. 22,652, 22,665 (May 25, 1989); *see* 55 Fed. Reg. 30,584, 30,593 (July 26, 1990) (same).
[93] Proposed Rule at 29,196-97 (describing averaging, banking, and trading provisions as "help[ing] manufacturers to employ a wide range of compliance paths").
[94] 42 U.S.C. § 7525(a)(1).
[95] 42 U.S.C. § 7525(a)(2).

NOx, but only for no "more than 5 percent of [a] manufacturer's production or more than fifty thousand vehicles or engines, whichever is greater."[96] This provision would be nonsensical under a fleetwide-averaging regime where, if applied, an OEM could give itself a waiver for large swaths of its fleet by over-complying for certain product lines well beyond its 5 percent or 50,000 vehicle allotment.[97] Together, the Clean Air Act regulatory framework contemplates EPA regulating vehicles individually. But this cannot be accomplished if there is not a clear emission standard applicable to a single vehicle at the start of a model year.

Moreover, EPA's Proposal further conflicts with the Clean Air Act by establishing a new class of medium duty vehicles that conflicts with the plain language of the CAA defining heavy-duty vehicles. Congress created specific lead time requirements for heavy-duty vehicles to ensure technological feasibility: "Any standard promulgated or revised under this paragraph and applicable to classes or categories of heavy-duty vehicles or engines shall apply for a period of no less than 3 model years beginning no earlier than the model year commencing 4 years after such revised standard is promulgated."[98] In the Proposed Rule, EPA lumps a newly-defined category of Class 2b and 3 "medium-duty vehicles" (with a gross vehicle weight rating between 8,501 and 14,000 pounds) in with light-duty vehicles. But medium-duty vehicles are actually "heavy-duty vehicles" under the Clean Air Act, which defines "heavy-duty vehicle" as "a truck, bus, or other vehicle manufactured primarily for use on the public streets, roads, and highways (not including any vehicle operated exclusively on a rail or rails) which has a gross vehicle weight (as determined under regulations promulgated by the Administrator) ***in excess of six thousand pounds***."[99] Presuming the Proposed Rule results in a final rule promulgated in 2024, any new standards for Class 2b or 3 vehicles cannot apply until model year 2028.[100] Furthermore, EPA is ignoring Congressional direction to issue separate standards for heavy-duty and light-duty vehicles by comingling them into the same fleet averaging, banking, and trading program (which is also unlawful, see Section III.A.1).[101]

2. EPA Fails to Adequately Evaluate ZEV Safety Risks as Required by Clean Air Act Section 202(a)(4)(B).

In setting new emissions standards, EPA must consider whether any technology used to comply with the requirements "will cause or contribute to an unreasonable risk to public health, welfare, or safety in its operation or function."[102] The Proposed Rule's health and safety assessment, however, is myopically limited to the health effects of tailpipe emissions and fails to fully account for all of the risks posed by ZEV mandates. Increased prices to the consumer resulting from EPA's proposed rule (when purchasing a new vehicle) likely will delay the purchase of all vehicles subject to the rule and slow fleet turnover. For example, nowhere in the Proposal

---

[96] 42 U.S.C. § 7521(b)(3).
[97] While Clean Air Act Section 202(b)(3) is specific to legacy light-duty vehicles through model year 1985 subject to a 1.5 grams/mile NOx standard and no longer directly applicable, the provision is incongruent with fleet-wide averaging, and no associated amendments to Section 202(a) would support a different reading today.
[98] *Id.*, § 7521(a)(3)(C).
[99] *Id.*, § 7521(b)(3)(C) (emphasis added).
[100] EPA's promulgation of standards for medium duty vehicles and light duty trucks along with other light duty vehicles is arbitrary and capricious as EPA itself recognizes that its approach – "for regulatory purposes" – differs from the statutory definition of heavy-duty vehicles in the Clean Air Act. *See* 88 Fed. Reg. at 29226, n. 382.
[101] *See* 42 U.S.C. § 7521(a)(3)(B) (recognizing additional requirements for heavy-duty vehicles).
[102] 42 U.S.C. § 7521(a)(4)(A).

does EPA assess how slower fleet turnover impacts safety and the environment. Older vehicles have fewer safety features and higher emissions profiles than new vehicles. Other interested parties have raised safety issues that EPA has a duty to analyze.[103] EPA must analyze and take comment on the safety issues associated with ZEV mandates prior to finalizing the Proposed Rule.

B. The Proposed Rule Contravenes the Clean Air Act's Direction that EPA's Regulations be Technologically Feasible

Section 202(a)(2) requires EPA to provide lead time to "permit the development and application of the requisite technology."[104] But, as discussed in Section IV.B, EPA's overly-aggressive demands for electrification cannot be supported—there will not be sufficient infrastructure to generate and transmit electricity and charge the vehicles EPA is requiring OEMs to produce. EPA has simply failed to provide both the OEMs, as well as the ancillary services required to sustain an electrified fleet, with enough time to develop the necessary infrastructure.[105] EPA's failure to adequately ensure sufficient infrastructure demonstrates that it is not providing sufficient lead time to "permit the development and *application* of the requisite technology, giving appropriate consideration to the cost of compliance within such period."[106]

Relatedly, Congress established the need to consider technology feasibility in establishing fuel economy regulations under the Energy Policy and Conservation Act ("EPCA"). Here, the National Highway Traffic Safety Administration ("NHTSA") "may not consider" the fuel economy of EVs in setting Corporate Average Fuel Economy (CAFE) standards.[107] Conducting joint EPA-NHTSA rulemakings for complementary GHG and CAFE requirements helps OEMs comply with both agencies' standards. But in forgoing joint rulemaking, EPA ignores Congress' determination that EVs cannot be considered when determining what is the maximum *feasible* fuel economy level from which to develop regulations. Allowing EPA to consider EVs and, in turn, establish *de facto* ZEV mandates (and *de facto* average fuel economy standards) ultimately skews the new vehicle market and impede NHTSA's ability to establish its own CAFE standards that comport with EPCA. Most importantly, such an approach directly contravenes the underlying premise of the Supreme Court's holding in *Massachusetts v. EPA* that "[EPA and NHTSA] obligations may overlap, but there is no reason to think the two agencies cannot both administer their obligations and yet avoid inconsistency."[108] After implementing GHG standards jointly with NHTSA's fuel economy standards since 2012, and despite Government Accountability Office recommendations to the contrary,[109] EPA separated the rulemaking to undo previously established MY 2023-2026 standards and, in this case, to avoid the direct statutory prohibition on consideration of EVs when establishing fuel economy standards.

---

[103] *See, e.g.*, https://www.nhtsa.gov/sites/nhtsa.gov/files/documents/12848-lithiumionsafetyhybrids_101217-v3-tag.pdf.
[104] 42 U.S.C. § 7521(a)(2).
[105] See AAI Comments at ii-iv.
[106] *Id.* (emphasis added).
[107] 49 U.S.C. § 32902(h). Here, NHTSA may not consider the fuel economy of "dedicated automobiles," which are defined as those that operate only on "alternative fuel." Alternative fuel, in turn, includes electricity. 49 U.S.C. § 32901(j).
[108] 549 U.S. 497, 532 (2007).
[109] GOVERNMENT ACCOUNTABILITY OFFICE, "NHTSA and EPA's Partnership for Setting Fuel Economy and Greenhouse Gas Emissions Standards Improved Analysis and Should be Maintained" (February 2010) *available at* https://www.gao.gov/assets/gao-10-336.pdf

As EPA considers the technological feasibility of its Proposal, it should further consider the OEMs' position that they will not possess adequate resources to adapt to these stringent requirements within the prescribed timeframe, especially in light of increasing global supply chain issues and price increases associated with battery demand.[110] EPA's proposal will require an unprecedented rate of vehicle technology change that the nation and OEMs have never experienced before.

C. In the Alternative, EPA Should Set Separate Emissions Standards for Each Vehicle Class.

The Clean Air Act authorizes EPA to establish and revise standards for the emissions of air pollutants from "any class or classes of new motor vehicles or new motor vehicle engines….that endanger public health or welfare"[111] Assuming for sake of argument EPA has authority to set emissions standards for EVs, which we posit it does not,[112] EPA should promulgate distinct emissions standards for each vehicle class on the basis of the vehicle's powertrain (e.g., diesel, gasoline, natural gas, electricity). At a minimum, this would obligate EPA to abandon its position that ZEVs are emission-less and account for upstream and other lifecycle emissions as the agency envisioned in its 2012 rule.[113] This approach would ensure that EPA is regulating relevant pollutants from specific vehicle classes and would promote a level playing field for different vehicle technologies.[114]

ZEVs are entirely distinct from other classes of vehicles. Their powertrain design frontloads emissions, meaning the air pollutants associated with these vehicles are emitted before operation (*i.e.,* during vehicle production and recharging). During operation, a ZEV experiences no direct drivetrain emissions. In contrast, most emissions from ICEVs generally occur during operation, not production and refueling. Such different emissions points require different regulatory standards.

EPA recognized the need to treat different motor vehicle technologies differently. In previous rulemakings, EPA distinguished between Otto-cycle (primarily gasoline-fueled vehicles) and diesel heavy-duty vehicles.[115] EPA also differentiated between gasoline- and diesel-fueled vehicles and those operated on natural gas.[116] And more than 30 years ago, EPA promulgated specific standards for methanol-fueled vehicles.[117] The regulations varied emission-control

[110] AAI Comments at ii-iv.
[111] 42 U.S.C.§ 7521(a)(1).
[112] As discussed in Section III.A., *supra*, the CAA sec. 202 does not authorize EPA to regulate ZEV emissions because EPA characterizes them as having "zero" emissions.
[113] 75 Fed. Reg. 25,324, 25,341 (May 7, 2010).
[114] 42 U.S.C. § 7521(a)(3)(A)(ii) ("In establishing classes or categories of vehicles or engines for purposes of regulations under this paragraph, the Administrator may base such classes or categories on gross vehicle weight, horsepower, type of fuel used, or other appropriate factors."). Although this section of CAA Section 202 references "heavy-duty" vehicles, this applies to light-duty vehicles that weigh more than 6,000 lbs gross vehicle weight rating, such as light-duty heavy trucks, and if EPA has authority to set emissions standards for EVs, the Clean Air Act does not otherwise limit EPA's discretion to expand its classification of vehicles by fuel type.
[115] See e.g., 40 C.F.R. §§86.098-10, 86.099-11.
[116] 59 Fed. Reg. 48472 (Sept. 21, 1994).
[117] 54 Fed. Reg. 14426 (April 11, 1989).
[117] *Id.* at 14428.

requirements based on fuel type.[118] For example, in promulgating regulations for methanol-fueled vehicles, EPA explained that "because the design and function of methanol vehicles is very much like that of their petroleum counterparts, the methanol emission control requirements are comparable (in most cases identical) to those already in existence."[119] At the same time, within the methanol vehicle rule, EPA noted that *"in some future cases, this criterion may not be sufficient to adequately determine the classification of a vehicle . . .* [EPA] may need to take into account other relevant factors, such as compression ratio, combustion characteristics, characteristics of the engine's operating thermodynamics, or intended in-use duty cycle."[120] In other words, EPA recognized the varying methods of converting energy into motive power could require different criterion (classification) for regulating different vehicles. And the agency did so in circumstances where the drivetrain technologies were substantially more similar to ZEV than to ICEV. To remain consistent in its regulatory approach, were EPA to have the authority to set emissions standards for ZEVs, it must promulgate separate emission standards that apply solely to ZEVs.

AFPM suggests that EPA establish separate emission standards based on the lifecycle emissions of a ZEV and ascribe those emissions to the vehicle over its useful life. Previous regulatory history supports such an approach.

For example, while EPA did not set widely varying emission standards for methanol-fueled vehicles versus "conventionally fueled" vehicles, the Agency discussed how lifecycle emissions were relevant to its determination of Clean Air Act vehicle emission standards:

> Methanol vehicles could have an impact on global warming (i.e., the "greenhouse effect") as well. While increased combustion efficiency may result in lower carbon dioxide (CO_2) emissions from methanol-fueled vehicles compared with petroleum-fueled vehicles, the overall impact of a shift to methanol-fueled vehicles on global warming is uncertain. *The analysis of the impact must include the effect of not only emissions from the vehicles, but also emissions from methanol production.*
>
> * * *
>
> In the long-term, the implications of using methanol as a transportation fuel are difficult to predict. Should petroleum and natural gas prices rise substantially, it is probable that methanol would be produced from coal. Assuming vehicle miles traveled, and other factors remain constant and assuming current process technology, *a methanol-fueled system using methanol derived from coal could result in as much as a doubling of the motor vehicle contribution to the greenhouse effect relative to the contribution of current petroleum fuels*.[121]

EPA's continued reliance on attribute-based regulation of light duty vehicles which focuses solely on the "footprint" of a vehicle cannot be justified in relation to the larger goals expressed in

---

[118] See, e.g., 40 C.F.R. §80-090-8(a)(1)(A)-(B), differentiating as between hydrocarbon standards for petroleum-fueled vehicles and organic material hydrocarbon equivalent for methanol-fueled vehicles; §86.090-11, imposing different standards for 1990 and later MY Otto-cycle heavy-duty vehicles from same weight methanol-fueled vehicles.
[119] *Id.* at 14428.
[120] *Id*. at 14429.
[121] *Id.* at 14451-2.

the Proposed Rule. The statute directs EPA to address "class or classes" of vehicles and EVs constitute such a severable class where emissions must be considered based on the full attributes (including lifecycle GHG emissions) of that class of vehicles.

The current Proposal tilts the scale in favor of EVs by proposing emissions standards that only a ZEV can meet, resulting in a de facto ban of ICEVs. EPA should instead consider an approach that accounts for the actual transportation related emissions rather than ignoring the upstream emissions of EVs and suggesting they are "zero." Setting emission standards that are technologically achievable would allow OEMs to reduce carbon emissions from each powertrain in a cost-effective manner. This would provide parity and fully account for total emissions impacts across multiple vehicle technologies.

IV. The Proposed Rule is Arbitrary and Capricious

Even if EPA had Congressional authority to promulgate the Proposed Rule, which it does not, the Proposal is substantively deficient and based on illogical reasoning and incomplete analysis. Therefore, it constitutes arbitrary and capricious decision-making.

A. Advanced Clean Cars II ("ACC II") Cannot be a Basis for this Rulemaking

EPA points to California's ACC II program and adoption by Section 177 states to support its projections of increased PEV penetration,[122] but the ACC II has not received a waiver, and EPA did not even have the waiver application when the Proposed Rule was published.[123] The CAA requires EPA to evaluate California's waiver request to ensure that California did not arbitrarily determine that it needs "ZEV mandates" to address compelling and extraordinary circumstances. As Principal Deputy Administrator for the Office of Air and Radiation Joe Goffman testified on June 21, 2023, EPA just received the waiver request. Given that the EPA official responsible for overseeing the California waiver request publicly acknowledged that EPA has not determined whether it will grant a waiver for ACC II, the Agency cannot rely on ACC II as a basis for this Proposal. Moreover, because California concedes that ACC II will not meaningfully address the impacts of climate change in California and ACC II will slow fleet turnover and retard California's progress toward meeting the NAAQS, California is NOT eligible for a waiver and ACC II is preempted. EPA's reliance on ACC II as support for this rule is pre-decisional and another example of arbitrary and capricious decision-making.

B. The Proposed Rule is Impracticable

1. EPA's Proposed Rule Ignores the Reality of Current ZEV Production.

In describing the need for this regulatory action, EPA suggests that rapid electrification resulting from the Proposed Rule either is already in progress or aligned with the automotive industry. In support, EPA cites public statements of the automotive industry to justify the proposed standards.[124] Representing 42 car companies, automotive suppliers, and automotive technology

[122] Proposed Rule at 29,118.
[123] 88 Fed. Reg. 29,189; *See, e.g.*, Initial Br. For Private Petitioners, *State of Ohio, et al. v. Envt'l Prot. Agency*, et al., No. 22-1081 (D.C. Cir. Oct. 24, 2022).
[124] Proposed Rule at 29,329.

companies that produce about 97 percent of the new vehicles sold in the United States, the Alliance for Automotive Innovation (AAI) submitted the following comments on this Proposal:

- The proposed GHG and criteria pollutant standards "are neither reasonable nor achievable in the timeframe covered in this proposal";[125]

- EPA's proposal cannot be met "without substantially increasing the cost of vehicles, reducing consumer choice, and disadvantaging major portions of the United States population and territory";[126]

The Proposed Rule's standards exceed even the public aspirations of OEMs' vehicle and market share targets.

EPA likewise assumes that the IRA and the BIL funds will be adequate to build the necessary electrification infrastructure. It is uncertain that (1) critical minerals will be available to manufacture ZEV batteries (see Section I.A.1); (2) consumers will buy EVs at the rate assumed by EPA (see Section IV.B.2); and (3) there will be ample electricity to power these vehicles (see Sections I.B and IV.B.3).[127] What is certain is that the Proposal's timeline is unachievable and completely detached from reality.[128] EPA also improperly relied on the general characterization of recent years of the light-duty and medium-duty market as supplemented by incentives in the BIL and IRA to support its proposition that there will be a rapid increase in ZEV market penetration. Setting aside the laws of supply and demand and the fact that the future availability of ZEVs is insufficient to meet the ZEV adoption requirements proposed by EPA (as discussed further below), EPA improperly relies on the number of models currently available on the free market as a surrogate for the number of actual units sold and in use. The underlying reality is that without federal regulation requiring vastly increased ZEV penetration, providing automakers certainty for long-term planning, automakers could not financially justify long-term investment in a technology with tepid consumer demand. The referenced electrification projections may be a function of OEMs striving to create certainty and minimize risk as they attempt to comply with forthcoming regulations. Indeed, the CEO of the Alliance for Automotive Innovation recently questioned the feasibility of the Proposed Rule – stating that the proposal was too aggressive and could benefit China:

> I've said the EPA proposal wasn't feasible without certain public policies and in light of today's market and supply chain conditions . . . . There's not enough charging and uncertain utility and grid capacity. Here's the big one – and where China looms largest – essentially no domestic or allied supply of battery critical minerals,

[125] Alliance for Automotive Innovation, Comments to the Environmental Protection Agency, Multi-Pollutant Emissions Standards for Model Years 2027 and Later Light-Duty and Medium-Duty Vehicles, Proposed Rule, Docket No. EPA-HQ-OAR-2022-0829 (hereinafter AAI Comments) at ii.
[126] *Id.*
[127] *Id*.
[128] Id.

> processing, and components until 2025 (and even then, nowhere near enough to supply what's needed).[129]

EPA notes that many OEMs and battery manufacturers announced plans to build gigafactories in North America due to government incentives like the IRA. But these are extraordinarily complex projects that will take many years to materialize if they progress to the point of battery production. In the DRIA, EPA states that, based on construction announcements by major automakers, "the U.S. will have more than 800 GWh of cell or battery manufacturing capacity by 2025, and ~1000 GWh by 2030, enough to supply from 10 to 13 million BEVs per year."[130] By contrast, Wood Mackenzie projects U.S. capacity of less than half that level, at 422 GWh/ year in 2030,[131] because many projects have failed to materialize or are delayed as market and other conditions change.

Regardless of the purported capacity, it is unlikely these factories will operate beyond 50 percent capacity for years. Mature battery factories today rarely operate above 80 percent utilization rates. For example, in 2022, there was 1,036 GWh of global battery production capacity, but only 450 GWh of actual production. While there was approximately 7TWh of forecast battery capacity planned as of September 2022, Benchmark Minerals Intelligence (BMI) forecast total global supply of Li-ion batteries to reach only 4.5 TWh by 2031 or a 64 percent utilization rate.[132] This step in the value chain could potentially create a critical bottleneck, in stark contrast to EPA's assumed 998 GWh capacity by 2030. Given the disparity in forecasts from different reputable sources, EPA's technology feasibility assessment should factor in sensitivity cases and acknowledge potential disruptions in the supply chain. Including such sensitivity cases is fully justified given EPA's experience in projecting available volumes of cellulosic biofuel for purposes of the RFS. EPA consistently overestimated production of liquid cellulosic biofuel from Cellulosic Biofuel Production 2010–2013 (RINs).

EPA's overreliance on the BIL, IRA, and California's unlawful ACC II further underscores the insufficiency of the Proposal's analysis. Citations to the BIL and IRA are speculative at best. Moreover, ACC II is not in effect and still requires a waiver. EPA cannot prejudge the outcome of that regulatory process before it even publishes the waiver package for public comment.

2. EPA's Proposed Rule Commands Impractical Adoption Rates.

Automakers may be publicly acquiescing to government demands, but this does not demonstrate that the technology and infrastructure will be available in the stated period and, most critically, that consumers are ready and willing to adopt electric vehicles. Indeed, many of the automakers have set "goals" for their electrification, premised explicitly on a litany of federal and state subsidies for purchase and infrastructure assistance. And these government demands, and

---

129 John Bozzella, EPA's EV Rules: What it Means for China and the U.S Auto Market. June 12, 2023, *available at* https://www.autosinnovate.org/posts/blog/epas-ev-rules-what-it-means-for-china-and-the-us-auto-market (accessed June 23, 2023).
130 DRIA at 3-20.
131 Wood Mackenzie, "The EPA plans to rev up US EV sales," (Apr. 14, 2023), *available at* https://www.woodmac.com/news/opinion/the-epa-plans-to-rev-up-us-ev-sales/.
132 BENCHMARK SOURCE, "Ambition versus reality: why battery production capacity does not equal supply" (Sept. 2, 2022) at Charts 5, 6, *available at* https://source.benchmarkminerals.com/article/ambition-versus-reality-why-battery-production-capacity-does-not-equal-supply.

indeed government subsidies, can vanish in an instant, through changes in administrations or judicial challenges.

As EPA acknowledges, the facts show that only between 2.2 and 4.4 percent of light duty vehicles *produced* in 2021 were electric, rising to about 8.4 percent in 2022.[133] Production may or may not translate into sales and vehicle registration. State-by-state EV registration data shows that the percentage of EV registrations relative to all registered vehicles ranged from 0.15 percent in Mississippi to 4.01 percent in California.[134] Thus, the ambitions of even the most aggressive OEM from a ZEV adoption rate perspective would require unprecedented sales over the next seven years.[135]

EPA offers no support for its conclusion that there will be substantial consumer adoption of ZEVs to achieve the increases projected by the Proposed Rule. To the contrary, recent polling shows that most Americans continue to say that they are unlikely, or will categorically refuse, to buy an EV. As just one example, a Gallup poll conducted in April revealed that only 4 percent of adults owned an EV and just 12 percent are seriously considering buying one. However, 41 percent of adults said they would never buy an EV, raising fundamental questions about how EPA can predict that ZEV sales will reach 67 percent in 2032.[136]

According to Wards Intelligence, through May 2023, Americans purchased 5.9 million ICEVs, representing 93 percent of all LDVs sold during the first five months.[137] At this pace, more than 14 million new ICEVs will be purchased during 2023.[138] With the continued sales of ICEVs, this Rule's effort to limit the ability to purchase ICEVs, and more than 50 percent of ICEVs remaining in service, it is mindboggling, as discussed in Section IV.6 below, that EPA never considered the alternative scenarios using vehicle technologies and lower carbon fuels.

EV charging infrastructure, range, and charging time remain top concerns for nearly half of U.S. customers.[139] OEMs expect that ZEV penetration will not be uniform across markets, with

---

[133] Proposed Rule at 29,189; Sebastian Blanco, Car And Driver, "Strict EPA Rules for 2027 – 2032 Vehicles Announced, Garnering a Range of Reactions" (Apr. 13, 2023) *available at* https://www.caranddriver.com/news/a43546970/new-strict-epa-mpg-rules-for-2027-2032-vehicles/.

[134] 2023 EV Charing Station Report: State-by-State Breakdown, June 16, 2023, available at https://zutobi.com/us/driver-guides/the-us-electric-vehicle-charging-point-report.

[135] VOLVO GROUP, "Report on the first quarter 2023," *available at* https://www.volvogroup.com/content/dam/volvo-group/markets/master/news/2023/apr/4519530-volvo-group-q1-2023.pdf; TUBES AND LUBES DAILY, "Volvo launches electric truck with longer range in N. America" (Jan. 2021) *available at https://www.fuelsandlubes.com/volvo-launches-electric-truck-with-longer-range-in-n-america/?mc_cid=b124969b23&mc_eid=4a00dc8f80* (Volvo Trucks set target that half of all trucks sold are electric by 2030); VOLVO GROUP, "Geared for Growth – Annual Report 2022," *available at* https://www.volvogroup.com/content/dam/volvo-group/markets/master/investors/reports-and-presentations/annual-reports/AB-Volvo-Annual-Report-2022.pdf.

[136] Megan Brenan, Gallup, Most Americans Are Not Completely Sold on Electric Vehicles (April 12, 2023). Retrieved a https://news.gallup.com/poll/474095/americans-not-completely-sold-electric-vehicles.aspxt .

[137] John Eichberger, *Decarbonizing Combustion Vehicles – A Critical Part in Reducing Transportation Emissions*, Transportation Energy Institute, June 2023. Available at Decarbonizing Combustion Vehicles – A Critical Part in Reducing Transportation Emissions - Transportation Energy Institute.

[138] *Id*.

[139] Phillipp Kampshoff, et al., McKinsey & Co., "Building the electric-vehicle charging infrastructure America needs" (Apr. 18, 2022) *available at* https://www.mckinsey.com/industries/public-sector/our-

larger impact in markets with more low carbon intensity electricity and greater electrical grid reliability.[140] Toyota announced that regional energy variation is the reason Toyota will provide a diversified range of carbon neutral options to meet the needs and circumstances in every country and region.[141] Toyota believes optionality facilitates the ability to adapt to change, while selecting a single option is an attempt to predict the future in uncertain times.[142]

Importantly, successful implementation of EPA's Proposed Rule depends on consumer choice as much as it depends on technological improvements. But there is evidence that premature embrace of ZEV may backfire if consumers grow frustrated with inadequate infrastructure. Consumer market demand will not, and cannot, increase to meet the Proposal's required supply. Charging capabilities is a key apprehension for nearly half the U.S. consumer market.

For example, in California, roughly one-fifth of consumers who initially purchased PHEVs or ZEVs subsequently went back to ICEVs based on frustration with convenience factors such as unavailability of charging.[143] As the study on discontinuance cited by EPA states, "[R]ange isn't correlated with discontinuance in PHEVs or ZEVs but satisfaction with and access to charging [is]."[144] Those with multiple vehicles and a single-family home find it easier to continue ownership than those with fewer vehicles or living in multi-unit dwellings, which could lower ZEV adoption rates as the ZEV market becomes more mainstream.[145] Finally, a survey of PHEV owners in California found that current PHEV would *not* purchase their PHEV without incentives, therefore EVs and PHEVs adoption may face more challenges over time.[146] Moreover, EPA ignores that current ZEV sales are linked to mandates that force increased prices of ICEVs to subsidize the mandated ZEV sales. Those mandates are under judicial review.

As discussed in more detail below, consumer market demand will not, and cannot, increase to meet the Proposal's required supply. Charging capabilities, which creates range anxiety, is a key apprehension for nearly half the U.S. consumer market. EVs have less range, both technically and practically. As noted by J.D. Power, "[T]he majority of EVs provide between

---

insights/building-the-electric-vehicle-charging-infrastructure-america-needs; EVBox, "6 reasons why your electric car isn't charging as fast as you'd expect," Jan. 6, 2023, *available at* https://blog.evbox.com/6-reasons-charging-times.

140 The North American Electric Reliability Corporation (NERC's) *2022 Long-Term Reliability Assessment* (Dec. 2022) projects reliability concerns for certain regional entities. A*vailable at* https://www.nerc.com/pa/RAPA/ra/Reliability%20Assessments%20DL/NERC_LTRA_2022.pdf.

141 Toyota Motor Corporation, '"Video: Media Briefing on Battery EV Strategies,'' Press Release, December 14, 2021. *available at* https://global.toyota/en/newsroom/corporate/36428993.html.

142 Id.

143 Hardman, S., and Tal, G., *Discontinuance Among California's Electric Vehicle Buyers: Why are Some Consumers Abandoning Electric Vehicles*, April 21, 2021, Report for National Center for Sustainable Transportation. *available at https://ncst.ucdavis.edu/research-product/discontinuance-among-californias-electric-vehicle-buyers-why-are-some-consumers*

144 *Id*. at 26.

145 *Id*.

146 *Id.* See also JATO Blog, "A breakdown of the US EV market by State shows more incentives equals more sales", April 9, 2019 (latest research shows current tax credits and other incentives in the US are unequal among states, and that EV sales are growing at the fastest rate in states offering financial incentives).

200 and 300 miles of range on a full charge."[147] This same article, however, also noted that EVs with less than 200-mile ranges (such as the 2022 Nissan Leaf at 149 miles or the 2022 Mazda MX-30 at 100 miles) are "either affordable or focused on performance."[148] With respect to longer range vehicles, claimed vehicle ranges of up to 516 miles are available, but this range comes at considerable cost. The number 1 range-rated vehicle by Car and Driver, the 2023 Lucid Air, carries a base price of $113,650. And while three out of the ten top-rated EVs by Car and Driver were more "reasonably priced" from $44,630 to $56,630, all other models within the top 10 cost anywhere from $74,800 to $110,295.[149]

Moreover, the time it takes to charge a ZEV compared to fueling an ICEV deters ZEV adoption.[150] Depending on the type of vehicle (ZEV v. PHEV) and charger (Level 1, Level 2, or Direct current fast charging equipment ("DCFCs")), charging times from empty to 80 percent charged can range from 40-50 hours (Level 1 charging) to 20 minutes to one hour (DCFC), although most PHEVs on the market do not work with DCFCs.[151] In early 2023, a Boston Globe survey around the Boston metropolitan area found DCFC chargers were unreliable, going offline for weeks or months at a time.[152] Since close to two-thirds of U.S. households do not purchase new vehicles, lower-income people are more likely to purchase less expensive, early generation PEVs with less range and using a Level 1 or Level 2 charger requires longer charge times.[153] These extended recharging times remain a barrier to EV adoption.[154]

Additional barriers to ZEV adoption by particularly low-income stakeholders, include but are not limited to restricted driving/battery range; inability to charge in different housing and work situations; high price points to purchase, maintain, and insure EVs; availability of replacement parts and qualified mechanics, as well as ease and cost of repairs; and unpredictability regarding future electricity costs. EPA cannot ignore these real-world limitations.

EPA requests comment on their approach to determining charging time, as set forth in the DRIA, Chapter 4.[155] EPA's analysis is contingent on unsupported assumptions regarding (1) U.S. consumers' adoption of and ability to purchase more expensive ZEVs (see Sections IV.B.2 and IV.E.2.ii); (2) the type of ZEV purchased (used ZEVs or PHEVs compatible with slower charging units or new ZEVs that can use DCFC) (Section IV,B.2 addresses charging times); (3) the

---

[147] *See* Sebastian Blanco, *List of EVs Sorted by Range* (Sept. 1, 2022), www.jdpower.com/cars/shopping-guides/list-of-evs-sorted-by-range.
[148] Id.
[149] *See* Nicholas Wallace, Austin Irwin, & Nick Kurczewski, *Longest Range Electric Cars for 2023, Ranked* (Mar. 23, 2023), https://www.caranddriver.com/features/g32634624/ev-longest-driving-range/.
[150] EVBox, EV Box Mobility Monitor (June 2022). Available at evbox-mobility-monitor-2022-intl.pdf (a study of EV adoption in France, Germany, the Netherlands, and the UK revealed that excessive charging time remains a deterrent to EV adoption).
[151] U.S. Department of Transportation, *Charger type and speed.* Available at https://www.transportation.gov/rural/ev/toolkit/ev-basics/charging-speeds.
[152] Aaron Pressman, "Inside the crazy, mixed-up world of electric-vehicle charger pricing," The Boston Globe, March 27, 2023. Available at Inside the crazy, mixed-up world of electric-vehicle charger pricing (boston.com).
[153] Hardman, Scott, et al. "A Perspective on Equity in the Transition to Electric Vehicles." *MIT Science Policy Review*, 20 Aug. 2021, sciencepolicyreview.org/2021/08/equity-transition-electric-vehicles/. Accessed 29 June 2023.
[154] Exro, Barriers to electric vehicle adoption in 2022. Available at Barriers to Electric Vehicle Adoption: The 4 Key Challenges (exro.com).
[155] 88 Fed. Reg. at 29,367.

availability of critical minerals and metals to expand the supply of reliable and renewable electricity (see Section I.B); and (4) the availability of reliable and affordable charging for all users (see Sections IV.B.4). Given the flaws in EPA's methodology that omits significant data sources and other factors and makes unsupported assumptions, EPA should revise its analysis concerning charging time and continue with promulgating a final rule for future emissions standards, that accounts for the reality of today's automotive market and not the public pronouncements of the automotive industry, a single state or group of states, or other unsupported estimates of future market growth.

3. EPA Fails to Adequately Assess the Availability of Electricity Generation, Distribution, and Transmission

Despite the potential for increased demands on domestic energy generation and generation capacity,[156] EPA offers little to no support that these demands will be sufficiently met. Similarly, EPA's DRIA offers scant analysis regarding the costs associated with meeting these increased infrastructure and energy generation/capacity needs beyond the flawed reliance on various legislative actions, such as the BIL and IRA.[157] Consequently, EPA is pushing a single technology at a pace that cannot be adopted within the time frame of its own proposal.[158]

Grid resiliency is at risk of further deterioration due to increasing power demand from electrification, not just in transportation. EPA overlooks this issue in another example of the agency's failure to address a major aspect of the Proposal. Notably absent from EPA's analysis is any demonstration that sufficient utilities and other infrastructure needed to support accelerated ZEV implementation will be available by MY27. Focusing solely on ZEV themselves, EPA has not adequately evaluated or grasped the time and resources required to permit, construct, and operate the necessary infrastructure to power these vehicles, while maintaining reliable and affordable electricity for all other power consumers. This is particularly concerning in light of the very real risk that the electric grid will not be able to meet the increased demand anticipated by the Proposed Rule.[159]

Power generation using traditional fuels has an advantage in that capacity is located near demand centers. Except for nuclear, any low-carbon power generation capacity must be located at the energy source (e.g., where the wind blows, water flows, sun shines). Supplying low-carbon

---

[156] *See, e.g.*, U.S. DRIVE, "Summary Report on EVs at Scale and the U.S. Electric Power System" (Nov. 2019), *available at* https://www.energy.gov/eere/vehicles/articles/summary-report-evs-scale-and-us-electric-power-system-2019 (summarizing impacts of light-duty vehicles on energy generation and generation capacity alone and acknowledging several potential challenges without including analysis of medium- and heavy-duty ZEVs).

[157] See, e.g., Salma Elmallah et al., Can distribution grid infrastructure accommodate residential electrification and electric vehicle adoption in Northern California? (Nov. 9, 2022), *available at* https://iopscience.iop.org/article/10.1088/2634-4505/ac949c (projecting that upgrades needed solely for the PG&E service area in Northern California, which serves 4.8 million electricity customers and is subject to aggressive targets for both EV adoption and electrification of residential space and water heating will add at least $1 billion and potentially $10 billion to PG&E's rate base).

[158] DRIA at 5-28.

[159] North American Electric Reliability Corporation, *2022 Long-Term Reliability Assessment* (Dec. 2022), 21, *available at* https://www.nerc.com/pa/RAPA/ra/Reliability%20Assessments%20DL/NERC_LTRA_2022.pdf (indicating that increased demand projections may lead to reliability concerns for the electric grid, especially as dual-peaking or seasonal peaking times change with increased electrification).

electricity to charge EVs also needs to resolve the transmission of that power to the demand center. Installation of transmission capacity in a timely manner is not guaranteed, or even likely. The Bureau of Land Management recently issued its record of decision for the SunZia Southwest Transmission Project more than 15 years after the project was proposed.[160] Once this incremental power is transmitted from supply location to a load center, there are potentially additional distribution constraints before the electrons reach charging stations and homes. Just to get a sense of the burden that charging will have on the electrical grid, One ZEV supercharger equals the launch of 70 air-conditioning units at once. Such an instant change in the power demand profile is a significant problem for the local distribution grid, requiring innumerable upgrades, such as replacement of nearly every distribution system transformer with a larger transformer, the costs of which are borne by all electric ratepayers. EV chargers typically used in a home (Level 2) can increase a home's peak load by 40 percent to 100 percent, which stress neighborhood transformers and compromise reliability.[161]

The intensity is further complicated in that the capacity factor (percentage of time a plant is likely to be available for generation) of thermal and photovoltaic solar (ranging from 7-32 percent) and wind (ranging from 23-46 percent) plants is so much lower than dispatchable (e.g., nuclear 93 percent) generation capacity.[162]

Therefore, it is not sufficient to evaluate total grid capacity; EPA must consider the ability of RTOs to supply power safely and reliably to all users during peak demand conditions and the impact of commercial charging on local grids, and work with other federal entities to ensure the growth in power demand stemming from an expanding ZEV fleet in the Proposed Rule can be safely and reliably supplied. Beyond the normal approximately four-year lead time for OEMs to make incremental changes to their production needed to meet emissions standard, the typical duration of an electricity transmission system capital project timeline is approximately ten years, meaning the additional electricity generation and distribution required by the Proposed Rule is unlikely to be available in the period covered by the Proposal. large-scale electric generation and storage projects are increasingly backlogged year-on-year due to long lead times for permitting and approvals, supply chain shortages, and shortage of skilled workers. While government programs have recently been put in place to help overcome some of these hurdles, it will take time for the grid to be upgraded quickly enough to overcome the constraints above.[163]

---

160 Emma Peterson, INSIDE CLIMATE NEWS, "SunZia Southwest Transmission Project Receives Final Federal Approval" (May 29, 2023) *available at* https://insideclimatenews.org/news/29052023/sunzia-transmission-project-approval/.

161 Matt Egan, "Extreme heat means two-thirds of North America could suffer blackouts this summer," Jan 26, 2023 (two-thirds of North America is at risk of energy shortfalls this summer during periods of extreme demand caused by air conditioning use). *See also* Gilleran, Madeline & Bonnema, Eric & Woods, Jason & Mishra, Partha & Doebber, Ian & Hunter, Chad & Mitchell, Matt & Mann, Margaret. (2021). Impact of electric vehicle charging on the power demand of retail buildings. Advances in Applied Energy. 4 ("[A]n electric vehicle station has the potential to dwarf a big box building's power demand if behind the same meter, increasing monthly peak power demand at the site by over 250%. Cold-climate areas paired with rate structures incorporating high demand charges are most susceptible for significant changes to the annual electricity bill, with increases as high as 88%."). As discussed in Section IV.B.2, charging time will decrease dramatically with DCFC chargers, but the trade-off is they require vastly more electricity.

162 ENERGY INFORMATION ADMINISTRATION "Electric Power Monthly" (June 27, 2023).

163 Gracie Brown, et al., MCKINSEY AND COMPANY, "Upgrade the grid: Speed is of the essence in the energy transition" (Feb. 1, 2022) *available at* https://www.mckinsey.com/capabilities/operations/our-

Regardless of whether OEMs even *could* comply with the Proposed Rule, they would likely be left in a position where there is no consumer demand, and fleet turnover declines because the infrastructure necessary to support the new ZEVs is either at capacity or nonexistent. Indeed, at least one study to date has concluded that, upon ZEVs becoming the norm in California, it could push the total demand for electricity beyond the existing capacity of the state's grid—turning ZEVs into zero electricity vehicles.[164] Even more important, meeting the electricity demand will require construction of new power plants, or electricity purchases from neighboring states, which require increased transmission and distribution capabilities.[165] Or, in the short term, electricity may come from fossil-fuel fired generators, in which case it makes more sense to leave the ICE in the car rather than beside it.

EPA ignores these constraints, relying on the hope that a massive expansion of renewable electricity generation and the transmission grid will occur in time to service EVs produced during MY 2027-2032. The Agency's expectations are unrealistic. While the Lawrence Berkley National Laboratory reports strong interest in clean energy, increasing delays in studying, building, and connecting new energy projects to the grid means that "much of this proposed capacity will not ultimately be built."[166] The high-rate project withdrawal is reflected in the fact that only 21 percent of the projects (representing 14 percent of capacity) seeking connection from 2000 to 2017 were constructed as of the end of 2022.[167] Other challenges cited by the Berkeley National Lab that prevent timely operation of new renewable energy projects include increased interconnection wait times, reaching agreements with landowners and communities, power purchasers, supply chain constraints, and financing.[168] EPA's refusal to examine the costs associated with grid updates required by the rule is another example of the agency's biased evaluation, resulting in an arbitrary and capricious regulatory decision.

4. EPA ignores the lack of reliable ZEV charging

The Proposal's success is partially contingent on the availability of "equitable, affordable charging."[169] Currently, ZEV charging is most available in metropolitan areas, with less investment occurring outside urban areas.[170] EPA's evaluation of the sourcing of critical minerals and building a secure supply chain for ZEVs does not consider how challenging it will be to meet the demand for copper needed for electric infrastructure (e.g., charging stations and storage) to accommodate increased electrical demand.[171] The Proposed Rule fails to even consider that copper demand is

insights/global-infrastructure-initiative/voices/upgrade-the-grid-speed-is-of-the-essence-in-the-energy-transitionl; DELOITTE, "2023 power and utilities industry outlook" *available* https://www2.deloitte.com/content/dam/Deloitte/us/Documents/energy-resources/us-eri-power-utilities-outlook-2023.pdf.

[164] Beth Daley, THE CONVERSATION, "Switching to electric vehicles could save the US billions, but timing is everything" (Dec. 4, 2018), *available at* https://theconversation.com/switching-to-electric-vehicles-could-save-the-us-billions-but-timing-is-everything-106227.

[165] *Id*.

[166] Berkeley Lab, *Electricity Markets and Policy: Queued Up: Characteristics of Power Plants Seeking Transmission Interconnection*, https://emp.lbl.gov/queues (last visited June 9, 2023).

[167] *Id*.

[168] *Id*.

[169] Joann Muller, "The electric car revolution hinges on equitable, affordable charging," Axios, Feb. 8, 2023. Available at The electric vehicle revolution hinges on equitable, affordable charging (axios.com).

[170] S&P GLOBAL MOBILITY, "EV Chargers: How Many Do We Need?" (Jan. 9, 2023), *available at* https://press.spglobal.com/2023-01-09-EV-Chargers-How-many-do-we-need.

[171] IEA Report 2022.

expected to rise by 53 percent when supply is expected to rise by only 16 percent by 2040.[172] Indeed, by 2030, the expected supply from existing mines and projects under construction is estimated to meet only 80 percent of copper needs by 2030[173]—not considering the anticipated increase in ZEV production anticipated by EPA's Proposed Rule. Domestic production of critical minerals required for battery production is insufficient to meet the projected demands. According to a review of multiple sources, there is a six-fold demand growth expectation by 2030 and approximately 15 times by 2040. This growth rate outpaces the market's ability to supply such minerals.

While a significant percentage of the charging installations deployed today are Level 2 EVSEs, dual charging installations to enable the flexibility of LD as well as MD and HDV charging will become increasingly important. DCFCs will enable broader market coverage, even for LDVs used in applications where they cannot sit for 6 hours and charge during off-peak, lower-cost electricity periods. As utility companies gear up to provide infrastructure installations, we should not minimize the impact of supply chain shortages/strains on the cost of materials necessary for installing supporting charging infrastructure in the short time ahead to 2032.

The DRIA admits its charging simulations to estimate charging network size *excluded* medium- and heavy-duty vehicles, which are also subject to EPA's EV mandate.[174] While these commercial vehicles may spend most of their time charging at private depot stations, these are mobile, commercial vehicles that will need to use (and strain) the charging network. It is arbitrary and capricious for EPA to omit those vehicles from its simulations.

Moreover, many available chargers are unreliable. A recent study on the reliability of fast chargers found that in 22.7 percent of the cases studied, chargers were nonfunctional because of "unresponsive or unavailable touchscreens, payment system failures, charge initiation failures, network failures, or broken connectors," and 4.9 percent of charging cable were too short to reach an EV's charge port.[175] Similarly, in a J.D. Power study, owners in high EV volume markets like California, Texas and Washington are finding the charging infrastructure inadequate and plagued with non-functioning stations.[176] This is a significant technological issue that calls into question the viability of the existing charging network as well as future deployments. Similarly, in a J.D. Power study, owners in high EV volume markets like California, Texas and Washington are finding the charging infrastructure inadequate and plagued with non-functioning stations.[177]

Demand charges can be punishing, and in some cases make or break the business case for transition from ICEVs to ZEVs, particularly for fleets and vehicles that require DCFC charging. Other considerations for high-reliability use cases should include provisional back-up power

---

[172] BLOOMBERGNEF, *Copper Miners Eye M&A as Clean Energy Drives Supply* (Aug. 30, 2022), *available at* https://about.bnef.com/blog/coppers-miners-eye-ma-as-clean-energy-drives-supply-gap/#:~:text=Copper%20demand%20is%20set%20to,and%20difficulty%20developing%20greenfield%20mines.
[173] IEA Report 2022.
[174] DRIA at 5-39, n. 107.
[175] Rempel, David and Cullen, Carleen and Bryan, Mary Matteson and Cezar, Gustavo Vianna, Reliability of Open Public Electric Vehicle Direct Current Fast Chargers. Available at SSRN: https://ssrn.com/abstract=4077554 or http://dx.doi.org/10.2139/ssrn.4077554
[176] J.D. Power. Press Release, "2022 U.S. Electric Vehicle Experience (EVX) Public Charging Study." *J.D. Power*, 17 Aug. 2022, www.jdpower.com/business/press-releases/2022-us-electric-vehicle-experience-evx-public-charging-study. Accessed 28 June 2023.

system considerations, which depend upon back-up generators or expensive stationary energy storage batteries. Absent comprehensive understanding of the dynamics between increased ZEV use and charging infrastructure needs, OEMs and consumers are vulnerable.

5. The Proposed Rule Incorrectly Assumes that a Secure Supply Chain Will Exist for ZEV Technologies.

a. The Proposed Rule Does Not Properly Account for the Reliance on Foreign Markets for Critical Minerals.

In the DRIA, EPA states "according to analyses by Department of Energy's Li-Bridge, no shortage of cathode active material or lithium chemical supply is seen globally through 2035 under current projections of global demand." But there are many sources that contradict this point. Looking forward toward 2030, based on current and anticipated global production plans, a global supply shortfall is likely to begin toward end of the decade if planned mining and brine projects do not deliver as expected. Some critical minerals could face shortages as early as next year.[178] The options for mitigating supply chain risks are increasingly limited. At current production rates, the world exhausts the minable reserves of copper, cobalt, and nickel in the 2030s. This timeline accelerates significantly with the greater production needed for EPA's envisioned energy transition. EPA's cherrypicked data on mineral availability is another example of EPA's failure to address a major aspect of the proposal, in this case obscuring real world obstacles to the Proposed Rule.

b. The Proposed Rule Over-Estimates the Ability for the U.S. to Source Materials and Fabricate Batteries Domestically.

The Proposed Rule fails to fully account for the challenges associated with creating and sustaining a viable domestic supply chain that can deliver production-ready batteries necessary to meet the Rule's assumed pace of electrification. Notably, the Rule does not carefully consider the impediments to a viable domestic supply chain because of mineral availability, mineral processing and manufacturing, and overall costs (see Section I.A.1 and Figures 2, 3, and 4).

EPA's DRIA severely overestimates both the availability of minerals and mining/processing infrastructure and capabilities in the U.S., assuming PEV production will not be dependent on foreign manufacture of battery cells.[179] In April, the United States' first and only cobalt plant decided to halt construction at the Idaho Cobalt Operations mine due to low cobalt prices, inflation, and the mine's remote location despite Jervois's beneficial support from federal grants—including a not-yet-approved $15 million award from the U.S. Department of Defense—for additional drilling and to pay for studies to assess the possibility of constructing a cobalt refinery in the U.S. [180] Given the Agency's lack of expertise in this area, it is not surprising EPA neglects to properly analyze mineral availability and mining processing capabilities.

---

[178] Lilly Lee, ENERGY INTELLIGENCE, *Mining the Gap to a Net-Zero Future* (May 15, 2023) *available at* https://www.energyintel.com/00000188-1e5f-d806-ad9f-5edfeb1d0000?utm_campaign=website&utm_source=sendgrid.com&utm_medium=email.

[179] DRIA at 3-20.

[180] *See, e.g.*, Shelley Challis, POST REGISTER, "Jervois shuts down Idaho Cobalt mine" (Apr. 7, 2023), *available at* https://www.postregister.com/messenger/news/jervois-shuts-down-idaho-cobalt-mine/article_efd97f32-d015-11ed-9424-bfb28220210c.html.

Though EPA mentions that OEMs are taking steps to secure domestically sourced minerals and related commodities to supply production for these plants, the OEM's recent comments express grave concern regarding the availability of critical minerals needed to produce batteries,[181] Moreover, many of those offtake agreements referred to EPA are with projects yet to be permitted, built, or commercialized at scale.[182] OEMs, cathode or anode producers, and battery manufacturers are internally assessing their raw material offtake agreements and expect that some projects will not materialize to fruition. ZEVs are projected to represent approximately 90 percent of lithium demand by 2030, so, contrary to the assumption in the DRIA, switching chemistries for other uses will not reduce the burden or price on lithium.

EPA suggests that improvements in recycling rates and enhancing recovery technologies at mines will reduce the need to develop new critical mineral sources. But this statement is misplaced. Recycling technologies for EV batteries remain nascent and cannot scale at a rate fast enough to alleviate supply shortages in the timeframe of the Proposed Rule. Moreover, even if those technologies develop at a faster than expected pace and commercial scale facilities are constructed, there will not be enough batteries to recycle to make the slightest dent in the quantity of critical minerals needed to build out EPA's projected battery demand (see Section I.A.1 for discussion of lack of critical minerals for batteries).

Considering the above, the Proposed Rule creates a multi-year—and perhaps insurmountable—dependence on foreign mineral production and this, coupled with domestic limitations in battery manufacturing capabilities, will make it impossible to sustain the viable domestic supply chain that EPA envisions. While EPA acknowledges that "much of the supply chain supporting the manufacture of ZEVs is located outside of the U.S.,"[183] it arbitrarily underplays this dependency by claiming that "more than half of battery cells and 84 percent of assembled packs in PEVs sold in the U.S. from 2010 to 2021 were produced in the U.S." Battery cell production, however, is just a piece of the value chain, and it cannot grow absent a stable supply of refined critical minerals and precursors. Even assuming critical minerals are available, a viable supply chain requires sufficient capacity of midstream refining operations prior to battery cell production. Such capacity does not exist. For instance, BMI foresees a 77 percent deficit in domestic available cathode active material to meet 2035 demands in North America (N.A.). And this estimate was done *prior* to the EPA Proposal.

While Congress and the Administration have taken steps to accelerate the supply chain, their efforts are insufficient to fully support the rate of production required by the Proposal. For example, U.S. supply of battery anode material is supported by the IRA and BIL, but the production of raw materials supply that feeds the production of battery anode material is not supported. Currently, Chinese battery firms are the most advanced and the majority of raw material mining and processing goes through Chinese entities. See Section I.A. and Figure 2. Thus, it will be difficult for many OEMs to meet the requirements for IRA credits in the near term.

---

[181] AAI Comments at iv-v.

[182] *See, e.g.*, Shelley Challis, Post Register, "Jervois shuts down Idaho Cobalt mine" (Apr. 7, 2023), *available at* https://www.postregister.com/messenger/news/jervois-shuts-down-idaho-cobalt-mine/article_efd97f32-d015-11ed-9424-bfb28220210c.html (describing Jervois's decision to halt construction at the Idaho Cobalt Operations mine due to low cobalt prices, inflation, and the mine's remote location despite Jervois's beneficial support from federal grants—including a not-yet-approved $15 million award from the U.S. Department of Defense—for additional drilling and to pay for studies to assess the possibility of constructing a cobalt refinery in the U.S.)

[183] DRIA at 3-20.

Without a domestic solution to this value chain, reliance on imports will only add to cost to the battery pack.[184]

Ignoring these potential supply chain shortfalls leads to further deficiencies in EPA's analysis. Indeed, limited supplies and constrained supply chains risk production downtime and inventory backlogs—and this is just for production of the ZEVs.[185] The Daimler Truck Group ("Daimler"), for example, has been and is likely to continue to be "acutely affected by an ongoing global shortage of semiconductors, which must be purchased on the global market."[186] And with the "rapidly rising demand for certain new technologies, such as electrified powertrains," Daimler anticipates higher product costs, supply bottlenecks, and "long-term increases in demand for battery cells, semiconductors, and certain critical materials, such as lithium." Taken together, Daimler anticipates these supply chain concerns would limit its "ability to meet demand for its *current* generation of vehicles (including its vehicles with conventional combustion engines) or commercialize its new [ZEVs] profitably (or at all)."[187] Daimler, of course, is not alone in these conclusions and yet EPA's Proposed Rule appears to reject outright any realistic assessment of future supply chains.

6. EPA failed to consider, let alone evaluate, alternative emissions reductions strategies

Despite all the well-known constraints with mandating electrification of the transportation sector and building the necessary nationwide infrastructure, EPA never considered, let alone evaluated, emissions reductions from modifications to ICEVs' emissions control systems, bio and renewable fuels, alternative fuels (e.g., hydrogen), and use of carbon capture and sequestration. To reduce carbon emissions and ensure energy security and independence, Congress created the RFS, which requires increasing volumes of renewable fuel to be blended into transportation fuel. The four categories of renewable fuel must emit anywhere from 20 percent to 80 percent fewer GHGs relative to the fossil fuel it replaces. In response to this mandate, U.S. refineries dramatically increased renewable fuel production and invested billions of dollars to expand U.S. production of liquid renewable fuels, which can now achieve 79 to 86 percent GHG emissions reductions as compared to petroleum fuels.[188]

According to the Energy Information Agency's June 2023 Short-Term Energy Outlook (STEO),

- Biomass diesel (which includes biodiesel and renewable diesel) production averaged 3.1 billion gallons in 2022. EIA expects production to average 4.0 billion gallons in 2023 and 4.8 billion gallons in 2024.

---

[184] Benchmark Minerals Intelligence, BMI (*see* Chart 2, 3 & 4).
[185] *See* Daimler Truck Group, *Annual Report 2022*, 141 *available at* https://www.daimlertruck.com/fileadmin/user_upload/documents/investors/reports/annual-reports/2022/daimler-truck-ir-annual-report-2022-incl-combined-management-report-dth-ag.pdf (describing Daimler Truck Group's reliance on certain commodities, like steel, copper, and precious metals that are usually sourced from individual suppliers, meaning that a single supplier's inability to fulfill delivery obligations can have detrimental effects for an entire production line).
[186] *Id.*
[187] *Id.*
[188] Hui Xu, Longwen Ou, Yuan Li, Troy R. Hawkins, and Michael Wang, *Environmental Science & Technology* 2022, *56* (12), 7512-7521. DOI: 10.1021/acs.est.2c00289

- Ethanol and renewable oxygenate production is expected to increase from 18.4 billion gallons in 2022 to 19.2 billion gallons in 2023, and to 20.4 billion gallons in 2024.
- Biodiesel production averaged 1.6 billion gallons in 2022. Production is expected to decline to 1.5 billion gallons in 2023, and to 1.4 billion gallons in 2024.
- Renewable diesel production averaged 1.5 billion gallons in 2022. Production is projected to increase to 2.4 billion gallons in 2023, and to 3.4 billion gallons in 2024.

In response to the RFS and other government programs encouraging the production of lower carbon renewable liquid fuels, U.S. refiners are undertaking significant capital expenditures to reduce GHG emissions such as:

- Taking advantage of Congress' 45Q tax credit for CCS, ethanol producers are looking to used carbon capture and sequestration to reduce GHG emissions from the 15 billion gallons of ethanol blended into our nation's gasoline.[189]
- Renewable diesel and sustainable aviation fuel production capacity will total 5.1 billion gallons per year if all announced expansion projects, which represent $10.8 billion in investments, are completed.[190]

Although the RFS, an EPA program, has achieved significant emissions reductions for more than a decade, there is no mention in the Proposal or the DRIA of alternative emissions standards that could be achieved through the use of additional changes to emissions control equipment, alternative fuels, or bio and renewable fuels. Lifecycle assessments (LCAs) of GHG emissions from ICEVs reveal that 73 percent of lifecycle GHG emissions come from fuel combustion.[191] By comparison, lifecycle emissions from ZEVs occur not from fuel combustion from the vehicle, but from fuel use and various energy and material inputs upstream from the vehicle. Therefore, EPA's failure to consider standards that reduce the carbon intensity of liquid fuels used in ICEVs and ignoring the carbon intensity of EVs is arbitrary and capricious. It results in a highly flawed assessment of emissions from new motor vehicles which "cause, or contribute to, air pollution" as envisioned in CAA section 202(a) and demonstrates its unvarnished bias in favor of EVs. The Agency's refusal to evaluate biofuels illustrates EPA's tunnel vision that proposes a single panacea for a highly complex problem in a rapidly changing world.

Finally, EPA also ignored the advances being made in carbon capture and sequestration (CCS) as an alternative means of reducing GHG emissions. While EPA touts available incentives for ZEVs in federal legislation, it overlooks federal incentives and private sector support for CCS technology. Many AFPM members are investing heavily in CCS technology to

---

[189] Erin Voegele, Carbon America to develop CCS project at Nebraska ethanol plant, Ethanol Producer Magazine, October 4, 2022 (Carbon America announced its third CCS project at a U.S. ethanol plant). Retrieved at https://ethanolproducer.com/articles/19655/carbon-america-to-develop-ccs-project-at-nebraska-ethanol-plant.
[190] EIA, U.S. renewable diesel capacity could increase due to announced and developing projects, Today in Energy, July 29, 2021. Retrieved at https://www.eia.gov/todayinenergy/detail.php?id=48916
[191] Decarbonizing Combustion Vehicles – A Critical Part in Reducing Transportation Emissions - Transportation Energy Institute.

reduce their GHG emissions.[192] This promising technology has the potential to decrease emissions. EPA arbitrarily ignored the promise of this technology.

D. EPA Cannot Adequately Substantiate the Need for Regulatory Action

EPA has not demonstrated a compelling need to accelerate emissions reductions within the time frame for which MY27–32 vehicles/engines are already being designed. EPA points primarily to the emissions associated with motor vehicles, presumably tailpipe emissions, but provides no information supporting the need for such an accelerated schedule beyond what is currently known. Rather, EPA makes conclusory assertions that the "need for regulatory action" is supported by the BIL and the IRA, which "together provide further support for a government-wide approach to reducing emissions by providing significant funding and support for air pollution and GHG reductions across the economy, including specifically, for the component technology and infrastructure for the manufacture, sales, and use of electric vehicles."[193] EPA notes that under the current standards, ZEV demand is doubling each year, from 2.2 percent of U.S. light-duty vehicle production in MY 2020, to 4.4 percent in MY 2021 and projected to reach 8.4 percent in MY 2022.[194] Congressional spending on EV charging or vehicle subsidies does not confer new authority on EPA to mandate EVs. For example, within the IRA, Congress merely appropriated additional funds "[i]n addition to amounts otherwise available" to the EPA for certain fiscal years to carry out various activities[195] and Congress did not amend or refer to section 202 of the Clean Air Act or any of the provisions of that Act on which EPA bases its proposed rule.[196] Thus, EPA's reliance on these enactments to justify and underwrite proposed standards' feasibility is arbitrary and capricious.

As discussed above, because EPA may only prescribe standards applicable to vehicles that "cause or contribute" to air pollution, its standards cannot account for ZEVs with no tailpipe emissions. However, if EPA is authorized to promulgate such standards, those standards must account for any upstream emissions from upstream electric generating units, the mining of battery materials, and the production of the vehicle.[197] Without consideration of upstream and full life-cycle impacts (e.g., frequent battery replacements), EPA has failed to inform the public of the comparative costs of emission reductions, whether from ZEVs, ICEVs, energy efficiency, or other sectors. EPA's continued failure to address this "major aspect of the problem" is another example of EPA moving toward its predetermined outcome—the forced electrification of U.S. transportation.[198] AFPM has continually put EPA on notice of the need to include a LCA to avoid

---

[192] AFPM members ExxonMobil, Chevron, Valero, and INEOS have been at the forefront of CCS. ExxonMobil invested in CCS for more than 30 years and maintains an equity stake in roughly one-fifth of all carbon capture projects worldwide. These projects "captured approximately 40 percent of all the captured anthropogenic carbon dioxide (CO2) in the world." Exxon's current carbon capture capacity of about nine million metric tons annually is the equivalent of planting 150 million trees every year.
[193] Proposed Rule at 29,187.
[194] Proposed Rule at 29,189.
[195] *See, e.g.*, sections 60106-60111 of the Inflation Reduction Act
[196] In contrast, section 60107 references in the title to that section funding "for Section 211(o) of the Clean Air Act."
[197] Proposed Rule at 29,353–55.
[198] *See, e.g.,* Comments of the American Fuel & Petrochemical Manufacturers on EPA's Reconsideration of a Previous Withdrawal of a Waiver of Preemption 10 (July 6, 2021), https://www.regulations.gov/comment/EPA-HQ-OAR-2021-0257-0139, Comments of the American Fuel &

an arbitrary comparison—the agency continues to ignore this issue of central relevance to EPA's benefit analysis.

For instance, the fuel source of a PEV, like a ZEV—a battery composed of carbon intensive minerals and the electricity generated to power the battery—produces emissions. The fact that emissions occur 100 percent upstream of the vehicle's operation and therefore fall outside of the tailpipe emissions calculation does not make these emissions any less significant. There is no logical basis for this omission because, as EPA is aware, concerns about GHG emissions relate to their longer-term global concentrations. Consequently, air pollutant emissions are an important consideration regardless of where such emissions occur. Without comparing lifecycle ZEV emissions to lifecycle emissions from ICEVs, EPA cannot know if or how much its standards are decreasing total emissions. Thus, while EPA is not required to solve all emissions problems in one rulemaking, EPA cannot claim to be solving part of the problem here without addressing upstream and downstream emissions. EPA's approach of mandating ZEVs cannot possibly be reasonable if it is merely shifting emissions from one source to another at the cost of hundreds of billions of dollars—trillions when costs to upgrade EV infrastructure are factored in—or could do so more cost-effectively by choosing a different approach.[199]

The flaw in EPA's approach is illustrated by the fact that emissions standards easily become meaningless by changing the engine's location. The proposed rule would treat a ZEV charged by a diesel-powered generator as if it had zero tailpipe emissions, notwithstanding the fact that it remains "powered" by a diesel engine located outside the vehicle. A LDV directly powered by a diesel engine inside the vehicle, however, is credited with the emissions produced by that engine. EPA's inconsistent approach begs the question of how nascent technologies such as a vehicle propelled by compressed air would be evaluated. Thus, the energy source of the "fuel" matters and EPA arbitrarily ignores lifecycle emissions from ZEVs and also proposes to *remove* requirements for upstream emissions calculations.[200] EPA admits "the program has now been in place for a decade, since MY 2012, with no upstream accounting and has functioned as intended, encouraging the continued development and introduction of electric vehicle technology."[201] EPA's mandate is to establish feasible standards rooted in the statute, not to ignore real-world emissions to "encourage" the development of its favored technology. EPA requested comment on whether it should account for upstream emissions for all fuel and vehicles. If technologies are being treated equally, as they must, the answer is an unequivocal yes.

EPA compounds this flaw by making unsupported assumptions regarding the total emissions impacts of its Proposal. While it claims that the overall analysis for combined

---

Petrochemical Manufacturers on EPA's/NHTSA's Proposed The Safe Affordable Fuel-Efficient Vehicles Rule for Model Years 2021-2026 Passenger Cars and Light Trucks 68-73 (Aug. 24, 2018), https://www.regulations.gov/comment/EPA-HQ-OAR-2018-0283-5698; Comments of the American Fuel & Petrochemical Manufacturers on EPA's California State Motor Vehicle Pollution Control Standards; Advanced Clean Trucks; Zero Emission Airport Shuttle; Zero Emission Power Train Certification; Request for Waiver of Preemption 7-12 (Aug. 2, 2022), https://www.regulations.gov/comment/EPA-HQ-OAR-2022-0331-0088.

[199] 5 U.S.C. § 706(2)(A); *cf.* Antonin Scalia, "Regulatory Review and Management," Regulation Magazine 19 (Jan./Feb. 1982) ("Is it conceivable that a rule would not be arbitrary or capricious if it concluded with a statement to the effect that 'we are taking the foregoing action despite the fact that it probably does more harm than good, and even though there are other less onerous means of achieving precisely the same desirable results'?").

[200] 88 Fed. Reg. at 29,197.

[201] *Id.* at 29,253.

downstream and upstream emissions "likely underestimates the net emissions reductions that may result" from the Proposed Rule, EPA fails to offer a data-based substantiation. The Proposed Rule failed to assess emissions from battery manufacturing or electricity production. EPA acknowledges that its standards will increase the demand for electricity and that demand will simultaneously increase emissions from the electric generating sector, but by making the unsupported assumption that low carbon electricity will be readily available, it makes no real attempt to quantify those emissions or compare them to alternative options for reducing emissions from this sector. EPA must provide a more comprehensive analysis to comply with its directive under the Clean Air Act and better assess the resulting impact of the Proposed Rule.

E. EPA's cost benefit analysis is impermissibly inadequate

Section 202(a) of the Clean Air Act does not mandate that EPA set standards to drive pollutant emissions down to zero. Rather, CAA section 202(a)(1) only requires that standards be promulgated for air pollutants which "may reasonably be anticipated to endanger public health or welfare." And in promulgating regulations, EPA must balance benefits to health and welfare against the time necessary to allow for the development and application of the requisite technology as well as costs of compliance.[202] With regard to heavy duty vehicles or engines, including the MDVs subject to the Proposed Rule, EPA standards are to reflect "the greatest degree of emission reduction achievable through the application of technology which the [EPA] determines will be available" during the relevant model year.[203] Rather than update ICEV standards, the Proposed Rule unlawfully forces a transition from ICEVs to ZEVs in the MY27–32 timeframe without properly evaluating all cost-effective means to address policy objectives and the time necessary for the development and application of requisite technology. EPA has not demonstrated that such a transition is feasible, let alone necessary.

1. EPA overstates the environmental benefits

EPA touts several emissions benefits in the Proposed Rule from shifting the light-duty vehicle fleet to ZEVs. But EPA's analysis is lopsided in favor of its preferred technology. In analyzing environmental costs and benefits, EPA overlooks negative environmental consequences of ZEVs from increased power generation, vehicle usage, ZEV tire wear, the EV manufacturing supply chain, and battery replacements and disposal at the end of their useful life. Notably, EPA fails to assess net emissions. Although EPA modeled changes to power generation anticipated by the Proposed Rule as part of its upstream analysis, EPA does not consider the potential degradation of air quality in areas in the direct vicinity of existing or new power plants.[204]

EPA assumes the power sector is expected to shift over time to using significantly more wind/solar generation and electricity storage (i.e., batteries), but ignores the environmental impacts of the overall increase in critical minerals demand for electrical grid storage and how that compounds the stress on critical minerals for the ZEVs themselves. But the expansion of electrical grids—even ignoring the Proposed Rule's increased demand—requires a large amount of earth minerals and metals. Copper and aluminum, which are both needed for ZEVs, are also the two main materials in wires and cables and, as described above, higher prices could have a major

[202] 42 U.S.C. § 7521(a)(2).
[203] 42 U.S.C. § 7521(a)(3)(A)(i).
[204] *Id.* at 29,379 (noting that although "[e]missions from upstream sources would likely increase in some cases (e.g., power plants) and decrease in others (e.g., refineries), EPA projects that the Proposed Rule will result in a total decrease in emissions of certain pollutants").

impact on future grid investments and EV costs.[205] The need for expanded grid capabilities simultaneous to expanded ZEV production places a more pressing demand on materials like copper and aluminum thereby increasing extraction and refining efforts throughout the global market.

As previously mentioned, EPA did not fully consider the impact of the rule on fleet turnover. The Agency is aware that the higher purchase price of new ZEVs will keep older cars and trucks on the road longer and that new ZEVs will increase particulate matter ("PM") emissions through increased tire and road wear. In another example of EPA's biased analysis, EPA estimated the value of health benefits from reductions in $PM_{2.5}$ emissions by multiplying $PM_{2.5}$-related benefit-per-ton ("BPT") values by the annual reduction in tons of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursor emissions (NOx and SO2) from displaced ICEVs.[206] However, EPA ignored the fleet turnover benefit that would result from replacing older ICEVs with new, more efficient, ICEVs. EPA also ignored its own National Emissions Inventory, which shows that roadway dust contributes more $PM_{2.5}$ emissions than the tailpipe. Roadway dust emissions, including particles from tire wear, are correlated with vehicle weight, so increases in fleet average vehicle weight would be expected to increase roadway dust $PM_{2.5}$ emissions.[207] Converting ICEs to ZEVs under the Proposal would significantly increase the average vehicle weight on U.S. roadways, which in turn would increase the entrained road dust emissions. Yet EPA did not include these PM sources or increases in the analysis. There also exist overall medium-duty truck weight restrictions, which could require a greater number of ZEVs to move the same tonnage of cargo, thus increasing the number of vehicles needed to haul the same amount of freight, vehicle miles traveled, and resulting PM emissions. EPA also ignores the GHG emissions associated with manufacturing more, less dense, remotely located intermittent generation sources and battery back-up, plus the need for more natural gas peaking capacity and massive transmission, substation, and transformer investment to integrate these technologies into the power grid. Those emissions are significant and may offset or eliminate the benefits that EPA calculates.

The mining sector will also need to grow significantly to meet ZEV demand as anticipated, and required, by the Proposed Rule. Mining is an energy- and environmental resource-intensive activity. Critical minerals for electric batteries such as lithium and copper are particularly vulnerable to water stress given their high-water usage.[208] And more than 50 percent of today's lithium and copper production is concentrated in areas with high water stress levels. Several major producing regions such as Australia, China, and Africa are also subject to extreme heat or flooding, which pose greater challenges in ensuring reliable and sustainable supplies. Strong focus on environmental best practices in this sector are needed to safeguard natural lands, biodiversity, and sustainable water use. Similarly, focus on ethical best practices is needed to protect indigenous peoples' rights, and to provide better child labor protections. These challenges call for sustainable and socially responsible producers to lead the industry. The accelerated ZEV technology penetration rate required under the EPA's proposal poses significant challenges for

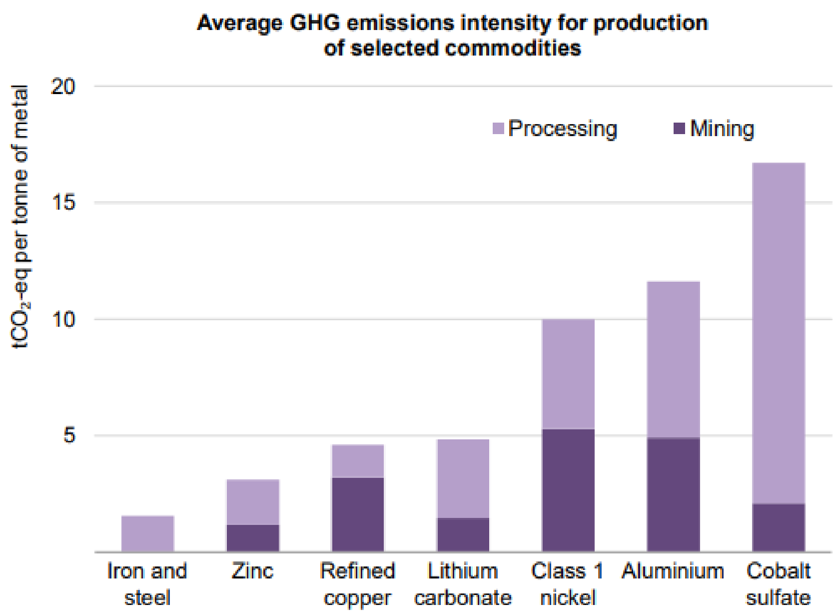
---

[205] IEA Report 2022.
[206] DRIA at 7-36.
[207] EPA, "2020 National Emissions Inventory (NEI) Data," *available at* https://www.epa.gov/air-emissions-inventories/2020-national-emissions-inventory-nei-data.
[208] *See* EIA 2022 Report.

the timely and widespread implementation of best practices to be developed, implemented, and ensure oversight mechanisms are working.[209]

In addition, activities associated with mining produce GHG emissions, particulate matter emissions, nitrogen oxide emissions, and other air pollutant emissions from mining equipment. As shown in **Figure 8**, mining and processing several minerals and metals used for ZEV production are carbon intensive.

Figure 8: [210]



Source: INTERNATIONAL ENERGY ADMINISTRATION

The process for extracting and processing critical minerals can be responsible for approximately 20 percent of the lifecycle GHG emissions from battery production.[211] EPA failed to weigh any of these consequences appropriately in the Proposed Rule.

EPA's Proposal unreasonably relies on comparing ICEV's and ZEV's performance based on EPA's own vastly different fuel economy testing procedures for these two different technologies and incorrectly assumes it is an apples-to-apples comparison. This error significantly undermines EPA's estimates of potential environmental benefits. EPA has cherry-picked the data underlying its analysis to boost the estimated environmental benefits from EVs compared to ICEVs by a significant percentage. EPA's proposal is based on performance data estimates of ICEV fuel economy using EPA's "5-cycle method", i.e., Federal Test Procedure-75

---

[209] For example, the United Nations Environment Programme is advising the Global Investor Commission on Mining 2030 to identify best practice standards for responsible mining. See Mining 2030 at https://mining2030.org/new-global-commission-launched-to-raise-mining-sustainability-standards-by-2030/.
[210] IEA Report 2022 at 17.
[211] H.C. Kim, et al., ENVIRONMENTAL SCIENCE AND TECHNOLOGY (Vol. 50) "Cradle-to-Gate Emissions from a Commercial Electric Vehicle Li-Ion Battery: A Comparative Analysis," (2016), pp. 7715–22.

("FTP") at regular and cold temperatures, Highway Fuel Economy Test ("HWFET") and High-Speed Driving (US06) and Use of Air Conditioning (SC03). EPA's proposal is also based on performance data estimates of ZEV fuel economy that (unlike the testing for ICEVs) never account for EVs operating: above a top speed of 60 mph (whereas ICEVs are tested at 80 mph), above an acceleration rate of 3.2 mph/sec (whereas ICEVs are tested at 8.46 mph/sec); in real world temperatures (ZEVs are tested at optimal battery performance temperatures of approximately 75 degrees F, while ICEVs are tested at 20 degrees F and 95 degrees F); with air conditioning and heating (EPA assumes ZEVs never used air conditioning or heating). *See* AFPM Comments on the Department of Energy Petroleum-Equivalent Fuel Economy Calculation and Petition for Rulemaking, 88 Fed. Reg. 21525 (April 11, 2023) (Attachment 3)

These discrepancies are unreasonable and arbitrary. If EPA's analysis were based on real-world fuel economy testing of ZEVs, it would show they use vastly higher amounts of electricity to travel the same distance, with a corresponding increase in power sector emissions and ZEV maintenance and battery replacement and associated environmental impacts. EPA must account for these differences and environmental impacts.

Another critical aspect of the Proposed Rule not comprehensively considered is that recycling of the battery and related electrical components of ZEVs is in a state of infancy and poses unique materials handling and safety challenges. EPA should consider the environmental profiles of both ZEVs and ICEVs in light of the production, operation, and disposal of the vehicle (its useful life). The following list provides just some of the electric battery disposal-related issues that are likely to impact the environment and need to be addressed by EPA in the Proposed Rule:

- Battery packs could contribute 250,000 metric tons of waste to landfills for every 1 million retired ZEVs.[212]
- Less than five percent of Li-ion batteries, the most common batteries used in ZEVs, are currently being recycled "due in part to the complex technology of the batteries and cost of such recycling."[213]
- Economies of scale will play a major role in improving the economic viability of recycling, for which currently cost is the main bottleneck. Increasing collection and sorting rates is a critical starting point.[214]
- The cathode is where most of the material value in a Li-ion battery is concentrated. Currently, there are numerous cathode chemistries being deployed. Each of these chemistries needs to be known, and then the appropriate method of recycling identified, which poses a challenge, as batteries pass through a global supply chain and all materials are not well tracked.
- Lithium can be recovered from existing Li-ion recycling practices but is not economical at current lithium prices.

[212] Kelleher Environmental, "Research Study on Reuse and Recycling of Batteries Employed in Electric Vehicles: The Technical, Environmental, Economic, Energy and Cost Implications of Reusing and Recycling EV Batteries", (September 2019) *available at* https://www.api.org/oil-and-natural-gas/wells-toconsumer/fuels-and-refining/fuels/vehicle-technology-studies.
[213] Gavin Harper, Roberto Sommerville, et al., NATURE, "Recycling lithium-ion batteries from electric vehicles" (Jan. 21, 2020) *available at* https://www.nature.com/articles/s41586-019-1682-5.
[214] IEA Report 2022.

- BMI forecasts that near-term recyclers are likely to use scrap material from the increasing number of gigafactories coming online versus used electric vehicle batteries. Scrap is anticipated to account for 78 percent of recyclable materials in 2025.[215]

- In 2022, BMI expected over 30 gigawatt hours of process scrap to be available for recycling, growing ten-fold across the next decade. Loss rates vary by region and tend to be higher in earlier years of a gigafactory.[216]

- Many 'spent' EV batteries still have 70-80 percent of their capacity left, which is more than enough to be repurposed into other uses such as energy storage and other lower-cycle applications for approximately another 10 years.[217] This will extend the time that batteries and raw materials remain in use and therefore increase the demand for virgin critical minerals.

- Clear guidance on repackaging, certification, standardization, and warranty liability of spent ZEV batteries would be needed to overcome safety and regulatory challenges reuse poses at scale.[218]

- Recycling ZEV batteries to recover high-value metals has not been proven to a commercial scale. The majority of analysts are aligned that recycling will not become an integral supplier of raw materials until the 2030s, and at that point, only will provide approximately 20 percent of demand.[219]

- Unlike ICEVs, EPA has recently stated that ZEV batteries may need to be handled as hazardous waste, further driving up the cost of such recycling efforts.[220]

- Whether sufficient recycling capacity can be permitted and constructed to facilitate the Proposal.

EPA must, therefore, conduct a full LCA to compare all environmental impacts to reasonably conclude that the Proposal will decrease environmental impacts rather than merely shift them.

2. The Proposal's costs are vastly understated

EPA estimates that the Proposed Rule will cost $26 billion dollars but will produce between $200–$220 billion in net discounted benefits.[221] EPA's conclusion is built on a shaky foundation of understated and hidden costs that when properly accounted for reveal that the costs of the Proposed Rule far exceed its benefits.

---

[215] Benchmark Minerals Intelligence, "Battery production scrap to be main source of recyclable material this decade" (Sept. 5, 2022) *available at* https://source.benchmarkminerals.com/article/battery-production-scrap-to-be-main-source-of-recyclable-material-this-decade.
[216] Id.
[217] Pagliaro, M. and Meneguzzo, F., "Review Article: Lithium battery reusing and recycling: A circular economy insight," *Heilyon* 5: E01866 (June 15, 2019) available at https://doi.org/10.1016/j.heliyon.2019.e01866
[218] IEA Report 2022.
[219] Benchmark Minerals Intelligence, *supra* at n. 105.
[220] Letter from Carolyn Hoskinson, Director, EPA Office of Resource Conservation and Recovery, "Lithium Battery Recycling Regulatory Status and Frequently Asked Questions," (May 24, 2023).
[221] Proposed Rule at 29,361-62.

EPA assumes that significant ZEV sales would occur in the absence of the Proposed Rule but fails to acknowledge that the aggressive level of OEM investments are being bade in direct response to anticipated increases in fuel economy requirements.[222], EPA excludes the vehicle costs associated with these ambitious automaker commitments that are linked to EPA standards. This is improper. In conducting the cost-benefit analysis EPA estimates that the rule will result in a 67 percent ZEV penetration rate and incorporates the emissions reductions associated with each of these vehicles. EPA cannot include the benefits of these ZEVs and exclude their costs.

While we have not had sufficient time to fully analyze EPA's cost analyses, we have been able to identify several significant deficiencies, each of which understates the true costs of the Proposal: (1) EPA significantly understated the costs of batteries required by the rule; (2) EPA understated the costs of ZEVs by focusing only on their purchase price and ignoring the impacts of manufacturers' emissions trading and cross-subsidization strategies; (3) EPA's analysis of operating costs and other costs of ownership is incomplete; and (4) EPA misstates the costs of EVSEs and completely ignores the costs of grid upgrades that will be necessitated under the Proposed Rule. We discuss each of these deficiencies below.

i. Battery costs

We start with a discussion of EPA's analysis of battery costs because it has significant impacts on ZEV production, operating, and disposal costs. EPA "substantially underestimates the costs of batteries,"[223] providing an inadequate analysis and ignoring the cost and long-term affordability of battery production. In the DRIA, EPA states that "despite recent short-term fluctuations in price, the price of lithium is expected to stabilize at or near its historical levels by the mid- to late-2020s, suggesting that the elevated battery costs being reported today will not persist."[224]

This analysis misses the mark. Between January 2021 and March 2022, the cost of lithium increased by 738 percent.[225] 2022 battery costs were $153 per kWh,[226] and cost reduction curves have already begun to flatten out. Indeed, battery costs rose 7 percent in 2022. With EPA's and other developing nations' push to electrify transportation and the concomitant need to deploy utility-scale batteries, the demand for lithium (and other critical minerals) is expected to grow exponentially. Even so, EPA assumes declining battery costs will reach $120 per kWh in 2032.[227]

---

[222] ALLIANCE FOR AUTOMOTIVE INNOVATION "Auto Innovators Statement on Final EPA GHG Rule" (December 20,2021 available at *https://www.autosinnovate.org/posts/press-release/statement-final-epa-ghg-rule*
[223] AAI Comments at iv.
[224] DRIA at 2-51.
[225] *See* Canada Energy Regulator, "Market Snapshot: Critical Minerals are Key to the Global Transition" (Jan. 18, 2023), *available at* https://www.cer-rec.gc.ca/en/data-analysis/energy-markets/market-snapshots/2023/market-snapshot-critical-minerals-key-global-energy-transition.html.
[226] Dept. of Energy, "Electric Vehicle Battery Pack Costs in 2022 Are Nearly 90% Lower than in 2008, according to DOE Estimates," (Jan. 9, 2023) *available at* https://www.energy.gov/eere/vehicles/articles/fotw-1272-january-9-2023-electric-vehicle-battery-pack-costs-2022-are-nearly.
[227] DRIA at 2-46 (resulting 75kWh battery).

EPA's reliance on an ICCT study to justify its estimate of falling battery costs is misplaced. ICCT ignored literature that PHEVs depreciate with certain models and makes losing greater value than others, like Tesla, especially those with long-range features. A May 2023 CBS article highlighted a statement from Kelley Blue Book, an automotive research company, that PHEVs generally depreciate faster than ICEVs.[228] Kelley Blue Book said that three-year-old PEVs hold 63 percent of their value compared to 66 percent for ICEVs.[229] Additionally, ICCT's battery cost curve does not account for the potential of rising PEV-related metal prices which can cause the price of battery packs to increase, as seen in 2022 and 2023. If ICCT's estimates of PEV battery pack costs were revised to be higher, PEVs are likely to be priced at a substantial premium compared to ICEVs.

While prices have since declined, price volatility should be expected to continue. Despite these very public findings, EPA asserts that "battery costs have continued to decline."[230] EPA points to the IRA as a mechanism to reduce battery prices, yet this law simply extended the existing battery subsidy and even limited its applicability through domestic sourcing and income requirements. Thus, EPA is relying on an existing program for the proposition that it will lower battery prices in the future. EPA is simultaneously ignoring that the increase in demand for batteries will raise their price.

Further complicating the projection of future battery prices is the fact that battery raw materials are not commodities, they are classified as specialty chemicals. As such pricing will not follow traditional commodity pricing structures, especially because these supplies are geographically concentrated in areas with geopolitical instabilities. Each OEM, cathode or anode producer, and battery manufacturer have their own specifications for the materials, and thus the raw materials must be refined and tested to meet their bespoke specification. Spot markets for battery materials are virtually non-existent and unlikely to develop in the near term. For example, most lithium contracts are written as long-term agreements, which are based on Fastmarkets' lithium index and a discount, and sometimes with a floor/ceiling mechanism to hedge against pricing volatility.

Ultimately, the volatility of material pricing will directly affect whether certain battery projects even materialize. And if they do, OEMs will need to increase their prices to ensure a steady supply. Morgan Stanley estimates ZEV makers will need to increase prices by 25 percent to account for rising battery prices.[231] EPA must consider these data and correct this aspect of its cost-benefit analysis.

Moreover, the minerals used for EV batteries are also essential to many components of a lower-carbon energy system beyond EV batteries, such as solar photovoltaic cells, wind turbines, and hydrogen electrolyzers. In addition, these minerals have multiple traditional uses, such as military defense systems, aerospace, mobile phones, computers, fiber-optic cables, semi-

---

228 Joe D'Allegro, What to know about buying a used electric vehicle as more hit the auto sales market, CNBC (May 21, 2023), https://www.cnbc.com/2023/05/21/what-to-know-about-buying-a-used-ev-as-more-hit-the-car-market.html. See also AAA Survey Shows EV Owners Should Be Concerned About Depreciation (insideevs.com).

229 Id.

230 Proposed Rule at 29,188.

231 James Thornhill, Bloomberg, "Morgan Stanly Flags EV Demand destruction as Lithium Soars" (Mar. 24, 2022), Chart 7, *available at* https://www.bloomberg.com/news/articles/2022-03-25/morgan-stanley-flags-ev-demand-destruction-as-lithium-soars#xj4y7vzkg.

conductors, medical applications, and even bank notes. Without substantial increases in new mining capacity (or massive shifts toward recycling), competition for these minerals will materially stiffen with increased electrification and the shift in underlying grid energy mix. An acceleration in demand for these key minerals could result in price volatility stemming from supply disruptions and/or geopolitical pressures. By contrast, the U.S. is much less reliant on foreign sources of petroleum energy sources. In fact, the U.S. has been a net exporter of gasoline and diesel since late 2009. And much of our petroleum imports come from friendly countries such as Canada.

EPA's proposal may impose additional costs of economic risk to individuals and small business owners who will be asked to depend on increasingly expensive infrastructure necessary to provide on-the-go fuel.[232] Durable and reliable EVs are therefore critical to ensuring that projected emissions reductions are achieved by this proposed program and costs of ownership are properly presented. EPA further states that it is proposing new battery durability requirements for light-duty and medium-duty ZEVs and PHEVs but this doesn't alter EPA's concession that it is relying on other programs, like California's, to implement battery durability and a suite of other customer assurance provisions to ensure customer demand.[233] EPA should consider inclusion of durability requirements in this proposal as 150 miles of range for singular battery life and 24,000-mile range of use (or two years) are well below the period of use for a comparable ICEV with a full tank of fuel and will impact consumers as there is not enough data with these technologies.

ii. EV Purchase Price

EPA assumes in MY 2032, there will be a \$3500-\$6100 price gap between EVs and ICEVs, with ICEVs costing less.[234] EPA's purchase price incorrectly assumes that every ZEV will be eligible for the maximum federal purchase incentive.[235] EPA asserts the relatively slight increase in the incremental cost of manufacturing a rule-compliant vehicle (Table 13-46 of the DRIA provides an average increase of \$1,164 by 2032) is based, in part, on the assumption battery manufacturers are eligible for the IRA's ten percent Production Tax Credit for modules manufactured in the U.S. It is arbitrary and capricious for EPA to ignore the likelihood that battery raw materials will not be mined in the U.S. or available for import from credit-qualifying countries, given Section I.A.1 of these comments illustrates China's dominance in processing critical minerals needed for ZEV batteries and the manufacture of ZEV batteries. Consequently, it is unrealistic for the Agency to assume ZEV purchases will be eligible for the full incentive.

EPA's Proposal fails to evaluate how government credits are embedded in vehicle pricing. For example, neither federal or state governments, or auto manufacturers explain how state ZEV credits, EPA GHG multiplier credits, and NHTSA CAFE EV multiplier credits are accounted for in both ZEV and ICEV vehicle price. There is increasing evidence that regulations which mandate EV sales—along with the cross-subsidies from gasoline and diesel vehicle buyers—are leading manufacturers to abandon sales of the least expensive and higher fuel economy gasoline and diesel vehicles that do not receive similar subsidization.[236] Cox Automotive found that "in

---

[232] 88 Fed. Reg. 4,296 (Jan. 24, 2023) (EPA Final Rule re Control of Air Pollution from New Motor Vehicles: Heavy-Duty Engine and Vehicle Standards).
[233] Proposed Rule at 29,284.
[234] DRIA at 4-20, Table 4-77
[235] AAI Comments at ii-iv.
[236] Steven G. Bradbury, Distinguished Fellow, The Heritage Foundation, Prepared Statement for the hearing entitled "Driving Bad Policy: Examining EPA's Tailpipe Emissions Rules and the Realities of a

December 2017, automobile makers produced 36 models priced at $25,000 or less. Five years later, they built just 10," pushing low-income buyers out of the new-car market and into the used-car market. Conversely, in December 2017 automobile manufacturers offered 61 models for sale with sticker prices of $60,000 or higher and in December 2022, they offered 90.[237] This is unacceptable. EPA and its sister agencies cannot create credits and then claim they do not affect vehicle price solely because they have not sought to quantify them.

Tellingly, EPA never estimates the annual price of a comparable ZEV and ICEV, for each year in which EPA proposes standards. EPA's bias towards EVs is demonstrated by EPA's statement that its OMEGA modeling "now incorporates a consumer choice element. This means that the impacts of, for example, a $40,000 BEV versus a $35,000 ICE vehicle of similar utility (i.e., a 14 percent increase for the BEV) is a much different consideration than a $6,000 incremental BEV cost versus a $1,000 incremental ICE cost (a 500 percent increase for the BEV)."[238] In other words, EPA set up its model to show the consumer ***price*** (not the actual real-world cost) of EVs have a lower percentage cost increase than the incremental absolute ***cost*** of switching from ICEVs to ZEVs.

Moreover, although the incremental vehicle manufacturing cost in EPA's High Battery Cost sensitivity is higher (Table 13-140 of the DRIA provides an average increase of $1,547 by 2032 for medium duty vehicles) than the Proposed Rule, EPA does not quantify how much of the increase in incremental cost is due to battery raw material prices. Finally, as part of its ZEV cost assessment EPA relies on data as old as 2017 but does not appear to account for the inflation of cost components in recent years. EPA should make it clear how it is accounting for not just typical inflation to normalize dollars in a similar year, but also the significant changes in supply chains in recent years that have led to significantly higher costs for ZEV parts and materials compared to older data points that EPA references.

EPA also assumes the increased supply of ZEVs—resulting from OEMs' planned production expansions and offering of more ZEV models, charging infrastructure, purchase incentives, and lower battery prices—will lead to lower ZEV prices.[239] EPA ignores that battery prices have begun to rise due to limited supply of minerals.[240] While there are some affordable EVs, these EVs typically have a range below 200 miles on a full charge.[241] If consumers want longer range EVs, they will pay a considerable purchase price as seven of the top ten, range-

---

Rapid Electric Vehicle Transition," before the Subcommittee on Economic Grown, Energy Policy, and Regulatory Affairs of the U.S. House of Representatives Committee on Oversight and Accountability, at 10 (May 17, 2023) *available at* https://oversight.house.gov/wp-content/uploads/2023/05/Bradbury-Prepared-Statement-for-17-May-2023-Oversight-Hearing.pdf

[237] *See* Sean Tucker, Are we witnessing the demise of the affordable car? Automobile makers have all but abandoned the budget market (MarketWatch Feb. 28, 2023), *available at* https://www.marketwatch.com/story/are-we-witnessing-the-demise-of-the-affordable-car-automakers-have-all-but-abandoned-the-budget-market-a68862f0 (last visited May 24, 2023).

[238] *See* RIA page 2-42, https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P10175J2.pdf.

[239] DRIA at 4-23.

[240] BLOOMBERGNEF "Lithium-ion Battery Pack Prices Rise for First Time to an average of $151/kWh" (Dec. 6, 2022) *available at* https://about.bnef.com/blog/lithium-ion-battery-pack-prices-rise-for-first-time-to-an-average-of-151-kwh/

[241] *See* Sebastian Blanco, *List of EVs Sorted by Range* (Sept. 1, 2022), www.jdpower.com/cars/shopping-guides/list-of-evs-sorted-by-range.

rated EVs cost anywhere from $74,800 to $110,295.[242] EPA's analysis also fails to account for the increased vehicle sales tax and property tax associated with the higher purchase price of ZEVs (even after myriad subsidy programs).

EPA's cost benefit analysis is implicitly built around much longer battery life than is currently achieved, as EPA does not factor in battery replacement costs or the environmental implications of additional battery production, recycling, and disposal. EPA cannot have it both ways – either the batteries are remarkably durable, or the costs of this Proposed Rule are dramatically understated. Even with massive direct and indirect subsidies, EVs are more expensive on average than their ICEV counterparts and unaffordable for many households. In the first calendar quarter of 2022, the average price of the top-selling light-duty ZEV in the U.S. was about $20,000 more than the average price of top-selling ICEV.[243] The price disparity has not improved, with the average price of light-duty EVs near $66,000 in August 2022 and continuing to rise.[244]

iii. EPA Must Consider Automobile Manufacturer Cross-Subsidies in Determining the Costs of the Proposal

While the purchase price differential between comparable ICEVs and ZEVs may be relevant for forecasting consumer demand, it does not reflect the true costs of the ZEVs required under the Proposed Rule. A ZEV typically costs tens of thousands of dollars more to produce than a comparable ICEV due primarily to the surging costs of critical minerals and resulting high costs of batteries.[245] Additionally, the Proposed Rule will force manufacturers to sell an increasing percentage of ZEVs each year that goes far beyond the consumer demand for the product at its true cost. To ensure compliance with the ZEV mandate under the Proposal, manufacturers will be forced to incentivize ZEV purchases through a practice called cross-subsidization.

Automobile cross-subsidization is a pricing strategy to spread the high cost of ZEVs across a manufacturer's other product offerings. Under this pricing convention, manufacturers set the prices of certain ICEVs higher than their production costs to generate additional profits that can then be used to offset losses incurred by selling ZEVs below their actual production costs. This operates as a hidden tax on ICEVs and results in the purchasers of ICEVs subsidizing the sale of ZEVs. Without cross-subsidies, ZEV mandates would fail.

---

[242] *See* Nicholas Wallace, Austin Irwin, & Nick Kurczewski, *Longest Range Electric Cars for 2023, Ranked* (Mar. 23, 2023), https://www.caranddriver.com/features/g32634624/ev-longest-driving-range/.
[243] Registration-weighted average retail price for the 20 top-selling ZEVs and ICEVs in the U.S. S&P Global, *Tracking BEV prices – How competitively-priced are BEVs in the major global auto markets?* May 2022.
[244] Andrew J. Hawkins, EV prices are going in the wrong direction (The Verge Aug. 24, 2022), *available at* https://www.theverge.com/2022/8/24/23319794/ev-price-increase-used-cars-analysis-iseecars (last visited May 24, 2023); *see also* Justin Banner, Latest Ford F-150 Lightning Price Hike Hands Chevy Silverado EV a $20K Advantage--The least-expensive electric F-150 Lightning now costs $4,000 more than it did late last year (Motortrend Mar. 30, 2023), *available at* https://www.motortrend.com/news/2023-ford-f-150-lightning-pro-price-increase-msrp/ (last visited May 24, 2023).
[245] *See* PCMag, Profit vs. the Planet, (Sept. 26, 2022), Profit vs. the Planet: Here's Why US Automakers Are All-In on Electric Vehicles | PCMag *last accessed* July 3, 2023 ("EVs are currently more expensive to manufacture than gas-powered vehicles because of spiking battery costs. The cost of lithium, the main ingredient, has skyrocketed since demand far exceeds the number of working mines that can supply it.").

While opaque, the magnitude of ZEV cross-subsidies is significant.[246] Ford's decision to report EV financial information separately beginning in 2023 provides an additional glimpse into the magnitude of cross-subsidization. Ford lost approximately $58,000 for each ZEV car it sold during the quarter.[247] This reported per-vehicle loss is more than an order of magnitude greater than EPA's estimates of the price differential between the two technologies. While cross-subsidization, tax credits, emissions trading, and other EV subsidies may hide the true costs of a ZEV mandate from consumers, EPA has a duty to quantify and present those costs that are attributable to the Proposed Rule. Pursuant to Executive order 12866:

> EPA is to "assess all costs and benefits of available regulatory alternatives, including the alternative of not regulating. Costs and benefits shall be understood to include both quantifiable measures (to the fullest extent that these can be usefully estimated) and qualitative measures of costs and benefits that are difficult to quantify, but nonetheless essential to consider.[248]

Ignoring actual ZEV production costs, including credit trading costs, is arbitrary and capricious.

EPA ignores this real-world regulatory compliance pricing scheme. EPA should quantify and explain this issue of central relevance to the Proposed Rule even if it may undermine the Administration's stated goal of electrifying the transportation fleet. As noted above, E.O. 12866 requires EPA to be a neutral decisionmaker and to fairly assess the costs and benefits of this Proposal. The Agency has not met its obligations under relevant Executive Orders, the Administrative Procedure Act, or CAA section 202(a), which requires "appropriate consideration to the cost of compliance." EPA has instead understated the costs of this Proposal.

Astonishingly, EPA makes no attempt to account for these real-world costs, nor to communicate to the public that, as the Proposal mandates a higher percentage of ZEV sales, the cross-subsidies must be paid for by a shrinking number of ICEV buyers and, therefore, must

---

[246] EPA's methodology ignores current EPA, DOE, NHTSA, and state regulations that add hundreds of billions of dollars in costs of ICEVs to cross-subsidize buyers of ZEVs. These cost transfers are in the form of: (1) state-mandated ZEV credit payments from ICEV manufacturers (i.e., ICEV buyers) to ZEV manufacturers (i.e., ZEV buyers); (2) current and future potential EPA GHG ZEV multiplier credit payments from ICEV manufacturers (i.e., ICEV buyers) to ZEV manufacturers (i.e., ZEV buyers); and, (3) NHTSA-mandated fuel economy ZEV multiplier credit payments from ICEV manufacturers (i.e., ICEV buyers) to ZEV manufacturers (i.e., ZEV buyers). A NHTSA presentation suggests that NHTSA EV multiplier credits alone subsidize each EV by more than $25,000, increasing the true average cost of every EV sold to over $90,000. *See* https://www.nhtsa.gov/sites/nhtsa.gov/files/2015sae-powell-altfuels_cafe.pdf; https://www.nhtsa.gov/sites/nhtsa.gov/files/2022-04/Model-Documentation_CAFE-MY-2024-2026_v1-tag.pdf; https://one.nhtsa.gov/cafe_pic/home/ldreports/manufacturerPerformance. Per the NHTSA information above, since MY2017 standards were ~35mpg and MY2017 Tesla FE performance (with multipliers) was 518.7 mpg, and since Tesla sold ~46,979 MY2017 vehicles in the U.S., then Tesla in MY2017 generated 227 million excess credits. If the market-value of these credits is ~$5.50 per 0.1 mpg shortfall per vehicle under the MY2017 CAFE standard of ~35 mpg, then these credits were worth approximately $1.25 billion, or $26,600 per EV that Tesla sold. [Calculation of estimated value: Credits = (518.7 – 35) x 46979 x 10 x CAFE Penalty of $5.50 per 0.1 mpg shortfall per vehicle]. Tesla may have banked, traded, or sold these credits. Tesla MY2022 sales in the U.S. were 484,351 and the CAFE civil penalty is now $15 per 0.1 mpg shortfall per vehicle.

[247] *See* Luc Olinga, TheStreet, *Ford Loses Nearly $60,000 for Every Electric Vehicle Sold,* (May 2, 2023) *available at* Ford Loses Nearly $60,000 for Every Electric Vehicle Sold - TheStreet (last accessed July 3, 2023).

[248] E.O. 12866, Section 1(a), Sept. 30, 1993.

significantly increase the average price of EVs. As EV prices rise, their sales and ICEV fleet turnover will slow, reducing environmental benefits and creating a significant drag on the economy.

iv. Total cost of ownership

EPA's proposal also vastly underestimates the cost of ownership for ZEV owners by assuming ZEVs achieve real-world fuel economy that is equivalent to EPA's test methods. They do not and it is not close. This error significantly undermines EPA's estimates of costs for both ZEV owners and associated power infrastructure and charging infrastructure requirements. As noted in the environmental benefits discussion above, EPA's proposal is based on performance data estimates of ICEV fuel economy using EPA's "5-cycle method." If EPA's analysis were based on real-world fuel economy testing of ZEVs, it would show they use vastly higher amounts of electricity to travel the same distance, with a corresponding increase in ZEV owner costs for electricity and ZEV maintenance and battery replacement. EPA must account for these real costs.

EPA's total cost of EV ownership incorrectly assumes each vehicle type of all new ICEV and ZEV will travel the same miles each year.[249] EVs have less range, both technically and practically. As noted by J.D. Power, "the majority of EVs provide between 200 and 300 miles of range on a full charge."[250] Studies show that the average electric car is driven 9,059 miles per year, compared with 12,758 miles for ICEVs.[251] By overestimating VMT, EPA compounds all other errors in its assumptions that all work in favor of ZEVs and to the detriment of ICEVs.

Another way that EPA justifies lower EV ownership costs is by failing to fully account for current state excise tax policies and insurance that establish higher costs for ICEV owners and lower costs for ZEV owners. Insurance premiums for PEVs are typically higher than comparable ICEVs because of higher repair and parts cost. The price premium depends on the make and model, age of the driver, geographic location, and state. According to ValuePenguin, insurance on a PHEV, depending on the model, could be 19 percent to 32 percent higher than comparable ICEV.[252] Another estimate from an Oct 2022 study from Self Financial concludes PEVs' annual insurance is $1,674, $442 more compared to an ICEV annual insurance premium of $1,232.[253]

Should EPA mandate that most new vehicles will be ZEVs, it will become increasingly untenable for ICEV owners to either further subsidize ZEV owners by paying higher excise taxes, or for states to suffer a shortfall in revenue collections by continuing to give preferential treatment to ZEV owners. EPA must acknowledge these significant costs necessarily must increase for ZEV owners as EPA mandates higher ZEV sales.

Finally, EPA's total cost of ownership analysis assumes dramatically lower retail fuel costs for ZEVs (around 60 percent less) than liquid fuels.[254] Real-world data squarely contradicts EPA's

---

[249] DRIA at 4-20, Table 4-7 (e.g., EPA assumes EV and ICEV sedans/wagons will both travel 15,700 miles per year).
[250] *See* Sebastian Blanco, *List of EVs Sorted by Range* (Sept. 1, 2022), www.jdpower.com/cars/shopping-guides/list-of-evs-sorted-by-range.
[251] iSeeCars, *The Most and Least Driven Electric Cars* (May 22, 2023), https://www.iseecars.com/most-driven-evs-study.
[252] How Much Does Electric Car Insurance Cost? - ValuePenguin.
[253] Electric Cars vs Gas Cars Cost in Each State | Self Financial.
[254] DRIA at 4-20, Table 4-7.

cost assumptions on EV charging. For example, California's ZEV mandates have contributed to the inflationary impacts on energy prices and on jobs in certain industries related to traditional fuels and vehicles. According to a 2021 California Public Advocates Office presentation to the California Public Utilities Commission, "it is already cheaper to fuel a conventional internal combustion engine (ICE) vehicle than it is to charge an EV" in the San Diego Gas & Electric Co. service area.[255] This is astonishing given that gasoline prices in California are the second highest in the nation, averaging approximately $4.01 per gallon of gasoline in 2021. Future projections afford consumers no relief, as the California Energy Commission projects that both commercial and residential electricity prices will continue to rise, reaching nearly $7 per gasoline-gallon equivalent for the commercial sector. Similarly, many in New England are finding it is costing more to charge up than fill up, paying $0.28 per kilowatt hour (double the price of the national average) in the fall of 2022.[256] EPA must revise its analysis to account for realistic electricity prices.

Finally, charging pricing has been unpredictable, with some stations charging by the minute instead of charging for electricity consumed.[257] Other charging stations offer multiple subscription plans or charge different rates at various times of day, resulting in significant price increases over the past few months.[258] Boston charging companies raised charging fees in response to New England utilities increasing their rates to 39 cents per kilowatt-hour in February 2023, from 27 cents a year earlier.[259]

v. Costs to upgrade electricity generation, transmission, and distribution

For EPA to achieve its GHG reduction aspirations in this Proposed Rule, all three of these challenges must be met: (1) sufficient materials to manufacture the required EVs, chargers, and grid upgrades, (2) consumer willingness to substitute ZEVs for ICEVs currently for sale, and (3) a low-carbon power generation grid capable of reliably supplying energy for this mode of transportation. Combined with other issues, such as a disorderly transformation of the generation base as conventional units are replaced with intermittent resources, raises questions of the grid's ability to reliably meet consumer demand on a regional basis. Despite these challenges, EPA incredibly assumes no increase in the cost of electricity to consumers (whether EV owners or others) associated with the proposed rulemaking. EPA underestimates the cost of electricity to all

[255] California Public Utilities Commission, "Utility Costs and Affordability of the Grid of the Future" (May 2021). Presentation from Mike Campbell, Public Advocates Office at 116-117 *available at* https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/office-of-governmental-affairs-division/reports/2021/senate-bill-695-report-2021-and-en-banc-whitepaper_final_04302021.pdf#page=117.

[256] Irina Ivanova, https://www.cbsnews.com/moneywatch?ftag=CNM-16-10abg0dFor some electric vehicle owners, recharging now more costly than filling up, CBS News Money Watch, Feb. 13, 2023. Available at Electric cars 2023: In some parts of the U.S., recharging now more costly than filling up - CBS News.

[257] Aaron Pressman, "Inside the crazy, mixed-up world of electric-vehicle charger pricing," The Boston Globe, March 27, 2023. Available at https://www.boston.com/news/the-boston-globe/2023/03/27/electric-vehicle-charger-pricing.

[258] *Id*.

[259] Id.

consumers, including EV owners, and omits the cost of grid upgrades and distributed energy resources have been excluded from these estimates.[260]

The U.S. needs to invest an estimated $4.5 trillion to fully transition the U.S. power grid to renewables during the next 10-20 years.[261] The cost of grid upgrade projects needed to support the incremental electricity demand growth from transportation is significant and can be quite variable. A particular case study of Northern California illustrated in IOP Science notes: "[T]he total cost of these upgrades will be at least $1 billion and potentially more than $10 billion" for a service area of 4.8 million electricity customers.[262] These costs need to be taken into consideration with expected demand growth, within detailed rate base calculations, and in concert with appliance upgrade costs to fully understand their ultimate impact on annual ratepayer expenditures. We agree with and support the Proposed Rule's acknowledgement that "a recent study found power needs as low as 200 kW could trigger a requirement to install a distribution transformer."[263] Other anecdotal evidence discussed within an RMI report highlights the expensive mistakes that can emerge from insufficient planning and engagement in details.[264]

EPA incorrectly assumes that ZEV owners will pay the national average residential electricity price to charge their vehicles. EPA fails to consider that the majority of ZEVs in the U.S. are located in utility service territories with some of the highest electricity rates in the country and that the average EV owner currently pays a much higher price to charge their ZEV at home than the national average residential electricity rate. Given that EV penetration has varied widely across the U.S., it would be arbitrary to assume that EVs will, unlike in the past, penetrate uniformly across the U.S. and thus that the average electricity price would be representative of the actual cost electricity. For example, California, which has roughly 40 percent of all registered ZEVs in the U.S., has a residential electricity rate that is roughly double the national average. Considering that EPA is modeling its rule after a California-like approach to mandate ZEVs, it would be more appropriate for EPA to assume similar real-world costs (at a minimum, given California's temperate climate). Moreover, EPA fails to consider that mandating such a high ZEV sales rate will necessarily require exponential increases in commercial ZEV charging at rates that are currently three, four or five times higher than the current national average residential electricity rate, depending on location and charging speed. Those customers who are not homeowners and not able to install their own charging stations and take advantage of charging at low-cost times will be adversely impacted. Instead, EPA uses a residential rate for electricity and does not consider peak power or time of use charges. California electric prices rose 42 percent - 78 percent between 2010 and 2020 and are projected to rise an additional 50 percent by 2030 as shown in **Figure 9**.

[260] U.S. Department of Energy, National Renewable Energy Laboratory, "The 2030 National Charging Network: Estimating U.S. Light-Duty Demand for Electric Vehicle Charging Infrastructure." June 2023. https://driveelectric.gov/files/2030-charging-network.pdf.

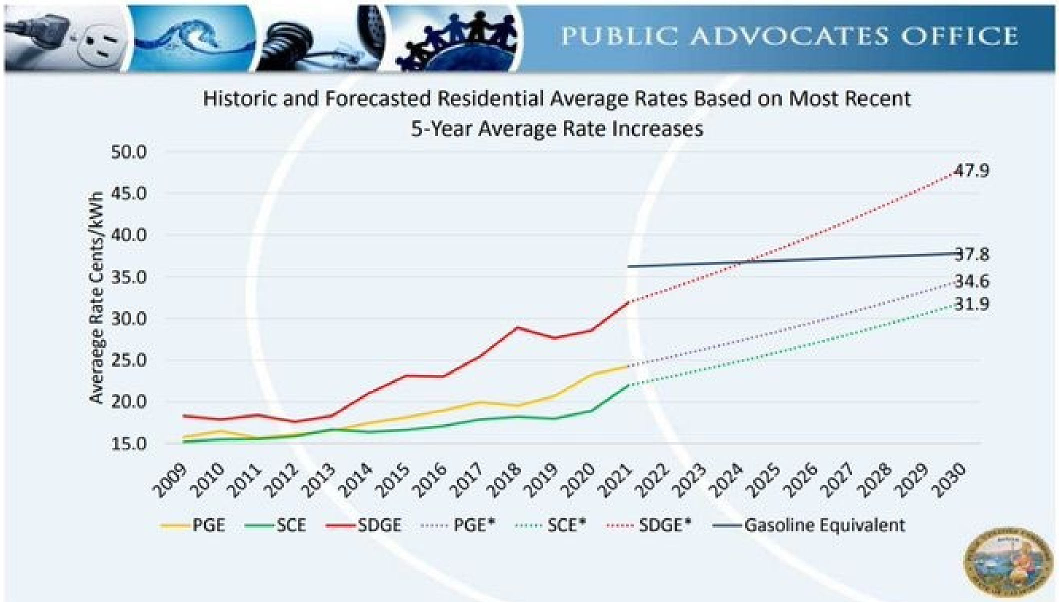
[261] Dan Shreve and Wade Schauer, *Deep decarbonization requires deep pockets* (June 2019), https://www.decarbonisation.think.woodmac.com/.

[262] Salma Elmallah et al., IOP SCIENCE, "Can distribution grid infrastructure accommodate residential electrification and electric vehicle adoption in Northern California?" (Nov. 9, 2022), *available at* https://iopscience.iop.org/article/10.1088/2634-4505/ac949c.

[263] DRIA at 5-35.

[264] Alessandra R. Carreon, et al., RMI, "Increasing Equitable EV Access and Charging" (2022) *available at* https://rmi.org/insight/increasing-equitable-ev-access-charging/.

Figure 9:



Source: Michael Shellenberger, Twitter (citing California Public Advocate's Office data), *April 27, 2021*).

Heaping additional demand for EV charging into this market could exacerbate already high electricity prices. This will be especially impactful to lower-income homeowners who may not be able to install dedicated charging units, forcing them to pay more out of pocket for charging during peak demand periods.[265]

EPA must revise its analysis to account for realistic electricity prices. The proposed ZEV mandate will require an enormous investment in power generation and distribution, resulting in nationwide increases in electricity bills that EPA has not considered. Of course, considering the additional trillions of dollars in costs would paint a clear picture that the costs of forced electrification far exceed even the inflated benefits EPA presented in the Proposed Rule.

vi. Charging infrastructure costs

EPA vastly underestimates the cost to build the required charging infrastructure. Even as new ZEVs are ready to enter into production, auto industry representatives have acknowledged the necessary infrastructure for electric vehicles continues to lag.[266] In 2020, there were a total of 103,582 publicly available non-proprietary charging outlets in U.S. (30 percent of which are located in 14 counties) for 3.04 million EVs on the road, a ratio of 29 EVs per charger.[267] In 2022, 51 percent of all new chargers were added in *2 percent* of U.S. counties, with California adding

---

[265] Hardman, Scott, et al., "A Perspective on Equity in the Transition to Electric Vehicles." *MIT Science Policy Review*, (Aug. 20 2021), *available at* https://sciencepolicyreview.org/2021/08/equity-transition-electric-vehicles/ (accessed June 29, 2023).
[266] ALLIANCE FOR AUTOMOTIVE INNOVATION, "Get Connected Electric Vehicle Quarterly Report" (Fourth Quarter 2022).
[267] ALLIANCE FOR AUTOMOTIVE INNOVATION, "Get Connected Electric Vehicle Quarterly Report" (Fourth Quarter 2022).

25 percent of the 2022 new charging capacity and 160 counties adding only one charger.[268] And the pace of installing new public chargers is not keeping up with current and projected EV sales, as the ratio of registered EVs to new chargers in 2022 was 38 to one.[269]

A 2023 EV Charging Station Report based on DOE's Alternative Fuel Data Center data highlights as the number of ZEVs in the U.S. increased by 42 percent, but the growth in public charging outlets increased by only 12 percent during the same time.[270] According to S&P Global's Mobility Special Report, U.S. charging infrastructure is not nearly robust enough to fully support a maturing electric vehicle market, and ZEV charging stations will need to quadruple between 2022 and 2025 and grow more than eight-fold by 2030.[271] There is lower investment into charging systems outside of major metro markets.[272] Of the 3,100 counties and city-counties in the U.S., 63 percent had five or fewer chargers installed; 39 percent had zero; and 53 percent of counties added no new chargers in 2022.[273]

EPA also did not include any cost of power distribution upgrade needed for EVSE installation, citing large uncertainty. While uncertainty may exist, EPA cannot assume there is no cost associated with this required upgrade. The National Renewable Energy Laboratory ("NREL") published new estimates of the need for ZEV charging infrastructure investment that finds:

> "A cumulative national capital investment of $53–$127 billion in charging infrastructure is needed by 2030 (including private residential charging) to support 33 million PEVs. The large range of potential capital costs found in this study is a result of variable and evolving equipment and installation costs observed within the industry across charging networks, locations, and site designs. The estimated cumulative capital investment includes:
>
> o $22–$72 billion for privately accessible Level 1 and Level 2 charging ports

---

[268] Id.
[269] Id.
[270] ZUTOBI, "2023 EV Charing Station Report: State-by-State Breakdown" (June 16, 2023) *available at* https://zutobi.com/us/driver-guides/the-us-electric-vehicle-charging-point-report.
[271] S&P Global Mobility. "EV Chargers: How Many Do We Need?" *News Release Archive*, (Jan. 9, 2023), https://press.spglobal.com/2023-01-09-EV-Chargers-How-many-do-we-need (accessed June 28, 2023).
[272] S&P Global Mobility. "EV Chargers: How Many Do We Need?" *News Release Archive*, (Jan. 9 2023), https://press.spglobal.com/2023-01-09-EV-Chargers-How-many-do-we-need, (accessed June 28, 2023). Currently EV charging is concentrated in high-income urban areas in California, Colorado, Massachusetts, Maryland, New Jersey, New York, and Oregon. Phillipp Kampshoff, et al., McKinsey & Co., "Building the electric-vehicle charging infrastructure America needs" (Apr. 18, 2022) *available at* https://www.mckinsey.com/industries/public-sector/our-insights/building-the-electric-vehicle-charging-infrastructure-america-needs.
[273] Alliance for Automotive Innovation. *Get Connected Electric Vehicle Quarterly Report, Fourth Quarter 2022*. *See also* S&P Global Mobility. "EV Chargers: How Many Do We Need?" *News Release Archive*, 9 Jan. 2023, https://press.spglobal.com/2023-01-09-EV-Chargers-How-many-do-we-need. Accessed 28 June 2023 (Texas currently has about 5,600 Level 2 non-Tesla and 900 Level 3 chargers, but by 2027 S&P Global Mobility forecasts the state will need about 87,500 Level 2 and 7,800 level 3 chargers – more than ten times the current number of Level 2 and 3 chargers - to support an expected the expected 1.1 million EVs at that time).

o $27–$44 billion for publicly accessible fast charging ports

o $5–$11 billion for publicly accessible Level 2 charging ports.[274]

Clearly, these cost estimates are vastly higher than the $7 billion in costs that EPA claims is needed over an even longer time frame. Given a general linear relationship between ZEV charging infrastructure costs and the number of registered ZEVs, it is reasonable to estimate (using the DOE numbers) a cost adder for charging infrastructure to each ZEV of (at least) $1,606 to $3,848. These costs are not shown by EPA and EPA's failure to account for them is arbitrary and unreasonable. Moreover, note that DOE's estimate excludes "the cost of grid upgrades and distributed energy resources."[275]

The BIL provides up to $7.5 billion to install 500,000 public chargers nationwide by 2030. "However, even the addition of half a million public chargers could be far from enough. In a scenario in which half of all vehicles sold are ZEVs by 2030—in line with federal targets—McKinsey estimates that America would require 1.2 million public EV chargers and 28 million private EV chargers by that year.[276] All told, the country would need almost 20 times more chargers than it has now."[277] EPA must address charger investment and reliability by more than just referencing EV subsidies in recent legislation.

However, building more charging stations is not enough. "Electricity purchased at a public charger can *cost five to ten times more than electricity at a private one*."[278] Lower-income consumers cannot afford to install solar photovoltaics, which proponents claim will allow ZEVs to be charged at home with emissions-free electricity.[279] Those who cannot afford private charging will end up paying vastly more for a re-charge than the wealthy. For those who simply cannot afford the upfront costs for a new EV or pay higher public charging rates, they may end up retaining older ICEVs for longer.

vii. Costs to maintain road infrastructure

EPA fails to account for infrastructure impacts from increased operation of heavier ZEVs on the road including road and bridge deterioration and commensurate reduced funding for infrastructure from fuel tax collections. These excluded costs are known to EPA and must be included in EPA's analysis—another example of EPA's failure to address a major aspect of the proposal.

EPA must, therefore, conduct a full cost analysis to compare *all* costs that must be incurred in order to achieve the environmental benefits EPA is claiming in the Proposal. EPA cannot

---

[274] National Renewable Energy Laboratory, *The 2030 National Charging Network: Estimating U.S. Light-Duty Demand for Electric Vehicle Charging Infrastructure*, June 26, 2023, at vii. Available at https://www.nrel.gov/docs/fy23osti/85654.pdf.
[275] Id.
[276] McKinsey, "Building the Electric Vehicle Charging Infrastructure America Needs," (Apr. 18, 2022), *available at* America's electric-vehicle charging infrastructure | McKinsey; *see also* S&P Global, "EV Chargers: How Many Chargers DO We Need?, (Jan. 9, 2023) (millions of chargers are needed).
[277] *Id.*
[278] *Id.*
[279] Jonathan A. Lesser, Short Circuit: The High Cost of Electric Vehicle Subsidies 4, Manhattan Institute (May 15, 2018), *available at* https://media4.manhattan-institute.org/sites/default/files/R-JL-0518-v2.pdf.

rationally claim an environmental benefit from its Proposal without also accounting for all the costs needed to bring about those environmental benefits.

V. The Proposal Fails to Provide Meaningful Opportunity for Public Comment

AFPM welcomes the opportunity to meaningfully engage with regulators to discuss cost-effective, efficient, and feasible measures to reduce the carbon intensity of, and criteria emissions from, the transportation sector. Unfortunately, the concurrent comment periods for this rule and EPA's proposed heavy-duty vehicle GHG emissions standards are insufficient to provide fully informed comments on either proposal.

Although AFPM was one of several entities requesting that EPA extend the comment period for both rules, the agency declined, claiming that its pre-publication release of material meant that the public in fact had 83 days to comment on the Proposed Rule and 66 days to comment on the heavy-duty GHG rule.[280] Contemporaneously with these proposals were two related rules addressing electric vehicles: (1) DOE published a proposal to revise its regulations regarding calculating a value for the petroleum-equivalent fuel economy of EVs for use in determining compliance with the CAFE program;[281] and (2) the IRS proposed regulations regarding the IRA's New Clean Vehicle Credit. The table below illustrates that in the span of 88 days (April 11 – July 5), interested parties were required to analyze 531 pages of proposed rules in the Federal Register and more than 30,000 pages of supporting material to understand the basis for each proposed rule. The page estimate excludes the voluminous amount of data supporting EPA's two proposed vehicle rules.

---

[280] June 2, 2023, letter from Joseph Goffman, EPA Principal Deputy Assistant Administrator, responding to Patrick Kelly, AFPM; *see also* letters from Alliance for Automotive Innovation, National Automobile Dealers Association, Hyundai-Kia America Technical Center, Inc., Hyundai Motor America, and National Center for Public Policy Research, *available at* https://www.epa.gov/regulations-emissions-vehicles-and-engines/proposed-rule-multi-pollutant-emissions-standards-model.

[281] 88 Fed Reg. 21,525, 21,526 (Apr. 11, 2023).

Proposed Rule	No. of Federal Register Pages	Publication Date	Comments Due	Comment Period (including pre-publication days)	Estimated Pages of Supporting Documents
Petroleum-Equivalent Fuel Economy Calculation	15	April 11, 2023	June 12, 2023	61 days	More than 500
Greenhouse Gas Emissions Standards for Heavy-Duty Vehicles—Phase 3 ("HDV Rule")	236	April 27, 2023	June 16, 2023	66 days	More than 20,000
Proposed Rule (Light-Duty Vehicles—Multi-Pollutant) ("LD/MD Rule")	263	May 5, 2023	July 5, 2023	83 days	More than 10,000
30D New Clean Vehicle Credit	17	April 17, 2023	June 16, 2023	60 days	~30

EPA's refusal to grant additional time to respond to the Proposal and the heavy-duty GHG rule denied the public ample time to formulate meaningful comments responsive to the underlying information in support of the Agency's proposal. The Agency's action is an arbitrary departure from its typical practice of granting reasonable extensions of time—often thirty days, but frequently sixty or even ninety—to provide meaningful input from the public on proposed rules.[282]

The Administrative Procedure Act requires opportunity for meaningful public input, and Executive Order 12866 states that, in most cases, agencies should provide a comment period "of not less than 60 days." Even counting the handful of additional days afforded by EPA's pre-publication release of the preambles, this period is not sufficient to adequately address the sweeping scope of EPA's proposals to force electrification of the nation's transportation fleet. Considerable time is required simply to read and respond to the sheer volume of material covered in each rulemaking docket, particularly given EPA's evident lack of rigor and discipline in its citation and characterization of underlying sources. As illustrated in these comments, our review identified numerous instances in which examination of sources cited by EPA as support for its conclusions indicated that characterization of these sources is inaccurate, incomplete, or misleading. Thus, to meaningfully respond to EPA's proposal, the public must fact-check EPA's

[282] Around the same time AFPM's extension request was denied, EPA saw fit to grant an extension of time to submit comments on the "Commercial Sterilization Facilities NESHAP." *See* EPA Docket EPA-HQ-OAR-2019-0178-0154.

work. There are 1,040 footnotes in the text of the HDV rule preamble and 908 in the LD/MDV rule. Assuming it takes an average of one hour to identify, locate or acquire and read the underlying reference work cited, and draft a meaningful comment in response, that equates to 130 eight-hour workdays that would be required just to fact-check the HD rule (65 days if one assumes this work takes only half an hour per cite on average). For the LD/MDV rule, which would equate to 113.5 eight-hour workdays (or 57 based on assuming 30 minutes per citation). This analysis does not include the time required to verify sources cited in the DRIAs, much less the 1,420 supporting and related materials posted to the HDV docket and the 429 posted to the LD/MDV docket.

Further, the short and concurrently running comment periods on these closely related rules are exacerbated by EPA's unduly narrow identification of industries affected by this rule. Under the heading "Does this action apply to me," EPA limits its identification of affected industries to entities with direct compliance obligations: motor vehicle manufacturers, commercial importers of vehicles and vehicle components, alternative fuel vehicle convertors, and medium duty engine & vehicle manufacturers.[283] Although EPA notes that "this table is not intended to be exhaustive…other types of entities could also be affected," EPA understands many entities necessarily rely on regulatory screening tools based on search terms tied to their own NAICS codes to alert them to new proposed rules that may impact them.

By narrowly limiting the identification of industries affected based on this extremely short and incomplete list of NAICS codes and by its arbitrary refusal to extend the comment periods, EPA has unreasonably constrained the number and types of entities that will find out about these proposed actions in time to comment. EPA appears to be counting on closing the comment period before consumers, retailers, farmers, fleet operators, bio and renewable fuel producers, small businesses, emergency response providers, local governments, or any of the host of other interests who will be affected by the profound changes in how light and medium duty vehicles are sold or even realize what is at stake. This sort of gamesmanship is at odds with EPA's responsibility under the Administrative Procedures Act and the Due Process clause of the U.S. Constitution.

VI. EPA's Consideration of Fuel Controls

EPA requested comment on potential changes to fuel controls to address PM emissions in the existing fleet. EPA specifically stated that it "has not undertaken sufficient analysis to propose changes to fuel requirements under CAA section 211(c) in this rulemaking and considers such changes beyond the scope of this rulemaking."[284] Since EPA has declared it is not actually proposing to change fuel controls in this Proposal, AFPM respectfully asserts that it cannot provide detailed comments on this issue at this time; however, we are more than willing to work with the Agency on this issue.

As noted above, AFPM sought a brief extension to the comment period, which EPA denied.[285] AFPM does not have adequate time to thoroughly review and comprehend EPA's supporting materials, conduct additional research into the unrealistic assumptions and conclusions embedded in the Proposed Rule, and provide informed comment on each aspect of a rule that has significant implications for our industry and the nation while also reviewing, researching, and providing comments on potential changes to fuel controls.

[283] Proposed Rule at 29,184.
[284] Proposed Rule at 29,397.
[285] See Section V.

That said, at an extremely high level, we would have significant concerns about the adverse impacts this would have on the supply of gasoline and the minuscule PM benefits that might be achieved. For example, EPA's assessment must include the significant impacts to refineries and the gasoline pool such potential measures would entail. The potential fuel controls measures would cut a significant amount of the gasoline pool that is not contributing to PM generation. This would translate into both economical and logistical impacts (*e.g.*, alternate disposition, or blending into diesel pool) that impacts costs to consumers. EPA should consider the significant contribution to PM from tire wear and entrained road dust, which account for a majority of the total $PM_{2.5}$ emissions associated with traffic.[286] EPA also must revise its flawed methodologies. For instance, the ASTM D7096 simulated distillation by gas chromatography (SimDis) proposed to either calculate PMI or to set high boiling point limits is not adequately precise to use as a control method and would generate significant errors. We also question the Agency's legal authority to move forward with these fuel controls, which have no environmental benefit for new motor vehicles.

Please contact the undersigned to explore these issues in greater detail. AFPM is happy to bring its members' technical expertise to this complex issue to help inform EPA's decision-making in this area.

*   *   *

In sum, AFPM urges EPA to rescind the Proposed Rule where EPA has no Congressional authority to redefine the automotive sector by mandating electrification under the guise of more stringent emissions standards. At the very least, EPA should reconsider the Proposed Rule considering these comments and the significant challenges facing electrification that were left unanalyzed and severely underestimated by EPA. We thank you for your consideration of these comments and are available for future discussion should you have questions.

Sincerely,

Leslie Bellas

Leslie Bellas
Vice President
Regulatory Affairs
American Fuel & Petrochemical
Manufacturers

[286] *See* https://www.epa.gov/air-emissions-inventories.

American
Fuel & Petrochemical
Manufacturers

1800 M Street, NW
Suite 900 North
Washington, DC
20036

202.457.0480 office
202.457.0486 fax
afpm.org

March 6, 2023

New York State Department of Environmental Conservation
Division of Air Resources
625 Broadway
Albany, NY 12233-325
ATTN: James Clyne, P.E.

-Submitted electronically via email to: air.regs@dec.ny.gov.

RE: Proposed Rulemaking 6 NYCRR Part 218, *Emission Standards for Motor Vehicles and Motor Vehicle Engines* and Part 200, *General Provisions.*

A. Introduction and summary of comments.

A1. AFPM and its interest in NYSDEC's proposed adoption of ACC II.

The American Fuel & Petrochemical Manufacturers (AFPM) appreciates the opportunity to comment on the New York State Department of Environmental Conservation (NYSDEC) proposed amendments to Title 6 of the New York Codes, Rules, and Regulations (NYCRR).[1] AFPM is a national trade association representing nearly all U.S. refining and petrochemical manufacturing capacity. AFPM members support more than three million quality jobs, contribute to our economic and national security, and enable the production of thousands of vital products used by families and businesses throughout the U.S. AFPM members are also leaders in producing lower carbon fuels, such as renewable diesel and sustainable aviation fuel.

A2. Summary of AFPM's reasons for opposing NYSDEC's proposal.

NYSDEC is proposing to adopt CARB's ACC II standards, but it is preempted from doing so. NYSDEC must consider whether the measures called for in the California ACC II rule conflict with or are otherwise preempted by the statutory mandates of federal legislation such as the Energy Policy and Conservation Act ("EPCA"); the federal Clean Air Act ("CAA"); and the Energy Independence and Security Act ("EISA"), including the Renewable Fuel Standard ("RFS") program.

For example, EPCA expressly preempts states from adopting regulations "relating to" fuel economy standards, and ACC II falls squarely within that preemptive footprint. Congress did not authorize the National Highway Traffic Safety Administration (NHTSA) or the Environmental Protection Agency (EPA)

---

[1] By making the following comments available to NYSDEC, AFPM, or any of its members, respectfully do not waive the ability to assert any additional argument at a later date. Additionally, AFPM, or any of its members, reserve the right to supplement or clarify these comments at a late date in one or more subsequent responses.

to waive this express preemption. ACC II is also impliedly preempted under EPCA because it conflicts with important objectives of EPCA and other federal statutes, including the RFS.

ACC II is also expressly preempted by the CAA. Unlike EPCA, EPA may waive this motor vehicle emissions standard preemption under certain conditions. However, California has not even applied to EPA for a waiver from this preemption for ACC II, let alone obtained it. Unless and until California obtains this waiver, New York is preempted by the CAA from adopting and enforcing ACC II.

Not only has California not obtained a waiver for ACC II, ACC II is not a valid subject for an EPA waiver. As our attached comments on CARB's ACC II proposal[2] (incorporated herein by reference) demonstrate, ACC II and CARB's analysis supporting it are flawed by CARB's failure to conduct an accurate lifecycle assessment (LCA). Without such an analysis, neither CARB nor NYSDEC can demonstrate that ACC II is needed to address compelling and extraordinary circumstances or that its benefits exceed its costs. Moreover, global climate change is not a "compelling and extraordinary condition" under Section 209(b)(1)(B) of the Clean Air Act, as California does not suffer any distinct, localized problem, and California's conditions related to global climate change are not "extraordinary" compared to other states.

Additionally, pending litigation in the D.C. Circuit challenges the CAA preemption waiver mechanism itself, as well as its application to California's greenhouse gas (GHG) regulations, including the predecessor program to ACC II, which relies on the same purported source of authority. Separate and apart from the other concerns our comments raise, NYSDEC should wait until this litigation is resolved before adopting ACC II.

ACC II also includes measures that may violate other constitutional provisions and principles. These include, but likely are not limited to, the Dormant Commerce Clause, which prohibits state regulations that improperly discriminate against out-of-state commercial interests or that unduly burden interstate commerce; the dormant foreign affairs preemption doctrine under the Supremacy Clause, which preempts state laws that intrude on the exclusive federal power to conduct foreign affairs; the Takings Clause of the Fifth Amendment, which precludes the taking of private property (or the elimination of entire industries) for public use without just compensation; and the equal sovereignty doctrine, which constrains the federal government from treating states disparately. New York must carefully consider and analyze these additional legal limitations in deciding whether to adopt the ACC II program, as any such adoption would likewise violate the same constitutional principles.

NYSDEC's analysis in support of its proposed adoption of ACC II is further arbitrary and capricious, including the decision to ignore actual emissions that would be accounted for in a properly conducted LCA. Furthermore, where it does not simply adopt CARB's analysis wholesale without meaningfully adjusting for the differences between the two states, it contains unsupported assertions as to the costs and benefits of its proposed action. NYSDEC's analysis thus fails to meaningfully analyze and transparently present the actual costs and benefits of its proposed action. Chief among the major issues NYDEC neglects are the need for electric grid updates to satisfy the significant increase in demand for electricity that ACC II will generate, the need to replace EV batteries and the resulting waste

[2] Also available at: https://www.arb.ca.gov/lists/com-attach/477-accii2022-AHcAdQBxBDZSeVc2.pdf

management challenges and lifecycle emissions impacts, and the rare mineral demand that will outpace supply and lead to an increase in battery costs, not a decrease as NYSDEC incorrectly projects.

In addition, NYSDEC should not ignore the broader geopolitical context against which it acts: the United States depends, and will necessarily continue to depend, on China for these minerals, and adopting policies like ACC II will only increase that dependence. A transition to so-called Zero Emission Vehicles (ZEVs) would expose New York residents to supply chain vulnerabilities largely beyond the control of regulators. For instance, by 2030, Wells Fargo projects a risk of shortages across all of the key components of EV batteries, except manganese.[3] This risk is exacerbated by long lead times for EV battery supply chains[4] and a reliance on geopolitical rivals who control those supply chains.[5]
Finally, adopting ACC II would constitute a regulatory taking requiring just compensation, which NYSDEC's proposal has not accounted for.

In light of the above, AFPM recommends that NYSDEC revoke this emergency rulemaking and start afresh through the standard rulemaking process, detailing its legal authority and providing a full accounting of the costs and benefits of the proposal. Considering AFPM's foregoing comments, NYSDEC also should reconsider whether to re-propose adopting ACC II *at all*, given that its adoption would be preempted by federal law.

The remainder of these comments discuss AFPM's serious concerns with NYSDEC's proposal to adopt California's ACC II. In section B, we focus on NYSDEC's failure to demonstrate that the legal authorities it cites support adoption of ACC II. In section C, we highlight the deficiencies in NYSDEC's environmental and economic analyses. In Sections D and E, we discuss federal preemption of ACC II and pending litigation. In Section F, we observe that adoption of ACC II constitutes a regulatory taking requiring just compensation. Finally, Section G describes some of the unintended consequences of California's initial foray into ZEV mandates under ACC I.

B. The legal authorities NYSDEC cites do not justify its proposal.

B.1 NYSDEC has not justified its use of "emergency" rulemaking procedures to adopt ACC II.

NYSDEC has not sufficiently analyzed the costs and benefits and environmental impacts necessary to support this emergency rulemaking. NYSDEC adopted ACC II "on an emergency basis," effective immediately as of December 13, 2022.[6] As authority for doing so, NYSDEC cited section 202(6) of the State Administrative Procedure Act (SAPA).[7] NYSDEC's invocation of this authority is misplaced. The proposal does not satisfy the requirements of the emergency-rulemaking provision that it cites. In any event, the action in question is plainly inappropriate for emergency rulemaking and adoption of regulatory procedures effective immediately with no prior opportunity for public comment, because it addresses an increase of ZEV mandates beginning in two years.

---

[3] Colin M. Langan, et al., *BEV Teardown Series: The Untold Electric Vehicle Crisis, Part 1: Tesla Model Y–The Pace Car*, WELLS FARGO, May 11, 2022.
[4] *See* 2022 Global EV Outlook (IEA May 2022) at 6-7, 178-79, *available at* https://www.iea.org/reports/global-ev-outlook-2022 (last visited Mar. 3, 2023)
[5] *Id.*
[6] N.Y.S. Reg. (Dec. 28, 2022), at 38, *available at* https://dos.ny.gov/system/files/documents/2022/12/122822.pdf (last visited Mar. 3, 2023).
[7] *Id.*

New York law authorizes NYSDEC to adopt a rule on an "emergency basis" only if the rule "is necessary for the preservation of the public health, safety or general welfare" and only when a formal rulemaking proceeding would be "contrary to the public interest."[8] NYSDEC cannot satisfy this standard, as immediate adoption of ACC II will not meaningfully alter global carbon emissions, much less to a degree needed to demonstrate that ACC II is "necessary" to preserve public health, safety, or general welfare. Indeed, New York is concurrently considering multiple other carbon abatement programs, including a low carbon fuel standard.[9] Likewise, the federal EPA sets light-duty vehicle standards to regulate carbon emissions from new motor vehicles. That both federal and state policymakers are actively considering multiple options for carbon reductions is *prima facie* evidence that an emergency rulemaking is neither necessary nor appropriate. Finally, even if such an emergency existed, for the time being NYSDEC's adoption of ACC II will do nothing to address it because the rule could not take effect until EPA issues a Clean Air Act waiver to California.[10]

Even if NYSDEC could satisfy the substantive requirements for emergency rulemaking, it has not complied with the emergency adoption rulemaking procedures to fully describe the specific reasons for circumventing the protections of a full and complete rulemaking. "A notice of emergency adoption" must

> include a statement *fully describing the specific reasons* for [the required] findings *and the facts and circumstances* on which such findings are based. Such statement shall include, at a minimum, a description of the nature and, if applicable, location of the public health, safety or general welfare need requiring adoption of the rule on an emergency basis; a *description of the cause, consequences, and expected duration of such need*; an *explanation* of why compliance with the requirements of subdivision one of this section would be contrary to the public interest; and an *explanation* of why the current circumstance necessitates that the public and interested parties be given less than the minimum period for notice and comment . . . .[11]

The notice's justification for emergency rulemaking reads in full:

> Failure to maintain the most stringent vehicle emissions standards possible by immediately adopting this rule will be detrimental to the public health and general welfare of New Yorkers. Compliance with the requirements of SAPA § 202(1) would be contrary to the public interest in this instance as the immediate adoption of this rule is necessary to preserve the public health and general welfare of the citizens of the State, due to the loss in GHG and co-pollutant emission reductions caused by a delay. In order to maintain the cleanest motor vehicle standards available to New York, we must adopt these standards now. This amendment is adopted as an emergency measure because time is of the essence.[12]

---

[8] SAPA § 202(6)(a)

[9] *See* Scoping Plan (N.Y.S. Climate Action Council Dec. 2022), *available at* https://climate.ny.gov/resources/scoping-plan/ (last visited Mar. 3, 2023) (including Secnario 2: Strategic Use of Low-Carbon Fuels).

[10] We address these issues below in greater detail in sections B.5 (CAA preemption) and C.4 (NYSDEC's GHG analysis).

[11] SAPA § 202(6)(d)(iv) (emphases added).

[12] N.Y.S. Reg. (Dec. 28, 2022), at 39.

This statement is wholly conclusory. The only specific finding is its assertion that immediate adoption of ACC II will avoid a "loss in GHG and co-pollutant emission reductions." But this single dependent clause identifies no basis to invoke emergency-rulemaking procedures that would not apply equally in the case of any other environmental regulation—*every* delay in environmental regulation could conceivably result in fewer reductions of some pollutant. Courts have invalidated attempts to use emergency-rulemaking authority where the acting agency gave only such general, conclusory statements of need, instead of complying with SAPA's notice requirements.[13]

In addition, the proposal's "Needs and Benefits" section states that there are ozone non-attainment areas in the state and that EPA will reclassify some areas as "severe" nonattainment. However, the CAA was designed to purposefully allow states flexibility to adopt control strategies and extend compliance deadlines while progressively adopting more stringent emission controls, many of which have already been undertaken at the federal and state level and simply need time for implementation to bring the area into attainment. Also, the overwhelming majority of NY is in compliance with the 2015 8-hr ozone standard and only the metro NYC area is designated as "moderate" nonattainment as of February 28, 2023.[14] While it is true the metro NYC area has been designated as "severe" nonattainment with the 2008 ozone standard, this designation was made at the request of New York to EPA, and as New York stated in the request, "New York State continues to exceed its Reasonable Further Progress emission reduction requirements."[15] Moreover, New York has not exceeded the new July 20, 2027 compliance deadline to attain the standard.[16] Most importantly, New York does not clearly explain to the public that its own 'business as usual' analysis shows that light-duty vehicle NOx emissions in the state under current regulations will drop by 73% (between 2025 and 2040), PM2.5 emissions will drop by 31% and CO2 emissions will drop by 35%.[17] Clearly, there is no emergency to further accelerate these emission reductions beyond levels already required under federal and state regulation, given that these emissions are declining rapidly.

In any event, this regulatory action is plainly inappropriate for emergency rulemaking. If NYSDEC adopts ACC II, this will result in a 12 year-long "ramp-up" of car standards and so-called "Zero Emission Vehicle"

---

[13] *See, e.g.*, *Demetriou v. N.Y.S. Dep't of Health*, 162 N.Y.S. 3d 673, 678 (Sup. Ct. Nassau Cty. 2022) (regulatory mask mandate "was promulgated as an emergency 'regulation'[,] however, respondents cannot support the 'emergency' classification other than to say the Commissioner chose to call it an emergency. It is clear that [the mask mandate] was promulgated *without any substantive justification* for the emergency adoption as required by [SAPA] as the only justification the respondents offered for emergency adoption was *entirely conclusory* . . . . As a result, the 'emergency' 'rule'. . . must fail as violative of the State Administrative Procedure Act.") (emphases added); *Brodsky v. Zagata*, 629 N.Y.S. 2d 373, 377 (Sup. Ct. Albany Cty. 1995) ("The State has failed to comply with the minimal requirements of SAPA. Simply put this record is devoid of any finding of immediate necessity, emergency, or undue delay because of a failure to follow the SAPA 'statement' requirement *fully describing the specific reasons* for such findings and facts. Further the Notice of Adoption did not explain *in any detail* why compliance with normal rule making procedure would be contrary to the public interest or why the current circumstances necessitate the use of emergency rule making procedure." (emphases added)).

[14] *See* https://www3.epa.gov/airquality/greenbook/ny8_2015.html.

[15] *See* NYSDEC SIP Attainment Demonstration, November 29, 2021, https://www.dec.ny.gov/docs/air_pdf/sipseriouso3nyma.pdf.

[16] *See* 87 Fed. Reg. 60,929 (Oct. 7, 2022), https://www.govinfo.gov/content/pkg/FR-2022-10-07/pdf/2022-20458.pdf#page=1.

[17] See the 'Tables' tab of the spreadsheet available at https://www.dec.ny.gov/chemical/8394.html, Advanced Clean Cars II (ACC II) Emissions Summary for New York State (Excel).

(ZEV) mandates,[18] beginning in model year 2026,[19] with no discernible immediate impact on New Yorkers. Therefore, there is no reason why NYSDEC could not have proposed to adopt ACC II, solicited comments, considered the comments, and decided whether to finalize its proposed action.[20] Indeed, the deficiencies in NYSDEC's regulatory impact analysis, discussed in Section C below, show that NYSDEC left much crucial work undone and has not provided the public with a sufficient basis to provide informed comment, or for itself to make a reasoned decision.

B.2 NYSDEC has not substantiated its assertions that adopting ACC II is aligned with the Climate Leadership and Community Protection Act.

NYSDEC's notice asserts that adoption of ACC II is "consistent with the requirements of New York's Climate Leadership and Community Protection Act," which "established GHG reduction requirements and other climate policy goals. . . . [T]he CLCPA includes numerous requirements regarding the reduction of GHGs, and [adoption of ACC II] will further reduce GHGs from motor vehicles in the State."[21]

But NYSDEC's analysis does not demonstrate that adopting ACC II would, in fact, align with the CLCPA's goals. The CLCPA requires *statewide* reductions of GHG emissions. NYSDEC's Regulatory Impact Statement acknowledges this fact as a general matter, yet fails to consider whether ACC II will in fact reduce New York State's *overall* GHG emissions profile, or whether there are more effective or less costly alternative means of doing so.[22]

As we explain in these comments and in our attached comments on CARB's ACC II proposal, in the absence of a lifecycle GHG emissions analysis, neither CARB nor NYSDEC can demonstrate the *statewide* GHG impact of ACC II.

Our attached comments on CARB's ACC II proposal include a study from Ramboll that evaluated whether alternative vehicle technology and fuel pathways could achieve life cycle GHG emission reductions similar or greater than the ACC II proposal. Unlike CARB's and NYSDEC's partial analysis, Ramboll evaluated the full life cycle impacts of ZEV technologies under the ACC II proposal to more completely and properly characterize the potential near-term and long-term GHG emissions performance. Ramboll considered other pathways that would not require a replacement of the entire transportation infrastructure system, and that would also not require the wholesale transformation of electric energy production and distribution infrastructure on an unprecedented short time scale. Instead, these other pathways would allow battery, hydrogen, and low-carbon intensity gaseous and liquid fueled vehicles to compete to achieve California's GHG targets for light-duty transportation in the quickest and most cost-

---

[18] On an LCA basis, of course, there is no such thing as a "zero-emission" vehicle, since all vehicles will have associated upstream and downstream emissions.
[19] *See generally* N.Y.S. Reg. (Dec. 28, 2022), at 40.
[20] *See generally* SAPA § 202 (Rulemaking procedure).
[21] N.Y.S. Reg. (Dec. 28, 2022), at 40; *see also id.* (adoption of ACC II is "consistent with the requirements of [the CLCPA] to further reduce greenhouse gas (GHG) emissions in the State . . . ."); RIS 9 (adoption of ACC II is "consistent with the CLCPA because [it] will further reduce GHG emissions from motor vehicles.").
[22] RIS 9 (CLCPA "among other things requires a 40 percent reduction in *Statewide* GHG emissions from 1990 levels by 2030, and an 85 percent reduction from 1990 levels by 2050.") (emphasis added). *See also* 6 NYCRR 496.1 ("This Part adopts limits on the emissions of greenhouse *gases from across the State and all sectors of the State economy* for the years 2030 and 2050, as a percentage of 1990 emission levels of 60 percent and 15 percent, respectively, as established in the Climate Leadership and Community Protection Act, Chapter 106 of the Laws of 2019.") (emphasis added).

effective manner. Ramboll's conclusions showed that CARB's attributions of GHG reductions to its proposed ACC II regulation were incomplete and emphasized the need for CARB to conduct a full lifecycle GHG emission assessment to quantify the cradle-to-grave effects of the draft ACC II proposal. Ramboll's study shows that a full LCA demonstrates that there are multiple GHG-reducing vehicle/fuel technologies that, individually or in combination, have equivalent GHG reductions as the ZEV-mandated ACC II proposal. CARB did not remedy these inadequacies in its analysis before adopting ACC II, and NYSDEC's own analysis suffers from the same deficiencies.

Even if CARB's analysis included the carbon emissions associated with battery production and had been otherwise adequate (which, as our comments on its proposal demonstrated, it was not), NYSDEC cannot simply rely on CARB. For NYSDEC to conduct an adequate LCA of the effects of adopting ACC II on statewide GHG emissions, it would need to consider factors such as the mix of the fuel base for generation supplied to the grid on which New York's ZEVs will charge, expected miles traveled by New York drivers, New York temperature trends throughout the year and their effect on charging needs and battery capabilities, and many other state-specific factors.

NYSDEC's omission of a LCA is especially troubling in light of the CLCPA's explicit requirement that regulations promulgated to achieve statewide GHG regulations "[i]ncorporate measures to minimize leakage."[23] There is no analysis of the potential for leakage in either NYSDEC's proposal or its Regulatory Impact Statement, let alone any discussion of how to minimize it. Far from NYSDEC demonstrating that its proposed action is aligned with CLCPA's goals, its proposal violates CLCPA's own requirements.

B.3 NYSDEC has not demonstrated that adoption of ACC II will further its task of mitigating the effects of criteria pollutants.

In the section of its Regulatory Impact Statement (RIS) addressing "Needs and Benefits," NYSDEC observes that it "is also tasked with mitigating the effects of criteria pollutants."[24] It is not clear what NYSDEC is referring to here. The RIS cites some fifteen state statutory provisions as authority,[25] but none of these appear to refer directly to criteria pollutants. NYSDEC is presumably referring to some combination of general statements of purpose in these state statutes regarding preserving air quality, the federal Clean Air Act,[26] and the state's State Implementation Plans approved by EPA pursuant to that Act.

As we explain in the section of these comments addressing NYSDEC's analysis in support of its proposal, and in our attached comments on CARB's proposed adoption of ACC II, without conducting an LCA,

---

[23] N.Y. Envir. Conser. Law § 75-0109(3)(e). NYSDEC is well-aware that life-cycle analysis is necessary to compare to the costs and benefits of electric vehicles compared to convention vehicles—AFPM informed NYSDEC of this obligation on another NYSDEC vehicle rulemaking. *See* Comments of American Fuel & Petrochemical Manufacturers on Proposed 6 NYCRR Part 218, Emission Standards for Motor Vehicles and Motor Vehicle Engines 6 NYCRR Section 200.9 (Nov. 17, 2021).

[24] RIS 10. *See also* RIS 74 ("The severity of New York State's air quality problems dictates that New York State must maintain compliance with recent improvements in the California standards to achieve necessary reductions of *pollutants that aid in the formation of ground-level ozone*, as well as climate change. Adhering to federal standards would impede New York's ability to attain and maintain ambient air quality standards and make reasonable further progress as required in its State Implementation Plan.") (emphasis added).

[25] RIS 2.

[26] 42 U.S.C. § 7401 *et seq.*

NYSDEC cannot demonstrate the overall effect that adoption of ACC II will have on criteria pollutant emissions in New York. NYSDEC therefore has not clearly identified the source and scope of this "task[]," and in any event has not adequately demonstrated that adopting ACC II will further carry it out. And even NYSDEC's own inadequate analysis, as discussed below, appears to show *millions* of dollars of costs per ton of criteria pollutants reduced—orders of magnitude above what EPA has recognized as cost-effective emissions reduction and an irrational basis for regulation.

B.4 New York State's "zero-emissions cars and trucks" statute does not support NYSDEC's adoption of ACC II.

NYSDEC cites, as further support for its proposal, state legislation from 2021 that calls for increased ZEV sales in New York, working towards a "goal" of ZEVs making up one hundred percent of new passenger cars and trucks sold or leased in the state by 2035.[27] But this legislative provision does not support NYSDEC's proposal, as the very next paragraph requires NYSDEC to "develop and propose" ZEV regulations "consistent with federal law."[28] As these comments explain,[29] adopting ACC II is inconsistent with federal law in at least three independent respects: it is preempted by EPCA and by the RFS, and unless and until EPA grants a Clean Air Act preemption waiver for ACC II, it is also preempted by the Clean Air Act. NYSDEC does not acknowledge this crucial caveat, let alone explain how its proposed adoption of ACC II is "consistent with federal law." Without doing so, NYSDEC cannot validly support its proposal by reference to this statute.

B.5 Clean Air Act Section 177 does not support NYSDEC's adoption of ACC II.

NYSDEC, as an additional reason for proposing to adopt ACC II, cites "maintain[ing] identicality with Section 177 of the Clean Air Act."[30] Indeed, NYSDEC says that this supposed "identicality" imperative is the "primary basis" why it did not consider retaining its current regulations, which reflect its prior adoption of ACC I.[31]

NYSDEC is misconstruing the Clean Air Act. Section 177 contemplates states adopting California's standards where "such standards are identical to the California standards *for which a waiver has been*

---

[27] *See* N.Y. Envir. Conser. Law § 19-0306-b. *See also* N.Y.S. Reg. (Dec. 28, 2022), at 39 (adoption of ACC II "consistent with . . . legislation signed by Governor Hochul in 2021 (Chapter 423, Laws of 2021), which commits the State to all new, light-duty on-road vehicle sales to be zero emission vehicles (ZEV) by 2035"); RIS 15 ("New York State legislation signed by Governor Hochul in 2021 (Chapter 423, Laws of 2021) commits 100% of all new, light-duty on-road vehicle sales in New York to be ZEVs by 2035 and directs the Department to develop and propose regulations like this ACC II proposal to help meet this target.").

[28] N.Y. Envir. Conser. Law § 19-0306-b(2).

[29] See below, Sections B.5 (CAA § 177) and D (preemptive effect of EPCA and other federal statutes).

[30] N.Y.S. Reg. (Dec. 28, 2022), at 40 ("In accordance with NYS State Administrative Procedures Act (SAPA) Section 202-b, this rulemaking does not include a cure period because *the Department is undertaking this rulemaking to maintain identicality* with Section 177 of the Clean Air Act." *See also* Revised Rural Area Flexibility Analysis 2 ("Section 177 of the federal Clean Air Act requires New York to maintain standards identical to California's to maintain the LEV program."); RIS 7 ("[S]ection 177 of the [Clean Air] Act permits states other than California to adopt and enforce standards for motor vehicle emissions, provided that such standards are identical to California's standards.").

[31] RIS 73 ("The option of maintaining the current ACC I program without adopting CARB's ACC II amendments was reviewed and rejected. The primary basis for this decision was that the Department believes this is not permitted under Section 177 due to the identicality requirement.").

granted."[32] California has apparently not even applied for, let alone obtained, an EPA waiver of Clean Air Act preemption for ACC II.[33] Section 177 on its face therefore provides no authority for NYSDEC to adopt ACC II, and any such adoption would be preempted by the CAA[34] unless and until EPA grants a preemption waiver for ACC II.[35]

NYSDEC's misunderstanding of CAA § 177 also exposes a fatal flaw in its "alternatives" analysis within its Regulatory Impact Statement.[36] Apart from its misguided reference to CAA § 177 and "identicality" with California, NYSDEC's alternatives analysis simply restates that "adoption of ACC II is consistent with Legislative directives to the Department." As we explain in these comments, this is incorrect. NYSDEC has therefore not provided the public with a meaningful consideration of alternatives as required by state law.[37]

NYSDEC's adoption of ACC II would, therefore, violate a separate provision of state law which applies when NYSDEC is "adopting any code, rule or regulation which contains a requirement that is more stringent than the [Clean Air] Act or regulations issued pursuant to the Act by the United States environmental protection agency [sic]."[38] This provision requires NYSDEC to provide "a *detailed* explanation of the reason or reasons that justify exceeding federal minimum requirements."[39] NYSDEC's confused and conclusory discussion of the possibility of adhering to federal standards does not satisfy this requirement.

NYSDEC says that its "*primary basis*" for rejecting the alternative of "maintaining the current ACC I program without adopting CARB's ACC II" was that "the Department believes this is not permitted under Section 177 due to the identicality requirement."[40]

---

32 42 U.S.C. § 7507(1) (emphasis added).

33 *See* Vehicle Emissions California Waivers and Authorizations (EPA), *available at* https://www.epa.gov/state-and-local-transportation/vehicle-emissions-california-waivers-and-authorizations (last visited Feb. 21, 2023) ("This page lists Federal Register notices that EPA has issued in response to California waiver and authorization requests."). As of February 21, 2023, this page reflected that it had last been updated June 13, 2022, months before California finalized the ACC II rulemaking.

34 *See* CAA § 209(a), 42 U.S.C. § 7543(a). Indeed, CAA § 209(a) preempts states from both "adop[ting]" and "enforc[ing]" a motor vehicle standard unless EPA issues a preemption waiver. This regulatory action is premature and unlawful.

35 *See Am. Auto. Mf'rs Ass'n v. Comm'r, Mass. Dep't. of Envt'l Prot.*, 998 F. Supp. 10, 17-18 (D. Mass 1997) ("A state regulation relating to control of emissions from new motor vehicles or engines can survive pre-emption if, in accordance with [Clean Air Act] § 177, it adopts and enforces standards which are 'identical to the California standards' for which the EPA has granted a waiver 'for such model year.' *But a state may not either adopt or enforce a standard which does not meet these requirements*. Put another way, under § 177, a state can pass regulations only if it accepts as the basis for its regulations a California "standard" which has been granted a waiver in accordance with § 209(b)." (citation omitted) (emphasis added)) (granting summary judgment for plaintiff and holding preempted Massachusetts state ZEV production, delivery, and reporting requirements).

36 *See* RIS 73-74.

37 *See* SAPA § 202-a(g) (Regulatory Impact Statement "shall contain . . . . [a] statement indicating whether any significant alternatives to the rule were considered by the agency, including a discussion of such alternatives and the reasons why they were not incorporated into the rule.").

38 N.Y. Envir. Conser. Law § 19-0303-4(a). NYSDEC incomprehensibly cites this as one of the provisions granting it statutory authority for its proposed action. RIS 2.

39 *Id.* (emphasis added).

40 RIS 73 (emphasis added).

NYSDEC is incorrect, for three reasons. First, as explained above, CAA § 177, far from requiring NYSDEC to adopt ACC II, in fact does not allow NYSDEC to adopt ACC II unless and until EPA grants a waiver for that program.

Second, ACC II is a California rulemaking establishing additional provisions of California's regulatory code, which are separate code sections for separate model years whose text explicitly provides that they are severable from the remainder of California's car-emissions regulations.[41] NYSDEC identifies no valid reason why it could not retain ACC I without also adopting ACC II,[42] especially since CAA Section 177 allows other states to adopt California's standards if "such standards are identical to the California standards for which a waiver has been granted for such model year."[43]

Third, NYSDEC could have repealed its existing regulatory requirements resulting from its prior adoption of ACC I, resulting in harmony with existing *federal* standards. CAA § 177 *allows* states to adopt California's standards under certain circumstances but does not *require* them to do so. NYSDEC did not consider this course of action (harmonizing with federal standards) as part of its alternatives analysis, further undermining that analysis.[44] Indeed, as shown below, NY has sound environmental, economic, and social reasons to not adopt ACC II.

---

[41] *See* CARB, Notice of Public Hearing to Consider Proposed Advanced Clean Cars II Regulations (Mar. 29, 2022), at 7, *available at* https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/accii/notice.pdf (last visited Feb. 21, 2023) ("The proposed amendments do not encompass substantive updates to CARB's existing greenhouse gas emission standards that are part of the existing ACC program in Section 1961.3 of title 13 of the California Code of Regulations.").

On the severability of ACC II, *see* Cal. Code Regs. tit. 13, § 1961.4(h) ("*Severability*. Each provision of this section is severable, and in the event that any provision of this section is held to be invalid, the remainder of both this section and this article [i.e., Approval of Motor Vehicle Pollution Control Devices (New Vehicles)] remains in full force and effect."); *id.* § 1962.4(*o*) (same).

[42] *See* 87 Fed. Reg. 14,332, 14,332/1 (Mar. 14, 2022) ("rescind[ing] EPA's 2019 waiver withdrawal, thus bringing back into force the 2013 ACC program waiver").

[43] 42 U.S.C. § 7507(1).

[44] NYSDEC did consider federal standards in a separate section of the RIS, *see* RIS 74, as required by SAPA § 202-a(h) (RIS "shall contain . . . . . [a] statement identifying whether the rule exceeds any minimum standards of the federal government for the same or similar subject areas and, if so, an explanation of why the rule exceeds such standards"). This section of the RIS states that "There are no federal ZEV or LEV programs currently available *as an alternative*." RIS 74 (emphasis added). To support this statement, NYSDEC notes that potential future federal regulations "may be similar to California's ACC regulation in stringency, but not timing," because federal rules "could not take effect before model year 2027," whereas ACC II takes effect beginning with model year 2026, and that "[t]he details regarding any potential federal program are unknown," whereas ACC II has more stringent emission standards and ZEV sales requirements "compared to current federal standards for the same vehicles." *Id.* But, as explained in Sections B.5 and D, NYSDEC is currently preempted from adopting ACC II. NYSDEC's failure to recognize this fact vitiates both its alternatives analysis and its separate discussion of existing federal standards.

The only additional reason NYSDEC gives for not adhering to federal standards is an assertion that doing so would impede New York's ability to attain and maintain federal ambient air quality standards (NAAQS) under the Clean Air Act. *Id.* This conclusory assertion with no supporting analysis does not constitute a reasoned basis to reject the option of adhering to federal standards. And, as we explain elsewhere in these comments, without conducting a lifecycle analysis, NYSDEC has no basis for its apparent view that adoption of ACC II will assist its air-quality efforts with respect to criteria pollutants or the NAAQS program. In fact, NYSDEC's analysis does not account for the risk of the opposite effect: mandating more expensive EVs may slow fleet turnover, which could delay penetration of lower-emitting technologies and further interfere with attainment and maintenance of NAAQS standards.

In short, not only does CAA § 177 fail to support NYSDEC's proposed adoption of ACC II, but the federal statutory provision in fact *preempts* adoption at this stage.

C. NYSDEC's analysis in support of its proposal is inadequate.

As a threshold matter, the accumulated weight of NYSDEC's unsupported and/or inadequately supported claims, projections, and assumptions in its regulatory analysis documents render its proposed adoption of ACC II arbitrary and capricious.[45]

C.1 NYSDEC's analysis regarding cars, car components, and their costs

NYSDEC repeatedly makes assumptions and predictions with no or inadequate support regarding cars, car components, and the costs of both.

For example, the "Economic and technological feasibility" section of NYSDEC's regulatory flexibility analysis begins:

> There are *numerous* models of passenger car, and light-duty trucks from several manufacturers currently available. *It is expected* that a growing number of ZEVs across all vehicle classes, including light-duty pickup trucks, will become suitable for more applications *as technology advances*.[46]

NYSDEC provides no details or other support for either its characterization of the currently available fleet of ZEVs or its "expect[ation]" that technological progress will increase that fleet sufficient to meet the requirements of its proposed adoption of ACC II. This is not a meaningful analysis of either feasibility or the important value of consumer choice (a concept which is recognized nowhere in NYSDEC's proposal or regulatory analysis). Moreover, NYSDEC fails to recognize and account for the myriad direct and indirect federal and state subsidies required to bring current and future ZEVs into the marketplace, and whether the continuation of these subsidies will be required for ZEV sales and technology to be feasible.

Similarly, with respect to battery costs, NYSDEC states that "battery costs have declined by almost 90 percent since 2010 *and are expected to continue to drop*."[47] NYSDEC here repeats CARB's mistake,

---

[45] *See N.Y.S. Ass'n of Ctys. v. Axelrod*, 577 N.E.2d 16, 20-21 (N.Y. 1991) ("[A]n an administrative regulation will be upheld only if it has a rational basis, and is not unreasonable, arbitrary or capricious. Administrative rules are not judicially reviewed pro forma in a vacuum, but are scrutinized for genuine reasonableness and rationality in the specific context.") (citations omitted).

See also Lynch v. N.Y.C. Civilian Complaint Review Bd., 98 N.Y.S.3d 695, 703 (Sup. Ct. N.Y. Cty. 2019) ("Courts have identified several grounds where a court might deem an agency rule invalid as arbitrary and capricious: (1) the agency fails to identify a rational basis for the rule ; (2) agency does not establish a rational relationship to agency's stated purpose; (3) agency does not demonstrate rule is based on a rational, documented, empirical determination; (4) agency fails to identify objective standards for implementing the program; and (5) agency allows for uneven enforcement against those whom it applies.") (citations omitted). As our comments below demonstrate, NYSDEC's proposal suffers from at least the first three of these five bases for invalidity.

[46] Revised Regulatory Flexibility Analysis for Small Businesses and Local Governments 3 (emphases added).

[47] RIS 47 (emphasis added). *See also* Revised Regulatory Flexibility Analysis for Small Businesses and Local Governments 3 ("Cost parity is anticipated to be achieved for a growing number of classes by 2035 as battery prices fall and technology improves."); Regulatory Impact Statement Summary 6 ("Battery storage cost is the

ignoring the question whether the likely future supply and demand trends for critical minerals and other battery components will allow for the necessarily massive supply ramp-up in conjunction with continued falling prices which its analysis "expect[s]." Indeed, NYSDEC's analysis does not mention "supply" (or "mineral(s)") anywhere, despite research and commentary warning that critical mineral and battery component supply issues will form a major obstacle to the type of ZEV ramp-up its proposed adoption of ACC II blithely assumes will happen seamlessly. NYSDEC's analysis further ignores that lithium-ion battery pack prices have in fact recently begun to *rise*, even before the true impacts of ACC II are felt. [48]

Elsewhere, NYSDEC flatly states that it "*believes* CARB's battery pack, non-battery component, fuel cell and hydrogen storage system, and delete engine cost estimates [i.e., internal combustion engine (ICE)

---

largest component of the incremental cost of a BEV. Battery costs have declined by almost 90 percent since 2010 and are expected to continue to drop. Battery costs are expected to drop from approximately $95.3/kWh in 2026 to $72.5/kWh in 2030.").

[48] BloombergNEF, Lithium-ion Battery Pack Prices Rise for First Time to an Average of $151/kWh (Dec. 6, 2022), *available at* https://about.bnef.com/blog/lithium-ion-battery-pack-prices-rise-for-first-time-to-an-average-of-151-kwh/ (last visited Feb. 26, 2023) ("Rising raw material and battery component prices and soaring inflation have led to the first ever increase in lithium-ion battery pack prices since [Bloomberg] began tracking the market in 2010. After more than a decade of declines, volume-weighted average prices for lithium-ion battery packs across all sectors have increased to $151/kWh in 2022, a 7% rise from last year in real terms. The upward cost pressure on batteries outpaced the higher adoption of lower cost chemistries like lithium iron phosphate (LFP). [Bloomberg] expects prices to stay at similar levels next year, further defying historical trends."); Graham Evans, A reckoning for EV battery raw materials (S&P Global Mobility Oct. 31, 2022), *available at* https://www.spglobal.com/mobility/en/research-analysis/a-reckoning-for-ev-battery-raw-materials.html (last visited Feb. 26, 2023) ("Geopolitical turbulence and the fragile and volatile nature of the critical raw-material supply chain could curtail planned expansion in battery production—slowing mainstream electric-vehicle (EV) adoption and the transition to an electrified future. Soaring prices of critical battery metals, as observed in the following chart from S&P Global Commodity Insights, are threatening supplier and OEM profit margins. This situation has quickly translated into increased component and vehicle prices, according to new analysis from S&P Global Mobility Auto Supply Chain & Technology Group. . . . S&P Global Mobility research clearly indicates that established battery raw material supply and processing operations under mainland Chinese ownership will continue to deliver much of the world's supply of lithium-ion batteries and their constituent key elements."); Mark P. Mills, The "Energy Transition" Delusion: A Reality Reset (Manhattan Institute Aug. 2022), at 8, 10, *available at* https://media4.manhattan-institute.org/sites/default/files/the-energy-transition-delusion_a-reality-reset.pdf (last visited Feb. 22, 2023) ("In the complex calculus of energy policies, the decarbonization road map also creates problematic realignments in energy supply chains. Start with the facts that the U.S. today is dependent on imports for 100% of some 17 minerals that are already listed as critical for national and economic security and that, for 28 other critical minerals, U.S. imports account for more than half of existing domestic demand. Factories that assemble batteries or solar hardware in this country would be equivalent to assembling conventional automobiles domestically but importing all the key components and all the fuel. . . . Today, the energy sector uses less than 15% of the various critical minerals that are also used for other purposes. But if transition goals were achieved, that share rises from 40% to 70% (at least). Just the pursuit of such an increase and shift in commodities usage would lead to higher and more volatile prices. Even in these early days of potential radical increases in demand, lithium prices are already up nearly 1,000% over the past two years, along with copper trading in a range that's double the long-run history, nickel trading at a five-year high after coming down from recent peaks, and aluminum prices at a 10-year high. Again, this is the case with SWB [solar, wind, and battery] meeting only a few percentage points of total global energy needs. Escalating mineral demands further will escalate their prices, which will have two macroeconomic impacts: it will increase the costs of the SWB hardware itself—thereby inflating the costs of already expensive transition policies—and it will increase the costs of other manufactured goods competing for the same minerals. The latter is broadly inflationary, and the former reverses the assumption built into all transition forecasts, i.e., that the SWB hardware inevitably becomes cheaper.").

manufacturing costs avoided] would similarly apply to vehicles sold in New York State."[49] No basis is provided for this "belief."

NYSDEC also notes that "Federal and state incentives are *currently* available to offset" higher vehicle and infrastructure costs that will result from adopting ACC II.[50] NYSDEC offers no details, nor any analysis of whether this state of affairs is likely to last and, if it does not, what would be the implications for the cost analysis and overall viability of the regulatory program. Indeed, the Internal Revenue Service has not even issued final guidance on its implementation of the "buy America" provisions of EV subsidies pursuant to the Inflation Reduction Act, subsidies which were designed to protect national security by applying exclusively to ZEVs with 40-100 percent of the battery critical minerals and value of components sourced from or manufactured or assembled in the U.S. or a free-trade partner country. If applied consistent with the statutory language, these subsidies are not available to most ZEVs in the market today. Moreover, NYSDEC does not even consider the extent to which its proposal depends on a basket of more valuable subsidies, whether or not they will continue indefinitely, or the market implications of an increasing percentage of vehicle sales depending on cross-subsidies from a shrinking number of gasoline vehicle buyers. NYSDEC must account for the following costs and market impacts which currently are ignored in its proposal:

- Zero-emission vehicle credits, or "ZEV credits." These credits are a currency created by the State of California to provide supplemental subsidies of EV sales to achieve their ZEV sales mandate. NYSDEC must disclose the cost of this incremental subsidy that manufacturers of EVs require (in addition to many other subsidies) to entice buyers to meet state EV sales mandates. If buyers wanted EVs, the ZEV credit price would be $0, but California and other states explicitly decided to not collect this data from automakers, so the public has no information about the costs of this scheme. NYSDEC must disclose who is paying the costs of the ZEV credits. Will New York gasoline and diesel vehicle buyers cover the costs of ZEV credits for EV sales in the state, i.e., will the MSRP of a gasoline pickup truck in New York be higher than the MSRP of a gasoline pickup truck in a state without a ZEV sales mandate and ACCII? If so, by how much? Or, will nationwide gasoline and diesel vehicle buyers cover these costs? If so, under what authority will New York impose these costs on consumers nationwide? How much do these costs increase the price of gasoline and diesel vehicles? Also, if state ZEV sales mandates increase and battery minerals become more scarce, the value of ZEV credits are certain to increase significantly; however, NYSDEC does not consider these costs.
- EPA GHG "multiplier" credits for EVs. These credits give an extra manufacturing subsidy to EV makers to meet EPA's GHG standards, despite EPA having no authority to do so, and are not based on any real-world avoided emissions. NYSDEC does not estimate the costs of this subsidy to the extent that its proposal increases EV sales. Similarly, NYSDEC does not consider that if EPA's GHG multiplier credits are determined to be unlawful and/or rescinded by regulation, the value of the ZEV credits must necessarily increase to offset them. NYSDEC should provide an estimate of the costs of these subsidy payments as a result of the proposal and which party(ies) will incur the costs of these subsidies, such as New York buyers of gasoline and diesel vehicles and/or nationwide purchasers of gasoline and diesel vehicles.

[49] RIS 52 (emphasis added).

[50] Revised Regulatory Flexibility Analysis for Small Businesses and Local Governments 3-4 (emphasis added).

- Corporate Average Fuel Economy (CAFE) "multiplier" credits. Automakers and the National Highway Traffic Safety Administration (NHTSA) seem to be applying a long-expired incentive originally created to spur the commercial availability of EVs. This treatment allowed automakers to divide the gallon of gasoline equivalent for alternative fuel vehicles, including EVs, by 0.15, effectively producing a 6.67 multiplier of fuel economy credits. While this provision expired in 2004, NHTSA appears to be continuing to apply it.[51] In other words, EVs have been receiving at least 667% of the real-world fuel economy they achieve on the road and EV manufacturers have been selling these credits to manufacturers of gasoline and diesel vehicles. NYSDEC should provide an estimate of the incremental costs of these subsidy payments as a result of the proposed rule and which party(ies) will incur the costs of these subsidies, such as New York buyers of gasoline and diesel vehicles and/or nationwide purchasers of gasoline and diesel vehicles.
- NYSDEC fails to consider that gasoline and diesel drivers pay significant federal and state liquid fuel taxes, comprising more than 60 cents per gallon on average of total fuel costs, to fund building and maintenance of federal and state roads, bridges, and even bicycle lanes. Conversely, EV drivers pay nothing or close to nothing. There are no federal taxes on electricity and most states either exempt most classes of electricity purchases from state taxes or apply de minimis taxes well below 1 percent. Gasoline and diesel drivers also pay higher registration fees and excise taxes in many states. NYSDEC must account for how ACCII will shrink the pool of gasoline and diesel vehicles paying taxes and the corresponding shortfall in tax receipts. This is a real and material cost that both California and NYSDEC have ignored.

Finally, NYSDEC ignores the fact that California and New York are very different states. New York has only about one-third as many vehicles as California, with EV registrations making up only a fraction of one percent of New York's fleet.[52] Unlike California, therefore, New York will effectively be starting from scratch and attempting to match California's goal of mandating EVs as *one hundred percent* new sales by 2035. Completely transforming New York's fleet in a short time will have severe distributional effects that NYSDEC has not acknowledged. Because New York City has unusually low car ownership compared to the rest of the country,[53] NYSDEC is placing the responsibility for full EV adoption disproportionately onto the state's suburban, small-town, and rural populations.

ZEVs are more expensive on average than their ICE vehicle counterparts and unaffordable for many households—in the first calendar quarter of 2022, the average price of the top-selling light-duty BEV in

---

[51] *See* National Highway Traffic Safety Administration, "Alternative Fuels in CAFE Rulemaking," presentation to SAE International (2015), https://www.nhtsa.gov/sites/nhtsa.gov/files/2015sae-powell-altfuels_cafe.pdf.

[52] *See* Nestor Gilbert, The Number of Cars in the US in 2022/2023: Market Share, Distribution, and Trends (Finances Online Jan. 9, 2023), *available at* https://financesonline.com/number-of-cars-in-the-us/ (last visited Feb. 26, 2023) (citing some 31.2 million registered cars for CA and 11.4 million for NY); Electric Vehicle Registrations by State, U.S. Department of Energy, Alternative Fuels Data Center, *available at* https://afdc.energy.gov/data/10962 (last visited Feb. 26, 2023) ("This chart shows the vehicle registration counts of all-electric vehicles (EVs) by state as of December 31, 2021.") (listing 51,870 registrations for NY, compared to 563,070 for CA, which the chart notes is "approximately 39% of EVs nationwide").

[53] *See* CEOs for Cities, New York City's Green Dividend (Apr. 2010), at 1, *available at* https://www.nyc.gov/html/dot/downloads/pdf/nyc_greendividend_april2010.pdf (last visited Feb. 26, 2023) ("New Yorkers own fewer than a third as many cars per capita as the average U.S. urban resident (about 23 per 100 residents compared to about 77 per 100 in most urban areas).").

the U.S. was about $20,000 more than the average price of top-selling ICE vehicles.[54] The price disparity has not improved, with the average price of light-duty EVs near $66,000 in August 2022 and continuing to rise.[55] By contrast, the median per capita and household incomes in New York are approximately $75,157 and $43,208, respectively.[56] Per New York Department of Transportation's ("NYDOT's") August 2022 NEVI Plan, "[n]early 13% of [New York's] population lives in poverty."[57] EV barriers to low-income stakeholders include, but are not limited to: limited driving/battery range; inability to charge in different housing and work situations; high price points to purchase, maintain, and insure EVs; availability of replacement parts and qualified mechanics, as well as ease and cost of repairs; and unpredictability regarding future electricity costs.

NYDOT has highlighted practical challenges inherent to EV adoption in its 2022 NEVI Plan. Per NYDOT, "[a]lthough much of [New York]'s population lives in metropolitan areas, most of the State's geography is rural in nature."[58] For example, "[a] drive from Montauk, on the easternmost area of Long Island, to Niagara Falls, in the western portion of the State, stretches more than 520 miles and requires a 9-hour drive."[59] Additionally, "[w]here development densities are extremely high, access to land and appropriate levels of electric power to support DCFC [Direct Current Fast Charging] can be challenging [in New York]; where development is low, particularly in areas that are extremely remote, access to three-phase power and cellular service for charging stations can also be a challenge."[60] "In such rural areas, DCFC are not likely to be profitable in the near-term due to limited traffic volumes which are expected to result low usage levels."[61] Additionally, according to NYDOT:

> "[R]esearch conducted by New York State's Department of Public Service (DPS) to identify immediate and long-term actions to best support ZEV market growth in New York State revealed the following related to publicly accessible DCFC:
>
> - The costs to "make-ready" a site for EV charging present an economic barrier to EV charging station developers. This includes electrical transformer upgrades, trenching and boring for conduits, conductors, poles, and towers.
>
> - For upstate DCFC station locations, where electric vehicle adoption rates are lower than the downstate New York City Metropolitan area, the expected

[54] Registration-weighted average retail price for the 20 top-selling BEVs and ICE vehicles in the U.S. S&P Global, *Tracking BEV prices – How competitively-priced are BEVs in the major global auto markets?*, May 2022.
[55] Andrew J. Hawkins, *EV prices are going in the wrong direction*, THE VERGE, Aug. 24, 2022, https://www.theverge.com/2022/8/24/23319794/ev-price-increase-used-cars-analysis-iseecars; *see also*, Justin Banner, *The Cheapest Ford F-150 Lightning Pro Sees Another Price Increase to Nearly Sixty Grand*, MOTORTREND, Dec. 15, 2022, https://www.motortrend.com/news/2023-ford-f-150-lightning-pro-price-increase-msrp/.
[56] Estimates as of July 1, 2021, representing the income over the past 12 months, in 2021 dollars. U.S. Census Bureau, *Quick Facts – New York*, https://www.census.gov/quickfacts/fact/table/NY,US/PST045222.
[57] New York Department of Transportation ("NYDOT"), *New York State National Electric Vehicle Infrastructure Formula Program Plan* [hereinafter NEVI Plan], at 9 (August 2022) file:///C:/Users/LQCSBH/AppData/Local/Temp/1/MicrosoftEdgeDownloads/7c7f9687-ec50-4c17-85ad-18275e06a3bc/National-Electric-Vehicle-Infrastructure-Formula-Program-Deployment-Plan.pdf.
[58] NEVI Plan at 11.
[59] NEVI Plan at 17.
[60] NEVI Plan at 14.
[61] *Id.*

> charging station utilization during the initial ten-year period of operation are estimated to result in negative 10-year net present value and initial return on investment, even with make-ready support."[62]

NYSDEC falls short in communicating such challenges, and representing the concerns of stakeholders associated with singular reliance on electrified transport in its assessment of ACC II.

C.2 NYSDEC's analysis of economic impacts

NYSDEC's consumer-impact analysis is notably thin. It makes multiple assumptions with little or no support.

NYSDEC notes that "[CARB's] analysis assumes all compliance costs are passed on to California vehicle purchasers." NYSDEC then asserts: "*It can be assumed* the net cost in New York would be similar, or slightly less, due to economies of scale with the addition of the New York fleet."[63] But this is hardly a reasonable assumption. Without a comparison of the respective state of California's and New York's electrical grids and the relative status of repairs to these grids that are underway, New York has no justification for this "cut and paste" analysis. Additionally, New York's climate differs from California's, with its colder weather negatively impacting charging efficiency and EV range, affecting both individual and systemic cost analyses.[64] Indeed, NYSDEC *nowhere* notes that its state's climate differs from California's climate, let alone analyzes the implications of this difference. Cold climate conditions like those experienced in New York have been shown to significantly reduce the battery range and efficiency of BEVs.[65] According to New York Department of Transportations' NEVI Plan dated August 2022, "[v]ery cold temperatures (below 30 degrees Fahrenheit) have a significant effect on electric battery and charging performance. Charging is much slower in cold temperatures, and DCFC may only charge at a fraction of their rated speed in cold temperatures. Further, all-wheel drive vehicles are more popular in snowy climates. These vehicles have lower range than identical vehicles with front or rear wheel drive, which could trigger the need for additional charging."[66]

---

[62] NEVI Plan at 29.

[63] RIS 70 (emphasis added).

[64] *See, e.g.,* Sean Tucker, Study: All EVs Lose Range in the Cold, Some More Than Others (Kelley Blue Book Dec. 29, 2022), *available at* https://www.kbb.com/car-news/evs-lose-range-in-the-cold/ (last visited Feb. 26, 2023) ("Range loss is a significant concern for electric vehicle (EV) owners. Refueling an EV takes longer, and public charging stations can be hard to find in many parts of the country. That scarcity requires EV owners to plan longer trips around recharging points — and to know they'll need to stop more frequently when the mercury drops."); Paul Shepard, Quantifying the Negative Impact of Charging EVs in Cold Temperatures (EEPower Aug. 8, 2018), *available at* https://eepower.com/news/quantifying-the-negative-impact-of-charging-evs-in-cold-temperatures/ (last visited Feb. 26, 2023) ("[A] new study on charging in cold temperatures suggests that industry and EV drivers still face charging challenges. The reason: cold temperatures impact the electrochemical reactions within the cell, and onboard battery management systems limit the charging rate to avoid damage to the battery. . . . [R]esearchers at Idaho National Laboratory looked at data from a fleet of EV taxis in New York City and found that charging times increased as temperatures dropped.").

[65] *See* Jon Witt, *Winter & Cold Weather EV Range Loss in 7,000 Cars*; RECURRENT, Dec. 12, 2022, https://www.recurrentauto.com/research/winter-ev-range-loss; *see also 20 popular EVs tested in Norwegian winter conditions*, NORWEGIAN AUTOMOBILE FEDERATION, Mar. 12, 2020, https://www.naf.no/elbil/aktuelt/elbiltest/ev-winter-range-test-2020/.

[66] NEVI Plan at 18.

NYSDEC also has failed to quantify the cost to utility ratepayers associated with subsidized EV charging rates by ratepayers that do not own or operate EVs. These rates and rate schedules are discriminatory and prohibited by federal and state law. For example, NY's largest utility offers below-market rates to EV owners: "Electric vehicle owners on the residential time-of-use rate are eligible for a reduced monthly customer charge. Instead of $21.46, you'll be charged $17.00 if you email us a copy of your electric vehicle registration document together with your account number annually every March. If you have an electric-vehicle-only meter and fail to submit your vehicle registration document together with your account number annually, your account may revert to a small business rate, which has a higher monthly customer charge of $28.10.[67] NYSDEC cannot justify ACC II as cost-effective when the state is providing owners and operators of electric vehicles and trucks with below-market rates compared other electricity customer classes. These rates are discriminatory, preferential and do not reflect the cost of providing electric service as required under federal and state law. In doing so, NYSDEC's proposal arbitrarily ignores the massive costs of upgrading the electric distribution system to serve EVs, including replacements and upgrades of transformers, circuits, conductors, substations, transmission, and generation.

Indeed, one utility that provides service to parts of New York has determined that EVs will require that every highway passenger plaza must be able to supply as much power as a sports stadium (5 MW) by 2030, and that of a small town (20 MW) by 2035 and that truck stops would require more than 30 MW of power capacity, an amount typical for a large industrial plant, by 2045. NYSDEC has failed to consider, let alone account for any of these costs and the associated emissions with building out and maintaining this new infrastructure. Notably, the study was specifically designed to represent forecasted electric demands if New York State achieves its "goals to achieve 30% zero-emission MHDV sales by 2030 and 100% by 2045."[68]

NYSDEC further notes that "[t]he effects of general cost increase due to the likelihood of out-of-state or used [light- and medium-duty vehicle] purchases have been shown to be unpredictable," and that "pre-buy" is "highly uncertain and may vary due to the dynamics of the industry," before concluding, in a *non sequitur* with no apparent connection to these acknowledgments of uncertainty, that it "believes a 'no-buy' scenario under which consumers choose to reduce purchasing of new vehicles regulated under the proposed regulation is unlikely."[69] Indeed, there is increasing evidence that regulations like ACC II, to mandate EV sales—along with the aforementioned cross-subsidies from gasoline and diesel vehicle buyers—are leading manufacturers to abandon sales of the least expensive and higher fuel economy gasoline and diesel vehicles that do not receive similar subsidization. Cox Automotive found that "in December 2017, automobile makers produced 36 models priced at $25,000 or less. Five years later, they built just 10," pushing low-income buyers out of the new-car market and into the used-car market. Conversely, in December 2017 automobile manufacturers offered 61 models for sale with sticker prices

[67] *See* conEdison, "Rate Options for EV Owners Charging at Home," https://www.coned.com/en/our-energy-future/technology-innovation/electric-vehicles/electric-vehicle-drivers/electric-vehicles-and-your-bill.
[68] *See* National Grid, "Electric Highways" (November 2022), https://www.nationalgrid.com/document/148616/download.
[69] RIS 70-71.

of $60,000 or higher and in December 2022, they offered 90.[70] Regulations like ACC I and ACC II are primary drivers of this trend toward eliminating affordable vehicles and NYSDEC must account for these market impacts to lower-income car buyers.

NYSDEC also has failed to, and must, account for how the costs of its mandate will significantly reduce the total sales of new automobiles, significantly delay fleet turnover, create large incentives to maintain and operate older gasoline and diesel vehicles, and increase the amount of NOx and VOC and PM2.5 emissions from the mobile fleet compared to not implementing the ACCII mandate. To the extent NYSDEC estimates any health benefits from its mandate, this estimate could show that its mandate will produce a net increase in NOx emissions, VOC emissions, and PM2.5 emissions.

Instead, after repeatedly noting fundamental uncertainties (which it does not try to qualitatively analyze much less quantify), NYSDEC manages to say what overall purchase scenarios are "unlikely." (Note that what NYSDEC is deeming "unlikely" is, in fact, the prospect that consumers will reduce their purchases of more expensive goods—which would seem to be axiomatically likely, at least in the absence of any explanation to the contrary.)

NYSDEC concedes ZEVs cost more up front, but asserts that "total cost of ownership is *likely* to be lower" than that of internal combustion engine-driven cars due to operational, fuel, and maintenance savings.[71] Again, without an analysis of the differences between New York's and California's existing and projected future charging infrastructure, and without consideration of the costs of the aforementioned cross-subsidies or an analysis of how many ZEV owners are expected to use commercial charging stations as compared to charging at home, NYSDEC has not justified its wholesale reliance on CARB's analysis and has not presented meaningful analysis of the impacts that adopting ACC II is likely to have *for New York.*

NYSDEC claims to be "unaware of any significant adverse impact to jobs and employment opportunities because of previous revisions" to its car standards.[72] NYSDEC does not indicate whether it looked into any such possible impacts. AFPM urges NYSDEC to consider, at a minimum, the impact from previous rounds of regulation on auto mechanics and disruption from squandering of sunk costs in the petroleum supply chain.[73]

By way of example, NYSDEC's Revised Job Impact Statement concedes that "[t]he proposed amendments to the regulations may adversely impact jobs and employment opportunities in New York State."[74] Extrapolating from CARB's estimates, NYSDEC estimates that there will be an approximate net loss of 43,214 jobs in the state of New York by 2040.[75] Yet NYSDEC proceeds to state that "[t]he

---

[70] *See* Marketwatch, "Are we witnessing the demise of the affordable car? Automobile makers have all but abandoned the budget market" (February 28, 2023), "https://www.marketwatch.com/story/are-we-witnessing-the-demise-of-the-affordable-car-automakers-have-all-but-abandoned-the-budget-market-a68862f0.
[71] RIS 71 (emphasis added).
[72] Job Impact Statement 1.
[73] *See also, e.g.*, Jim Barrett & Josh Bivens, The stakes for workers in how policymakers manage the coming shift to all-electric vehicles (Economic Policy Institute Sept. 22, 2021), *available* at https://www.epi.org/publication/ev-policy-workers/ (last visited Feb. 22, 2023); Carlos Waters, How electric vehicle manufacturing could shrink the Midwestern job market (CNBC Sept. 4, 2022), *available at* https://www.cnbc.com/2022/09/04/ev-manufacturing-may-shrink-us-midwest-auto-parts-trade.html (last visited Feb. 22, 2023) (researchers estimate "electric vehicles could require 30% less manufacturing labor when compared with conventional cars")
[74] NYSDEC, *Revised Job Impact Statement*, at 1, https://www.dec.ny.gov/docs/air_pdf/emer218ACC2_.pdf.
[75] NYSDEC, *Regulatory Impact Statement*, at 63-64, https://www.dec.ny.gov/docs/air_pdf/emer218ACC2_.pdf.

proposed adoption of the ACC II regulation is not expected to result in any significant impact to employment."[76] New York stakeholders should have been afforded an opportunity to evaluate the data, costs, and assumptions underlying ACC II before NYSDEC proceeded with an emergency rulemaking.

NYSDEC does not expect adoption of ACC II "to have adverse impacts on car dealers," and expects "no change in the competitive relationship with out-of-state businesses."[77] This seems to assume, with no evidence cited, that no New York dealer competes for business with any dealer in a state that has not adopted ACC II. Even assuming this assumption made sense for California, with its vast spaces and lengthy, often rugged border areas separating it from neighboring states, it does not for New York. New York is considerably more compact, and the greater New York City area, especially, borders on densely populated areas of other states where cross-border competition for car sales is self-evidently a concern.

NYSDEC concedes vehicle purchasers will pay more for new ZEVs, particularly due to the cost of battery packs, but "[i]ncreased ZEV purchase costs *are expected to be* offset in part by state and federal purchase rebates and reduced operation and maintenance costs."[78] As discussed above, NYSDEC has done no analysis of the details of these rebate policies, their expected duration, and the impact if they do not endure. Additionally, NYSDEC appears to have entirely disregarded the cost of battery replacement, which needs to be done more often than the purchase of a new vehicle itself. Similarly, NYSDEC ignores all costs associated with recalls of unreliable, mandated vehicles. Consumers and society both bear real costs from this, as well as from associated waste and recycling impacts.[79]

NYSDEC "estimates" that adoption of ACC II will have a "directionally similar" employment impact to the one suggested in CARB's analysis.[80] NYSDEC then attempts a crude, back-of-the-envelope calculation of employment impacts for New York, by simply multiplying CARB's figures by the ratio of New York's and California's light duty sales and total non-farm statewide employment figures—both of which it asserts are 0.53, the latter with reference to federal Bureau of Labor Statistics and state Department of Labor data, the former with no citation at all.[81] It does this to project total employment impacts, as well as sector-specific impacts.[82] Again, "[NYS]DEC estimates that ACC II will have a directionally similar impact on employment for reasons like those assumed by California."[83] Here, at least, NYSDEC is refreshingly forthright: it has not done a real analysis of the employment impacts on its state, deferring instead to CARB both for figures and methodology.

Elsewhere, in the impact document specifically addressing jobs, NYSDEC concedes that employment at gas stations, repair shops, and parts retailers "may be adversely impacted," but "anticipate[s] that any

---

[76] *Id.* at 72.

[77] Revised Job Impact Statement 3; *see also* Rural Area Flexibility Analysis 3, Regulatory Flexibility Analysis for Small Businesses and Local Governments 5.

[78] Regulatory Flexibility Analysis for Small Businesses and Local Governments 2 (emphasis added).

[79] Significant environmental impacts arise from the ZEV lifecycle, including raw material acquisition and processing, and battery production, transport, disposal, and recycling. *See, e.g.,* Perry Gottesfeld, *Electric cars have a dirty little recycling problem–batteries*, CANADA'S NATIONAL OBSERVER, Jan. 22, 2021, https://www.nationalobserver.com/2021/01/21/opinion/electric-cars-have-dirty-little-recycling-problem-their-batteries.

[80] RIS 58.

[81] RIS 59.

[82] RIS 59, 62.

[83] RIS 62.

losses in these sectors will be offset by" jobs in EV charging and tech training.[84] This is not a reasonable assumption, absent substantiation. Auto mechanics for traditional cars are typically engaged for a full workday. The employment needs for monitoring and maintaining an EV charging station are, on their face, likely to differ. NYSDEC should compare the employment profile of an EV charging station as compared to that of maintenance and refueling jobs at ICE service stations. Without conducting meaningful analysis, NYSDEC's "anticipation" of an "offset" is not rational.

C.3 NYSDEC's analysis of criteria pollutant emissions

NYSDEC's analysis of criteria pollutants in the Regulatory Impact Statement is facially deficient.

NYSDEC first presents a table purporting to show "California Statewide ACC II Upstream Emissions Relative To Baseline" for each calendar from 2026 through 2040 for the criteria pollutants NO_x and $PM_{2.5}$.[85] Although NYSDEC does not specify this on the table itself, its discussion elsewhere in the Statement suggests that these figures are a result of California's use of "CARB's EMFAC2021 and Vision models."[86] These tables appear to show a reduction of 0.07 tons per day of NO_x emissions in 2026, increasing to 6.62 tons per day in 2040, and a reduction of zero tons per day of $PM_{2.5}$ emissions in 2026, increasing to 0.92 tons per day in 2040.

Another table purports to show the same range of figures (again, *for California*) "includ[ing] vehicle, fuel production, and fuel delivery emissions."[87] These figures are higher than the ones in the previous table: NO_x reductions of 0.59 tons per day in 2026, rising to 27.96 tons per day in 2040, and $PM_{2.5}$ reductions of 0.03 tons per day in 2026, rising to 1.39 tons per day in 2040.

A third table, finally, purports to show California's "Statewide Wells-to-Wheels Emission Benefits" from ACC II.[88] These figures are, again, for the most part higher than the previous tables: NO_x reductions of 0.7 tons per day in 2026, rising to 34.6 tons per day in 2040, and $PM_{2.5}$ reductions of 0.0 tons per day in 2026, rising to 2.3 tons per day in 2040.

NYSDEC offers no narrative discussion of these values, and no explanation of the tables' origins beyond the reference to "CARB's EMFAC2021 and Vision models" mentioned above. NYSDEC describes "EMFAC2021" only as "a California-specific emissions model," and the "Vision" model as being "used to estimate upstream emissions from transportation fuel and electric power industries."[89] Both statements are supported only by footnotes to the general landing page for the respective models, providing the

[84] Job Impact Statement 2.

[85] RIS 41, Table 26.

Note that, while the heading of this table suggests that the figures represent "upstream" emissions reduction predictions, NYSDEC does not explain the difference between these figures and those on the following table, whose label indicates that its figures "include[] vehicle, fuel production, and fuel delivery emissions." NYSDEC needs to clarify whether these tables represent different forms of "upstream" estimates or whether Table 26 is mislabeled and instead contains a "tailpipe" estimate. This lack of clarity prevents informed comment.

[86] RIS 36.

[87] RIS 42, Table 27.

[88] RIS 43, Table 28.

[89] RIS 36.

public no way to assess whether these tables actually represent a valid LCA or to interrogate the assumptions and inputs used.[90]

In any event, these California tables are irrelevant to analyzing the effects of adopting ACC II on criteria pollutant emissions *in New York.* Without conducting a thorough and transparent LCA NYSDEC cannot demonstrate the true impact of adopting ACC II on criteria emissions *in New York*. This is particularly the case in light of differences between the two states' electric grids, a fundamental difference affecting emissions impacts which NYSDEC should have explicitly accounted for and analyzed. Instead, NYSDEC does exactly the opposite. As discussed in more detail in Section C.4 below, it assumes without analysis or accounting for costs that New York will have an entirely renewable-powered grid by 2040, and apparently views this assumption as relieving it from any obligation to meaningfully analyze the criteria pollutant emissions resulting from the impact of EV mandates on its *actually existing* grid. Indeed, as threadbare as is the California analysis that NYSDEC presents, its New York analysis manages to be even more deficient.

First, NYSDEC informs the reader that "New York State emission benefits and WTW [well-to-wheels] benefits resulting from proposed adoption of ACC II are based on ICCT MOVES3 modeling."[91] But whereas NYSDEC supported its reference to California's models with at least a footnote to websites discussing those models generally, here *for its own model*, its footnote reads only "Add footnote[.]"[92] The reader is left completely in the dark as to how NYSDEC derived the tables purporting to show New York emission benefits.

Those tables are two. First, a table purports to show "New York Annual ACC II Benefits Compared to Business-as-Usual Scenario," in a similar format to the prior tables for California.[93] These tables appear to show a reduction of 0.13 tons per day of NOx emissions in 2026, increasing to 4.31 tons per day in 2040, and a reduction of 0.01 tons per day of PM2.5 emissions in 2026, increasing to 0.41 tons per day in 2040.[94]

Second, a table purports to show "Cumulative ACC II Emissions Benefits Compared to Business-as-Usual Scenario, 2025-2040 (NYS Model Year 2026 Implementation)."[95] This table indicates for NO_x 1,065 tons of emissions reduced by 2030; 4,25 tons by 2035; and 11,594 tons by 2040; for $PM_{2.5}$, the table indicates 87 tons by 2030; 445 tons by 2035; and 1,153 tons by 2040. (These numbers differ from the numbers presented in the Regulatory Impact Statement Summary and the *New York State Register* notice, as explained below.) Notably, this appears to reflect a cost of more than one million dollars per ton of NO_x emissions reduced, and ten million dollars per ton of $PM_{2.5}$ reduced—figures that are orders of magnitude what the federal EPA generally considers "cost-effective" emissions reductions.[96]

---

[90] *See* RIS 36 nn.22, 23 (linking respectively to https://arb.ca.gov/emfac/ and https://ww2.arb.ca.gov/resources/documents/vision-scenario-planning).
[91] RIS 44.
[92] RIS 44 n.24.
[93] RIS 45, Table 30.
[94] Notably, these final figures are lower than what appears to be the corresponding figures for the California Table, RIS 41, Table 26.
[95] RIS 46, Table 31.
[96] *See* N.Y.S. Reg. (Dec. 28, 2022), at 40 ("The average annual and incremental costs of ACC II ZEV and LEV IV

The Regulatory Impact Statement's presentation raises multiple unanswered questions regarding this information. Does NYSDEC mean to imply a difference between the New York tables and California tables because the former are "Compared to Business-as-Usual Scenario" whereas the latter are "Relative to Baseline?" And why does NYSDEC refer to "New York state emission benefits *and WTW benefits*"—the latter term implying something considering more than merely direct, tailpipe emissions—when neither of the New York emissions tables use the acronym "WTW" or otherwise indicate consideration of emissions other than from the tailpipe? This inscrutable presentation prevents informed comment.

The benefits claim presented in NYSDEC's proposal in the *New York State Register* reads as follows:

> New York emission benefits and WTW benefits resulting from proposed adoption of ACC II are based on ICCT MOVES3 modeling. The cumulative emissions benefits (2025-2040) of ACC II relative to a business-as-usual scenario are 15,231 tons of NOx, 1,373 tons of PM2.5, and 190 million metric tons of carbon dioxide equivalent.[97]

These claims lack citation. They appear to be taken verbatim from NYSDEC's Regulatory Impact Statement Summary document.[98] These numbers are found nowhere in the Regulatory Impact Statement itself, nor in any of the other documents bundled together with it on NYSDEC's website. And they differ, with no explanation, from the figures presented in the tables in the Statement, as set forth above.[99] It is impossible to provide informed comment on these issues of central relevance to this rulemaking.

In addition, EVs also result in a significant increase in tire wear and associated particulate matter emissions in the areas where they operate. Neither California nor New York has evaluated these emissions.

> Torque loads on drive tires will increase not only thanks to the higher output of electric motors compared to internal combustion engines, but also because regenerative braking will impart torsional forces on tires in the opposite direction. This will affect tire tread wear as well as sidewalls. And it will be more of a consideration in high stop-and-go applications — the exact type of local delivery operations that many see as one of the best applications for electric vehicles. "Higher torque on the drive axle will result in higher wear rate,' says Hinnerk Kaiser,

regulations in New York State from 2026 to 2040 are estimated to be approximately $1.1 billion and $1,629 respectively. The Total cumulative costs are estimated to be approximately $16.1 billion by 2024 [*sic*]."); 87 Fed. Reg. at 74,718/2 (supplemental proposal in rulemaking regulating volatile organic compound and methane emissions from oil and gas facilities) ("[T]he EPA proposes to find that cost-effectiveness values up to $5,540/ton of VOC reduction are reasonable for controls that we have identified as BSER [the best system of emission reduction] and within the range of what the EPA has historically considered to represent cost effective controls for the reduction of VOC emissions. Similarly, for methane, the EPA finds the cost-effectiveness values up to $1,970/ton of methane reduction to be reasonable for controls that we have identified as BSER in both the November 2021 proposal and this supplemental proposal, well below the $2,185/ton of methane reduction that EPA has previously found to be reasonable for the industry.") (footnotes omitted).

[97] N.Y.S. Reg. (Dec. 28, 2022), at 40.

[98] *See* Regulatory Impact Statement Summary 6.

[99] *Compare* Regulatory Impact Statement Summary 6 (15,321 tons NO_x; 1,373 tons $PM_{2.5}$), *with* RIS 46, Table 31 (11,594 tons NO_x; 1,153 tons $PM_{2.5}$). Notably, the figures for CO_2-equivalent emissions also vary, with 180 million metric tons cited in Table 31, compared to 190 in the *Register* and Summary documents.

Continental's head of product development. "In addition, a higher share of braking torque can increase the risk of irregular wear phenomena — heel and toe wear."[100]

On the crucial question of what emissions benefits will result *in New York* from its proposed adoption of ACC II, NYSDEC has presented confusing and conflicting figures with no support. Even under the most lenient standard, this violates principles of notice, transparency, and rationality.

C.4 NYSDEC's analysis of GHG emissions

NYSDEC's GHG emissions analysis suffers from the flaws discussed above with respect to its criteria pollutant analysis, as much of the GHG analysis is presented in the same run of tables as the criteria-pollutant analysis, subject to the same unsourced, unexplained, or confusing presentation. Fundamentally, without a thorough and transparently presented LCA, NYSDEC has no way of knowing the true GHG impact of adopting ACC II—and certainly has not presented sufficient analysis for informed public comment.

The GHG analysis contains additional flaws. First, NYSDEC concedes that "[a]doption of ACC II would reduce on-road emissions, *but would increase electric generation emissions*."[101] But, without any analysis, NYSDEC asserts: "New York expects to have a carbon-neutral electric grid powered by renewable sources by 2040 to comply with the CLCPA requirements."[102] (Strangely, NYSDEC appears to include this assumption into its calculation of environmental benefits, while not accounting for the enormous costs that this grid transformation will most certainly entail.) NYSDEC does not cite any specific provision of the CLCPA,[103] nor does it provide any analysis of the anticipated timeline and scale or costs for its "expect[ation]" that New York will "have a carbon-neutral grid" by 2040. Nor does it address the impact on its projections for the feasibility of a transition to an all-EV new-car fleet five years *before* that date, the impact of an aggressive EV mandate that actually starts in 2026, and on associated GHG emissions. Nor does NYSDEC discuss the recent closure of the Indian Point nuclear power facility in New York, and the consequent increased reliance on fossil fuels[104] that calls into question both NYSDEC's "expect[ation]" and the assumptions underlying the adoption of the CLCPA in 2019. NYSDEC also omits analysis of the needs for battery production and replacement, and resulting carbon emissions. Battery manufacturing in China and other foreign nations, as well as associated global mining activity, are carbon-intensive activities that NYSDEC's analysis completely omits. This failure to conduct a true LCA again places a "thumb on the scale," obscuring the true impact of adopting ACC II.

---

[100] What Will Electrification Mean for Truck Tires? - Equipment - Trucking Info, https://www.truckinginfo.com/10151115/what-will-electrification-mean-for-truck-tires.
[101] RIS 65 (emphasis added).
[102] RIS 65.
[103] *But see* N.Y. Envir. Conser. Law § 75-0103(13)(b) (calling for "scoping plan" to include "Measures to reduce emissions from the electricity sector by displacing fossil-fuel fired electricity with renewable electricity or energy efficiency.").
[104] *See* Thomas *C.* Zambito, NY's fossil fuel use soared after Indian Point plant closure. Officials sound the alarm (Journal News July 22, 2022), *available at* https://www.lohud.com/story/news/2022/07/22/new-york-fossil-fuels-increase-after-indian-point-nuclear-plant-shutdown/65379172007/ (last visited Feb. 22, 2023); Patrick McGeehan, Indian Point Is Shutting Down. That Means More Fossil Fuel (New York Times Apr. 12, 2021), *available at* https://www.nytimes.com/2021/04/12/nyregion/indian-point-power-plant-closing.html (last visited Feb. 22, 2023).

For its monetization of projected health benefits from GHG emission reductions, NYSDEC says it used "COBRA" modeling, "based on ICCT MOVES3 modeling of ACC II in New York State."[105] (NYSDEC does not specify whether its monetization of projected health benefits from GHG reductions also includes criteria pollutants.) The link that it provides to this modeling does not work.[106] And NYSDEC's representation of its claims in table form[107] is puzzling: It only presents monetized benefits for 2040, not any intervening year. Moreover, in 2040, notwithstanding a tremendous, forced increase in electricity demand, NYSDEC unrealistically projects *zero* burden from "increased electric generation emissions." Although NYSDEC's main narrative acknowledges "increase[d] electric generation emissions," its table does not appear to assign any cost to those emissions.

Nor does NYSDEC analyze the potential impact on fleet turnover from mandates that increase vehicle cost. This could perversely slow adoption of emission-reducing technology. Vehicle consumers likely prefer to have a full range of choices available, not to have EVs mandated, and that they do not support EV subsidies that distort the market. Without accounting for these market dynamics, NYSDEC cannot meaningfully predict the actual emissions impact of its adoption of ACC II.

D. ACC II is preempted by federal law.

Congress has not authorized federal executive agencies or states to force a transition to EVs through government mandates.[108] Indeed, this is a major policy question that is the subject of several lawsuits pending before the D.C. Circuit. When Congress has spoken on vehicle electrification, it has specifically prohibited EV mandates,[109] required studies,[110] and provided financial incentives with strict eligibility limits based on domestic production requirements and income levels.[111] The decision to force a transition to EVs and ban the sale of ICEVs would constitute a major question of political and economic significance for which Congress must provide a clear statement; no such clear statement exists.

D.1 ACC II is expressly preempted by the Energy Policy Conservation Act.

NYSDEC lacks authority to adopt or enforce any regulation "related to" fuel-economy standards under the Energy and Policy Conservation Act (EPCA). EPCA's broad preemption provision prevents California and NYSDEC from adopting regulations when they are "related to" fuel economy, regardless of any accompanying localized pollution benefits. This provision is self-executing, meaning that no agency action is necessary for it to be effective—the lack of a NHTSA regulation expressly preempting NYSDEC's adoption of ACC II does not affect EPCA's preemptive effect. This provision also contains no authority to grant a waiver of preemption.

ACC II is clearly related to fuel-economy standards. Courts have found that state regulations "relate to" federal matters when they have a "connection with" or contain a "reference to" these matters. NYSDEC's

[105] RIS 65.
[106] *See* RIS 65 n.42. While this link leads to a "NO RESULTS FOUND" page, NYSDEC may be referring to the document located at https://theicct.org/wp-content/uploads/2021/06/nys-hdv-regulation-benefits-2-may2021.pdf. But Table 47 (RIS 66) does not appear in this document. Again, NYSDEC is providing no transparency into its claims or their support, depriving the public of any meaningful opportunity to comment.
[107] RIS 66, Table 47 (Annual COBRA-estimated Economic Values of New York Adopting ACC II).
[108] *See West Virginia v. EPA*, 142 S. Ct. 2587 (2022).
[109] See 49 U.S.C. § 32902(h) (prohibiting considering dedicated automobiles, which includes electric vehicles).
[110] *See* Energy Independence and Security Act § 206.
[111] *See generally* Inflation Reduction Act.

Regulatory Impact Statement specifically discusses the fuel savings that it projects will result from this rulemaking.[112] NYSDEC cannot avoid EPCA's preemptive effect by characterizing this rule as an environmental regulation despite its clear implications for fuel economy. Indeed, because emissions of the greenhouse gas carbon dioxide are "essentially constant per gallon combusted of a given type of fuel," the fuel economy of a vehicle and its carbon-dioxide emissions are two sides of the same coin.[113] Accordingly, "any rule that limits tailpipe [greenhouse gas] emissions is effectively identical to a rule that limits fuel consumption."[114]

An EV mandate thus has more than a mere "connection with" fuel economy—it has a direct connection, and courts have had little trouble finding federal preemption of state laws promoting hybrid or electric vehicles, including in New York.[115] New York's adoption of ACC II "relates to" fuel economy even more clearly than the taxi rules at issue in *Metropolitan Taxicab* and is thus expressly preempted by EPCA.

D.2 ACC II conflicts with important federal statutory objectives.

A critical failing of ACC II is that in its haste to phase-out oil and gas production and refinery industries it does not consider the impact to the remainder of our energy system. ACC II will sharply curtail, if not eliminate, the demand for biofuels, and will overburden electricity supply. Nor did NYSDEC consider the impact to other essential products such as jet fuel, asphalt, sulfur, petrochemicals, and lubricants. This willful blindness places ACC II on a collision course with multiple Congressionally mandated programs expressly designed to have the opposite impact: Congress wants to increase biofuels production and ensure a reliable electricity supply. Because ACC II undermines and conflicts with the fulfillment of these Congressional objectives, it is necessarily preempted.

It is a "well-established principle that the Supremacy Clause, U.S. Const., Art. VI, cl. 2, invalidates state laws," like ACC II, "that interfere with, or are contrary to federal law."[116] Even where Congress has not completely displaced state regulation in a specific area, state law is nullified to the extent that it actually conflicts with federal law. Such conflicts arise "when compliance with both state and federal law is impossible" and "when the state law 'stands as an obstacle to the accomplishment and execution of the full purposes and objectives of Congress.'"[117] The ACC II program fails on both counts and is, therefore, expressly and/or impliedly preempted by federal law.

First, Congress' intention to increase production, distribution, and use of biofuels is expressed in no less than three statutes, which do everything from mandating biofuel blending in liquid fuel to incentivizing its production through loans and loan guarantees. EPCA includes provisions related to the integration of

---

[112] RIS 71 ("The ACC II program offers vehicles with stricter standards that can lead to fuel cost savings . . . .).

[113] 75 Fed. Reg. at 25,324, 25327 (May 7, 2010).

[114] *Delta Constr. Co. v. EPA*, 783 F.3d 1291, 1294 (D.C. Cir. 2015).

[115] *See, e.g., Metropolitan Taxicab Bd. of Trade v. City of New York*, 615 F.3d 152, 157 (2d Cir. 2010) (holding EPCA preempts local taxi-fleet rules merely *encouraging* the adoption of hybrid taxis).

[116] *Hillsborough Cty., Fla. v. Automated Med. Lab'ys, Inc*., 471 U.S. 707, 712-13 (1985) (citations omitted).

[117] *Capital Cities Cable, Inc. v. Crisp*, 467 U.S. 691, 699 (1984) (quoting *Hines v. Davidowitz*, 312 U.S. 52, 67 (1941)); *see also, e.g.*, *Sutton 58 Assocs. LLC v. Pilevsky*, 164 N.E. 3d 984, 990 (N.Y. 2020) ("[W]hen federal and state law conflict, federal law prevails and state law is preempted. . . . Preemption of state law may occur by express statutory provision or through implication, the latter of which may be accomplished through either federal preemption of the field of a particular subject matter or the existence of an irreconcilable conflict between federal and state law.") (internal quotation marks and citations omitted).

alternative fuels in the transportation sector and requires a "reasonable distribution" of the burden of any energy-use restrictions. The Federal Power Act provides for investment in alternative fuels through grant programs and loan guarantees. And the Energy Independence and Security Act (EISA) includes specific provisions to increase energy security through increased production of biofuels under the RFS program and requires blending of increasing volumes of biofuel and other renewable fuels.[118] Specifically, the ACC II Program conflicts with these federal objectives and deprives federal funding programs of value by mandating complete electrification of the transportation sector. These programs set aside significant funding for the development and use of liquid fuels for transportation, with the expectation that these fuels will continue to play an important role in meeting transportation energy demand for many years.

By contrast, ACC II would eliminate any role for these alternative fuels for new vehicles in New York by requiring 100% ZEVs and PHEVs (Plug-in Hybrid Electric Vehicles) by 2035, removing a substantial portion of the demand for these fuels and depriving federal investments of significant value. This deprivation is made worse by the potential—indeed California's expectation, which NYSDEC's proposal has now confirmed—that other states may adopt California's engine and motor vehicle emission standards under Section 177 of the Clean Air Act, 42 U.S.C. § 7507 and the potential that manufacturers are unlikely to produce two separate fleets (177 states vs. the rest of the country).

Further, ACC II expressly contradicts EPCA's requirement that any burdens stemming from energy-use restrictions be reasonably distributed across all industry sectors, instead placing the entirety of the burden of these restrictions on the oil and gas production and refinery sectors of New York's economy as NYSDEC has now proposed to do.

Second, federal policy explicitly supports "the modernization of the Nation's electricity transmission and distribution system to maintain a reliable and secure electricity infrastructure that can meet future demand growth." 42 U.S.C. § 17381. The ACC II program conflicts with this policy by introducing material security and reliability risks to New York's electricity grid, and to the grid of other states who may adopt ACC II.

The rapid electrification of the transportation sector will both substantially increase electricity demand in New York and other states who may adopt ACC II and increase dependence on electricity services, amplifying the risk that the grid will be targeted for either physical or cyber-attacks. A 2021 Government

[118] *See* EPCA (42 U.S.C. § 6374, requiring alternative fuel use by light duty Federal vehicles; *id.* § 6391(b) (prohibiting "[u]nreasonably disproportionate share of burden" between segments of the business community and requiring that, "[t]o the maximum extent practicable, any restriction under authorities to which this section applies on the use of energy shall be designed to be carried out in such manner so as to be fair and to create a reasonable distribution of the burden of such restriction on all sectors of the economy")); Federal Power Act (42 U.S.C. § 16501: Commercial byproducts from municipal solid waste and cellulosic biomass loan guarantee program – loans by private institutions for the construction of facilities for the processing and conversion of municipal solid waste and cellulosic biomass into fuel ethanol; *id.* § 16503: Sugar ethanol loan guarantee program; *id.* § 16071: Grant program for the acquisition of alternative fueled vehicles or fuel cell vehicles and the installation of related infrastructure)); Energy Independence and Security Act of 2007 (EISA) (Title 42, Chapter 152, Subchapter II: Programs for investment in biofuel research and infrastructure, centered around "increasing energy security," which is of special federal concern; 42 U.S.C. § 7545(o)(2)(B)(ii): Establishes requirements related to determining the applicable volume of cellulosic biofuel for the calendar years 2023 and later, based on considerations such as available infrastructure, consumer costs, and energy security.

Accountability Office Report found that "[t]he grid's distribution systems face significant cybersecurity risks—that is, threats, vulnerabilities, and impacts—and are increasingly vulnerable to cyberattacks."[119] According to the report, these risks "are compounded for distribution systems because the sheer size and dispersed nature of the systems present a large attack surface."[120] As demand increases due to accelerated electrification, grid security will pose a greater challenge due to additional resource buildout. Further, the report found that increased use of networked consumer devices that are connected to the grid's distribution systems—including electric vehicles and charging stations—also potentially introduce vulnerabilities because "distribution utilities have limited visibility and influence on the use and cybersecurity of these devices."[121] ACC II will therefore introduce new vulnerabilities to the nation's distribution system by significantly increasing the use of consumer devices.

In addition, the increased demand for electricity under New York's proposed adoption of ACC II will worsen existing instabilities in New York's and in the grids of states that may adopt ACC II, compromising grid reliability in direct contravention of federal policy. New York's grid reliability is already under threat.[122] ACC II will increase demand despite existing shortfalls, undermining federal requirements targeting increased grid reliability.

Because NYSDEC's proposed adoption of ACC II conflicts with and presents an obstacle to clearly stated federal objectives, NYSDEC lack the authority to promulgate these regulations—and indeed is preempted from doing so.

E. **Uncertainty arising from pending D.C. Circuit litigation makes it inappropriate for NYSDEC to adopt ACC II at this time.**

NYSDEC's proposed adoption of ACC II relies on the implicit premises that California has authority to promulgate ACC II. This in turn assumes that ACC II is not preempted by the Clean Air Act, by EPCA, or by the RFS.[123] As we explain elsewhere in these comments, however, ACC II is in fact preempted by EPCA.[124] And litigation pending before the D.C. Circuit challenges the constitutionality of the Clean Air Act preemption-waiver mechanism as a whole, as well as its specific application in the case of California's GHG regulations.[125]

---

[119] Gov't Accountability Office, Electricity Grid Cybersecurity: DOE Needs to Ensure Its Plans Fully Address Risks to Distribution Systems, GAO-21-81, at 11 (Mar. 2021). *Available at* https://www.gao.gov/assets/gao-21-81.pdf (last visited Feb. 20, 2023).

[120] *Id.*

[121] *Id.* at 18.

[122] *See* James E. Hanley, NYISO: New York Electric Grid Remains at Risk (Empire Center June 15, 2022), *available at* https://www.empirecenter.org/publications/nyiso-new-york-electric-grid-remains-at-risk/ (last visited Feb. 26, 2023) ("New York's electrical grid could fail as early as 2023, if the state experiences a sustained 98-degree heat wave. . . . NYISO does not back down from the warning given in their 2021-2030 Comprehensive Reliability Plan that the state may soon reach a 'tipping point' where electricity production and transmission capabilities are insufficient to meet demand.").

[123] *See* Interv. For Pet'r Br., *NRDC v. NHTSA*, Doc. 1976944 (Dec. 8, 2022) (D.C. Cir. No. 22-1080) (arguing ZEV mandates are impliedly preempted by the Renewable Fuel Standard).

[124] *See Ohio v. EPA*, No. 22-1081 (D.C. Cir. filed May 5, 2022). *See also Texas v. EPA*, No. 22-1144 (D.C. Cir. filed June 30, 2022) (challenging Department of Transportation's Corporate Average Fuel Economy (CAFE) rulemaking, alleging violation of statutory prohibition on incorporating EV mandates into such regulations).

[125] *See Ohio v. EPA*, No. 22-1081 (D.C. Cir.).

Briefing in the D.C. Circuit on this matter is ongoing,[126] and it will be argued this Fall, with resolution by the Circuit expected in 2024. Separate and apart from all other issues raised in these comments, NYSDEC at a minimum should wait until the federal judiciary has decided these disputed issues before adopting ACC II. To rush forward with adoption now risks considerable disruption and whipsawing of regulated parties' and other stakeholders' expectations and investments, as well as wasted NYSDEC resources.

F. NYSDEC's adoption of ACC II constitutes a regulatory taking requiring just compensation.

NYSDEC's plan to eventually phase out the sales of all ICEVs constitutes a regulatory taking.[127] In determining whether a regulatory taking has occurred, "[s]everal factors are particularly relevant, including the regulation's economic effect on the landowner, the extent to which the regulation interferes with reasonable investment-backed expectations, and the character of the government action."[128]

AFPM members have invested substantial amounts of money in making their refineries, terminals and distribution networks and renewable fuel facilities safe and productive and, therefore, have significant investment-backed expectations with respect to their properties, at least some of which may be forced to close as a result of NYSDEC's proposed adoption of CARB's electric vehicle mandate. New York landowners also would be harmed. Landowners across the state receive royalties from renting their land to companies. Policies that shut down oil facilities would prevent companies and New York landowners from realizing these investment-backed expectations. Thus, such adoption would constitute a regulatory taking based on its substantial interference with these expectations, and the state would be obligated to provide just compensation for companies' losses.

Therefore, as NYSDEC considers the potential costs of policies that would shut down oil facilities, it should—at a minimum—account for the estimated costs of just compensation for the loss of property use and interference with investment-backed expectations that would inevitably result.

G. California's struggles present a cautionary tale for New York.

NYSDEC should consider the implications that a strategy focused on a singular technology may have on community decision-making, consumer choice, and the unintended consequences that reliance on electrification may present, including foreign supply chain disruptions and forced labor in the production of the raw materials needed to manufacture batteries.[129]

California policymaking is hardly an unqualified success story. Its climate policies—like the ZEV sales mandates—have had major inflationary impacts on gasoline and energy prices, as well as negative impacts on jobs in certain industries that are directly related to traditional fuels and vehicles.[130] While often lauded as the measuring stick for GHG emission reduction policies, California's transportation fuel

---

[126] *See, e.g.*, Ford Motor Co. et al, Intervenor for Respondent Brief, Document No. 1985804 (filed Feb. 13. 2023).
[127] *See* N.Y. Const. art. I, § 7; U.S. Const. 5th Amend. "Both the [New York] State and Federal Constitutions require that owners receive just compensation when private property is taken for public use." *RAG Herkimer, LLC v. Herkimer Cty.*, 208 A.D.3d 1016, 1017 (App. Div. 4th Dep't 2022) (internal quotation marks omitted).
[128] *In re New Creek Bluebelt, Phase 4*, 205 A.D. 3d 808, 811 (App. Div. 2d Dep't 2022) (citation omitted).
[129] *See* U.S. Department of Energy, *2022 List of Goods Produced By Child Labor or Forced Labor*, at 50-51, https://www.dol.gov/sites/dolgov/files/ILAB/child_labor_reports/tda2021/2022-TVPRA-List-of-Goods-v3.pdf.
[130] California Legislative Analyst's Office, *Assessing California's Climate Policies – An Overview* (Dec. 21, 2018).

prices are now the highest in the nation, averaging approximately $4.62 per gallon of gasoline.[131] According to a 2021 Report from the California Public Utilities Commission, "it is already cheaper to fuel a conventional ICE vehicle than it is to charge an EV" in the San Diego Gas & Electric Co. service area.[132] The California Energy Commission projects that both commercial and residential electricity prices will continue to rise, reaching over $8/gasoline gallon equivalent ("GGE") by 2026 for the residential sector and nearly $7/GGE for the commercial sector.[133] If environmental justice is truly a commitment for New York, it should carefully consider the criticisms of California's climate approach, such as those leveled by The Two Hundred, which point out the disproportionate impacts to working and minority communities.[134]

As California has faced rolling blackouts and historic energy prices, Governor Newsom in his May 2022 state budget proposal, has pivoted to the use of traditional fuel infrastructure to ensure system reliability to protect against outages.[135]

Moreover, unworkable ZEV sales mandates put New York at risk of missing out on real carbon reductions available through incentivizing low-carbon liquid fuels and by encouraging the development of emerging carbon removal technologies.

H. Conclusion

NYSDEC must conduct a meaningful public notice and comment process for its complex proposal to adopt ACC II. There are significant technical, economic, and legal facts and analysis that NYSDEC has ignored or inadequately addressed in its process, in violation of the law. NYSDEC should address these process and analysis deficiencies by conducting technical working groups to foster stakeholder participation in scenario development and assessment.

Multitechnology pathways can help the state achieve faster and more certain emission reductions while expanding ways to reduce greenhouse gas emissions, to comply with the goals established by the CLPCA and other New York legislation. NYSDEC should evaluate and propose performance standards as an alternative to its proposed adoption of ACC II and its ZEV mandate.

Thank you for the consideration of our comments. AFPM would welcome the opportunity to discuss these comments and recommendations in more detail with you. Please feel free to contact us at DThoren@afpm.org with any questions or concerns.

Attachment

---

131 AAA, *California Average Gas Prices – Current Avg.*, https://gasprices.aaa.com/?state=CA (accessed Feb. 7, 2023).

132 CPUC, Utility Costs and Affordability of the Grid of the Future: An Evaluation of Electric Costs, Rates, and Equity issues Pursuant to P.U. Code § 913.1, at 116-117 (May 2021).

133 CEC, "Presentation - Transportation Energy Demand Forecast," 21-IEPR-03 (Dec. 14, 2021).

134 *See* Plaintiffs' Complaint, *The Two Hundred for Homeownership, et al. v. California Air Resources Board, et al.*, No. 1:22-CV-01474.

135 *See* https://www.ebudget.ca.gov/2022-23/pdf/Revised/BudgetSummary/ClimateChange.pdf.

American
Fuel & Petrochemical
Manufacturers

1800 M Street, NW
Suite 900 North
Washington, DC
20036

202.457.0480 office
202.457.0486 fax
afpm.org

October 16, 2023

Ann Carlson, Acting Administrator
National Highway Traffic Safety Administration
U.S. Department of Transportation
West Building, Ground Floor, Rm. W12–140
1200 New Jersey Avenue SE
Washington, DC 20590

Attention: Docket ID No. NHTSA–2023–0022
Submitted to the Federal eRulemaking Portal (www.regulations.gov)

Re: Corporate Average Fuel Economy Standards for Passenger Cars and Light Trucks for Model Years 2027–2032 and Fuel Efficiency Standards for Heavy-Duty Pickup Trucks and Vans for Model Years 2030–2035; 88 Fed. Reg. 56,128 (August 17, 2023) NHTSA–2023–0022

Dear Acting Administrator Carlson:

The American Fuel & Petrochemical Manufacturers (AFPM) submits these comments in response to the National Highway Traffic Safety Administration's (NHTSA's or Agency's) proposed rule, Corporate Average Fuel Economy Standards for Passenger Cars and Light Trucks for Model Years 2027–2032 and Fuel Efficiency Standards for Heavy-Duty Pickup Trucks and Vans for Model Years 2030–2035 (hereinafter "Proposal" or "Proposed Rule").[1] AFPM represents the U.S. refining and petrochemical industries, and, as such, has a strong interest in this rulemaking.

AFPM shares NTHSA's goal of improving the efficiency of our nation's transportation fleet. Indeed, our members are investing heavily in technologies and processes that continue to reduce the carbon intensity of fuels and have long worked with automakers to improve the fuel efficiency of internal combustion engines. Importantly, investments in reducing the carbon intensity of fuel can reduce the lifecycle carbon intensity of new and existing vehicles, offering the potential to achieve faster emission reductions at a lower overall cost to society.

AFPM is committed to the development of policies that reduce greenhouse gas emissions and improve the fuel efficiency of our nation's transportation fleet.[2] Such policies must, however, strike a balance between several statutorily mandated factors, including improved efficiency, technical feasibility, affordability, and our nation's energy and resource security. They must also be technology neutral and solidly grounded in legal authority granted by Congress—in this case, authority granted to NHTSA by the Energy Policy and Conservation Act (EPCA) as amended by

[1] 88 Fed. Reg. 56,128 (August 17, 2023).
[2] For example, over the last several years, AFPM has been actively advocating for legislation that would require new automobiles to be designed and warrantied to run on a minimum octane rating of 95 RON, which would enable higher compression engines and better fuel efficiency.

the Energy Independence and Security Act (EISA), 49 U.S.C. §§ 32901-32919 (hereafter collectively "EPCA"). NHTSA's Proposal fails to adequately consider these factors and goes beyond its statutory authority.

I. BACKGROUND

A. AFPM

AFPM represents the U.S. refining, petrochemical, and midstream industries. In addition to actively pursuing emissions reductions from their operations, our members are increasingly investing in renewable fuels such as ethanol, renewable gasoline, renewable diesel, and sustainable aviation fuel. We are committed to delivering affordable and reliable fuels that power our transportation needs and enable our nation to thrive. Importantly, the U.S. refining and petrochemical industries are critical assets for U.S. energy and national security, a fact which NHTSA insufficiently considers.

Ongoing investments to maintain and improve their manufacturing facilities have made U.S. refineries among the most advanced and efficient in the world. Our companies regularly upgrade, expand, and modernize to increase their efficiency and complexity to meet the changing demand for their products.

In 2022, the U.S. petroleum refining industry invested $13.0 billion to maintain and upgrade their facilities, an increase of 21 percent compared to 2021. Over the next five years the industry is expected to invest $60 billion in their operations.

Our members' environmental stewardship is just as strong, as they spend billions of dollars and the ingenuity of their world-class workforce to reducing emissions and becoming more efficient, conserving energy and water, reducing waste, and preserving and restoring the land and ecosystems around them.

As producers of liquid transportation fuels, AFPM members are directly impacted by this rulemaking regulating the vehicles that consume these products. AFPM members also purchase, lease, and contract for thousands of vehicles and are therefore impacted by this rulemaking, which will increase the prices of new and used motor vehicles and have safety implications associated with operating and sharing the road with those vehicles. AFPM is therefore within the zone of interest of this rule.

B. Regulatory background

NHTSA's Proposal for new fuel economy standards for passenger cars and light trucks and for heavy-duty pickup trucks and vans (HDPUVs) comes on the heels of multiple other sweeping federal and state proposals in the past 6-12 months that would interact in complicated ways to completely transform the transportation industry in the United States.[3] This is in addition

[3] *See e.g.,* Environmental Protection Agency, Multi-Pollutant Emissions Standards for Model Years 2027 and Later Light-Duty and Medium-Duty Vehicles, Proposed Rule, 88 Fed. Reg. 29,184 (May 5, 2023);

to several rulemakings established since 2021 by the three major regulatory regimes establishing standards for motor vehicles—NHTSA, U.S. Environmental Protection Agency (EPA), and California Air Resources Board (CARB)—that would address model year (MY) 2023 and beyond, all of which are presently being challenged.[4] In addition, the Department of Energy (DOE) is in the process of evaluating and proposing changes to the petroleum equivalency factor (PEF) utilized by NHTSA and other agencies to account for the "fuel efficiency" of electric vehicles (EVs) (also referred to as ZEVs[5]).[6]

Yet despite the wave of new regulations facing all facets of the transportation sector, in issuing the Proposed Rule, NHTSA has declined to issue a joint rule with EPA—as it has previously—and, perhaps more importantly, failed to harmonize its rulemaking to reduce unnecessary and costly regulatory burden. The standards in the Proposed Rule would contribute to the challenging regulatory landscape facing the industry. We urge NHTSA to reconsider the Proposed Rule in light of the following comments.

II. EXECUTIVE SUMMARY OF AFPM COMMENTS ON THE PROPOSED RULE

New fuel efficiency standards must be grounded in statutory authority. Congress requires NHTSA to set "maximum feasible" fuel economy standards for passenger cars and light trucks at levels that manufacturers can achieve based on four specifically enumerated factors: (i) technological feasibility, (ii) economic practicability, (iii) the effect of other motor vehicle standards of the Government on fuel economy, and (iv) the need for the United States to conserve energy. Similarly, for commercial medium-duty and heavy-duty vehicles and work trucks, including

---

Department of Energy, Petroleum-Equivalent Fuel Economy Calculation, Notice of Proposed Rulemaking; Request for Comment, 88 Fed. Reg. 21,525 (April 11, 2023); Environmental Protection Agency, Greenhouse Gas Emissions Standards for Heavy-Duty Vehicles—Phase 3, Notice of Proposed Rulemaking, 88 Fed. Reg. 25,926 (April 27, 2023); and California Air Resources Board, Advanced Clean Cars (ACC) II standards (see rulemaking documents at https://ww2.arb.ca.gov/rulemaking/2022/advanced-clean-cars-ii) and corresponding section 177 state adoption proposals.

[4] *Texas v. EPA*, No. 22-1031 (D.C. Cir. argued Sept. 14, 2023) (challenging the EPA Greenhouse Gas (GHG) standards for light-duty vehicles for model year 2023 and later); *Nat. Res. Def. Council v. NHTSA*, No. 22-1080 (D.C. Cir. argued Sept. 14, 2023) (challenging National Highway Traffic Safety Administration's Corporate Average Fuel Economy (CAFE) standards for model years 2024-2026; *Ohio et al. v. EPA et al*., No. 22-1081 (D.C. Cir. argued Sept. 15, 2023) (challenging the decision by EPA to reinstate the California Section 209 waiver under the Clean Air Act).

[5] Note that the term "zero emissions vehicle" ("ZEV"), and even near-ZEVs as referenced by NHTSA, is a misnomer. ZEVs are not actually zero emission when accounting for the vehicle lifecycle, including GHG and criteria pollutant emissions associated with electricity generation required for charging certain ZEVs and production of the ZEV vehicle and battery. We recognize that in the Proposed Rule, NHTSA uses "ZEV" to refer only to those vehicles with a specific meaning under California's EV program, but for ease of review, "ZEVs" is used throughout these comments and encompasses all of the EV technologies, including strong hybrid vehicles ("SHEVs") and plug in electric vehicles ("PEVs") such as plug-in hybrid electric vehicles ("PHEVs") and battery electric vehicles ("BEVs").

[6] Department of Energy, Petroleum-Equivalent Fuel Economy Calculation, Notice of Proposed Rulemaking; Request for Comment, 88 Fed. Reg. 21,525 (April 11, 2023).

HDPUVs, NHTSA must set "maximum feasible" fuel economy standards that are (i) appropriate, (ii) cost-effective, and (iii) technologically feasible.

For the reasons set forth below and in the attached Appendices, NHTSA has departed from Congressional intent and proposed standards that do not meet statutory requirements. In particular, we believe that NHTSA exceeds its legal authority by setting the fuel economy standards at a level that is not feasibly achievable by internal combustion engine vehicles (ICEVs), effectively establishing a *de facto* electric vehicle mandate. EPCA does not afford NHTSA such authority. We also believe that NHTSA does an inadequate job balancing the factors EPCA requires it to consider when establishing fuel economy standards for passenger cars and light duty trucks, as well as HDPUVs, and that the agency should be more transparent and realistic about the costs and benefits of the Proposed Rule and the impact that the implicit electric vehicle mandate would have on consumers, supply chains, and national security. Appendix A, AFPM Legal Review of NHTSA's Proposed CAFE Standards for MYs 2027-2032 Passenger Cars and Light Trucks and Fuel Efficiency Standards for MYs 2030-2035 Heavy-Duty Pickup Trucks and Vans (AFPM Legal Review), and Appendix B, Trinity Consultants Technical Review of NHTSA's Proposed CAFE Standards for MYs 2027-2032 Passenger Cars and Light Trucks and Fuel Efficiency Standards for MYs 2030-2035 Heavy-Duty Pickup Trucks and Vans (Trinity Technical Review), further detail AFPM's concerns and comments on the Proposed Rule, as summarized below, and demonstrate that the Proposed Rule exceeds NHTSA's statutory authority.

III. NHTSA'S PROPOSAL COMPROMISES ENERGY AND NATIONAL SECURITY

NHTSA fails to adequately analyze the energy and national security implications of its Proposal. In contrast to the time EPCA was passed in the aftermath of the Arab Oil Embargo, the U.S. is now a net exporter of crude oil and petroleum products. The U.S. is also the world's largest producer of biofuels, including ethanol and renewable diesel. Our domestic liquid fuels industries have made the U.S. more energy secure. NHTSA's EV mandate policy trades away our hard-earned energy security to countries that control the supply of battery raw materials, most notably China. As a result, NHTSA's Proposal needlessly compromises our energy and national security.

NHTSA's EV mandate will make U.S. automakers dependent on foreign suppliers for battery minerals and EV manufacturing. China maintains a controlling position in the material extraction, processing, and battery production necessary to produce EVs. China's dominance extends into countries on other continents where the mineral extraction occurs by owning a full or partial stake in mines and other assets in mineral extraction. And in most cases, the areas of the world where battery raw materials are extracted are more politically unstable than the sources of imported petroleum. NHTSA needs to consider that the energy security landscape has changed dramatically over the last decade and recognize that a forced vehicle electrification strategy, particularly in the timeline of the Proposed Rule, puts U.S. energy and national security in reverse.

IV. THE PROPOSED CAFE STANDARDS VIOLATE EPCA BY FAILING TO ESTABLISH MAXIMUM FEASIBLE AVERAGE FUEL ECONOMY STANDARDS FOR PASSENGER CARS AND LIGHT-DUTY-TRUCKS

NHTSA's proposed standards for passenger cars and light-duty trucks exceed NHTSA's statutory authority and are not achievable nor feasible for the industry in the timeframe proposed. Importantly, in proposing these unachievable standards, NHTSA relied on factors that it is statutorily prohibited from considering. As set forth below, NHTSA inappropriately accounted for ZEVs in its baseline and standard modeling, despite a clear statutory directive and Congressional intent not to consider EVs.[7] Congress included an explicit prohibition to ensure that EVs remain the compliance flexibility that Congress intended them to be – and not become a regulatory mandate. Despite that clear prohibition, NHTSA openly considered electric vehicles in deciding the maximum fuel-economy level that automakers can feasibly achieve. NHTSA evades the clear statutory prohibition by introducing extratextual exceptions to the application of its authority, specifically that NHTSA considered electric vehicles by assuming EVs in the vehicle fleet in establishing a modeling baseline. As a result, the proposed standards are not feasibly achievable by ICEVs effectively establishing an EV mandate.

V. THE PROPOSED CAFE STANDARDS VIOLATE EPCA BY FAILING TO ESTABLISH MAXIMUM FEASIBLE AVERAGE FUEL ECONOMY STANDARDS FOR HEAVY DUTY PICKUP TRUCKS AND VANS (HDPUVS)

NHTSA must set "maximum feasible" fuel economy standards for commercial medium-duty and heavy-duty vehicles and work trucks, including HDPUVs that are "appropriate, cost-effective, and technologically feasible."[8] NHTSA's proposed standards fail to meet these requirements. Fuel efficiency is proposed, on average, to increase by 10 percent per year, year over year, for MY 2030–2035 under NHTSA's preferred alternative. NHTSA has done little to evaluate that such stringency increase is "appropriate, cost-effective, and technologically feasible" for the commercial HDPUV fleet and in fact has abrogated its responsibility to do so by assuming that the majority of the HDPUV fleet would have largely become compliant by 2030 under the "No Action" alternative. By failing to explain these factors, NHTSA has prevented the public's ability to provide informed comment.

NHTSA asserts wide discretion in considering what is "appropriate" for the medium- and heavy-duty fleet yet fails to consider how appropriate it is to consider electric vehicles in a standard regulating the efficiency of ICEVs. All of the same concerns about NHTSA's Proposal for passenger cars and light trucks, including concerns that NHTSA's purported discretion exceeds its statutory authority and raises "major questions," concerns that the Proposal is not feasible, and security concerns related to relying on electrification are equally relevant to the proposed HDPUV standards. This includes over-estimating the Proposal's assumed energy conservation and environmental benefits that fail to adequately consider the Proposal's impact on the generation, transmission, and distribution of electricity, and the full lifecycle "cradle to grave"

[7] 49 U.S.C. § 32902(h)(1)
[8] 49 U.S.C. § 32902(k)(2).

impacts of electric vehicle ownership. Similar to NHTSA's treatment of passenger cars, NHTSA does not conduct a full lifecycle analysis of medium- and heavy-duty vehicles that is necessary to fully assess the Proposal's environmental impact and necessary for NHTSA to assert any co-benefit from the Proposal.

Negative consequences to consumers and commercial operators, including on employment, are ignored in the Proposal. Businesses must respond to the significant costs to commercial fleet operators associated with the purchase, use, and maintenance of HDPUV ZEVs. NHTSA declined to consider that the Proposal may have dramatic effects on commercial business models, including companies that may not be capable of operating as many vehicles, or employing as many staff. NHTSA similarly over-estimates the technical feasibility of the Proposal by assuming exponential growth in the adoption of electric HDPUVs that currently don't exist, and without a full assessment of the range needs of EVs in commercial use.

Appendix A AFPM Legal Review and Appendix B Trinity Technical Review elaborate on each of these factors and demonstrate that NHTSA's Proposal does not meet EPCA's statutory requirements.

VI. NHTSA'S DRAFT ENVIRONMENTAL IMPACT STATEMENT FAILS TO SATISFY THE NATIONAL ENVIRONMENTAL POLICY ACT

As submitted in simultaneous comments to NHTSA's EIS docket, AFPM believes NHTSA has failed to take a sufficient hard look or analyze sufficient reasonable alternatives to satisfy the National Environmental Policy Act (NEPA).

As detailed in Appendix C AFPM Comments on NHTSA's Draft Environmental Impact Statement (DEIS) (AFPM DEIS Comments) and incorporated herein by reference, NHTSA's alternatives are inadequate. Specifically, NHTSA failed to consider a range of feasible alternatives. Indeed, two passenger car and light tuck alternatives (PC3LT5 and PC6LT8) and one heavy duty alternative (HDPUV14) are so infeasible that NHTSA could not adopt them. Moreover, NHTSA's Proposal implicates the major questions doctrine and, therefore, NHTSA lacks the authority to adopt the proposed standard. Finally, NHTSA's alternatives do not address reasonably available, cost-effective mitigation measures.

NHTSA's analyses of the ability of the proposed CAFE standards to conserve energy, air quality impacts, and direct and indirect impacts on climate change and GHG emissions are based on faulty assumptions and the analysis is highly uncertain. The DEIS's lifecycle assessment system boundary is woefully narrow, failing to analyze all environmental impacts (e.g., land use, resource depletion, water use, and eutrophication) associated with extracting all raw materials needed to produce and operate EVs and ICEVs. Moreover, NHTSA must conduct a systemic, interdisciplinary evaluation of the economic impact (e.g., impact on jobs and worker wages), safety considerations, and the proposed standard's impact on fleet turnover and local air quality.

VII. THE PROPOSAL FAILS TO PROVIDE MEANINGFUL OPPORTUNITY FOR PUBLIC COMMENT

AFPM welcomes the opportunity to meaningfully engage with regulators to discuss cost-effective, efficient, and feasible measures to improve the fuel efficiency of the transportation sector. Unfortunately, the 60-day comment period is not sufficient to coordinate an adequate response to the sheer volume of data in the rulemaking docket. Upon publication of the Proposed Rule itself in the Federal Register, additional materials including various modeling scenarios and technical analyses, that amount to over 5,000 pages of technically complex materials were made available, including a technical correction published twelve days later. NHTSA refused to grant AFPM's request for additional time, despite Executive Order 12866 guidance that a 60-day comment period is the minimum expectation. The sweeping scope of NHTSA's Proposal to completely transform the U.S. transportation industry requires considerably more time, particularly considering the numerous instances in which NHTSA's analysis is inaccurate, incomplete, or misleading. NHTSA also narrowly limited the identification of industries affected by the Proposal by providing a short and incomplete list of NAICS codes in the Federal Register publication. Taken together, NHTSA's actions are at odds with its responsibilities under the Administrative Procedure Act and the Due Process Clause of the U.S. Constitution.

VIII. CONCLUSION

Rather than secure our nation's energy and national security, NHTSA departed from Congressional intent by proposing standards that do not meet statutory requirements. NHTSA exceeded its legal authority by setting the fuel economy standards at a level that is not achievable by ICEVs, effectively establishing a *de facto* EV mandate. Despite EPCA's explicit instruction, NHTSA improperly considered EVs when setting CAFE standards for passenger cars and light-duty trucks. NHTSA failed to set "maximum feasible" fuel economy standards that ICEVs can achieve based on the four statutory factors, Similarly, the proposed fuel efficiency standards for commercial medium-duty and heavy-duty vehicles and work trucks, including HDPUVs are not (i) appropriate, (ii) cost-effective, and (iii) technologically feasible. For these reasons, NHTSA should withdraw the Proposed Rule.

Respectfully submitted,

Leslie Bellas
Vice President, Regulatory Affairs
American Fuel & Petrochemical Manufacturers

APPENDIX A

AFPM Legal Review of NHTSA's Proposed CAFE Standards for MYs 2027-2032 Passenger Cars and Light Trucks and Fuel Efficiency Standards for MYs 2030-2035 Heavy-Duty Pickup Trucks and Vans

Table of Contents

I. INTRODUCTION ... 1
II. NHTSA'S PROPOSAL COMPROMISES ENERGY AND NATIONAL SECURITY ... 1
A. The Proposal would make OEMs dependent on foreign suppliers for battery minerals and EV manufacturing ... 2
B. Availability of North American Crude, Refining, and Biofuel capacity makes the U.S. energy-secure ... 11
C. NHTSA should not conflict with Congressional objectives as expressed in the Energy Independence and Security Act and the Renewable Fuel Standard (RFS) ... 14
1. Proposed CAFE standards for passenger cars and light trucks and fuel efficiency standards for HDPUV discourage development and use of liquid renewable fuels ... 14
2. NHTSA should not discourage the continued decarbonization of fuels ... 15
III. THE PROPOSED CAFE STANDARDS FOR PASSENGER CARS AND LIGHT-DUTY-TRUCKS ARE UNLAWFUL ... 15
A. NHTSA is prohibited from considering the fuel economy of electric vehicles when determining the maximum feasible fuel economy standards for passenger cars and light-duty trucks ... 16
1. NHTSA improperly included EVs in the baseline and standard modeling. ... 19
2. NHTSA's ZEV penetration assumptions in the baseline and standard modeling are overly optimistic. ... 22
3. Removing the improperly included ZEVs from NHTSA's baseline and standard setting years renders NHTSA's Proposal infeasible. ... 24
B. The proposed standards are unachievable and do not establish the maximum feasible average fuel economy ... 25
1. The proposed standards are not technologically feasible ... 26
a) Scarce supplies of critical minerals will prevent sufficient production of EV batteries to meet this EV mandate. ... 27
b) The Proposed Rule has not adequately examined the implications for U.S. electric system reliability. ... 29
i. NHTSA has not adequately demonstrated that the U.S. electrical grid and transmission grid can reliably support the assumed penetration rates. ... 29
ii. Global supplies of critical minerals and metals are inadequate to support the required electrical grid expansion. ... 34
c) Charging infrastructure is not sufficient to meet NHTSA's EV penetration assumptions ... 36
d) The proposed timeline is impracticable. ... 36
i. Current battery and EV production is insufficient to support the assumed EV penetration rates during the standard setting years. ... 37
ii. The grid cannot be expanded within the timeline contemplated by the rule ... 39

iii. The required charging infrastructure cannot be deployed during the standard setting years. 40
e) NHTSA assumes unrealistic consumer EV adoption rates 40
2. The Proposed NHTSA standards are not economically practicable. 43
a) NTHSA failed to consider the significant cost to produce batteries needed for EVs contemplated under its proposed standards.......... 45
b) NHTSA ignores the increased purchase price of EVs and reduction in consumer choice that will result from its Proposal. 48
i. NHTSA's overly optimistic assumptions regarding the IRA do not reflect the true cost to electrify light-duty vehicles 49
c) NHTSA's Proposal does not account for the true total cost of ownership associated with EVs. 50
i. NHTSA's Proposal will disproportionately disadvantage low-income Americans both financially and practically.......... 51
ii. NHTSA has not adequately weighed the factors affecting liquid and electric fuel prices. 52
iii. NHTSA's Proposal will lead to cross-subsidization, shifting costs associated with increased EV penetration rates to those purchasing ICEVs.......... 55
d) NHTSA failed to adequately account for the total cost required to upgrade and expand the grid.......... 56
e) NHTSA overlooks the significant costs of installing required charging capacity. 57
f) Evaluate impact on fuel tax revenue (Highway Trust Fund). 59
3. The proposed standards do not adequately or correctly consider other government standards impacting motor vehicles. 63
a) NHTSA improperly considered CARB's ZEV regulations and EPA's existing GHG standards. 64
4. The proposed standards do not appropriately address the need to conserve energy. 65
b) NHTSA underestimates the energy consumption of EVs and overestimates the energy consumption of ICEVs............. 65
c) NHTSA overstates the environmental benefits of the Proposed Rule.......... 67
i. Increased vehicle costs associated with the Proposed Rule will reduce fleet turnover. 67
ii. Increased roadway emissions due to heavier vehicles. 68
iii. Impact of additional electrical generation needed. 69
iv. Mining sector environmental impacts. 69
v. NHTSA should conduct a full life-cycle analysis for EVs to account for their true environmental costs.......... 70
IV. THE PROPOSED RULE VIOLATES NHTSA'S STATUTORY AUTHORITY BY FAILING TO ESTABLISH MAXIMUM FEASIBLE AVERAGE FUEL

ECONOMY STANDARDS FOR HEAVY DUTY PICKUP TRUCKS AND VANS (HDPUVS) 72
A. Appropriateness 73
1. National security and energy security considerations are largely ignored 74
2. The Proposal over-estimates the amount of energy conservation for HDPUV EVs 74
3. The environmental benefits of HDPUV EVs are over-estimated and HDPUV ICEVs are under-estimated 75
4. Important regulatory effects to consumers and commercial operators, including on employment, are ignored 75
B. Cost-Effectiveness 76
C. Technical Feasibility 76
V. THE DRAFT ENVIRONMENTAL IMPACT STATEMENT IS INADEQUATE 77
VI. THE PROPOSAL FAILS TO PROVIDE MEANINGFUL OPPORTUNITY FOR PUBLIC COMMENT 78
VII. CONCLUSION 80

Table of Figures

Figure 1: Metal intensity – ICE vs. EV 3
Figure 2: U.S. lack of critical mineral extraction or processing capacity 5
Figure 3: China’s share of the lithium-ion battery supply chain in 2022 6
Figure 4: U.S. risk exposure to critical energy resources 7
Figure 5: Existing and expected U.S. renewable diesel production capacity (2010-2024) 13
Figure 6: NHTSA Baseline BEV Assumptions 17
Figure 7: Impact of Eliminating ZEVs on NHTSA’s Baseline Fleet Fuel Economy – 2027 to 2032 20
Figure 8: Impact of Eliminating ZEVs on NHTSA’s Baseline Fleet Fuel Economy – 2022 to 2050 21
Figure 9: Regulatory Compliance Manufacturer Counts from the NTHSA and No-ZEV Baselines During the Standard Setting Years 26
Figure 10: NERC 2023 Summer Risk Assessment 31
Figure 11: ZEV registrations by RTO 32
Figure 12: EV Power Requirement by RTO 33
Figure 13: Regulatory Compliance Costs from the NTHSA and No-ZEV Baselines During the Standard Setting Years 44
Figure 14: Regulatory Compliance Costs from the NTHSA and No-ZEV Baselines 2022 to 2050 45
Figure 15: NHTSA Baseline EV Assumptions by EV Range 46
Figure 16: Baseline BEV Sales Fractions by Model Year for the Sensitivity Cases and NHTSA Baseline 47
Figure 17: Historical and Forecasted Electricity Rates for California 53
Figure 18: Revenue Sources for Highway Trust Fund 60
Figure 19: HTF Spending and Revenue after the BIL 60
Figure 20: Impact of Eliminating ACC II Regulations NHTSA’s Baseline Fleet Fuel Economy 2027 to 2032 64
Figure 21: Average GHG emissions intensity for production of selected commodities. 70

I. INTRODUCTION

New fuel economy standards for passenger cars and light trucks and fuel efficiency standards for heavy-duty pickup trucks and vans (HDPUVs) must be grounded in legal authority granted to NHTSA by the Energy Policy and Conservation Act (EPCA), as amended by the Energy Independence and Security Act (EISA), 49 U.S.C. §§ 32901-32919 (hereafter collectively "EPCA"). As described further below, NHTSA's Proposal fails to adequately consider these factors and goes beyond its statutory authority.

Congress requires NHTSA to set "maximum feasible" fuel economy standards for passenger cars and light trucks at levels that manufacturers can achieve based on four specifically-enumerated factors: (i) technological feasibility, (ii) economic practicability, (iii) the effect of other motor vehicle standards of the Government on fuel economy, and (iv) the need for the United States to conserve energy.[9] Similarly, for commercial medium-duty and heavy-duty vehicles and work trucks, including HDPUVs, NHTSA must set "maximum feasible" fuel efficiency standards that are (i) appropriate, (ii) cost-effective, and (iii) technologically feasible.[10] NHTSA's proposed standards depart from Congressional intent and do not meet EPCA's statutory requirements. In particular, NHTSA exceeds its legal authority by setting the fuel economy standards at a level that is not feasibly achievable by internal combustion engine vehicles (ICEVs), effectively establishing a *de facto* electric vehicle (EV) (also referred to as ZEV[11]) mandate. EPCA does not afford NHTSA such authority. Also, NHTSA inadequately balances the factors EPCA requires it to consider when establishing fuel economy standards for passenger cars and light duty trucks, as well as HDPUVs. The agency should be more transparent and realistic about the costs and benefits of the Proposed Rule and the impact that the implicit EV mandate would have on consumers, supply chains, and national security.

II. NHTSA'S PROPOSAL COMPROMISES ENERGY AND NATIONAL SECURITY

Congress passed EPCA in the aftermath of the Arab Oil Embargo and authorized NHTSA to establish fuel economy standards to increase energy security and reduce dependence on foreign oil. Thanks to American ingenuity and tremendous efficiency in the refining sector, the United States (U.S.) produces more oil and refined products than it ever has in its history. NHTSA's Proposed Rule fails to adequately analyze its national security implications, an issue of central relevance to the primary purpose of its enabling statute.

Horizontal drilling technology, combined with advanced completions procedures, allowed the U.S. to experience a dramatic improvement in crude and gasoline production since EPCA's

[9] 49 U.S.C. § 32902(f).
[10] 49 U.S.C. § 32902(k)(2).
[11] Note that the term "zero emissions vehicle" (ZEV), and even near-ZEVs as referenced by NHTSA, is a misnomer. ZEVs are not actually zero emission when accounting for the vehicle lifecycle, including GHG and criteria pollutant emissions associated with electricity generation required for charging certain ZEVs and production of the ZEV vehicle and battery. We recognize that in the Proposed Rule, NHTSA uses "ZEV" to refer only to those vehicles with a specific meaning under California's EV program, but for ease of review, "ZEVs" is used throughout these comments and encompasses all of the EV technologies, including strong hybrid electric vehicles (SHEVs) and plug in electric vehicles (PEVs) such as plug-in hybrid electric vehicles (PHEVs) and battery electric vehicles (BEVs).

passage, so much so that the U.S. is now a net exporter of energy.[12] In 2022, the U.S. was both the world's top oil producer and oil refiner, responsible for ~20% of refined products globally.[13] At the same time, the Renewable Fuel Standard (RFS) and the industry's commitment to renewable fuels has lowered the carbon intensity of transportation fuels. U.S. total annual crude oil exports have increased steadily since 2010 and reached a record high in 2022 of about 3.58 million barrels per day (b/d).[14] The U.S. refining sector is exceedingly competitive in the global marketplace and is well positioned to excel in markets outside of the U.S. As Energy Information Administration (EIA) data show, U.S. exports of finished gasoline more than doubled between 2010 and 2019, from 1.07 million barrels annually to 2.97 million barrels. Additionally, an estimated 70,000 industrial and consumer products rely on chemicals or oil-based feedstocks produced at our members' refineries.[15]

While liquid fuels have never been stronger in America, the Agency is effectively forcing electrification which requires substantial, foreign-sourced raw and processed materials to produce ZEV batteries. This Proposal, taken to its logical end, would put the U.S. into a situation resembling the oil embargoes of the 1970s, where foreign actors control majorities of the critical raw material supplies used to provide transportation mobility services for the U.S. consumer. Indeed, China dominates the global supply chain for battery production. Forced electrification would make the United States beholden to China and other nations controlling the minerals required to manufacture ZEV batteries and other components. As a result, NHTSA's Proposal compromises the United States energy and national security interests.

A. The Proposal would make OEMs dependent on foreign suppliers for battery minerals and EV manufacturing

NHTSA's Proposal incorporates ZEV penetration rates into its underlying baseline calculation and modeling of the proposed standards. However, NHTSA has not sufficiently considered the serious dearth of domestic materials required to facilitate the contemplated EV production. The supply chain necessary to support these new technologies is far from assured and is likely to increase dependence on critical raw materials from foreign sources. Over-reliance on EVs on the timeline required by the Proposed Rule will result in a non-resilient transportation sector that is vulnerable to unexpected disruptions. For instance, both the federal government and the private sector recognize that critical minerals are essential to the future of ZEVs. Unstable critical mineral supply chains could disrupt this future. ZEVs, as compared to ICEVs, have a much

---

[12] "U.S. energy facts explained: imports and exports" U.S. Energy Information Administration (EIA), available at https://www.eia.gov/energyexplained/us-energy-facts/imports-and-exports.php ("The United States has been an annual net total energy exporter since 2019.").

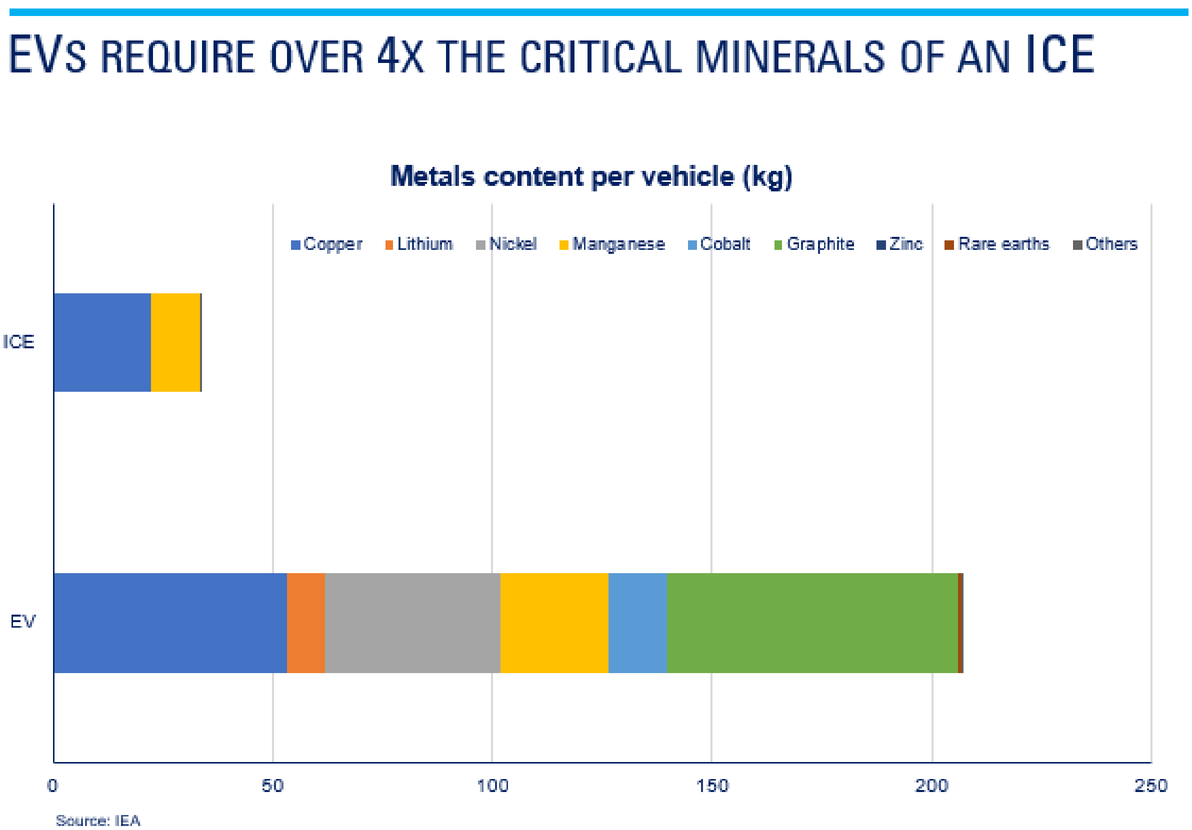
[13] Department of Energy, Pathways to Commercial Liftoff: Decarbonizing Chemical and Refining, Sept. 2023 at 1. Available at Pathways to Commercial Liftoff: Decarbonizing Chemicals & Refining (energy.gov).

[14] "Petroleum & Other Liquids – Exports" U.S. Energy Information Administration (EIA), available at https://www.eia.gov/dnav/pet/pet_move_exp_dc_NUS-Z00_mbblpd_a.htm.

[15] Department of Energy, Pathways to Commercial Liftoff: Decarbonizing Chemical and Refining, Sept. 2023 at 12. Available at Pathways to Commercial Liftoff: Decarbonizing Chemicals & Refining (energy.gov).

greater reliance on several critical minerals, as seen in Figure 1 below. There are six minerals critical to the production of ZEVs: cobalt, copper, graphite, lithium, manganese, and nickel.[16]

Figure 1: Metal intensity – ICE vs. EV[17]



The intensity of other critical minerals in the manufacturing of EVs is driven by the chemistry used in batteries. While new battery chemistries and types (*e.g.*, solid-state batteries) could potentially reduce the reliance on these critical minerals in the future, these technologies are unlikely to be commercially viable before model year (MY) 2032. Moreover, even if a new, less critical-mineral-intense battery technology emerges, EVs would still rely on sufficient copper availability for mass production of vehicles and expansion of the grid.

These minerals are essential to many components of a lower-carbon energy system beyond ZEV batteries, such as solar photovoltaic cells, wind turbines, and hydrogen electrolyzers. In addition, these minerals have multiple traditional uses, such as military defense systems, aerospace, mobile phones, computers, fiber-optic cables, semi-conductors, medical applications, and even bank notes. Without substantial increases in new raw material extraction capacity, competition for these minerals will materially stiffen with increased electrification and the shift in

[16] INTERNATIONAL ENERGY ADMINISTRATION, "The Role of Critical Minerals in Clean Energy Transitions," (revised March 2022) *available at* https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions. [hereinafter IEA Report 2022].

[17] TURNER, MASON & COMPANY. "Evaluation of EPA's Assumptions and Analyses Used in Their Proposed Rule for Multi-Pollutant Emissions Standards" (June 7, 2023) (Research funded by AFPM and available upon request) [hereinafter "Turner Mason Report"].

underlying grid energy mix. An acceleration in demand for these key minerals could result in price volatility stemming from supply disruptions and/or geopolitical pressures. It is not reasonable for NHTSA to turn its back on this issue of central relevance in the Proposal.

This new demand for foreign-sourced materials will upset the decades of progress the U.S. has made in energy security where we are currently a net exporter of petroleum and petroleum products and undermine the security provided by the domestic refining industry. Sourcing critical minerals and building a secure, North American supply chain for EVs, on the timeline required by the Proposed Rule, is not guaranteed as foreign production and processing of critical minerals have an established, large market share and competitive advantage today. The lack of a domestic manufacturing sourcing requirement for HDPUV in Inflation Reduction Act ("IRA") further promotes sourcing of foreign critical material for battery production.

NHTSA's reliance on unrealistic ZEV penetration rates in its baseline calculation and standard modeling severely overestimates both the availability of minerals and processing infrastructure and capabilities in the U.S. Regarding the availability of critical minerals, especially those essential to the manufacturing of a Li-ion battery, the supply is dominated by three lithium producing countries as summarized in Figure 2 below. Of the foreign nations that produce cobalt, molybdenum, and other minerals needed to produce BEVs, China has disproportionate influence. While 70% of global cobalt production comes from the Democratic Republic of Congo,[18] most of the mines are owned/operated by China and more than 60 percent of cobalt processing is located in China. China produces 67 percent of the world's graphite.[19] The U.S. imports most of its manganese from Gabon, a less geopolitically stable country that recently experienced a military coup,[20] providing 65 percent of the United States' supply.[21]

---

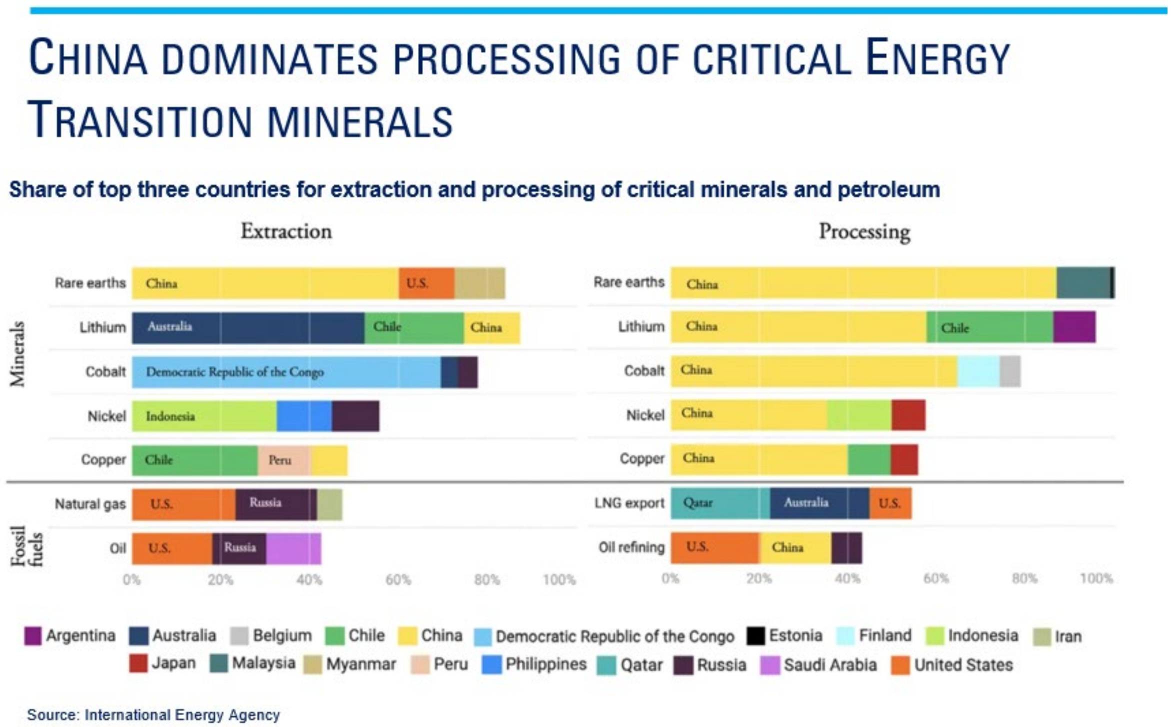
[18] International Energy Agency, *The Role of Critical Minerals in Clean Energy Transitions* (March 2022), *available at* https://iea.blob.core.windows.net/assets/ffd2a83b-8c30-4e9d-980a-52b6d9a86fdc/TheRoleofCriticalMineralsinCleanEnergyTransitions.pdf.

[19] Robinson, G.R., Jr., Hammarstrom, J.M., and Olson, D.W., 2017, Graphite, chap. J of Schulz, K.J., DeYoung, J.H., Jr., Seal, R.R., II, and Bradley, D.C., eds., Critical mineral resources of the United States—Economic and environmental geology and prospects for future supply: U.S. Geological Survey Professional Paper 1802, p. J1–J24, https://doi.org/10.3133/pp1802J.

[20] UN News, *UN chief 'firmly condemns' Gabon coup, notes reports of election abuses* (August 30, 2023), *available at* https://www.un.org/africarenewal/magazine/august-2023/un-chief-%E2%80%98firmly-condemns%E2%80%99-gabon-coup-notes-reports-election-abuses.

[21] OEC, "Manganese Ore in the United States" (Mar. 2023) *available at* https://oec.world/en/profile/bilateral-product/manganese-ore/reporter/usa.

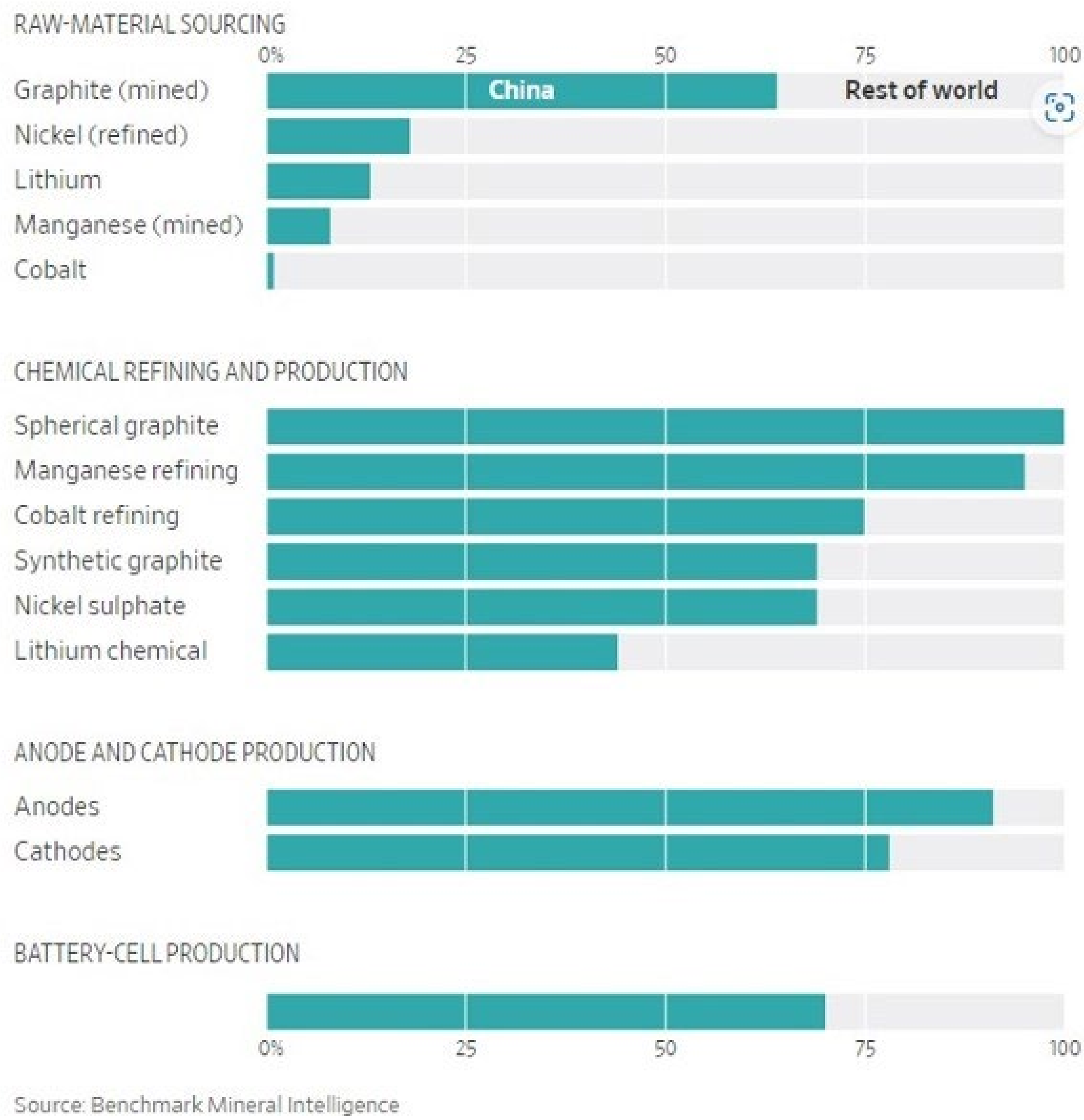
Figure 2: U.S. lack of critical mineral extraction or processing capacity



China's dominance does not stop at critical mineral extraction and processing. China produces 75 percent of all Li-ion batteries and houses the production capacity for 70 percent of cathodes and 85 percent of anodes (both key battery components).[22] Figure 3 details China's dominance of the lithium-ion battery supply chain in 2022.

[22] International Energy Agency, "Global Supply Chains of EV Batteries," (July 2022), https://iea.blob.core.windows.net/assets/961cfc6c-6a8c-42bb-a3ef-57f3657b7aca/GlobalSupplyChainsofEVBatteries.pdf.

Figure 3: China's share of the lithium-ion battery supply chain in 2022



Conversely, the U.S. currently plays a very small role in the global EV supply chain, with only 7 percent of battery production capacity.[23] In fact, Ford Motor Company announced last month that it is "pausing" construction of one of its electric battery plants in Michigan to ensure the products are price competitive.[24]

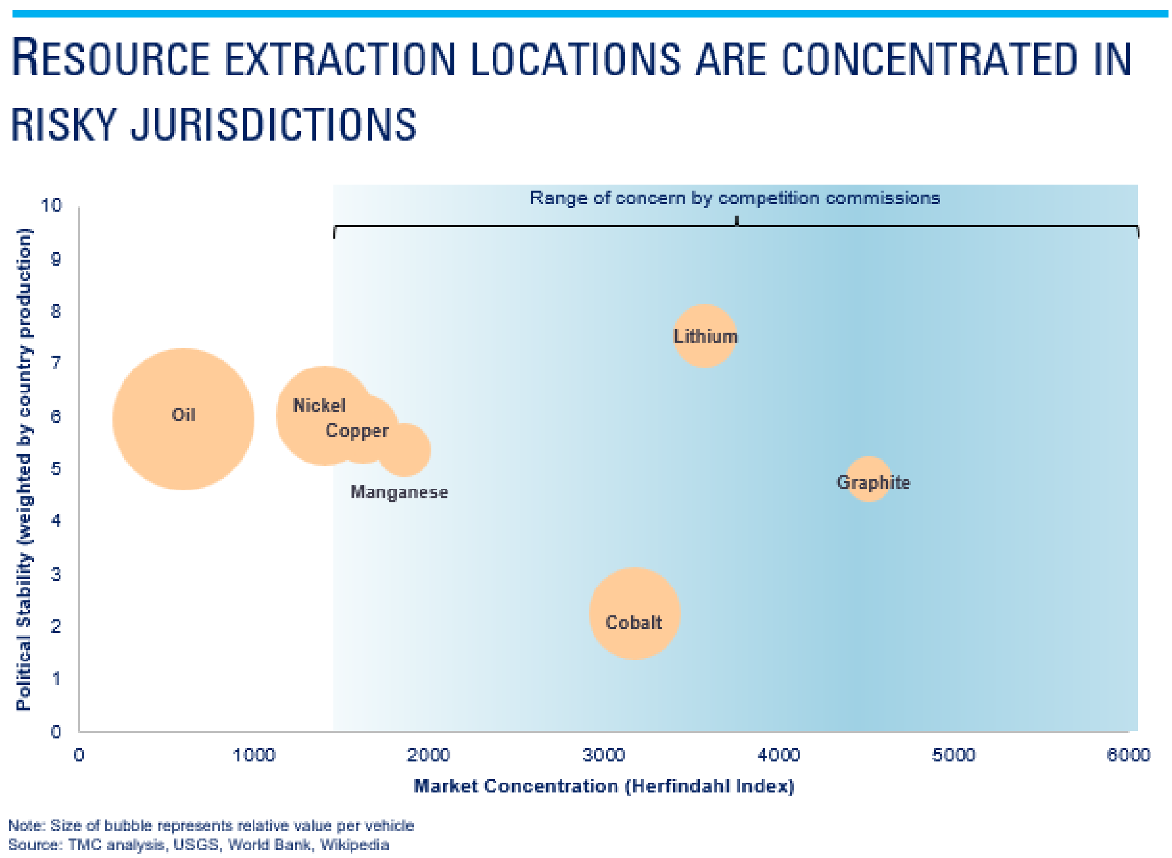
---

[23] *See id*. Regardless of recent funding awarded by the Department of Energy to construct three battery plants, the domestic supply of these critical minerals remains unchanged and, once these manufacturing facilities are permitted, constructed, and operable, they will rely heavily on foreign-sourced materials to maximize capacity and output, if even possible.

[24] Jack Ewing, Ford Halts Work on EV Battery Plant in Michigan, New York Times, Sept. 25, 2023. Retrieved from https://www.nytimes.com/2023/09/25/business/energy-environment/ford-battery-plant-michigan.html.

In contrast to oil, which has a lower global market concentration than the critical minerals required for EVs, Figure 4 below shows that the most critical materials for EVs are also in less politically stable jurisdictions. Other than lithium production which is dominated by Australia (52%), all other critical EV minerals have a political stability index less than oil. As demand for these commodities grows, the market concentration (and ability to exert power over pricing and access) swings towards producers in less politically stable countries. Producer countries having market power have the potential to impact not only price, but the ability for consumer countries to influence other issues, such as sanctity of commercial contracts, labor and/or human rights, and environmental standards in the producing jurisdictions. The significance of this issue is compounded by the fact that multiple critical minerals are needed for EV production, so a disruption in the supply of a single mineral can disable the entire supply chain. The operation of ICEVs, on the contrary, relies on a natural resource for which there is an abundant domestic supply.

Figure 4: U.S. risk exposure to critical energy resources



The invasion of Ukraine reminds governments and businesses of the importance of assessing, planning, and mitigating risks. As we have seen with Europe shifting to several new natural gas supplies (mostly through LNG receipts), supply diversification is an important way to mitigate risk. The key tenet of risk mitigation is not about removing the likelihood of a risk but about reducing its impact to an acceptable level; this is the primary justification for the U.S. holding a Strategic Petroleum Reserve. Exposing U.S. mobility to the risk of critical mineral supply availability raises an energy security question: How best does the U.S. trade risks it can mitigate for risks it cannot?

Despite the significant energy security concerns raised by increased reliance on critical minerals resulting from NHTSA's implicit EV mandate, the Proposed Rule minimizes such concerns as "emerging energy security considerations" and gives them limited and superficial consideration. NHTSA asserts that "energy security has traditionally referred to the nation's ability to reliably acquire petroleum in sufficient quantities to meet domestic demand (for gasoline, in particular), and to do so at an acceptable cost," and then observes that "[h]owever, as the number of electric vehicles on the road continues to increase, the concept of energy security is *likely* to expand to encompass the United States' ability to supply the materials necessary to build these vehicles and the additional electricity necessary to power their use."[25] NHTSA acknowledges that "the most commonly used vehicle battery chemistries include materials that are either scarce or expensive, are sourced from potentially insecure or unstable overseas sites, and can pose environmental challenges during extraction and conversion to usable material," and further that "[k]nown supplies of some of these critical minerals are also highly concentrated in a few countries and therefore face the same market power concerns as petroleum products."[26] Despite these acknowledgements, NHTSA nonetheless "does not include costs or benefits related to these emerging security considerations in its analysis for this proposed rule."[27] This omission is arbitrary and capricious.

NHTSA's assertion that the concept of energy security does not currently encompass the United States' ability to supply the materials necessary to build these vehicles is unsupported, contrary to the current realities of the vehicle battery market, and is owed no deference. As reported by the International Energy Agency,

> "[a]utomotive "lithium-ion (Li-ion) battery demand increased by about 65% to 550 GWh in 2022, from about 330 GWh in 2021, primarily as a result of growth in electric passenger car sales [ ]. In China, battery demand for vehicles grew over 70%, while electric car sales increased by 80% in 2022 relative to 2021, with growth in battery demand slightly tempered by an increasing share of PHEVs. Battery demand for vehicles in the United States grew by around 80%, despite electric car sales only increasing by around 55% in 2022. While the average battery size for battery electric cars in the United States only grew by about 7% in 2022, the average battery electric car battery size remains about 40% higher than the global average, due in part to the higher share of SUVs in US electric car sales relative to other major markets, as well as manufacturers' strategies to offer longer all-electric driving ranges. Global sales of BEV and PHEV cars are outpacing sales of hybrid electric vehicles

[25] Draft TSD Chapter 6.2.4.6 Emerging Energy Considerations, 6-58 (emphasis added).
[26] 88 Fed. Reg. at 56,254.
[27] *Id*.

(HEVs), and as BEV and PHEV battery sizes are larger, battery demand further increases as a result."[28]

The increasing global demand for vehicle batteries and the critical materials that make up those batteries is significant and will continue to expand in response to government initiatives, including, if adopted, NHTSA's proposed CAFE standards for passenger cars and light trucks and fuel efficiency standards for HDPUVs resulting in an implicit EV mandate. The concept of energy security already encompasses the United States' ability to supply these critical materials—whether NHTSA chooses to acknowledge it or not—and failing to meaningfully consider the issue at this critical juncture could result in NHTSA plunging the U.S. into dependence on foreign suppliers for these energy related materials and the inherent risks that accompany energy dependence.

In the Draft Technical Support Document (TSD) for Corporate Average Fuel Economy Standards for Passenger Cars and Light Trucks for Model Years 2027–2032 and Fuel Efficiency Standards for Heavy-Duty Pickup Trucks and Vans for Model Years 2030–2035 July 2023, NHTSA notes the geopolitical challenges related to accessing vehicle battery materials but then dilutes the risks by including additional facts and data related to other more stable aspects of the mining and processing of critical minerals. No amount of select data, however, can disguise the current reality, acknowledged by NHTSA, that "a significant share of processing for lithium is currently done in China," "China is the largest importer of unprocessed lithium," "the leading producer of refined cobalt," "one of the leading producers of primary nickel products," "one of the leading refiners of nickel into nickel sulfate, the chemical compound used for cathodes in lithium-ion batteries," and "one of the leading processors of graphite intended for use in lithium-ion batteries as well."[29] Although the Draft TSD and a handful of references acknowledge China's dominance over the critical minerals needed for EVs, the NPRM does not address or mention China in the context of "energy security considerations." [30]

[28] See the section "Trends in Batteries" from "Global EV Outlook" International Energy Agency, 2023 (internal quotations omitted). Available at Trends in batteries – Global EV Outlook 2023 – Analysis - IEA.

[29] Draft TSD, Chapter 6.2.4.6 Emerging Energy Considerations, at 6-58-6-59. Although NHTSA acknowledges that China has 65% of the global total mining production of graphite, with Mozambique following at 13%, Madagascar at 8%, Brazil at 7% and the US at 0%, NHTSA nonetheless asserts that "[o]btaining graphite for batteries does not currently pose geopolitical obstacles." *Id.* at 6-59. NHTSA does allude to potential future concerns commenting that "the U.S. International Trade Commission (USITC) notes that Turkey has great potential to become a large graphite producer, due to its large reserves shown in the final column of Table 6-26, which would make its political stability of increased larger concern," but stops short of acknowledging current market concerns. *Id.*

[30] As a harbinger of potential future market and supply manipulation by China in connection with vehicle battery materials, China recently blocked international sales of two rare minerals essential to manufacturing semiconductors – gallium and germanium – due to claimed national security concerns. Jon Emont, "China Controls Minerals that Run the World – and It Just Fired a Warning Shot at U.S.", The Wall Street Journal, July 7, 2023, available at https://www.wsj.com/articles/china-controls-minerals-that-run-the-worldand-just-fired-a-warning-shot-at-u-s-5961d77b. We also note China's apparent withholding of graphite from Sweden. As China seeks to gain market share in the European battery market, one of the most competitive firms in Europe's battery business, Northvolt of Sweden, has been largely cut off from its Chinese suppliers of graphite for the past three years. "Why is China blocking graphite exports to Sweden?", The Economist, June 22, 2023, available at https://www.economist.com/business/2023/06/22/why-is-china-blocking-graphite-exports-to-sweden.

Following the Draft TSD discussion of the vehicle battery critical materials market, NHTSA again avoids concluding that the apprehensions raised are a current energy security concern and states instead that "[t]he agency will continue to monitor these issues going forward and determine whether access to these materials constitutes a new form of energy security for which future analyses must account."[31] For the reasons explained herein, U.S. access to these materials is a form of energy security and we respectfully request that NHTSA engage in the appropriate statutory analysis for both the passenger car and light truck standards as well as the HDPUV standards, and in particular for HDPUVs for which NHTSA's determination is not prohibited from including EVs.[32] There are numerous studies and public commentary that discuss critical minerals in the context of U.S. energy security, which attest to the common sense understanding that critical minerals are a part of U.S. energy security[33] and which it would be arbitrary and capricious for the agency to ignore. Similarly, in response to NHTSA's decision to "not include costs or benefits related to these emerging energy security considerations in its analysis for this proposed rule" and NHTSA's request for "comment on whether it is appropriate to include an estimate in the analysis and, if so, which data sources and methodologies it should employ,"[34] we would have welcomed the opportunity to submit additional data if sufficient time was allotted to provide comment on NHTSA's 260+ page NPRM and 5,000+ pages of supporting documentation.

Beyond the EV itself, electricity networks need a large amount of copper and aluminum. The need for grid expansion that would result from this rapid increase in electricity demand underpins a doubling of annual demand for copper and aluminum.[35] China possesses over half of the entire world's aluminum smelting capacity. NHTSA's Proposed Rule does not consider the demand for copper. For example, recent data concludes that sourcing copper for electric infrastructure (*e.g.*, charging stations and storage) needed to accommodate increased electrical demand will be challenging.[36] Demand for copper is expected to rise by 53% when supply is

[31] Draft TSD, Chapter 6.2.4.6 Emerging Energy Considerations, at 6-60.
[32] NHTSA confirmed that "[t]he discussion about energy security effects of passenger car and light truck standards applies for HDPUVs as well." 88 Fed. Reg. at 56,352.
[33] *E.g.* Critical Minerals and the Question of Energy Security, Citigroup Inc. (June 30, 2023), https://icg.citi.com/icghome/what-we-think/global-insights/insights/critical-minerals-and-the-question-of-energy-security-; Morgan D. Bazilian, The Inflation Reduction Act Is the Start of Reclaiming Critical Mineral Chains, Foreign Policy (September 16, 2022), https://foreignpolicy.com/2022/09/16/inflation-reduction-act-critical-mineral-chains-congress-biden/; Rodrigo Castillo and Caitlin Purdy, China's role in supplying critical minerals for the global energy transition: What could the future hold?, Brookings (August 1, 2022), https://www.brookings.edu/articles/chinas-role-in-supplying-critical-minerals-for-the-global-energy-transition-what-could-the-future-hold/; Energy Security and the risk of disorderly change, IEA, https://www.iea.org/reports/world-energy-outlook-2021/energy-security-and-the-risk-of-disorderly-change (last visited Oct. 16, 2023). Indeed, according to Deputy Secretary of Energy David Turk, "American energy security and 21st century competitiveness hinge on a robust supply of critical minerals and materials," thus recognizing that critical minerals raise energy security concerns. U.S. Departments of Energy, State and Defense to Launch Effort to Enhance National Defense Stockpile with Critical Minerals for Clean Energy Technologies (February 25, 2022), https://www.energy.gov/ia/articles/us-departments-energy-state-and-defense-launch-effort-enhance-national-defense.
[34] 88 Fed. Reg. at 56,254.
[35] INTERNATIONAL ENERGY AGENCY, *The Role of Critical Minerals in Clean Energy Transitions* (March 2022), *available at* https://iea.blob.core.windows.net/assets/ffd2a83b-8c30-4e9d-980a-52b6d9a86fdc/TheRoleofCriticalMineralsinCleanEnergyTransitions.pdf.
[36] *Id.*

expected to rise by only 16%.[37] Indeed, by 2030, the expected supply from existing mines and projects under construction is estimated to meet only 80% of copper needs by 2030[38]—without even considering the supply and demand implications from increased reliance on EVs in the transportation sector.

B. Availability of North American Crude, Refining, and Biofuel capacity makes the U.S. energy-secure

Unlike critical minerals, the U.S. is the largest producer of crude oil and petroleum products in the world. We are also home to the world's largest biofuels industry.[39] Our refineries and petrochemical producers are the most competitive in the world, taking advantage of a sophisticated workforce, low-cost resources, refinery complexity, and scale to compete with even the largest state-owned enterprises in foreign markets. In 2022, the crude oil processed by U.S. refineries was 84 percent sourced from North America. The U.S. produces more crude and refined products than it consumes and became a net exporter of crude and refined petroleum products in late 2019, after being a net exporter of refined products for the past decade.[40] NHTSA's Proposal undervalues the energy security aspects of the domestic petroleum industry, particularly by failing to distinguish between sources of imported crude oil, ignoring that 70 percent and 84 percent of imported and total crude oil, respectively, is sourced from North America. The Proposal also ignores the significant pipeline connectivity between the U.S. and our North American trading partners, as well as the unique configurations of each U.S. refinery. For example, many U.S. refiners take advantage of harder to refine, less expensive heavier crude oils, which are not produced in the U.S. and must be sourced from Canada or other heavy crude producers. U.S. energy leadership means that the energy security impacts of reduced oil imports are not as significant as they historically had been. It also means that reduced U.S. demand for liquid fuels will impact U.S. oil producers as much, if not more so, than existing trading partners.

U.S. refiners are also critical suppliers of fuel to the U.S. military. In the most recent contract year, U.S. refiners provided 750 million gallons of fuel on the West Coast alone, supporting force readiness for conflict in the Pacific. NHTSA did not assess the impact of likely refinery closures on military operations and readiness.

The positive contributions of the domestic petroleum sector on U.S. energy security would have been more apparent if NHTSA had not relied on out-of-date information and flawed assumptions regarding U.S. energy production. In EIA's Annual Energy Outlook (AEO) 2023 released earlier this year, U.S. crude production is higher than 2022, as are U.S. net exports of petroleum products, petroleum consumption is lower and U.S. refining capacity is lower. These changes call into question the validity of NHTSA's estimate of the reduction in U.S. imports of crude oil that result from the Proposed Rule. The EIA confirmed that "total U.S. energy exports in

---

[37] BLOOMBERGNEF, *Copper Miners Eye M&A as Clean Energy Drives Supply* (Aug. 30, 2022), *available at* https://about.bnef.com/blog/coppers-miners-eye-ma-as-clean-energy-drives-supply-gap/#:~:text=Copper%20demand%20is%20set%20to,and%20difficulty%20developing%20greenfield%20mines.
[38] INTERNATIONAL ENERGY AGENCY, *The Role of Critical Minerals in Clean Energy Transitions* (March 2022), *available at* https://iea.blob.core.windows.net/assets/ffd2a83b-8c30-4e9d-980a-52b6d9a86fdc/TheRoleofCriticalMineralsinCleanEnergyTransitions.pdf [hereinafter IEA Report 2022].
[39] EIA, Energy Kids "Biofuel Basics" available at https://www.eia.gov/kids/energy-sources/biofuels/.
[40] EIA, "Oil imports and petroleum product explained" (Jun. 12, 2023) *available at* https://www.eia.gov/energyexplained/oil-and-petroleu m-products/imports-and-exports.php.

2022 were highest on record" and that "[t]he United States has been an annual net total energy exporter since 2019."[41] More specifically, "[i]n 2022, total petroleum exports were about 9.58 million barrels per day (b/d) and total petroleum imports were about 8.32 million b/d, making the U.S. an annual net total petroleum exporter for the third year in a row."[42] Moreover, "[t]otal petroleum net exports were about 1.26 million b/d in 2022," an increase over 2021, with imports decreasing from 8.47 million b/d to 8.32 million b/d and exports increasing from 8.54 million b/d to 9.58 million b/d.[43]NHTSA makes unsupported and overly simplistic assumptions in its attempt to assess the energy security impacts of the Proposed Rule. NHTSA asserts "[t]he proposed standards would decrease domestic consumption of gasoline, producing a corresponding decrease in the Nation's demand for crude petroleum, a commodity that is traded actively in a worldwide market."[44] NHTSA further asserts that "when U.S. oil consumption is linked to the globalized and tightly interconnected oil market, as it is now, the only means of reducing the exposure of U.S. consumers to global oil shocks is to reduce their oil consumption and the overall oil intensity of the U.S. economy. Thus, the reduction in oil consumption driven by fuel economy standards creates an energy security benefit."[45] This unsupported assumption of an energy security benefit, however, does not adequately consider the significant shift in U.S. energy exports and imports.

NHTSA acknowledges that "the nation now has a capacity to produce gasoline that considerably exceeds its current domestic consumption."[46] NHTSA further states that "this surplus of gasoline appears likely to increase in the coming years, as EIA's AEO 2022 reference case (EIA, 2022) anticipates that domestic gasoline consumption will continue to decline until nearly 2040. Thus, barring significant disinvestment in domestic refinery capacity, the United States projects to remain a net exporter of gasoline through the next several decades."[47] Moreover, NHTSA notes that [t]aken together, the forecasts of declining U.S. gasoline consumption and rising net exports of refined petroleum products reported in AEO 2022 suggest that that EIA expects the U.S. to grow as a net exporter of refined petroleum products—including gasoline—through nearly 2040."[48] Further, NHTSA's analysis "assumes that the anticipated reduction in domestic gasoline consumption is unlikely by itself to significantly affect domestic crude oil production, domestic gasoline refining, or U.S. exports and imports of crude petroleum."[49]

To support its assertion of an energy security benefit, NHTSA relies on its discussion in Chapter 6.2.4.3 of the Draft TSD and specifically that "DOT has elected to assume that changes in oil consumption caused by changes to fuel economy and fuel efficiency standards will have no impact on domestic oil production."[50] It defies reason to conclude that a *de facto* EV mandate will not affect domestic oil production. NHTSA then assumes (wrongly) that "100 percent of any

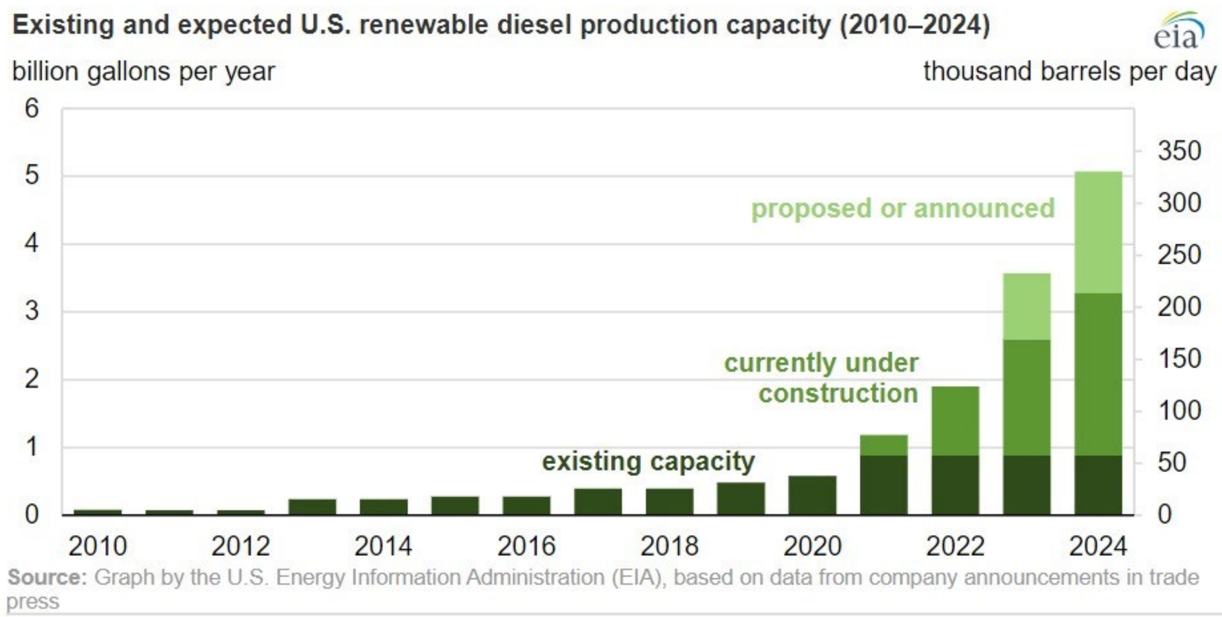
---

[41] "Oil and petroleum products explained: Oil imports and exports" U.S. Energy Information Administration (EIA), last updated August 9, 2023, available at https://www.eia.gov/energyexplained/oil-and-petroleum-products/imports-and-exports.php.
[42] *Id.*
[43] *Id.*
[44] 88 Fed. Reg. at 56,253.
[45] 88 Fed. Reg. at 56,318.
[46] Draft TSD at 6-46.
[47] Draft TSD at 6-46.
[48] Draft TSD at 6-46–6-47.
[49] Draft TSD at 6-47.
[50] Draft TSD at 6-47.

decrease in fuel consumption attributable to higher CAFE standards will be reflected in lower oil imports."[51]

NHTSA also provides little analysis of the impact of this rule on the U.S. biofuels, renewable fuels, or agricultural industries. The U.S. is the world's largest biofuels producer, yet the PRIA, the Draft TSD, and the Proposed Rule do not even mention renewable fuels. According to the U.S. Energy Information Agency (EIA), the existing US renewable diesel production capacity is expected to double by 2025.[52] Specifically, production capacity will expand from 0.6 billion gallons per year by the end of 2020 to 3 billion gallons by 2024.

Figure 5: Existing and expected U.S. renewable diesel production capacity (2010-2024)[53]



Proposed or announced projects could add 1.8 billion gal/y by 2024, bringing US renewable diesel production to a total of 5.1 billion gal/y (330,000 b/d) by the end of 2024.[54] EIA's figures exclude global biofuel production capacity and renewable diesel imports into the United States. The International Energy Agency (IEA) likewise projects the expansion of worldwide biodiesel and hydrotreated vegetable oil production capacity in critical international markets between 2019 and 2025.[55]

---

[51] Draft TSD at 6-47.
[52] *See* Energy Information Agency (EIA), Domestic renewable diesel capacity could more than double by 2025. February 3, 2023. Retrieved from https://www.eia.gov/todayinenergy/detail.php?id=55399&src=email.
[53] Energy Information Agency, US renewable diesel capacity could increase due to announced and developing projects July 29, 2021. Retrieved from https://www.eia.gov/todayinenergy/detail.php?id=48916
[54] *Id*.
[55] https://www.iea.org/data-and-statistics/charts/biodiesel-and-hvo-production-overview-for-key-globalmarkets-2019-2025.

Despite the significant investment in U.S. and global renewable diesel production capacity to increase renewable diesel production, NHTSA's analysis is devoid of any consideration of the impact of its proposed standards on the biofuel industry. Considering the implications for the renewable fuels industry, as well as the significant impact it will have on the agricultural producers that supply the industry, this glaring omission underscores the arbitrary nature of this rulemaking.

C. NHTSA should not conflict with Congressional objectives as expressed in the Energy Independence and Security Act and the Renewable Fuel Standard (RFS)

The Proposed Rule stands in direct contrast to other legislation, such as the Renewable Fuel Standard Program ("RFS"), whereby Congress mandated that "gasoline sold or introduced into commerce in the United States" must contain renewable fuels[56] and, in 2022, must include billions of gallons of renewable fuel.[57] Congress demonstrated in the RFS that when it wants to transform the transportation sector, it does so with precision and within the context of a prescribed statutory framework.

1. Proposed CAFE standards for passenger cars and light trucks and fuel efficiency standards for HDPUV discourage development and use of liquid renewable fuels

To reduce carbon emissions and ensure energy security and independence, Congress created the RFS, which requires increasing volumes of renewable fuel to be blended into transportation fuel. The four categories of renewable fuel must emit anywhere from 20 percent to 80 percent fewer GHGs relative to the fossil fuel it replaces. In response to this mandate, U.S. refineries dramatically increased renewable fuel production and invested billions of dollars to expand U.S. production of liquid renewable fuels, which can now achieve 79 to 86 percent GHG emissions reductions as compared to petroleum fuels.[58]One example is renewable diesel that is a "drop-in" fuel and can be used in the existing diesel fuel distribution system and existing diesel vehicles.

According to the Energy Information Agency's June 2023 Short-Term Energy Outlook (STEO), biomass-based diesel (which includes biodiesel and renewable diesel) production averaged 3.1 billion gallons in 2022, and EIA expects production to average 4.0 billion gallons in 2023 and 4.8 billion gallons in 2024. EIA expects ethanol and renewable oxygenate production to increase from 18.4 billion gallons in 2022 to 19.2 billion gallons in 2023, and to 20.4 billion gallons in 2024.

In response to the RFS and other government programs encouraging the production of lower carbon renewable liquid fuels, U.S. refiners are undertaking significant capital expenditures to lower the carbon intensity of fuel such as taking advantage of Congress' 45Q tax credit for carbon capture and sequestration (CCS). Ethanol producers are also looking to use CCS to reduce carbon intensity from the 15 billion gallons of ethanol blended into our nation's gasoline.[59]

---

[56] 42 U.S.C. § 7545(o)(2)(A)(i).
[57] *Id.*, § 7545(o)(2)(B); 87 Fed. Reg. 39,600 (July 1, 2022).
[58] Hui Xu, Longwen Ou, Yuan Li, Troy R. Hawkins, and Michael Wang, *Environmental Science & Technology* 2022, *56* (12), 7512-7521. DOI: 10.1021/acs.est.2c00289
[59] Erin Voegele, Carbon America to develop CCS project at Nebraska ethanol plant, Ethanol Producer Magazine, October 4, 2022 (Carbon America announced its third CCS project at a U.S. ethanol plant).

Similarly, renewable diesel and sustainable aviation fuel production capacity will total 5.1 billion gallons per year if all announced expansion projects, which represent $10.8 billion in investments, are completed.[60]

2. NHTSA should not discourage the continued decarbonization of fuels

Lifecycle assessments (LCAs) of GHG emissions from ICEVs reveal that 73 percent of lifecycle GHG emissions come from fuel combustion.[61] By comparison, lifecycle emissions from EVs occur not from fuel combustion from the vehicle, but from fuel use and various energy and material inputs upstream from the vehicle. NHTSA fails to consider that reducing the carbon intensity of liquid fuels used in ICEVs and ignoring the carbon intensity of EVs is arbitrary and capricious. It results in a highly flawed assessment of emissions.

The IEA forecasts a foundational role for refined petroleum products and liquid fuels in the coming decades, even as the global energy sector evolves.[62] The key to meeting global demand is to utilize the most efficient assets, find low-cost methods to abate carbon emissions, and utilize the expertise of the U.S. refining and petrochemical sectors in scaling energy technology. The U.S. refining and petrochemical industries are well positioned to lead the world in scaling CCS cost-effectively and utilizing clean hydrogen as part of the refining process. The 45Q tax credit in the IRA – a tax credit for stored and utilized CO_2 – and the $12 billion in federal funding to support U.S. carbon management has the potential to remove hundreds of millions of tons of CO_2 each year.[63] Similarly, the IRA's 45V hydrogen production tax credit awards up to $3 per kilogram if hydrogen is produced for projects lowering GHG carbon intensity. Several U.S. refiners are investing in low-carbon hydrogen production that can lower the carbon intensity of production and fuel transportation vehicles.

The competitiveness of the U.S. refining industry is critical in maintaining our energy security and NHTSA standards that arbitrarily shift transportation energy use from liquid fuels to electricity unnecessarily harm our energy security and limit opportunities to reduce carbon emissions.

III. THE PROPOSED CAFE STANDARDS FOR PASSENGER CARS AND LIGHT-DUTY-TRUCKS ARE UNLAWFUL

NHTSA's proposed standards for passenger cars and light-duty trucks go beyond NHTSA's statutory authority and establish standards that are neither achievable nor feasible for the industry. In proposing these unachievable standards, NHTSA ignored plain statutory language prohibiting it from considering EVs when determining maximum feasible fuel economy. Moreover, NHTSA failed to adequately weigh the four factors set forth in EPCA: technological feasibility,

---

[60] EIA, U.S. renewable diesel capacity could increase due to announced and developing projects, Today in Energy, July 29, 2021. Retrieved at https://www.eia.gov/todayinenergy/detail.php?id=48916
[61] Decarbonizing Combustion Vehicles – A Critical Part in Reducing Transportation Emissions - Transportation Energy Institute.
[62] See Marathon Petroleum Corporation, Perspectives on Climate-Related Scenarios (June 2021), at 1, available at 2021-MPC-MPLXClimateReport.pdf (marathonpetroleum.com).
[63] Department of Energy, The Pathway to: Carbon Management Commercial Liftoff, undated. Accessed Carbon Management - Pathways to Commercial Liftoff (energy.gov)https://liftoff.energy.gov/carbon-management/.

economic practicability, the effect of other motor vehicle standards of the Government on fuel economy, and the need of the United States to conserve energy.

A. NHTSA is prohibited from considering the fuel economy of electric vehicles when determining the maximum feasible fuel economy standards for passenger cars and light-duty trucks

EPCA expressly provides that NHTSA "may not consider" the fuel economy of electric vehicles and dual-fueled vehicles, in setting fuel-economy standards for passenger cars.[64] Section 32902(h)(1)'s text is plain: it provides that in "carrying out" the responsibility to set fuel-economy standards, NHTSA "may not consider" the fuel economy of electric vehicles.[65] Moreover, NHTSA cannot consider the fuel economy of PHEVs when operated on electricity.[66] Congress included this explicit prohibition to ensure that electric vehicles remain the compliance flexibility that Congress intended them to be—and do not become a technology-forcing regulatory mandate. The Act does not define "consider," so that word must be "interpreted as taking [its] ordinary, contemporary, common meaning at the time Congress enacted the statute."[67] In 1988, as today, to consider meant to "take into account."[68] So Section 32902(h)(1) bars NHTSA from taking into account electric vehicles' fuel economy in setting standards.

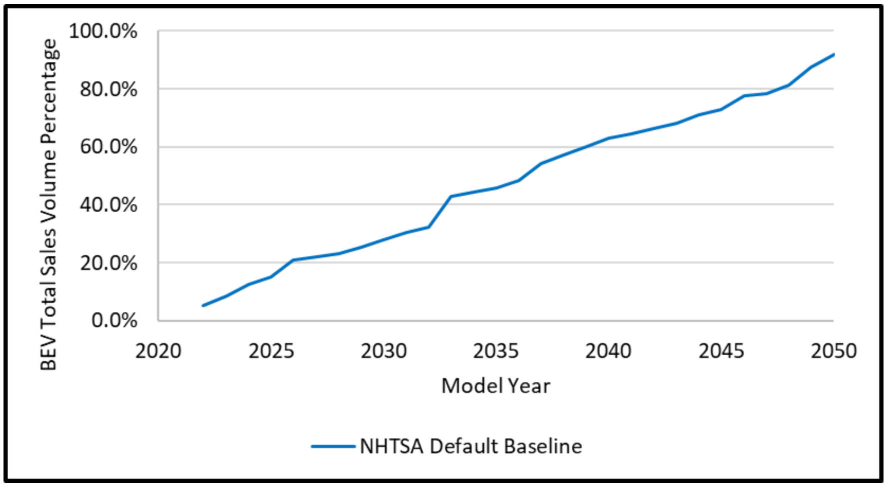
NHTSA seeks to evade EPCA's clear statutory prohibition by introducing extratextual exceptions to its reach. Specifically, the agency interprets 49 USC § 32902(h) as "preventing NHTSA from setting CAFE standards that effectively require additional application of dedicated alternative fueled vehicles in response to those standards, not as preventing NHTSA from being aware of the existence of dedicated alternative fueled vehicles that are already being produced for other reasons besides CAFE standards."[69] NHTSA further asserts that "Modeling the application of BEV technology in MYs outside the standard-setting years allows NHTSA to account for BEVs that manufacturers may produce for reasons other than the CAFE standards, without accounting for those BEVs that would be produced because of the CAFE standards."[70] This reading conflicts with the unambiguous statutory text and would defeat Congress's intent to ensure that electric vehicles remain an option for compliance flexibility and do not become a regulatory mandate.

Despite that clear prohibition, NHTSA openly considered electric vehicles—including those currently in the fleet and EVs the agency predicted would be produced in response to California's and other States' zero-emission-vehicle mandates and EPA's prior greenhouse-gas

[64] 49 U.S.C. § 32902(h)(1) and 32902(h)(2) (NHTSA shall consider dual-fueled vehicles, such as PHEVs "to be operated only on gasoline or diesel fuel.").
[65] 49 U.S.C. § 32902(h)(1).
[66] 49 U.S.C. § 32902(h)(2).
[67] *Guedes v. Bureau of Alcohol, Tobacco, Firearms & Explosives*, 45 F.4th 306, 315 n.3 (D.C. Cir. 2022).
[68] American Heritage Dictionary 313 (2d ed. 1985); *see also* Random House Dictionary of the English Language 434 (2d ed. 1987) ("to think carefully about, esp. in order to make a decision"); Funk & Wagnalls New International Dictionary of the English Language 287 (1984) (to "make allowance for"); Black's Law Dictionary 306 (6th ed. 1990) (to "give heed to").
[69] *Id.*
[70] *Id.*

standards—in deciding the maximum fuel-economy level that automakers can feasibly achieve.[71] As proposed, the standards are not feasibly achievable by ICEVs and as demonstrated in Figure 6 below, effectively establish an electric vehicle mandate.

Figure 6: NHTSA Baseline BEV Assumptions[72]



The statutory directive includes no qualifications or carveouts. Instead, Congress used mandatory language: "may not consider."[73] Such language "indicates a command that admits of no discretion on the part of the person instructed to carry out the directive."[74] In other words, Congress forbade NHTSA to account for the fuel economy of any electric vehicle, from any model year, for any purpose when setting fuel-economy standards. No exceptions—full stop.[75]

NHTSA's contrary reading improperly adds words to the statute that distort its meaning. In effect, NHTSA reads Section 32902(h)(1) as if it provided that NHTSA "may not consider" the fuel economy of electric vehicles unless the electric vehicles are not produced solely to comply with NHTSA's standards in the model years at issue in the rulemaking (i.e., the "standard setting years"). That is, NHTSA believes that it may consider the fuel economy of some electric vehicles, so long as its standards are not forcing the manufacture of those vehicles in the model years covered by its rule. But "[t]he subsection's text contains no limiting term that restricts its reach" in this way.[76] And NHTSA is not free to "supply words ... that have been omitted."[77] "By introducing

[71] "NHTSA has not taken the additional step of removing BEVs from the baseline fleet, and we continue to assume that manufacturers will meet their California ZEV obligations whether or not NHTSA sets new CAFE standards. We reflect those manufacturer efforts in the baseline fleet." 88 Fed. Reg. 56,319.
[72] Trinity Consultants, Review of NHTSA's Proposed CAFE Standards for Mys 2027-2032 Passenger Cars and Light Trucks and Fuel Efficiency Standards for MYs 2030-2035 Heavy-Duty Pickup Trucks and Vans. October 16, 2023. Hereinafter "Trinity Technical Review." and included as Appendix B.
[73] *See United States v. Palomar-Santiago*, 141 S. Ct. 1615, 1620-21 (2021) ("may not" is "mandatory language").
[74] *Ass'n of Civilian Technicians, Mont. Air Chapter No. 29 v. FLRA*, 22 F.3d 1150, 1153 (D.C. Cir. 1994).
[75] *See Freytag v. Comm'r*, 501 U.S. 868, 874 (1991) ("[C]ourts 'are not at liberty to create an exception where Congress has declined to do so.'" (quoting *Hallstrom v. Tillamook Cnty.*, 493 U.S. 20, 27 (1989))).
[76] *Id.* at 873-84.
[77] Antonin Scalia & Bryan Garner, Reading Law: The Interpretation of Legal Texts 93 (2012); *see Bates v. United States*, 522 U.S. 23, 29 (1997) ("[W]e ordinarily resist reading words or elements into a statute that do not appear on its face.").

a limitation not found in the statute," NHTSA "alter[s], rather than ... interpret[s]" Section 32902(h)(1).[78] However, for reasons that are utterly opaque and contrary to its stated reason for including EVs in the baseline, NHTSA complies with Section 32902(h)(2)'s matching requirement by considering dual-fueled vehicles (e.g., plug-in hybrid electric vehicles or (PHEVs)) to operate *only* on gasoline or diesel fuel and *excluded* from the baseline the electric portion of PHEV operation. There is absolutely no reason why NHTSA should apply Section 32902(h)(1) differently than Section 32902(h)(2) as both contain unambiguous directives to exclude vehicles running on electricity from the baseline.

NHTSA chiefly argued that it must consider EVs in order to develop a baseline "that represents the world in the absence of further regulatory action" and to ignore them would create an "artificial baseline that pretends that dedicated alternative fueled vehicles do not exist."[79] NHTSA relies on "OMB Circular A-4"—a regulatory guidance document that does not distinguish among specific agencies—to support this proposition.[80] This argument is wrong from beginning to end, as the Circular never condoned a baseline contrary to the law.

To begin with, it ignores that NHTSA did not consider only the fuel economy of electric vehicles in the "analytical baseline" that supposedly reflects the "reality" that would exist regardless of whether NHTSA increased the standards. That is unlawful on its own—but NHTSA also included in the model the fuel economy of additional electric vehicles that manufacturers would introduce, irrespective of the CAFE standard, during the standard setting years MY2027-2032. NHTSA's argument also ignores that the "analytical baseline" does not reflect "reality" for all manufacturers. A baseline that includes the electric vehicles of manufacturers that chose to use them as a compliance mechanism or to cater to a particular type of consumer does not reflect the "reality" of manufacturers that chose different compliance options and focused on different market segments.

Likewise, NHTSA relies on ZEV penetration rates pursuant to California's Advanced Clean Cars II ("ACC II") rulemaking in both the baseline and standard setting years. As discussed in Sections III.A.2 and III.A.3 below, elimination of EVs resulting from the ACC II regulations, which have yet to receive EPA approval, considerably reduced the fuel economy of the light-duty fleet. However, many automakers will likely not meet the ACC II ZEV penetration rates and will instead rely on credits or payment of fines to comply with CAFE within the timeframe of the Proposal. These unrealistic and unsubstantiated electric vehicle penetration rates do not reflect the "reality" of the industry.

In all events—to state the obvious—an Office of Management and Budget Circular cannot trump a statute. Whenever Congress directs an agency not to consider a certain factor, it is presumably requiring the agency to exclude an aspect of "reality" from its analysis—if the factor were not "real," there would be no need to direct the agency to disregard it. Congress may have

---

[78] *Little Sisters of the Poor Saints Peter & Paul Home v. Pennsylvania*, 140 S. Ct. 2367, 2381 (2020).
[79] 88 Fed. Reg. 56,319.
[80] *Id.*

good reasons for deciding that a factor that is "real" nevertheless is not relevant to the task at hand.[81]

That is precisely what Congress did here when, to protect the incentives it created, Congress decided that NHTSA "may not consider the fuel economy of dedicated automobiles."[82] It in no way defies "reality" to require NHTSA to continue setting fuel-economy standards based on what is achievable for ICEVs, while creating incentives for alternative-fuel vehicles. NHTSA may not like that policy choice, but it "may not rewrite clear statutory terms to suit its own sense of how the statute should operate."[83] Section 32902(h)(1) reflects a congressional judgment that the Act should give manufacturers the flexibility and incentive to produce alternative-fuel vehicles, but should not impose a de facto mandate by setting standards that presume that manufacturers will produce those vehicles. That judgment was "hardly irrational."[84] NHTSA may prefer a different policy that allows it to pursue its electrification goal, but "[i]f policy considerations suggest that the current scheme should be altered, Congress must be the one to do it."[85]

1. NHTSA improperly included EVs in the baseline and standard modeling.

When NHTSA considered the statutory factors set forth in Section 32902(f), it repeatedly relied on the modeling results of a fleet that included EVs. NHTSA did not explain why it would have (or reasonably could have) found that the proposed standards are the maximum feasible standards that manufacturers can achieve in model years 2027-2032 without EVs, as Section 32902(h)(1) requires. Nor did it provide any modeling to show how a fleet could comply with the final standards without any EVs and the high imputed fuel economy they contribute to the average fuel economy of the fleet.

In developing the baseline calculation and modeling for the Proposed Rule, NHTSA improperly considered the fuel economy of EVs.[86] This results in an inflated baseline and No Action scenario that ripples through to inappropriately inflate the alternatives evaluated and proposed standards. NHTSA's baseline calculation is premised on unrealistic and unsubstantiated assumptions regarding ZEV penetration rates, thereby causing the proposed standards in years following the baseline to carry through these faulty assumptions. NHTSA's reliance on this prohibited factor makes compliance with the proposed standards appear more technologically feasible and economically practicable than it actually is. In doing so, NHTSA violated Section 32902(h)(1).

Trinity Consultants evaluated the impact of eliminating ZEVs in CAFE modeling.[87] As shown in the figures below, the baseline fleet fuel economy (passenger and light truck) is

[81] *See*, *e.g.*, 49 U.S.C. § 41734(h) (directing Secretary of Transportation to determine "basic essential air service" without considering "slot availability" at high-density airports); 42 U.S.C. § 300gg-111(c)(5)(D) (directing arbitrators not to consider certain prices in determining reimbursement rates for healthcare services); 16 U.S.C. § 808(d)(1) (directing the Federal Energy Regulatory Commission not to consider adequacy of transmission facilities).
[82] 49 U.S.C. § 32902(h)(1).
[83] *Util. Air Regul. Grp. v. EPA*, 573 U.S. 302, 328 (2014).
[84] *See Landstar Express Am. v. Fed. Mar. Comm'n*, 569 F.3d 493, 499 (D.C. Cir. 2009) (Kavanaugh, J.).
[85] *Intel Corp. Inv. Policy Comm. v. Sulyma*, 140 S. Ct. 768, 778 (2020).
[86] TSD at 3-65 to 3-84.
[87] Appendix B Trinity Technical Review at 4.

dramatically lower than the NTHSA baseline when ZEVs are excluded. The exclusion of ZEVs from the baseline would have resulted in substantially lower fuel economy than the proposed CAFE standards.

Figure 7: Impact of Eliminating ZEVs on NHTSA's Baseline Fleet Fuel Economy – 2027 to 2032

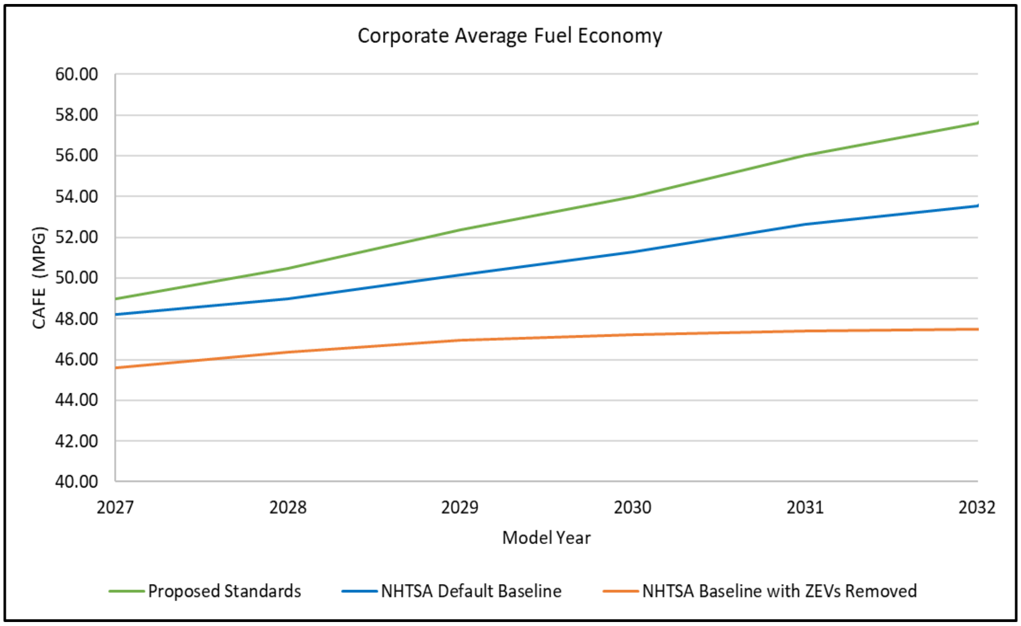
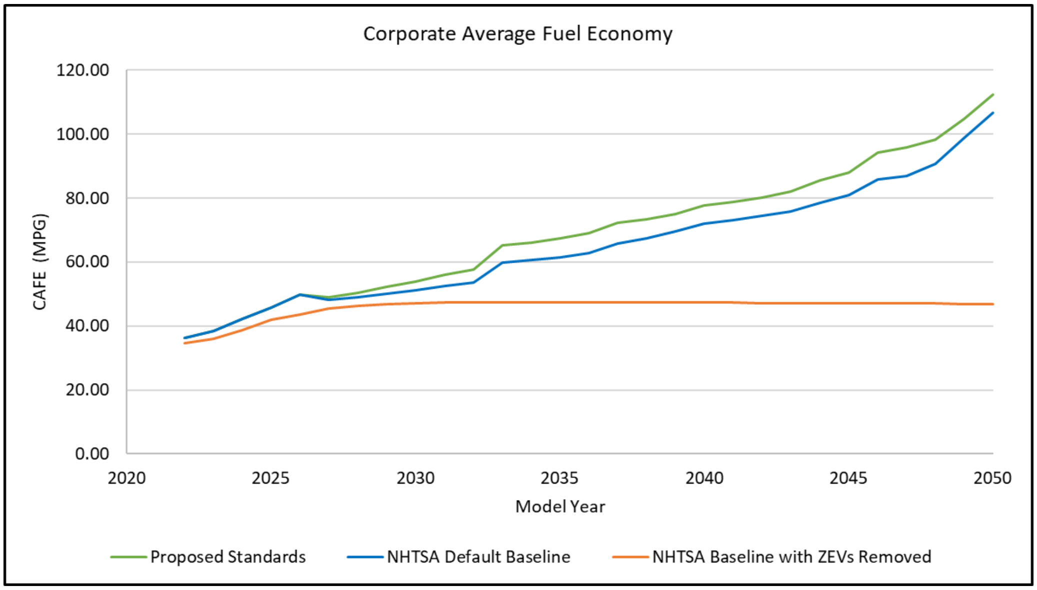


Figure 8 below shows the same data as above and extended to 2050. As Trinity Consultants points out, the modeled reduction in the rate of light duty fuel economy in 2027 to 2032 "implies that there doesn't appear to be a real need for the proposed CAFE standards as the fuel economy of the light-duty fleet is forecast to skyrocket post 2032 based on the assumptions NTHSA has incorporated into the CAFE model."[88]

[88] *Ibid.*

Figure 8: Impact of Eliminating ZEVs on NHTSA's Baseline Fleet Fuel Economy – 2022 to 2050



NHTSA's proposed fuel-economy standards are based on a projected baseline fleet that includes EVs that NHTSA predicted automakers would produce even if NHTSA did not impose more stringent fuel economy standards in model years 2027-2032. Specifically, NHTSA's No Action Alternative assumes:

- The existing national CAFE and GHG standards are met, and that the CAFE and GHG standards for MY 2026 finalized in 2022 continue in perpetuity
- Manufacturers who committed to the California Framework Agreements met their contractual obligations for MY 2022
- The HDPUV MY 2027 standards finalized in the Phase 2 program continue in perpetuity
- Manufacturers will comply with the ZEV/ACC2/ACT standards that California has adopted, and other states have agreed to follow through 2035
- Manufacturers will make production decisions in response to estimated market demand for fuel economy or fuel efficiency, considering estimated fuel prices, estimated product development cadence, the estimated availability, applicability, cost, and effectiveness of fuel-saving technologies, and available tax credits
- NHTSA's estimates of ways that each manufacturer could introduce new PHEVs and BEVs in response to state ZEV mandates.[89]

In each case, NHTSA violated section 32902(h)(1)'s unambiguous command not to "consider the fuel economy" of electric vehicles when setting fuel-economy standards for

[89] 88 Fed. Reg. 56,259.

passenger cars and light-duty trucks. In practice, this results in proposed standards that simply cannot be achieved without the use of EVs.

2. NHTSA's ZEV penetration assumptions in the baseline and standard modeling are overly optimistic.

Even if NHTSA were permitted to consider EVs in its analysis (which it is clearly statutorily prohibited from doing), its assumptions are not realistic. NHTSA's assumption that automakers will comply with existing Federal CAFE and GHG standards as well as California's aggressive ACC II and ACT standards are unrealistic. Manufacturers have already indicated that compliance with these programs is challenging and, for many, unlikely.[90] Many manufacturers will have to rely on compliance flexibilities, such as the use of credits, or the payment of civil penalties.

In particular, NHTSA's assumptions regarding ZEV penetration rates stemming from California's ZEV regulations and adoption by Section 177 states are faulty and misplaced. NHTSA considered California's ACC I (LD ZEV requirements through MY 2025), ACC II (LD ZEV requirements from MYs 2026-2035), and Advanced Clean Trucks (ACT) (trucks in classes 2b through 8 for MYs 2024-2035) in the modeling analysis of compliance pathways. Without any apparent consideration of compliance data, NHTSA asserts it is "confident" that "manufacturers will comply with the ZEV programs because they have complied with state ZEV programs in the past and they have made announcements of new ZEVs demonstrating an intent to comply with the requirements going forward."[91] Additionally, NHTSA argues that modeling compliance with these programs accounts for "technology improvements that manufacturers would make even in the absence of CAFE standards", which "allows NHTSA to gain a more accurate understanding of the effects of the proposed rulemaking."[92] However, these compliance considerations are unrealistic and overly optimistic.[93]

As a threshold issue, ACC I, ACC II, and ACT are preempted by federal law. EPCA preempts states from adopting or enforcing any regulation "related to" fuel-economy standards, regardless of any accompanying localized pollution benefits. This provision is self-executing, meaning no agency action is necessary for it to be effective. Moreover, Congress did not authorize NHTSA or EPA to waive this preemption provision. ACC I and ACC II are clearly related to fuel-economy standards. Courts have found that state regulations "relate [] to" federal matters when they have a "connection with" or contain a "reference to" these matters.[94] Indeed, because carbon dioxide emissions are "essentially constant per gallon combusted of a given type of fuel," the fuel

---

[90] Alliance for Automotive Innovation, Comments to the Environmental Protection Agency, Multi-Pollutant Emissions Standards for Model Years 2027 and Later Light-Duty and Medium-Duty Vehicles, Proposed Rule, Docket No. EPA-HQ-OAR-2022-0829 (hereinafter AAI Comments) at 1-60, and 66-70.

[91] 88 Fed. Reg. at 56,176.

[92] *Id.*

[93] NHTSA similarly chose to account for the Department of Energy's ("DOE") proposed new petroleum equivalency factor ("PEF") in its calculations for the Proposed Rule. Under DOE's proposal, the fuel economy value of electric vehicles would be significantly less when using the proposed new PEF than the value achieved under the current/existing PEF. By accounting for the current/existing PEF in the baseline calculation (which gives a significantly higher fuel economy value to electric vehicles) but using the new proposed PEF beginning in MY 27 during the standard setting years, NHTSA inflates the baseline fuel economy value from which the proposed standards are developed. This effectively makes NHTSA's proposed standard appear more technologically feasible than it actually is.

[94] *See e.g.*, *California Restaurant Association v. City of Berkeley*, (9th Cir. April 17, 2023).

economy of a vehicle and its carbon-dioxide emissions are two sides of the same coin.[95] Accordingly, "any rule that limits tailpipe [greenhouse gas] emissions is effectively identical to a rule that limits fuel consumption."[96] Any proposed rule establishing ZEV mandates (and thus de facto average fuel economy standards) impedes NHTSA's ability to establish fuel economy standards that satisfy EPCA's requirements.[97]

ACC I and ACC II are also expressly preempted by the Clean Air Act (CAA), which provides that "No State or any political subdivision thereof shall adopt or attempt to enforce any standard relating to the control of emissions from new motor vehicles . . . ."[98] Unlike EPCA, EPA may grant California a preemption waiver under the CAA under certain conditions.[99] Before a waiver can be granted, the CAA requires EPA to evaluate California's waiver request to ensure that California did not arbitrarily determine that it needs "ZEV mandates" to address compelling and extraordinary circumstances.[100] ACC I is subject to an active legal challenge pending before the D.C. Circuit,[101] and EPA has not determined whether it will grant a waiver for ACC II; therefore NHTSA cannot rely on ACC II in the development of its baseline or proposed standards. Moreover, because California concedes that ACC II will not meaningfully address the impacts of climate change in California and ACC II will slow fleet turnover and retard California's progress toward meeting the NAAQS, California cannot demonstrate that it "needs" the waiver and ACC II is therefore preempted. NTHSA's reliance on ACC II in its analysis and standard setting is pre-decisional and inappropriate.

Even if NHTSA were permitted to rely on ZEV penetration assumptions from California's ZEV mandates, NHTSA's compliance assumptions are faulty. NHTSA asserts that "[t]he CAFE Model brings manufacturers into compliance with ACC II and ACT first in the baseline, solving for the technology compliance pathway used to meet increasing ZEV standards."[102] Further, NHTSA "did not assume compliance with ZEV requirements through banking of credits when simulating the program in the CAFE Model and focus instead on simulating manufacturer's compliance fully through the production of new ZEVs."[103] These assumptions are simply unrealistic – automakers have already indicated that the penetration rates required under these programs are unachievable. Many automakers will rely on the use of credits in their compliance planning, and many may also be forced to pay penalties for non-compliance in years where ZEV penetration rates are not met, and credits are unavailable or too expensive. NHTSA concedes in the proposal: "while it looks like manufacturers are falling short of required fuel economy levels in the light truck fleet (and choosing instead to pay civil penalties), NHTSA notes that this appears to be the result of a relatively small number of companies, which affects the overall average achieved levels.[104]

[95] 75 Fed. Reg. at 25,324, 25327 (May 7, 2010).
[96] *Delta Constr. Co. v. EPA*, 783 F.3d 1291, 1294 (D.C. Cir. 2015).
[97] See AFPM Comments to EPA Notice of Proposed Rulemaking: Multi-Pollutant Emissions Standards for Model Year 2027 and Later Light-Duty and Medium-Duty Vehicles, EPA-HQ-OAR-2022-0829-0714 at 25.
[98] 49 U.S.C. § 7543(a).
[99] *Id. at* § 7543(b).
[100] 42 U.S.C. 7543(b)(1)(B).
[101] *Ohio v. EPA*, D.C. Cir. No. 22-1081.
[102] 88 Fed. Reg. 56,176
[103] *Id.*
[104] EPCA requires NHTSA to set standards at a "maximum feasible" level based on four underlying statutory factors. NHTSA's acknowledgement that manufacturers inability to meet the standards based on technological improvements to vehicles' liquid fuel economy and NHTSA's own predicted compliance

The agency's overall assessment is that the light truck standards are maximum feasible even though they may be challenging for some individual companies to achieve."[105] NHTSA admits it considered the use of credits as a compliance pathway in its modeling for prior rulemakings, but declines to do so here simply because of the "complicated nature of accounting for the entire credit program."[106] NHTSA cannot ignore this viable and necessary compliance pathway simply because it is complicated. Nor can it ignore the reality that many automakers may simply be unable to comply with the ZEV penetration requirements of these programs, even with the credit compliance pathway available, which is itself evidence the standards are infeasible.

NHTSA also makes factually inaccurate assumptions about the number of states that have adopted or are planning on adopting California's ZEV programs. For "ease of modeling", NHTSA incorrectly includes "every state that officially committed to adopting the requirements by the start of December 2022 (regardless of MY start date) . . . as being part of the unified ACC II states group . . . ."[107] Additionally, NHTSA "consider[s] all ACC II states together and do[es] not model specific states' years of joining."[108] NHTSA falsely assumes that 17 states have adopted the California ZEV mandate and models compliance of all 17 states with the ZEV mandate for every year of its compliance modeling.[109] However, NHTSA overestimates the states that have actually adopted ACC II[110] and does not accurately account for states that have indicated they will adopt the program for only portions of the relevant program period. As a threshold issue, these assumptions should not be necessary in NHTSA's rulemaking in the first place, considering NHTSA's statutory prohibition from considering such vehicles. However, if NHTSA nonetheless considers EVs it must do so carefully and accurately. NHTSA instead adds an inflated assumption of 177 states (e.g., Pennsylvania has not adopted the ZEV mandate provisions on ACC I, and has not publicly indicated any plans to adopt ACC II) on top of an already inflated assumption that these penetration rates will be met without the use of any flexibilities, including credit banking and trading. These assumptions are inaccurate, and only serve to make NHTSA's proposed standards look feasible when they truly are not.

3. Removing the improperly included ZEVs from NHTSA's baseline and standard setting years renders NHTSA's Proposal infeasible.

NHTSA's inclusion of EVs in both the baseline and the standard-setting years is critical to its determination regarding whether the proposed standards are feasible or not. Without the inclusion of EVs in the baseline and standard setting analysis, it is all but certain that NTHSA would find a lower proposed standard is the maximum feasible. Indeed, even with significant levels of ZEV penetration assumed, NHTSA's Compliance Report indicates a majority of automakers will not be able to comply with NHTSA's proposal.

---

challenges that will lead to civil penalties that will increase vehicle prices demonstrate that the proposed rule exceeds the maximum feasible standard requirement set forth in EPCA.

[105] 88 Fed. Reg. 56,137.

[106] *Id.*

[107] 88 Fed. Reg. 56,177.

[108] *Id.*

[109] 88 Fed. Reg. at 56,177, n.153.

[110] NHTSA incorrectly assumes that an additional sixteen (16) Section 177 states will implement ACC II—when some states, including Virginia and Pennsylvania, have not initiated a rulemaking process to adopt the standard.

As reflected in Figure 7 and Figure 8 above and discussed in Section III.A.1, removing ZEVs from NHTSA's baseline and standard setting years results in a substantially lower baseline fleet fuel economy. Moreover, using the statutorily compliant lower baseline results in a substantially larger required fuel economy increase to achieve NHTSA's proposed CAFE standards. Using the statutorily compliant "no-ZEV" baseline resulting in the substantially larger required fuel economy increase renders NHTSA's proposed standards infeasible and undermines NHTSA's determination that its proposed standards are the "maximum feasible."[111]

The impracticability of NHTSA's proposed standards is further reflected in Figure 9 below, showing the number of manufacturers estimated to be able to comply with the proposed standards in 2027-2032 when ZEVs are removed from the baseline and standard setting years. An analysis of the substantial fuel economy increase required to achieve the Proposed Rule when a statutorily compliant "no-ZEV" baseline is used, reveals that only one manufacturer would be able to comply with NHTSA's proposed CAFE standards in 2027-2032.[112]

B. The proposed standards are unachievable and do not establish the maximum feasible average fuel economy

In determining what level of average fuel economy is the "maximum feasible," there are certain factors NHTSA "shall consider" and other factors NHTSA "may not consider." NHTSA "shall consider": (i) "technological feasibility," (ii) "economic practicability," (iii) "the effect of other motor vehicle standards of the Government on fuel economy," and (iv) "the need of the United States to conserve energy."[113] As described in more detail below, NHTSA has not properly considered these statutorily prescribed factors. By increasing standards beyond the capabilities of the fleet of internal combustion engines demanded by consumers, NHTSA departs from Congressional intent to set maximum feasible fuel economy standards based on the statutory factors set forth in EPCA. This results in a Proposal that is misaligned with reality. The Proposed Rule amounts to a *de facto* electric vehicle mandate, ultimately requiring automakers to drastically transition their fleets from ICEVs to EVs in the MY27–32 timeframe without demonstrating that such a transition is feasible.

NHTSA's Proposal goes well beyond not only its statutory authority but also beyond reason and logic. The Proposed Rule increases reliance on imported critical minerals and metals for battery production and grid expansion that could have serious negative consequences for our energy and national security. The supply chain for key minerals needed to produce electric vehicle batteries is not assured and will require dramatic increases to meet expected demand. The extraction and processing of battery critical minerals is concentrated in politically unstable or unfriendly nations. Domestic copper and aluminum smelting capacity is insufficient to meet grid expansion needs, and new mines can take over a decade to increase domestic supply. The deployment timeline necessary to develop new resources for batteries and the grid is impracticable and presents unnecessary risks to our energy and economic security. In contrast, domestically consumed liquid fuels sourced from petroleum and bio feedstocks are largely sourced in North America, and the U.S. benefits from its position as a net exporter of petroleum

---

[111] Appendix B Trinity Technical Review at 4.
[112] Appendix B Trinity Technical Review at 5. Trinity notes that two manufacturers are excluded from its count of non-compliant manufacturers given that they exclusively sell electric vehicles and thus have zero sales in the no-ZEV case.
[113] 49 U.S.C. § 32902(f).

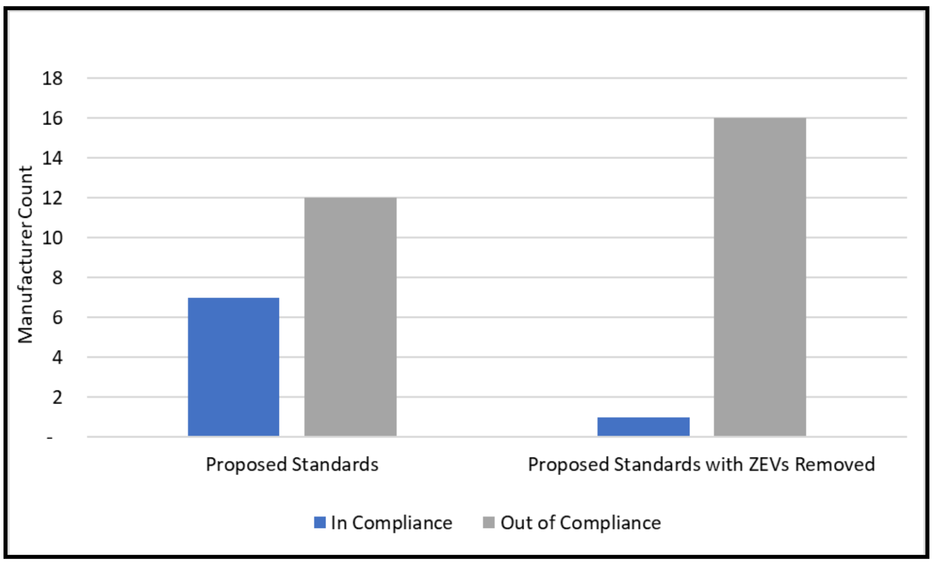
and refined product exports. Moreover, the Proposed Rule would serve to further increase vehicle costs and reduce consumer choice. In sum, NHTSA consistently skews its analysis in favor of its preferred technology—EVs, effectively ignoring or downplaying the significant associated costs and challenges.

1. The proposed standards are not technologically feasible

NHTSA failed to demonstrate that production of EVs at the assumed penetration rates in the timeline of the Proposed Rule is technologically feasible. NHTSA's online data portal for CAFE compliance data shows several major automakers with negative credit balances as of 2017 reporting data, with significantly greater shortfalls predicted for 2019.[114] This data shows that even under less stringent standards, automakers were unable to comply without relying upon credits. Manufacturers are struggling to meet existing standards, and NHTSA has not demonstrated they can meet more stringent standards.

Using the CAFE model, Trinity Consultants evaluated the number of auto manufacturers projected to be compliant with the proposed standards.[115] As Figure 9 below shows, a significant majority of automakers will be out of compliance, and if ZEV assumptions are removed, only a single manufacturer would meet the proposed standards.

Figure 9: Regulatory Compliance Manufacturer Counts from the NTHSA and No-ZEV Baselines During the Standard Setting Years



NHTSA's analysis fails to address the lack of sufficient critical minerals needed to produce EV batteries and expand the electrical grid and charging infrastructure in the timeline of the Proposed Rule. EV production simply cannot achieve the assumed levels given the current material and supply chain constraints, which are unlikely to abate during the standard setting years. Further, the infrastructure necessary to operate such vehicles is critically important to increased EV adoption. NTHSA overlooks this issue in the Proposed Rule. NHTSA fails to demonstrate that sufficient charging stations, utilities, and other infrastructure needed to support

---

[114] NHTSA, MY 2011-2019 Credit Shortfall Report, October 15, 2019.
[115] Appendix B Trinity Technical Review at 6.

accelerated EV implementation will be available by the time of the Proposed Rule. As engine manufacturers have acknowledged, even as new EVs are ready to enter into production, the necessary infrastructure for electric vehicles continue to lag, especially when multiple facilities are needed to support these different fuel and powertrain technologies.[116] NHTSA has not adequately evaluated or grasped the time and resources required to permit, construct, and operate the necessary infrastructure to power these vehicles. This is particularly concerning in light of the very real risk that the electric grid will not be able to meet the increased demand anticipated by the Proposed Rule.[117]

a) Scarce supplies of critical minerals will prevent sufficient production of EV batteries to meet this EV mandate.

NHTSA relies on unsubstantiated and unrealistic EV penetration rates in its baseline calculation and modeling. In doing so, NHTSA fails to fully account for the challenges associated with creating and sustaining a viable domestic supply chain that can deliver the production-ready batteries necessary to meet the assumed pace of electrification. In fact, insufficient mineral availability, processing and manufacturing, and overall costs pose significant, if not insurmountable, impediments to a viable domestic supply chain.

Current domestic production of critical minerals required for battery production is insufficient to meet the projected demands. According to a review of multiple sources, there is a six-fold demand growth expectation by 2030 and approximately 15 times by 2040. This growth rate outpaces the market's ability to supply such minerals. These minerals are not available today, mining capacity cannot be increased as quickly as required to meet the assumed rate of production, and at-scale recycling capabilities will not be available in the foreseeable future. As described in Section III.B.1.d.i, development and expansion of mining and processing projects take years to become operational, if they even make it to that point. Just this past April, the United States' first and only cobalt plant decided to halt construction at the Idaho Cobalt Operations mine due to low cobalt prices, inflation, and the mine's remote location despite Jervois's beneficial support from federal grants—including a not-yet-approved $15 million award from the U.S. Department of Defense—for additional drilling and to pay for studies to assess the possibility of constructing a cobalt refinery in the U.S.[118]

Improvements in recycling rates and enhancing recovery technologies at mines will not be available in time to reduce the need to develop new sources of critical minerals. Recycling technologies for EV batteries remain nascent and cannot scale at a rate fast enough to alleviate supply shortages within the timeframe of the Proposed Rule. Moreover, even if those technologies

---

[116] *See* Jack Roberts, Truck Tech, "5 Takeaways from ACT Expo 2020," (May 20, 2022), *available at* https://www.truckinginfo.com/10172184/5-take-aways-from-act-expo-2022 (citing Cummins CEO Tom Linebarger as warning ACT Expo attendees that the undertaking will cost multiple trillions of dollars to accomplish).

[117] North American Electric Reliability Corporation, *2022 Long-Term Reliability Assessment* (Dec. 2022), 21, *available at* https://www.nerc.com/pa/RAPA/ra/Reliability%20Assessments%20DL/NERC_LTRA_2022.pdf. (indicating that increased demand projections may lead to reliability concerns for the electric grid, especially as dual-peaking or seasonal peaking times change with increased electrification)

[118] *See*, *e.g.* , Shelley Challis, POST REGISTER, "Jervois shuts down Idaho Cobalt mine" (Apr. 7, 2023), *available at* https://www.postregister.com/messenger/news/jervois-shuts-down-idaho-cobaltmine/article efd97f32-d015-11 ed-9424-bfb2822021 0c.html.

develop at a faster than expected pace and commercial scale facilities are fully permitted, litigated, and constructed, there will not be nearly enough batteries to recycle to counter the shortfall in the quantity of critical minerals needed to meet the projected battery demand. Moreover, many 'spent' EV batteries still have 70-80 percent of their capacity left, which is more than enough to be repurposed into other uses such as energy storage and other lower-cycle applications. This will extend the time that batteries and raw materials remain in use.[119]

Automakers' recent comments to EPA's Multi-Pollutant Emissions Standards Proposed Rule express grave concern regarding the availability of critical minerals needed to produce batteries.[120] OEMs, cathode or anode producers, and battery manufacturers are internally assessing their raw material offtake agreements and expect that some projects will not materialize to fruition. EVs are projected to represent approximately 90 percent of lithium demand by 2030, so switching chemistries for other uses will not reduce the burden or price on lithium.[121]

In light of the above, the Proposed Rule creates a long-term dependence on foreign mineral production and this, coupled with present domestic limitations in battery manufacturing capabilities, will make it impossible to sustain a viable domestic supply chain in the timeline of the Proposed Rule. Even assuming critical minerals are available, a viable supply chain requires sufficient capacity of midstream mineral refining operations prior to battery cell production. Such capacity does not exist. For instance, Benchmark Minerals Intelligence (BMI) foresees a 77 percent deficit in domestic available cathode active material to meet 2035 demands in North America (and this estimate does not account for recent proposals that would drastically increase EV production demands).[122]

Additionally, current government efforts are insufficient to accelerate the supply chain. For example, U.S. supply of battery anode material is supported by the IRA and BIL, but the production of raw materials supply that feeds the production of battery anode material is not supported. As described above in more detail, Chinese battery firms are currently the most advanced and the majority of raw material mining and processing goes through Chinese entities. Thus, it will be difficult for many OEMs to meet the requirements for IRA credits in the near term and few batteries would qualify for the tax credit. Without a domestic solution to this value chain, reliance on imports may add to the cost of the battery pack.[123]

These material availability and supply chain constraints are not simply a short-term problem until domestic production capabilities ramp-up. Any reliance on or consideration of public

---

[119] Engel, H., Hertzke, P., & Siccardo, G. (2019, April). Second-life EV batteries: The newest value pool in Energy Storage. McKinsey Center for Future Mobility, available at https://www.mckinsey.com/~/media/McKinsey/Industries/Automotive%20and%20Assembly/Our%20Insights/Second%20life%20EV%20batteries%20The%20newest%20value%20pool%20in%20energy%20storage/Second-life-EV-batteries-The-newest-value-pool-in-energy-storage.ashx

[120] AAI Comments at iv-v.

[121] McKinsey & Co., Lithium Mining: How new production technologies could fuel the global EV revolution, April 12, 2022. Available at https://www.mckinsey.com/industries/metals-and-mining/our-insights/lithium-mining-how-new-production-technologies-could-fuel-the-global-ev-revolution

[122] Benchmark Materials Intelligence, "Ambition versus reality: why battery production capacity does not equal supply" (Sept. 2, 2022) at Charts 5, 6, *available at* https://source.benchmarkminerals.com/article/ambition-versus-reality-why-battery-production-capacity-does-not-equal-supply.

[123] Ibid, (*see* Chart 2, 3 & 4).

statements or public commitments of OEMs regarding plans to develop infrastructure such as construction of gigafactories in North America, is tenuous at best given the highly complex nature of these projects, which require many years, significant resources, and government approvals/permits to materialize (if they even materialize at all). As described in more detail in Section III.B.1.d.i, if these factories do materialize, they are likely to operate at rates significantly lower than their full capacity, making actual capacity significantly lower than total projected capacity.

Limited supplies and constrained supply chains risk production downtime and inventory backlogs—and this is just for production of the EVs.[124] The Daimler Truck Group ("Daimler"), for example, has been and is likely to continue to be "acutely affected by an ongoing global shortage of semiconductors, which must be purchased on the global market."[125] And with the "rapidly rising demand for certain new technologies, such as electrified powertrains," Daimler anticipates higher product costs, supply bottlenecks, and long-term increases in demand for battery cells, semiconductors, and certain critical materials, such as lithium." Taken together, Daimler anticipates these supply chain concerns would limit its "ability to meet demand for its current generation of vehicles (including its vehicles with conventional combustion engines) or commercialize its new [ZEVs] profitably (or at all)."[126] Daimler, of course, is not alone in these conclusions.

As NHTSA considers the technological feasibility of its proposal, it should account for the likelihood that automakers are unable to obtain adequate resources to adapt to these stringent requirements, especially in light of increasing global supply chain issues and price increases associated with battery demand.

b) The Proposed Rule has not adequately examined the implications for U.S. electric system reliability.

NHTSA's proposed standards rely on the unsubstantiated assumption that the U.S electrical and transmission grid will be available to power the massive numbers of EVs that will enter the market. In reality, current U.S. electrical and transmission grid infrastructure falls drastically short of being able to meet the charging needs of NHTSA's EV penetration assumptions. Expansion and upgrades are also unrealistic within the timeline of the Proposal due to significant supply constraints.

i. NHTSA has not adequately demonstrated that the U.S. electrical grid and transmission grid cannot reliably support the assumed penetration rates.

Even assuming sufficient EVs can be manufactured with the corresponding consumer demand to buy them, NHTSA has not fully considered whether the electrical and transmission

---

[124] *See* Daimler Truck Group, *Annual Report 2022*, 141 *available at* https://www.daimlertruck.com/fileadmin/user_upload/documents/investors/reports/annual-reports/2022/daimler-truck-ir-annual-report-2022-incl-combined-management-report-dth-ag.pdf (describing Daimler Truck Group's reliance on certain commodities, like steel, copper, and precious metals that are usually sourced from individual suppliers, meaning that a single supplier's inability to fulfill delivery obligations can have detrimental effects for an entire production line).

[125] *Id.*

[126] Id.

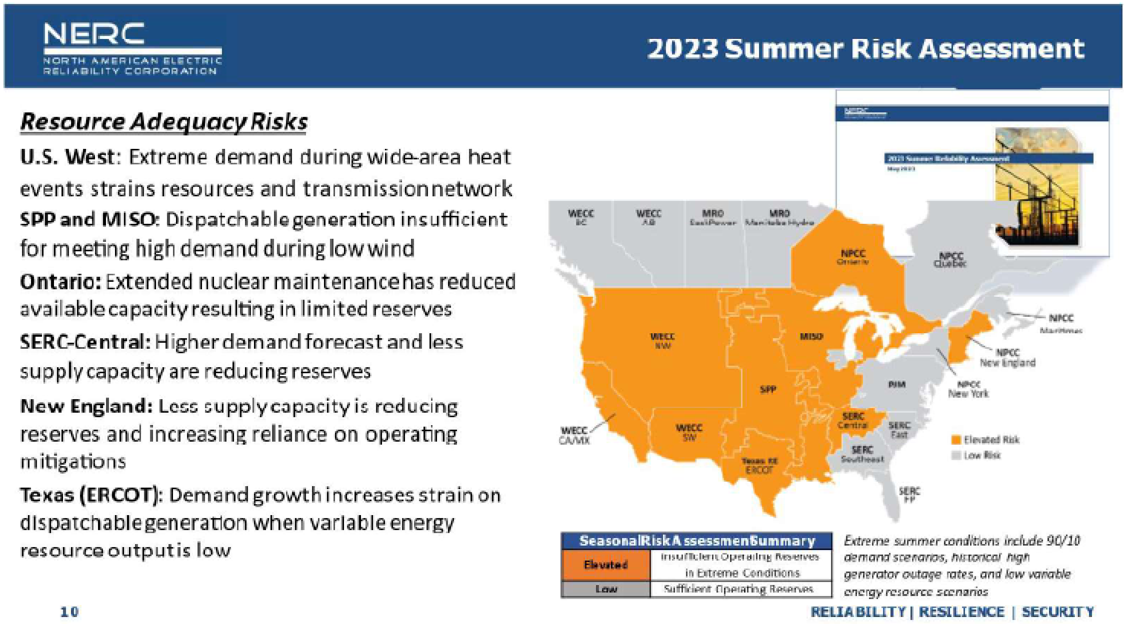
grid will be sufficient to support them. Grid resiliency is at risk of further deterioration due to increasing power demand from electrification, not just in transportation.

The Proposal will drastically strain our nation's electricity system. In the U.S., the estimated increase in energy consumption is 15 percent by 2050, without consideration of NTHSA's Proposal (let alone the proposals of EPA, CARB and other agencies, which will combine to require a drastic fleet transition and spike in electricity demand). Notably, this value is likely much higher considering the anticipated increase of between 900 and 2,000 percent electricity purchased for transportation by 2050 with the increased adoption of EVs.[127] The Department of Energy concluded that transmission systems must expand by 60 percent by 2030 and triple that capacity by 2050 to meet the Administration's emissions goals.[128] An author of the Princeton University's Net-Zero America Project[129] said "The current power grid took 150 years to build. Now, to get to net-zero emissions by 2050, we have to build that amount of transmission again in the next 15 years and then build that much more again in the 15 years after that. It's a huge amount of change."[130]

Yet, our electricity generation and transmission systems are increasingly challenged to keep up with current demand. As shown in Figure 10, the North American Electric Reliability Corporation's (NERC) recent summer assessment shows roughly two-thirds of the U.S. faced increased resource adequacy risk in the summer of 2023.[131]

[127] EIA, "U.S. energy consumption increases between 0% and 15% by 2050" (Apr. 3, 2023) *available at* https://www.eia.gov/todayinenergy/detail. ph p?id=56040#:- :text=U. S. %20energy%20consu mption%20increases%20between%200%25%20and%2015%25%20by%202050.
[128] Evan Halper and Timothy Puko, "Biden's Ambitious Climate Plans for EVs Face These Big Hurdles," The Washington Post, April 16, 2023.
[129] E. Larson, et al., Net-Zero America: Potential Pathways, Infrastructure, and Impacts, Final report, Princeton University, (Oct. 29, 2021).
[130] Molly Seltzer, PRINCETON, "Big but Affordable Effort Needed for America to Reach Net-Zero Emissions by 2050, Princeton Study Shows" (Dec. 15, 2020) *available at* www.princeton.edu/news/2020/12/15/bigaffordable-effort-needed-america-reach-net-zero-emissions-2050-princeton-study. Accessed 28 June 2023.
[131] NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION, "2023 Summer Reliability Assessment" (May 2023).

Figure 10: NERC 2023 Summer Risk Assessment[132]



Depending on where you are, the long-term reliability assessment is not much better. NERC's 2022 Long-Term Reliability Assessment of the U.S. analyzed the electrical grid and the entities delivering power to the continental United States during 2023-2032.[133] Regional operators of the power grid—Regional Transmission Organizations (RTOs) or Independent System Operators (ISO)—are responsible for transmission, but also balancing a regional power system to ensure that supply constantly matches demand. The grids in some RTOs are already under various degrees of stress. Several operating regions are still at-risk during periods of peak demand, including the Midcontinent ISO (which will face challenges in meeting above-normal peak demand), the SERC—Central area (where, compared to the summer of 2022, forecasted peak demand has risen by over 950 MW while growth in anticipated resources has remained flat) and the Southwest Power Pool (where reserve margins have fallen as a result of increasing peak demand and declining anticipated resources).[134] Combined with other issues, such as a disorderly transformation of the generation base as conventional units are replaced with intermittent resources, increased electrification raises questions about the grid's ability to reliably meet consumer demand on a regional basis.

Future electricity demand is expected to grow due to government policies for ZEV adoption and energy transition programs. The California Energy Commission staff estimates that by 2030,

---

132 NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION, "2023 Summer Energy Market and Electric Reliability Assessment" (May 18, 2023), *available at* https://www.ferc.gov/newsevents/news/presentation-report-2023-summer-energy-market-and-electric-reliability-assessment

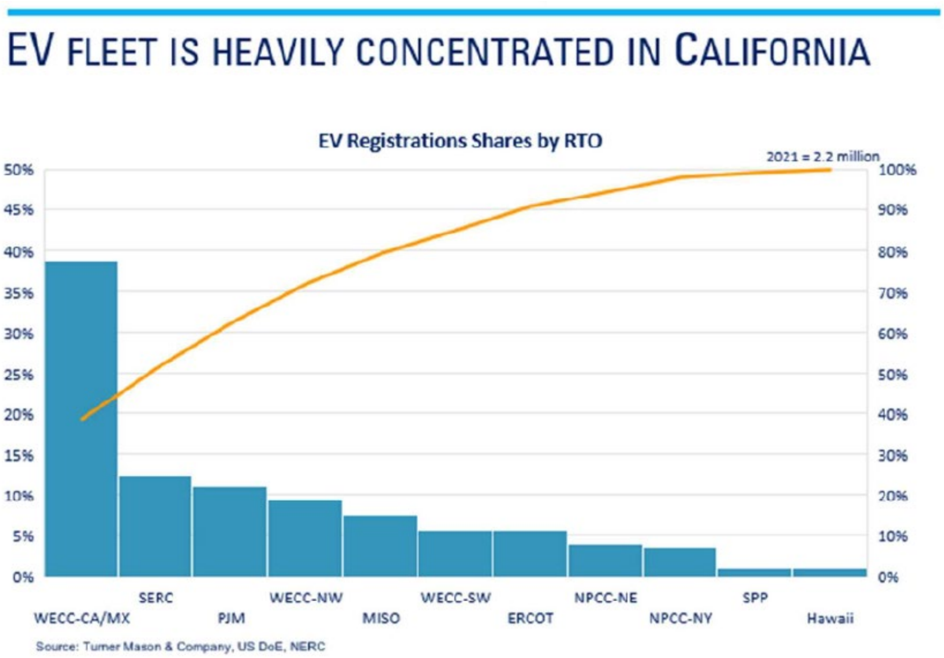
133 NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION, "2022 Long Term Reliability Assessment" (December 2022), *available at* https://www.nerc.com/pa/RAPNra/Reliability%20Assessments%20DL/NERC L TRA 2022.pdf.

134 NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION, "2023 Summer Reliability Assessment" (May 2023) at 23, *available at* https://www.nerc.com/pa/RAPNra/Reliability%20Assessments%20DL/NERC SRA 2023.pdf.

an additional 5,500 MW of demand at midnight and 4,600 MW of demand at 10:00 a.m. on a typical weekday will be needed for plug-in ZEV charging.[135] This is an increase of 25 and 20 percent, respectively, at those times. State and local policies for transitioning appliances and heating systems, such as banning natural gas stoves, can also affect projections of electricity demand and daily load shapes.[136] Moreover, as global temperatures rise, increased use of air conditioning will draw a greater load from the grid. As recently reported, "two-thirds of North America is at risk of energy shortfalls this summer during periods of extreme demand."[137]

The ability to charge these vehicles is driven by the ability of the RTOs and ISOs to manage regional or local power grids to supply electricity on demand. By 2022, more than 50 percent of EVs were concentrated in California (WECC-CA/MX), Florida (SERC), and Texas (ERCOT).[138] The distribution of the EV fleet across RTOs can be seen in Figure 11, in which state shares of EV registrations are allocated across RTOs.[139]

Figure 11: ZEV registrations by RTO[140]



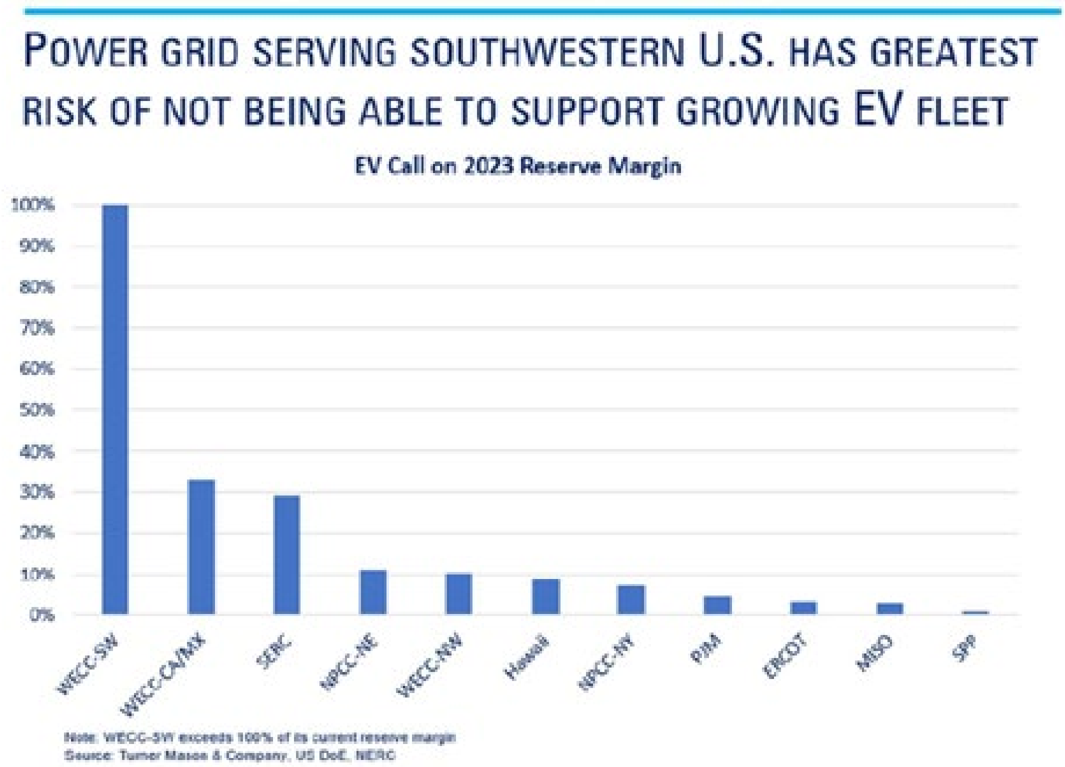
The grid's ability to charge EVs is driven by the ability to manage regional or local power grids to supply electricity on demand. By 2022, over 50% of EVs were concentrated in California, Florida, and Texas.[141] The distribution of the EV fleet across RTOs can be seen Figure 12, which

---

[135] Id.
[136] Id.
[137] https://www.cnn.com/2023/06/26/business/heat-wave-power-blackout/index.html.
[138] S&P GLOBAL MOBILITY, "EV Chargers: How Many Do We Need?" (Jan. 9, 2023), *available at* press.spglobal.com/2023-01-09-EV-Chargers-How-many-do-we-need.
[139] There are several states which are covered by more than one RTO. For this high-level assessment, the Turner Mason Report allocates state EV sales by roughly the geographic footprint of each RTO within the state.
[140] Turner Mason Report.
[141] Turner Mason Report.

shows that the greatest stress is not in California (although it is significant in California), but rather in the southwestern U.S. In the southwestern U.S., electricity demand from ZEV charging is expected to completely consume the 2023 reserve margin for the WECC-SW grid, leaving no reserve margin to address emergency conditions.

Figure 12: EV Power Requirement by RTO



In contrast, power generation using traditional fuels has an advantage in the capacity being located near demand centers. Except for nuclear, any lower-carbon power generation capacity must be located at the energy source (e.g., where the wind blows, water flows, sun shines). Supplying lower-carbon electricity to charge EVs also needs to resolve the transmission of that power to the demand center. NHTSA makes the unsubstantiated presumption that the installation of transmission capacity will occur in a timely manner. The Bureau of Land Management (BLM) recently issued its record of decision for the SunZia Southwest Transmission Project more than 15 years after the project was proposed.[142] Once this incremental power is transmitted from supply location to a load center, there are potentially additional distribution transmission constraints before the electrons reach charging stations and homes. One supercharger equals the launch of 70 air-conditioning units at once. Such an instant change in the power demand profile is a significant problem for the local distribution grid. This is compounded by the fact that Level 2 EV chargers, typically used in a home, can increase a home's

[142] Emma Peterson, INSIDE CLIMATE NEWS, "SunZia Southwest Transmission Project Receives Final Federal Approval" (May 29, 2023) *available at* https://insideclimatenews.org/news/29052023/sunzia-transmission-project-approval/.

peak load by 40% to 100%, which can stress neighborhood transformers and compromise reliability.

The intensity is further complicated in that the capacity factor (percentage of time a plant is likely to be available for generation) of solar (28%) and wind (36%) plants is so much lower than dispatchable (typically 90+%) generation capacity. To put the intensity of effective generation capacity in perspective, solar and wind farms require almost three times as much copper to meet the load of a typical (combined cycle gas turbine) natural gas plant. Moreover, NHTSA has failed to account for the impacts of new regulations on the grid, including the effect of EPA's new proposed carbon dioxide standards for fossil-fuel fired power plants.[143] NHTSA fails to account for how the increased demand for baseload and peaking power as a result of the Proposed Rule can be met as affordable base-load generators are rapidly phased out. Even in California, where renewable energy is a priority, daily evening peak load is still routinely supplied by approximately 70 percent fossil fuels.[144]

Despite the projected increased demands on U.S. energy generation and storage capacity,[145] NTHSA offers little to no support that these demands will be sufficiently met. NHTSA cannot blindly propose a standard without accounting for the infrastructure needed to support its Proposal.

ii. Global supplies of critical minerals and metals are inadequate to support the required electrical grid expansion.

Without existing energy generation and storage in place to support NHTSA's Proposal, the U.S. energy and transmission grid would require significant expansion and upgrades to support the assumed EV penetration rates. This raises significant concerns regarding the availability of materials needed to expand and upgrade the grid. Beyond materials needed to produce an EV itself, the electricity networks needed to charge these vehicles also require a large amount of copper and aluminum.[146] The need for grid expansion that would result from this rapid increase in electricity demand underpins a doubling of annual demand for copper and aluminum.[147] Most supply of these materials will come from overseas, as the United States lacks current production capacity or the ability to increase such capacity in time to meet the increased demand.

---

143 EPA, New Source Performance Standards for Greenhouse Gas Emissions From New, Modified, and Reconstructed Fossil Fuel-Fired Electric Generating Units; Emission Guidelines for Greenhouse Gas Emissions From Existing Fossil Fuel-Fired Electric Generating Units; and Repeal of the Affordable Clean Energy Rule, 88 Fed. Reg. 33,240 (May 23, 2023).

144 *See, e.g.*, CALIFORNIA ISO, "Today's Outlook" (accessed June 13, 2023), *available at* https://www.caiso.com/TodaysOutlook/Pages/supply.html#section-supply-trend (showing data from Aug. 4, 2022, indicating more than 70 percent of energy from natural gas, coal, and imports).

145 *See, e.g.*, U.S. DRIVE, "Summary Report on EVs at Scale and the U.S. Electric Power System" (Nov. 2019), *available at* https://www.energy.gov/eere/vehicles/articles/summary-report-evs-scale-and-us-electric-power-system-2019 (summarizing impacts of light-duty vehicles on energy generation and generation capacity alone and acknowledging several potential challenges without including analysis of medium- and heavy-duty ZEVs).

146 IEA Report 2022.

147 *Id.*

Aluminum is critical to expanding the electric grid and lightweighting vehicles. The United States does not supply much of the world's aluminum. Instead, China, Russia, and India lead global production with an estimated 45 million metric tons per year. China possesses more than half of the entire world's aluminum smelting capacity and produces by far the most aluminum of any country at over 36 million tons per year.[148] The United States, by contrast, produces approximately 1 million tons per year. Similarly, countries supplying the most copper are Chile, Peru, China, and the Democratic Republic of the Congo. These countries supply ten times the amount produced domestically.

Experts predict our demand for these materials will rise dramatically, but we lack the ability to source them domestically. The latest data concludes sourcing copper for electric infrastructure (e.g., charging stations and storage) needed to accommodate increased electrical demand will be challenging.[149] Copper demand is expected to rise by 53 percent, while supply is expected to rise by only 16 percent.[150] U.S. import dependency for copper has grown from 10 percent in 1995 to 40 percent in 2020, with projections of copper import dependency reaching between 55 percent and 67 percent between 2020 and 2040.[151] Other estimates predict that by 2030 supply from existing mines and projects under construction is estimated to meet only 80 percent of copper needs by 2030[152]—not considering the increase in EV production anticipated by the Proposed Rule.

As mentioned below, establishing new mines, particularly in the United States, is not a near-term solution. Permitting and authorizing new domestic mining and smelting capacity requires a substantial amount of time and government support. Globally, regulatory approval for new copper mines is at its lowest level in a decade.[153] As a case in point, the Resolution copper deposit in Arizona was discovered in 1995. This world-class resource has been stranded without the necessary regulatory approvals for over 27 years. As recently as May 19, 2023, the U.S. Forest Service told a federal court it was suspending approval of a land swap between the project (owned by Rio Tinto and BHP) and several Native American groups.[154] The land swap was approved by the U.S. Congress in 2014, but the completed environmental report was blocked in March 2021. Other copper mining projects in Alaska and Minnesota have been halted by this

[148] Andy Home, "Global aluminum production pendulum swings back to China" (June 21, 2022) *available at* https://www.mininq.com/web/column-qlobal-aluminum-production-pendulum-swinqs-back-to-china/.
[149] IEA Report 2022.
[150] BLOOMBERGNEF, "Copper Miners Eye M&A as Clean Energy Drives Supply" (Aug. 30, 2022), *available at* https://about.bnef.com/blog/coppers-miners-eye-ma-as-clean-energy-drives-supplygap/#:-:text=Copper%20demand%20is%20set%20to,and%20difficulty%20developing%20greenfield%20mines.
[151] S&P GLOBAL, "The Future of Copper Will the Looming Supply Gap Short-Circuit the Energy Transition?" (July 2022) *available at* https://cdn.ihsmarkit.com/www/pdf/0722fThe-Future-of-Copper Full-Report 14July2022.pdf.
[152] IEA Report 2022.
[153] Ernest Scheyder, REUTERS, "Copper Industry Warns of Looming Supply Gap without More Mines" (Apr. 21, 2023) *available at* www.reuters.com/markets/commodities/copper-industry-warns-loominq-supplygap- without-more-mines-2023-04-20/.
[154] Ernest Scheyder, REUTERS "U.S. Forest Service Pauses Timeline for Rio Tinto Arizona Copper Mine" (May 19, 2023) *available at* https://www.reuters.com/leqal/us-forest-service-pauses-timeline-rio-tintoarizona-copper-mine-2023-05-19/.

administration, resulting in increased import dependence.[155] NHTSA simply has not accounted for the lack of critical materials needed to facilitate such drastic EV penetration rates.

c) Charging infrastructure is not sufficient to meet NHTSA's EV penetration assumptions

In addition to the underlying power generation and supply needed to support the assumed EV penetration rates, a drastic overhaul of U.S. EV charging infrastructure would also be required. NHTSA fails to consider the critical need for "equitable, affordable charging."[156] Currently, EV charging is most available in metropolitan areas, with less investment occurring outside urban areas.[157] While a significant percentage of the charging installations deployed today are Level 2 EVSEs, dual charging installations to enable the flexibility of passenger car, light truck, and HDPUV charging will become increasingly important. Direct current fast charging equipment (DCFCs) will enable broader market coverage, even for passenger cars used in applications where they cannot sit for 6 hours and charge during off-peak, lower-cost electricity periods. As utility companies gear up to provide infrastructure installations, NHTSA should not minimize the impact of supply chain shortages necessary for installing supporting charging infrastructure.

Even where charging infrastructure may be available in theory, it often is unavailable to consumers in practice. For example, many available chargers are unreliable. A recent study on the reliability of fast chargers found that in 22.7 percent of the cases studied, chargers were nonfunctional because of "unresponsive or unavailable touchscreens, payment system failures, charge initiation failures, network failures, or broken connectors," and 4.9 percent of charging cable were too short to reach an EV's charge port.[158] Similarly, in a J.D. Power study, owners in high EV volume markets like California, Texas and Washington are finding the charging infrastructure inadequate and plagued with non-functioning stations.[159] This is a significant technological issue that calls into question the viability of the existing charging network as well as future deployments. Given that the Proposal will create additional charging demand, NHTSA must analyze and identify a solution. Absent comprehensive understanding of the dynamics between increased ZEV use and charging infrastructure needs, automakers and consumers are vulnerable.

d) The proposed timeline is unrealistic

NHTSA's proposed timeline is simply infeasible. NHTSA has not adequately accounted for the sourcing of materials required for EV production, charging infrastructure, and an enormous

---

155 Jim Vinoski, "There's Not Enough Copper for Our Electrification Plans-and Biden Is Making It Worse," Forbes, April 28, 2023, *available at* www.forbes.com/sites/jimvinoski/2023/04/28/theres-not-enoughcopper-for-our-electrification-plansand-biden-is-making-it-worse/?sh=19ca0a5d1fbf.

156 Joann Muller, "The electric car revolution hinges on equitable, affordable charging," Axios, Feb. 8, 2023, *available at* https://www.axios.com/2023/02/08/electric-vehicle-charging-stations-equity.

157 S&P Global Mobility, "EV Chargers: How Many Do We Need?," Jan. 9, 2023, *available at* https://press.spglobal.com/2023-01-09-EV-Chargers-How-many-do-we-need.

158 Rempel, David and Cullen, Carleen and Bryan, Mary Matteson and Cezar, Gustavo Vianna, "Reliability of Open Public Electric Vehicle Direct Current Fast Chargers," April 7, 2022, *available at* SSRN: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4077554.

159 J.D. Power. Press Release, "2022 U.S. Electric Vehicle Experience (EVX) Public Charging Study," August 2022, *available at* www.jdpower.com/business/press-releases/2022-us-electric-vehicleexperience-evx-public-charging-study.

buildout of both electricity generation and transmission capacity.[160] Even setting aside the significant supply limitations and national security concerns described above, there simply is not enough time to implement the upgrades and expansion required to support NHTSA's Proposal.

i. Current battery and EV production is insufficient to support the assumed EV penetration rates during the standard setting years.

NHTSA's assumptions in the baseline and standard modeling regarding EV penetration rates are unrealistic given the current and projected battery and EV production rates during the proposed CAFE standard period. Automakers have repeatedly said as much, reiterating these concerns to EPA, NHTSA, and CARB.[161] EV battery and vehicle production rates will need to increase significantly over a short time period to meet NHTSA's assumed penetration rates. NHTSA has not demonstrated that such a drastic production and capacity ramp up is achievable in the time allotted. Indeed, it is not. In fact, the only way the proposal is achievable is through the use of fictitious multipliers that distort the calculated fuel efficiency of EVs.[162]

Estimates of cell or battery manufacturing capacity over the next decade vary widely. Battery manufacturing facilities or gigafactories are extraordinarily complex projects that will take many years to materialize if they progress to the point of battery production. Wood Mackenzie projects U.S. battery manufacturing capacity at 422 GWh/ year in 2030,[163] because many projects have failed to materialize or are delayed as market and other conditions change. Further, it is unlikely that these factories will operate beyond 50 percent capacity for years. Mature battery factories today rarely operate above 80 percent utilization rates. For example, in 2022, there was 1,036 GWh of global battery production capacity, but only 450 GWh of actual production. While there was approximately 7TWh of forecast battery capacity planned as of September 2022, Benchmark Minerals Intelligence (BMI) forecast total global supply of Li-ion batteries to reach only 4.5 TWh by 2031 or a 64 percent utilization rate.[164] This step in the value chain could potentially create a critical bottleneck.

Beyond the lack of infrastructure needed to manufacture EVs, the raw material supplies for such manufacturing are also insufficient. NHTSA severely overestimates the availability of minerals and the mining/processing infrastructure and capabilities in the U.S. The development of natural resources projects, like critical mineral mining and processing, can easily require over

---

[160] See AAI Comments at i-ii (EPA's proposed GHG and multi-pollutant rule for MY 2027 and after are infeasible within the prescribed timeframe).

[161] *See, e.g.*, Alliance for Automotive Innovation, Comments to U.S. Environmental Protection Agency Multi-Pollutant Emissions Standards for Model Years 2027 and Later Light-Duty and Medium-Duty Vehicles Proposed Rule, No. EPA-HQ-OAR-2022-0829-0701 (July 5, 2023); Alliance for Automotive Innovation, Advanced Clean Cars 2, Auto Innovators Comments (May 31, 2022).

[162] If the Department of Energy finalizes its proposed adjustments to the EV Petroleum Equivalence Factor, see 88 Fed. Reg. 21,525 (April 11,2023), these CAFE standards will be clearly unachievable if NHTSA fails to significantly adjust its standards.

[163] Wood Mackenzie, "The EPA plans to rev up US EV sales," Apr. 14, 2023, *available at* https://www.woodmac.com/news/opinion/the-epa-plans-to-rev-up-us-ev-sales/.

[164] Benchmark Minerals Intelligence Source, "Ambition versus reality: why battery production capacity does not equal supply," Sept. 2, 2022, at Charts 5, 6, *available at* https://source.benchmarkminerals.com/article/ambition-versus-reality-why-battery-production-capacity-does-not-equal-supply.

a decade. Increasing supply is not merely a matter of increasing current production. Increasing mining production is limited by significant regulatory hurdles and capital investment requirements. Globally, it takes on average over 16 years to move mining projects from first discovery to production.[165]

Establishing new mines, particularly in the U.S., also requires a substantial amount of time just to obtain necessary permits and authorizations. As mentioned earlier as a case in point, the Resolution copper deposit in Arizona was discovered in 1995. This world-class resource has been trying to acquire the necessary regulatory approvals for over 27 years. As recently as May 19, 2023, the U.S. Forest Service told a federal court it was suspending approval of a land swap between the project (owned by Rio Tinto and BHP) and several Native American groups.[166] The land swap was approved by the U.S. Congress in 2014, but the completed environmental report was blocked in March 2021. Even with the requisite authorizations in hand, mine development and production can take years. For an open pit mine, it takes about 7 to 8 years from discovery to first ore; for a subsurface mine, the time frame is more like 10 to 12 years.

The ability to quickly scale minerals production is further affected by ore quality, which in recent years has been declining, and thus requires more material to be mined, more resources such as water in stressed areas for processing, and ultimately greater environmental impacts. For example, the average ore grade for copper discoveries decreased in excess of 25 percent during the last 15 years. In that same period, total energy consumption increased at a higher rate (46 percent) than production (30 percent).[167] Extraction (i.e., mining and processing) of metal content from lower-grade ores requires removing more overburden to access the ore body, which requires more energy, exerting upward pressure on production costs, greenhouse gas and criteria pollutant emissions, and waste volumes. And once the raw material is mined, it must be qualified. This is not a mine-to-producer scenario. It is a specialty chemical that must be tested at different stages for safety, consistency of product output, and performance before it can be qualified for use in battery/ZEV manufacturing. Substantial lead time is needed to qualify battery-grade materials as they go through a very rigorous, staged approach. Careful attention to putting up projects on the scale of raw material resource extraction and gigafactories requires time, careful consideration, and intensive safety precautions. Accelerating the buildup of a domestic battery value chain should not overstep aspects of safe project development.

The required critical minerals are not available at scale today and raw material extraction capacity simply cannot be increased as quickly as required to meet the assumed production rates. Production cannot continue at the assumed rates without the necessary raw materials and infrastructure, which take time to develop.

---

[165] International Energy Agency, "The Role of Critical Minerals in Clean Energy Transitions," March 2022, *available at* https://iea.blob.core.windows.net/assets/ffd2a83b-8c30-4e9d-980a-52b6d9a86fdc/TheRoleofCriticalMineralsinCleanEnergyTransitions.pdf.

[166] Ernest Scheyder, Reuters, "U.S. Forest Service pauses timeline for Rio Tinto Arizona copper mine," May 19, 2023, *available at* https://www.reuters.com/legal/us-forest-service-pauses-timeline-rio-tinto-arizona-copper-mine-2023-05-19/.

[167] Calvo, G.; Mudd, G.; Valero, A.; Valero, A. Decreasing Ore Grades in Global Metallic Mining: A Theoretical Issue or a Global Reality? *Resources* 2016, *5*, 36 *available at* https://doi.org/10.3390/resources5040036.

ii. The grid cannot be expanded within the timeline contemplated by the rule

It is also unlikely that the U.S. energy and transmission grid can be upgraded quickly enough as assumed by NHTSA's Proposed Rule. Beyond the normal approximately four-year lead time for vehicle manufacturers to make incremental changes to their production, the typical electricity transmission system capital project timeline is approximately ten-years and would need to be accelerated to have a chance to support the proposed EV demand, while current large-scale electric generation and storage projects are increasingly backlogged year-on-year due to long lead times for permitting and approvals, supply chain shortages, and shortage of skilled workers. While government programs have recently been put in place to help overcome some of these hurdles, they will take time for the benefits to be realized.[168]

A recent DOE-funded study finds that: "[o]nly ~21% of projects (14% of capacity) requesting interconnection from 2000-2017 reached commercial operations by the end of 2022"; "[c]ompletion rates are even lower for wind (20%) and solar (14%); and "[t]he average time projects spent in queues before being built has increased markedly. The typical project built in 2022 took 5 years from the interconnection request to commercial operations."[169]

According to the National Mining Association, it can take up to 10 years to obtain a permit to commence mining operations in the U.S., while permitting takes two years in Canada and Australia.[170] "[U]nless the permitting process can be improved, U.S. mining developments will continue to take longer to come online and carry more financial risks compared with the rest of the world, China's domination of battery manufacturing and critical minerals production will continue for a longer period, and the U.S. will find it increasingly difficult to acquire the metals and minerals it needs for its long-term clean-energy goals."[171] The Bureau of Land Management placed a 20-year moratorium on mining rare earth minerals, such as copper, nickel, and cobalt, from almost a quarter of a million acres of Minnesota, effectively killing the proposed Twin Metals copper-nickel mine project.[172]

NHTSA ignores the significant supply constraints, permitting hurdles, and financial challenges associated with expanding the U.S. energy and transmission grid. Consequently,

---

[168] Gracie Brown, et al., "Upgrade the grid: Speed is of the essence in the energy transition," McKinsey and Company, Feb. 1, 2022, *available at* https://www.mckinsey.com/capabilities/operations/our-insights/global-infrastructure-initiative/voices/upgrade-the-grid-speed-is-of-the-essence-in-the-energy-transitionl; Deloitte, "2023 power and utilities industry outlook" *available* https://www2.deloitte.com/content/dam/Deloitte/us/Documents/energy-resources/us-eri-power-utilities-outlook-2023.pdf.

[169] *See* Lawrence Berkeley National Laboratory, "Queued Up: Characteristics of Power Plants Seeking Transmission Interconnection As of the End of 2022," *available at* https://emp.lbl.gov/sites/default/files/queued_up_2022_04-06-2023.pdf.

[170] National Mining Association, "Delays in the U.S. Mine Permitting Process Impair and Discourage Mining at Home," May 31, 2021, *available at* https://nma.org/wpcontenUuploads/2021/05/Infographic_SNL_minerals_permitting_S. 7 updated.pdf.

[171] Jason Lindquist, "Don't Pass Me By - With Many Steps Required, Mining Projects Face Trickiest Path To Approval," RBN Energy Blog, June 30, 2023, *available at* https://rbnenergy.com/dont-pass-me-by-with-many-steps-required-mining-projects-face-trickiest-path-to-approval.

[172] 88 Fed. Reg. 6308 (Jan. 31, 2023).

NHTSA is pushing EV technology at a pace that cannot be adopted within the timeframe of its own Proposal.

iii. The required charging infrastructure cannot be deployed during the standard setting years.

NHTSA's Proposal would also require a major overhaul of EV charging infrastructure in the U.S. This overhaul requires investment and action not only from the energy and automotive sectors, but by state and local governments, businesses, and individuals. NHTSA glosses over this extremely complex issue despite ample evidence suggesting that range anxiety and lack of sufficient charging infrastructure remain a critical hurdle to the willingness of Americans to purchase EVs.

Many of the same mineral supply issues that apply to EV production and energy grid expansion also apply to the installation of charging infrastructure. However, this issue is further compounded by significant logistical issues, including complicated considerations about how to provide Americans in different living situations with access to affordable charging options. NTHSA cannot effectively require Americans to shift to EVs without providing for the necessary time and resources to facilitate the real-world requirements of these vehicles.

e) NHTSA assumes unrealistic consumer EV adoption rates

Even if manufacturing facilities, necessary raw material supplies, and grid and charging infrastructure were sufficient to support the proposed standards, the consumer demand for EVs is simply lacking. Automakers may be publicly acquiescing to government demands, but this does not demonstrate that the technology and infrastructure will be available in the stated period and, most critically, that consumers are ready and willing to adopt electric vehicles. Indeed, many of the automakers have set "goals" for their electrification, premised explicitly on a litany of federal and state subsidies for purchase and infrastructure assistance. And these government demands, and indeed government subsidies, can vanish in an instant, through changes in administrations or judicial challenges.

As NHTSA itself acknowledges, at most only about 5 percent of the light duty vehicle fleet in 2022 were BEVs.[173] And even if production rates are slightly higher, this is unlikely to be representative of actual consumer adoption rates. In reality, projected production rates may or may not translate into sales and vehicle registration. State-by-state EV registration data shows that the percentage of ZEV registrations relative to all registered vehicles ranged from 0.15 percent in Mississippi to 4.01 percent in California.[174] Thus, the ambitions of even the most aggressive OEM from a consumer EV adoption rate perspective would require unprecedented sales over the next seven years.[175]

---

173 Draft TSD at 3-78–3-79 and Table 3-73.

174 2023 EV Charing Station Report: State-by-State Breakdown, June 16, 2023, *available at* https://zutobi.com/us/driver-guides/the-us-electric-vehicle-charging-point-report.

175 VOLVO GROUP, "Report on the first quarter 2023," *available at* https://www.volvogroup.com/content/dam/volvo-group/markets/master/investors/reports-and-presentations/interim-reports/2023/volvo-group-q1-2023-eng.pdf; Tubes And Lubes Daily, "Volvo launches electric truck with longer range in N. America," January 2021, *available at*

Finally, NHTSA's overly optimistic assumptions regarding EV performance and cost are used to support its implicit assumptions regarding EV adoption and its explicit evaluation of environmental benefits (see Section III.B.4 below). Trinity Consultants reviewed NHTSA's assumptions in the TSD to assess the physical and environmental effects of the proposed standards.[176] It is well known EVs have a more limited range, need charging infrastructure, and cost more than ICEVs and hybrid vehicles, Yet Section 4.3 of the TSD makes no mention of EVs' limited range and the need for recharging when discussing how the vehicles miles traveled (VMT) input was derived. Instead, after ignoring the impacts of limited range and charging infrastructure and assuming adoption of "BEV2" vehicles with a range of 250 miles, NHTSA assumes lower operating costs that will result in EVs being driven more than other types of vehicles. It is precisely limited EV range and the lack of reliable and affordable charging infrastructure that explains recent polling showing that most Americans continue to say that they are unlikely, or will categorically refuse, to buy an EV. As just one example, a Gallup poll conducted in April revealed that only 4 percent of adults owned a ZEV and just 12 percent are seriously considering buying one. However, 41 percent of adults said they would never buy an EV, raising fundamental questions about NHTSA's assumed EV penetration rates.[177] In contrast, according to Wards Intelligence, through May 2023, Americans purchased 5.9 million ICEVs, representing 93 percent of all LDVs sold during the first five months.[178] At this pace, more than 14 million new ICEVs will be purchased during 2023.[179] With the continued sales of ICEVs, NHTSA should follow its statutory mandate to focus on alternative scenarios using ICEV technologies and renewable fuels.

The last twenty years have clearly signaled that consumer reluctance remains a huge barrier. Even after 20 years on the market, hybrid vehicles and other electric vehicle technologies have achieved low sales in comparison to their ICEV counterparts. Sales of these vehicles have fallen short of the levels necessary to meet the current model year standards, let alone those proposed. Historic marketing campaigns, tax subsidies, and benefits for various special privileges, including the use of HOV lanes and preferred parking spots, failed to generate adequate consumer interest. This can only lead to the conclusion that, despite a variety of incentives, consumers simply do not accept these vehicles in the proportion required to meet either the existing standards or the proposed standards.

---

https://www.fuelsandlubes.comlvolvo-launches-electric-truck-withlonger-range-in-n-americal?mccid=b124969b23&mceid=4a00dc8f80 (Volvo Trucks set target that half of all trucks sold are electric by 2030); VOLVO GROUP, "Geared for Growth - Annual Report 2022," *available at* https://www.volvogroup.com/content/dam/volvo-group/markets/master/investors/reports-andpresentations/annual-reports/AB-Volvo-Annual-Report-2022.pdf.

[176] See Appendix B Trinity Technical Review at 12.

[177] Megan Brenan, "Most Americans Are Not Completely Sold on Electric Vehicles", Gallup, April 12, 2023, *available at* https://news.gallup.com/poll/474095/americans-not-completely-sold-electric-vehicles.aspxt.

[178] John Eichberger, "Decarbonizing Combustion Vehicles -A Critical Part in Reducing Transportation Emissions", Transportation Energy Institute, June 2023, *available at* https://www.transportationenergy.org/resources/blog-post/decarbonizing-combustion-vehicles-a-critical-part-in-reducing-transportation-emissions/.

[179] *Id*.

EV charging infrastructure, range, and charging time remain top concerns for nearly half of U.S. customers.[180] OEMs expect that ZEV penetration will not be uniform across markets, with larger impact in markets with more low carbon intensity electricity and greater electrical grid reliability.[181] Toyota announced that regional energy variation is the reason they will provide a diversified range of carbon neutral options to meet the needs and circumstances in every country and region.[182] Toyota believes optionality facilitates the ability to adapt to change, while selecting a single option is an attempt to predict the future in uncertain times.[183]

Importantly, successful implementation of NHTSA's Proposed Rule depends on consumer choice as much as it depends on technological improvements. But there is evidence that premature embrace of EV may backfire if consumers grow frustrated with inadequate infrastructure. Consumer market demand will not, and cannot, increase to meet the Proposal's required supply.

Insufficient charging capabilities, which creates range anxiety, is a key apprehension for nearly half the U.S. consumer market. For example, in California, roughly one-fifth of consumers who initially purchased PHEVs or EVs subsequently went back to ICEVs based on frustration with convenience factors such as unavailability of charging.[184] Those with multiple vehicles and a single-family home find it easier to continue ownership than those with fewer vehicles or living in multi-unit dwellings, which could lower EV adoption rates as the EV market becomes more mainstream.[185] Finally, a survey of PHEV owners in California found that current PHEV owners would not purchase their PHEV without incentives, therefore EV and PHEV adoption may face more challenges over time.[186]

EVs have less range, both technically and practically. As noted by J.D. Power, "[T]he majority of EVs provide between 200 and 300 miles of range on a full charge."[187] This same article, however, also noted that EVs with less than 200-mile ranges (such as the 2022 Nissan Leaf at 149 miles or the 2022 Mazda MX-30 at 100 miles) are "either affordable or focused on

---

[180] Phillipp Kampshoff, et al., McKinsey & Co., "Building the electric-vehicle charging infrastructure America needs" (Apr. 18, 2022) *available at* https://www.mckinsey.com/industries/public-sector/our-insights/building-the-electric-vehicle-charging-infrastructure-america-needs; EVBox, "6 reasons why your electric car isn't charging as fast as you'd expect," Jan. 6, 2023, *available at* https://blog.evbox.com/6-reasons-charging-times.

[181] The North American Electric Reliability Corporation (NERC's) *2022 Long-Term Reliability Assessment* (Dec. 2022) projects reliability concerns for certain regional entities. *Available at* https://www.nerc.com/pa/RAPNra/Reliability%20Assessments%20DL/NERC L TRA 2022.pdf.

[182] Toyota Motor Corporation, "'Video: Media Briefing on Battery EV Strategies," Press Release, December 14, 2021. *available at* https://global.toyota/en/newsroom/corporate/36428993.html.

[183] *Id*. At 26.

[184] Hardman, S., and Tai, G., *Discontinuance Among California's Electric Vehicle Buyers: Why are Some Consumers Abandoning Electric Vehicles*, April 21, 2021, Report for National Center for Sustainable Transportation. *Available at* https://ncst.ucdavis.edu/research-product/discontinuance-among-californias-electric-vehicle-buyers-why-are-some-consumers.

[185] *Id*.

[186] *Id*. *See also* JATO Blog, "A breakdown of the US EV market by State shows more incentives equals more sales", April 9, 2019 (latest research shows current tax credits and other incentives in the US are unequal among states, and that EV sales are growing at the fastest rate in states offering financial incentives).

[187] *See* Sebastian Blanco, *List of EVs Sorted by Range* (Sept. 1, 2022), www.jdpower.com/cars/shoppingguides/list-of-evs-sorted-by-range.

performance."[188] With respect to longer range vehicles, claimed vehicle ranges of up to 516 miles are available, but this range comes at considerable cost. The number 1 range-rated vehicle by Car and Driver, the 2023 Lucid Air, carries a base price of $113,650. And while three out of the ten top-rated EVs by Car and Driver were more "reasonably priced" from $44,630 to $56,630, all other models within the top 10 cost anywhere from $74,800 to $110,295.[189]

Moreover, the time it takes to charge an EV compared to fueling an ICEV deters EV adoption.[190] Depending on the type of vehicle (BEV v. PHEV) and charger (Level 1, Level 2, or DCFCs), charging times from empty to 80 percent charged can range from 40-50 hours (Level 1 charging) to 20 minutes to one hour (DCFC), although most PHEVs on the market do not work with DCFCs.[191] In early 2023, a Boston Globe survey around the Boston metropolitan area found DCFC chargers were unreliable, going offline for weeks or months at a time.[192] Since close to two-thirds of U.S. households do not purchase new vehicles, lower-income people are more likely to purchase less expensive, early generation PEVs with less range and using a Level 1 or Level 2 charger requires longer charge times.[193] These extended recharging times remain a barrier to EV adoption.[194]

Additional barriers to EV adoption by particularly low-income stakeholders, include but are not limited to restricted driving/battery range; inability to charge in different housing and work situations; high price points to purchase, maintain, and insure EVs; availability of replacement parts and qualified mechanics, as well as ease and cost of repairs; and unpredictability regarding future electricity costs. NHTSA cannot ignore these real-world limitations. NHTSA should revise its analysis to account for the reality of today's automotive market and consumer demand.

2. The Proposed NHTSA standards are not economically practicable.

When determining maximum feasible fuel economy standards, NHTSA is required to consider economic practicability. In doing so, NHTSA must transparently calculate and explain the proposal's costs and benefits using realistic assumptions. Yet NHTSA fails to consider the true cost implications of its Proposal; when taken into consideration these significant costs made NHTSA's proposed standards economically impracticable.

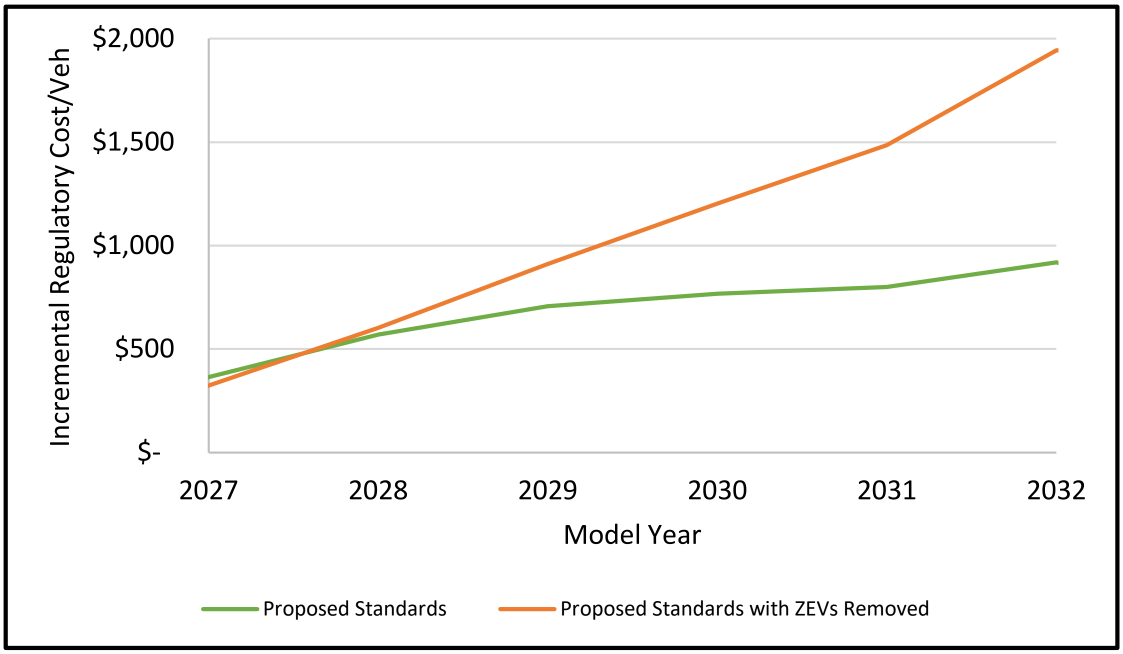
Using the CAFE model, Trinity Consultants examined the costs of compliance with the proposed standards on a dollar per vehicle basis using what NTHSA refers to as the "regulatory

---

188 *Id*.
189 *See* Nicholas Wallace, Austin Irwin, & Nick Kurczewski, *Longest Range Electric Cars for 2023, Ranked* (Mar. 23, 2023), https://www.caranddriver.com/features/g32634624/ev-longest-driving-range/.
190 EVBox, EV Box Mobility Monitor (June 2022). *Available at* evbox-mobility-monitor-2022-intl.pdf (a study of EV adoption in France, Germany, the Netherlands, and the UK revealed that excessive charging time remains a deterrent to EV adoption).
191 U.S. Department of Transportation, *Charger type and speed*. *Available at* https://www.transportation .gov/rural/ev/toolkit/ev-basics/charging-speeds.
192 Aaron Pressman, "Inside the crazy, mixed-up world of electric-vehicle charger pricing," The Boston Globe, March 27, 2023. *Available at* Inside the crazy, mixed-up world of electric-vehicle charger pricing (boston.com).
193 Hardman, Scott, et al. "A Perspective on Equity in the Transition to Electric Vehicles." *MIT Science Policy Review*, 20 Aug. 2021, sciencepolicyreview.org/2021/08/equity-transition-electric-vehicles/. Accessed 29 June 2023.
194 Exro, Barriers to electric vehicle adoption in 2022. *Available at* Barriers to Electric Vehicle Adoption: The 4 Key Challenges (exro.com).

cost" which is the combination of technology costs and fines for the 19 light-duty vehicle manufacturers considered in the NHTSA analysis to be in compliance with the standard by the end of the 2032 period.[195] The regulatory costs for compliance with the proposed standards from the NHTSA baseline as well as the "no-ZEV" baseline are shown in Figure 13. As illustrated, regulatory costs are higher from the no-ZEV baseline during the entire period from 2027 through 2032 with the difference amounting to approximately $1,000 per vehicle in 2032.[196] These higher costs result from the modeled need for greater production of more strong hybrid electric vehicles (SHEV) in the no-ZEV case. Further, the number of manufacturers estimated to be able to comply with the proposed CAFE standards in 2032 drops from 7 with the NTHSA baseline to 1 with the No-ZEV baseline. However, this may be an artifact of the CAFE modeling constraints under the No-ZEV case.[197]

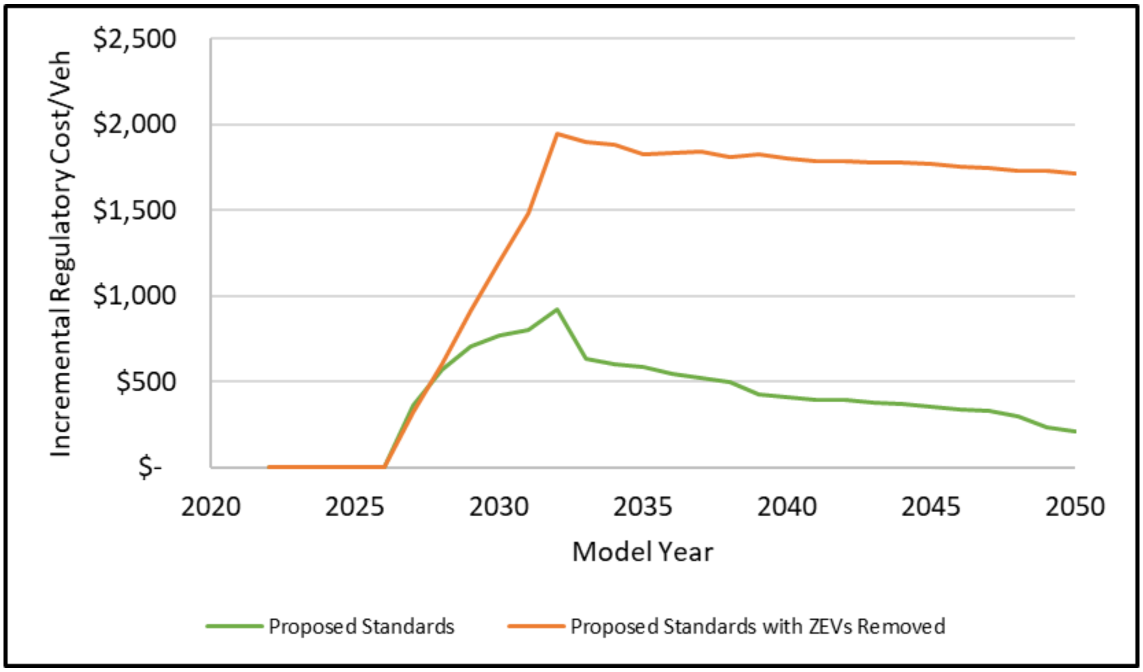
Figure 13: Regulatory Compliance Costs from the NTHSA and No-ZEV Baselines During the Standard Setting Years[198]



Looking at compliance costs from 2022 through 2050 with NHTSA and no-EV baselines, compliance costs are zero through 2026, and then the same for the standard setting years, as shown in Figure 13 (Regulatory Compliance Costs from NHTSA and no-ZEV Baselines during the Standard Setting Years). However, beyond 2032, the compliance costs using the NHTSA baseline drop due to NHTSA's unrealistic assumptions regarding EV costs. Similarly, the compliance costs for the no-EV baseline also drop at a slower rate. See Figure 14 (Regulatory Compliance Costs from NHTSA and no-EV Baselines 2022-2050). What is notable is the difference in compliance costs between the two baselines, reaching a maximum difference of approximately $1,750 per vehicle during 2035-2040.

195 See Appendix B Trinity Technical Review at 4.
196 *Ibid.*
197 *Ibid.*
198 *Ibid.*

Figure 14: Regulatory Compliance Costs from the NTHSA and No-ZEV Baselines 2022 to 2050

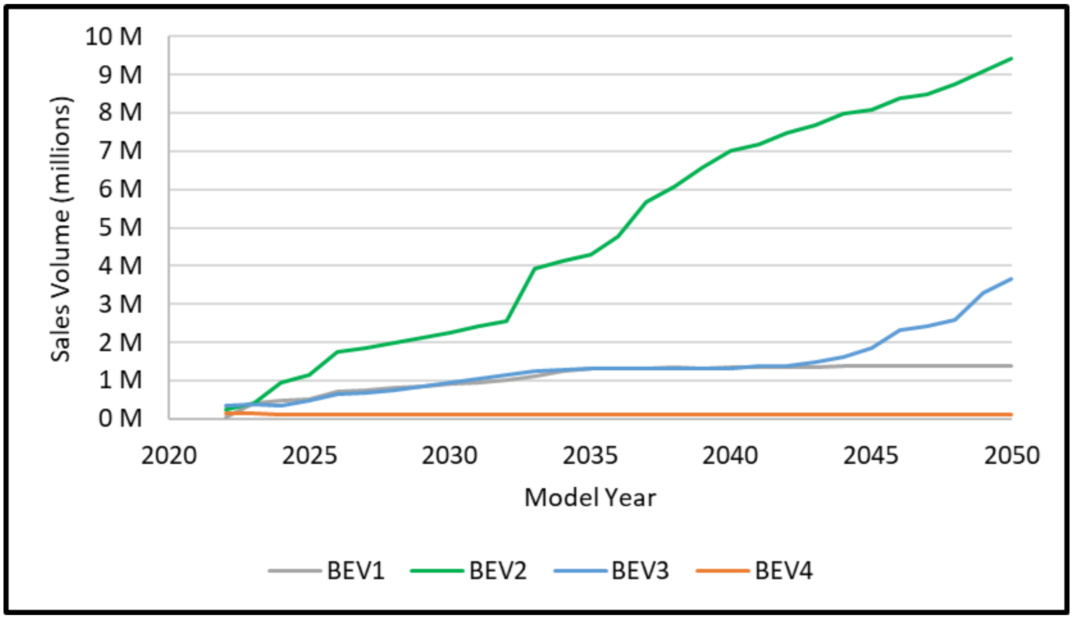


a) NTHSA failed to consider the significant cost to produce batteries needed for EVs contemplated under its proposed standards.

NHTSA has not properly accounted for the cost and long-term affordability of battery production. As described above, sufficient supplies of raw materials, including critical minerals, needed to produce batteries for EVs are not domestically available forcing automakers to increasingly rely on foreign suppliers (see Section II.A above). Without a domestic solution to these supply limitations, reliance on imports will only add cost to the battery pack.[199] Battery costs are a critical component of NHTSA modeling and significantly affect the projected ZEV adoption rates. Using the NHTSA's CAFE model, Trinity Consultants evaluated NHTSA's assumptions regarding the distribution of EV sales as a function of battery range in the baseline fleet. As shown in Figure 15, NHTSA assumed the vast majority of EVs that will be sold in the United States will be "EV2s" with an estimated range of 250 miles, rather than higher-range vehicles requiring larger, more expensive batteries.

[199] Benchmark Minerals Intelligence, BMI (*see* Chart 2, 3 & 4).

Figure 15: NHTSA Baseline EV Assumptions by EV Range



This assumption is significant given the well documented concern that range anxiety is a limiting factor of EV adoption and the fact that NHTSA's assumption is necessary to lower the apparent cost of EVs in other areas of the agency's analysis, such as ensuring that more vehicles are able to qualify for the Clean Vehicle Tax Credit.

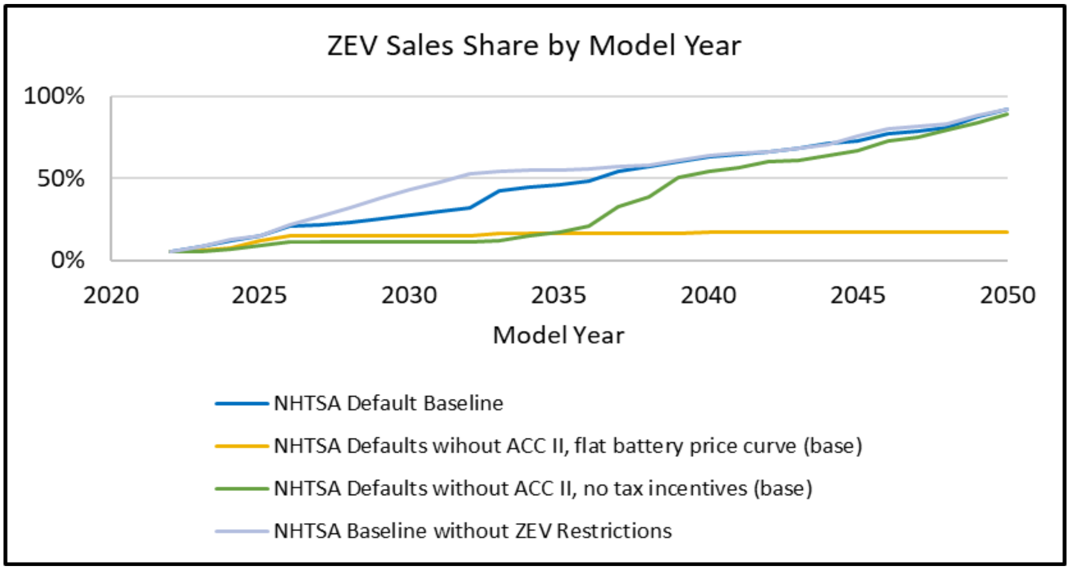
As discussed above, NHTSA violated EPCA by including EVs in the baseline used to develop its proposed CAFE standards. To demonstrate the impact of NHTSA's assumptions regarding EV performance and cost, Trinity conducted a sensitivity analysis that eliminates (1) restrictions on EVs during the standard setting years, (2) the availability of federal EV and battery tax incentives, and (3) the decreases in battery costs due to the "learning curve."[200] As shown in Figure 16 below,[201] NHTSA's assumptions regarding EV performance and cost and the impact of ACC II compliance predict 50 percent of light-duty vehicle sales will be in EVs in 2032, and reaching almost 100 percent by 2050.

---

[200] While the Preliminary Regulatory Impact Analysis (PRIA) lacked information on learning curve effects from 2022 through 2050, Figure 9-11 of the PRIA illustrates that from 2022 (reference case) through 2040, NHTSA projects a 43 percent drop in battery cost *before* learning curve impacts other EV components and tax credits are considered. Optimistic assumptions such as this and aggressive cost reductions attributed to learning are what leads to the agency's forecasts of large increase in the sale of ZEVs, suggesting the agency accelerated learning to justify its costs analysis. *See* Appendix B Trinity Technical Review at 13-14.

[201] Appendix B Trinity Technical Review at 16.

Figure 16: Baseline BEV Sales Fractions by Model Year for the Sensitivity Cases and NHTSA Baseline



The fact that the other sensitivity analyses eliminating ZEV restrictions and tax incentives predict similar levels of EV sales demonstrates just how vital NHTSA's assumptions regarding projected battery costs are to the forecasts of the future vehicle fleet composition.

The critical mineral markets do not support NHTSA's assumptions. Critical minerals used in battery production experience drastic price volatility. Between January 2021 and March 2022, the cost of lithium increased by 738%.[202] While prices have since declined, price volatility should be expected to continue. Future lithium-ion battery production will be heavily subsidized if the BIL and IRA remain in place, which likely serves as an impediment to actually reducing the cost of the battery. Moreover, 2022 battery costs were $153 per kWh,[203] and cost reduction curves have already begun to flatten out. Indeed, battery costs rose 7 percent in 2022.

Further complicating the projection of future battery prices is the fact that battery raw materials are not commodities, they are classified as specialty chemicals. As such, pricing will not follow traditional commodity pricing structures, especially given where these supplies are geographically concentrated in areas with geopolitical instabilities. Each OEM, cathode or anode producer, and battery manufacturer have their own specifications for the materials, and thus the raw materials must be refined and tested to meet their bespoke specification. Spot markets for battery materials are virtually non-existent and unlikely to develop to maturity in the near term. For example, most lithium contracts are written as long-term agreements, which are based on price indices plus a discount, and sometimes with a floor/ceiling mechanism to hedge against pricing volatility. With the United States and other developing nations' push to electrify transportation and the concomitant need to deploy utility-scale batteries, the demand for lithium

---

[202] *See* Canada Energy Regulator, "Market Snapshot: Critical Minerals are Key to the Global Transition" (Jan. 18, 2023), *available at* https://www.cer-rec.gc.ca/en/data-analysis/energy-markets/market-snapshots/2023/market-snapshot-critical-minerals-key-global-energy-transition.html.

[203] DOE, "Electric Vehicle Battery Pack Costs in 2022 Are Nearly 90% Lower than in 2008, according to DOE Estimates," (Jan. 9, 2023) *available at* https://www.energy.gov/eere/vehicles/articles/fotw-1272-january-9-2023-electric-vehicle-battery-pack-costs-2022-are-nearly.

(and other critical minerals) is expected to grow exponentially. This need is only magnified by the fact that the minerals used for EV batteries are also essential to other systems and contexts, including solar photovoltaic cells, wind turbines, and hydrogen electrolyzers, as well as supporting multiple traditional uses, such as military defense systems, aerospace, mobile phones, computers, fiber-optic cables, semi-conductors, medical applications, and even bank notes.

Even where OEMs are taking steps to secure domestically sourced minerals and related commodities to supply production for these plants, these projects are speculative and have yet to be permitted, built, or commercialized at scale. As described above in Section III.B.1.d.i, many of these projects simply will not materialize. Ultimately, the volatility of material pricing will have a direct effect on the viability of these battery projects. If they do come to fruition, OEMs will need to increase their prices to ensure a steady supply. Morgan Stanley estimates BEV makers will need to increase prices by 25 percent to account for rising battery prices.[204]

Battery costs will in turn have significant impacts on EV production, operating, and disposal costs. NHTSA's analysis is inadequate and ignores the cost and long-term affordability of battery production.

b) NHTSA ignores the increased purchase price of EVs and reduction in consumer choice that will result from its Proposal.

Automakers will inevitably be forced to pass on the increased costs associated with producing EVs, including the cost of sourcing scarce and insecure materials, expanding and developing manufacturing capabilities, and research and development costs. NHTSA fails to consider the very real possibility that many automakers simply will not be able to comply with federal and state regulatory requirements and will be forced to pay civil penalties due to non-compliance. Automakers faced with such scenarios will have no choice but to account for such costs in their pricing strategies. NHTSA's Proposal also fails to evaluate how government credits are embedded in vehicle pricing. For example, neither federal or state governments, nor auto manufacturers explain how state ZEV credits, EPA GHG multiplier credits, and NHTSA CAFE EV multiplier credits are accounted for in both ZEV and ICEV vehicle prices.

There is increasing evidence that regulations mandating ZEV sales—along with the cross-subsidies from gasoline and diesel vehicle buyers—are leading manufacturers to abandon sales of the least expensive and higher fuel economy gasoline and diesel vehicles that do not receive similar subsidization.[205] Cox Automotive found that "in December 2017, automobile makers produced 36 models priced at $25,000 or less. Five years later, they built just 10," pushing low-income buyers out of the new-car market and into the used-car market. Conversely, in December 2017 automobile manufacturers offered 61 models for sale with sticker prices of $60,000 or higher

[204]James Thornhill, Bloomberg, "Morgan Stanly Flags EV Demand destruction as Lithium Soars" (Mar. 24, 2022), Chart 7, *available at* https://www.bloomberg.com/news/articles/2022-03-25/morgan-stanley-flags-ev-demand-destruction-as-lithium-soars#xj4y7vzkg.

[205] Steven G. Bradbury, Distinguished Fellow, The Heritage Foundation, Prepared Statement for the hearing entitled "Driving Bad Policy: Examining EPA's Tailpipe Emissions Rules and the Realities of a Rapid Electric Vehicle Transition," before the Subcommittee on Economic Grown, Energy Policy, and Regulatory Affairs of the U.S. House of Representatives Committee on Oversight and Accountability, at 10 (May 17, 2023) *available at* https://oversight.house.gov/wp-content/uploads/2023/05/BradburyPrepared-Statement-for-17 -May-2023-Oversight-Hearing. Pdf

and in December 2022, they offered 90.[206] NHTSA and its sister agencies cannot claim they do not affect vehicle price of credits solely because they have not sought to quantify the impact of their policies mandating ZEV sales.

Ultimately, consumers will be faced with significantly fewer choices when purchasing vehicles, particularly affordable ones. The limited supply of affordable EVs typically have a range below 200 miles on a full charge.[207] If consumers want longer range EVs, they will pay a considerable purchase price as seven of the top ten, range-rated EVs cost anywhere from $74,800 to $110,295.[208]

Consumers will also experience increased vehicle sales tax and property tax associated with the higher purchase price of ZEVs (even after myriad subsidy programs).

Even with significant direct and indirect subsidies, ZEVs are more expensive on average than their ICEV counterparts and unaffordable for many households. In the first calendar quarter of 2022, the average price of the top-selling light-duty ZEV in the U.S. was about $20,000 more than the average price of top-selling ICEV.[209] The price disparity has not improved, with the average price of light-duty ZEVs near $66,000 in August 2022 and continuing to rise.[210]

NHTSA must account for the implications of its Proposed Rule, which will result in vehicle price increases across vehicle types while also reducing consumer choice.

i. NHTSA's overly optimistic assumptions regarding the IRA do not reflect the true cost to electrify light-duty vehicles

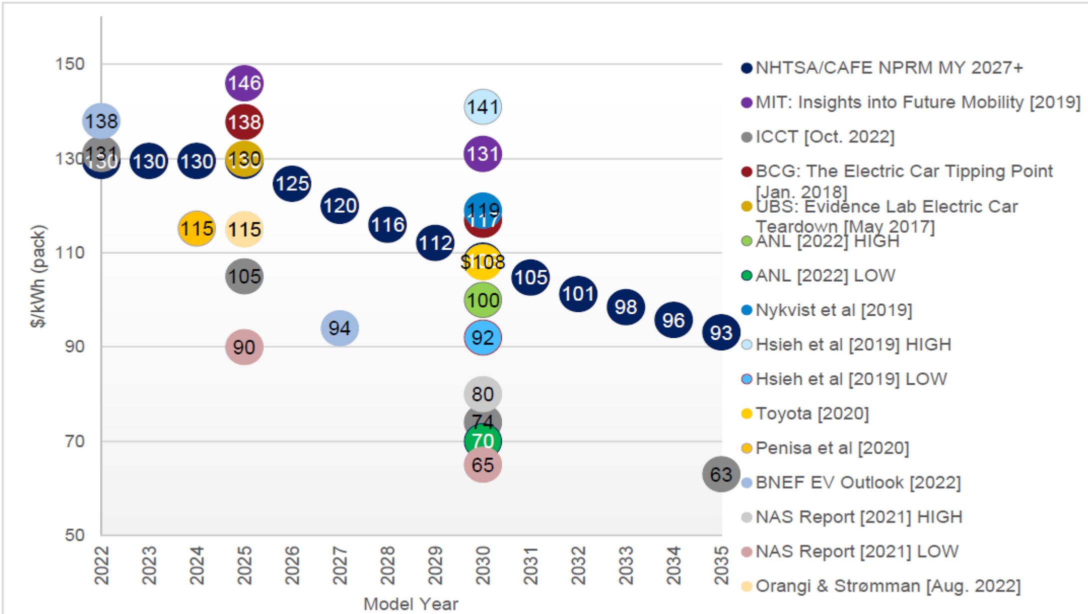
The TSD presents current costs to electrify light-duty vehicles ranging from $3,500 to $6,000 per vehicle.[211] However, this cost is dramatically discounted through the end of 2050 in NHTSA's analysis by applying the battery production tax credit and the vehicle purchase credit from MY 2024 through 2033. As detailed in Trinity's Report, NHTSA assumes the federal battery production tax credit values will increase during 2024 through 2030, and then decrease in 2033.[212]

---

[206] *See* Sean Tucker, Are we witnessing the demise of the affordable car? Automobile makers have all but abandoned the budget market (MarketWatch Feb. 28, 2023), *available at* https://www.marketwatch.com/story/are-we-witnessing-the-demise-of-the-affordable-car-automakershave-all-but-abandoned-the-budget-market-a68862f0 (last visited May 24, 2023).
[207] *See* Sebastian Blanco, *List of EVs Sorted by Range* (Sept. 1, 2022), www.jdpower.com/cars/shoppingguides/list-of-evs-sorted-by-range.
[208] *See* Nicholas Wallace, Austin Irwin, & Nick Kurczewski, *Longest Range Electric Cars for 2023, Ranked* (Mar. 23, 2023), https://www.caranddriver.com/features/g32634624/ev-longest-driving-range/.
[209] Registration-weighted average retail price for the 20 top-selling ZEVs and ICEVs in the U.S. S&P Global, *Tracking BEV prices – How competitively-priced are BEVs in the major global auto markets*? May 2022.
[210] Andrew J. Hawkins, "EV prices are going in the wrong direction," The Verge, August 24, 2022, *available at* https://www.theverge.com/2022/8/24/23319794/ev-price-increase-used-cars-analysis-iseecars (last visited May 24, 2023); *see also* Justin Banner, Latest Ford F-150 Lightning Price Hike Hands Chevy Silverado EV a $20K Advantage–The least-expensive electric F-150 Lightning now costs $4,000 more than it did late last year (Motortrend Mar. 30, 2023), *available at* https://www.motortrend.com/news/2023-ford-f-150-lightning-pro-price-increase-msrp/ (last visited May 24, 2023).
[211] TSD at Table 3-91.
[212] See Appendix B Trinity Technical Review at 13.

NHTSA then applies these tax credits to its assumed battery production costs. *See* Figure 3-32 of the TSD, reproduced below.

Figure 3-32: Comparing Battery Pack Cost Estimates from Multiple Sources



NHTSA's application of the tax credits to battery production reduces battery cost during the period they are assumed to be available. While these federal tax credits may lower battery production costs, they may be eliminated, modified, or manufacturers may not pass these cost savings to consumers to offset losses on current EV sales.[213]

NHTSA uses the same framework for the federal clean vehicle tax credit, showing an EV purchase tax credit ranging from $1,000 to $5,000 during 2024 through 2028, and remaining at $5,000 in 2028 through 2033.[214] NHTSA applies these tax credits to current EV cost values of $3,500 to $6,000 per vehicle to dramatically reduce the cost of EVs before the production learning curve takes effect and the battery production tax credits are taken into account.[215] Once again, it is unclear that the federal clean vehicles tax credit will be available at the levels assumed by NHTSA or that they will persist that far into the future.

c) NHTSA's Proposal does not account for the true total cost of ownership associated with EVs.

Beyond the increased initial cost to purchase a new EV, consumers may also face other long-term costs associated with owning an EV, including increased electricity demands; increased tax, insurance, repair and battery replacement costs; reduced range capacities; and unpredictable

213 *See* Luc Olinga, TheStreet, *Ford Loses Nearly $60,000 for Every Electric Vehicle Sold*, (May 2, 2023) *available at* Ford Loses Nearly $60,000 for Every Electric Vehicle Sold – TheStreet (last accessed July 3, 2023).
214 See Appendix B Trinity Technical Review at 13-14.
215 *Id.*

(and often unreasonable) charging rates. NHTSA must account and assess these potential costs in its Proposal.

i. NHTSA's Proposal will disproportionately disadvantage low-income Americans both financially and practically.

NHTSA did not adequately consider the Proposal's impact on lower income households. While NHTSA recognizes that lower income households typically own older vehicle models,[216] NHTSA must also acknowledge that battery replacement costs are incurred later in a vehicle's lifetime and assess the impact a battery replacement will have on a lower income household. Battery replacements can make the cumulative cost for EV operation and maintenance higher than gasoline or diesel-powered vehicles.[217]

NHTSA assumes EV owners will utilize at home changing, reducing charging costs, the frequency of mid-trip recharging events, and travel-time costs.[218] While many EV owners may opt to install residential charging stations at their homes, this is simply not an option for many Americans. Financial and/or logistical constraints may prohibit many ZEV owners from having accessible EV charging infrastructure at home. For those who simply cannot afford the upfront costs for a new EV or pay higher public charging rates, they may end up retaining older ICEVs for longer.

It may not be economically feasible for many EV owners to charge using public DCFC equipment. About one-third of the U.S. population lives in multi-unit housing[219] and they would likely rely on recharging their vehicle at commercial DCFC stations. "Electricity purchased at a public charger can cost five to ten times more than electricity at a private one."[220] Those who cannot afford private charging will end up paying vastly more for a re-charge than the wealthy. These costs to lower income and commercial EV users are not acknowledged in the Draft TSD. According to one article that explains the different costs of recharging BEVs, using a publicly available DCFC system is the most expensive way to recharge a BEV costing 60% more than refueling a similarly sized ICEV.[221] Car and Driver put it this way: "[I]f you're buying an electric car to save on fuel costs, make sure you plug in at home."[222] Lower-income consumers also cannot afford to install solar photovoltaics, which proponents claim will allow EVs to be charged at home with emissions-free electricity.[223]

NHTSA must also account for increased overall EV ownership costs due to current state excise tax policies and insurance that establish higher costs for EV owners. Insurance premiums

---

216 88 FR 56,373 (August 17, 2023).
217 Furch, J., Konečný, V. & Krobot, Z. Modelling of life cycle cost of conventional and alternative vehicles. *Sci Rep* 12, 10661 (2022). https://doi.org/10.1038/s41598-022-14715-8
218 Draft TSD Chapter 6.1.4.1 Value of Travel Time Savings, 6-6.
219 *See* https://www.census.gov/population/www/cen2000/censusatlas/pdf/14_Housing.pdf (accessed 2/17/20).
220 *Id*.
221 Jim Gorzelany, "What it Costs to Charge and Electric Vehicle," https://www.myev.com/research/ev-101/what-it-costs-to-charge-an-electric-vehicle, accessed January 31, 2021.
222 *See* "Our Tesla Model 3 Proves EVs Are Cheaper When Charged at Home," Car and Driver, January 11, 2021, https://www.caranddriver.com/news/a35152087/tesla-model-3-charging-costs-per-mile/.
223 Jonathan A Lesser, Short Circuit: The High Cost of Electric Vehicle Subsidies 4, Manhattan Institute (May 15, 2018), *available at* https://media4.manhattan-institute.org/sites/default/files/R-JL-0518-v2.pdf.

for PEVs are typically higher than comparable ICEVs because of higher repair and parts costs. The price premium depends on the make and model, age of the driver, geographic location, and state. According to ValuePenguin, insurance on a PHEV, depending on the model, could be 19 percent to 32 percent higher than comparable ICEV.[224] Another estimate from an Oct 2022 study from Self Financial concludes PEVs' annual insurance is $1,674, $442 more compared to an ICEV annual insurance premium of $1,232.[225]

Low-income Americans will be affected by a litany of additional increases associated with the cost of owning an EV, including taxes, higher insurance rates, and limited availability of replacement parts and qualified mechanics. On top of this, EVs with longer range capabilities cost significantly more—middle- and low-income Americans will not be able to afford EVs with longer range capacities, ultimately requiring them to pay more to charge low-range vehicles more frequently. While overall cost of ownership will increase with EVs, Americans will also be faced with significantly reduced consumer choice when purchasing vehicles. As described above, regulations that outright or implicitly require EV sales, like NHTSA's proposal here, are the primary drivers in manufacturers abandoning their less expensive and higher fuel economy gasoline and diesel vehicles. NHTSA must account for this trend toward eliminating affordable vehicles. Though EVs will play a role in the future automotive markets, their acceptance should be market driven by consumer choice, not by government regulation.

ii. NHTSA has not adequately weighed the factors affecting liquid and electric fuel prices.

NHTSA must also consider the relative differences in fuel prices that consumers will face. EVs do not achieve a real-world fuel economy that is equivalent to the agency's applied fuel economy test methods. As noted in the environmental benefits discussion below, NHTSA's Proposal is based on performance data estimates of ICEV fuel economy using EPA's "5-cycle method." If NHTSA's analysis were based on real-world fuel economy testing of EVs, it would show they use vastly higher amounts of electricity to travel the same distance, with a corresponding increase in ZEV owner costs for electricity and ZEV maintenance and battery replacement. NHTSA must account for these real costs.

In reality, EVs have less range than ICEVs, both technically and practically. As noted by J.D. Power, "the majority of EVs provide between 200 and 300 miles of range on a full charge."[226] One study shows that the average 3-year-old electric car is driven 9,059 miles per year, compared with 12,758 miles for ICEVs.[227] Other research suggests EVs travel only 5,300 miles per year.[228] NHTSA's analysis assumes a longer battery life than is currently achieved, as NHTSA does not factor in battery replacement costs or the environmental implications of additional battery

---

[224] Dillon Leovic, "How Much Does Electric Car Insurance Cost?," ValuePenguin, June 1, 2023, *available at* https://www.valuepenguin.com/how-having-electric-car-affects-your-auto-insurance-rates.
[225] "Electric Cars vs Gas Cars Cost in Each State," Self Financial, *available at* https://www.self.inc/info/electric-cars-vs-gas-cars-cost/.
[226] *See* Sebastian Blanco, List of EVs Sorted by Range (Sept. 1, 2022), www.jdpower.com/cars/shoppinqquides/list-of-evs-sorted-by-ranqe.
[227] iSeeCars, *The Most and Least Driven Electric Cars* (May 22, 2023), https://www.iseecars.com/mostdriven-evs-study.
[228] Burlig, F., Bushnell, J., Rapson, D., Wolfram, C., "Low Energy: Estimating Electric Vehicle Electricity Use," National Bureau of Economic Research Working Paper 28451, http://www.nber.org/papers/w28451.

production, recycling, and disposal. Additionally, charging downtime and range limits of EVs will likely reduce vehicle operation time. Therefore, commercial enterprises, including small businesses, using EVs will need to deploy more vehicles to provide the same level of service currently provided by ICEVs. NHTSA must accurately account for the difference in vehicle miles traveled by EVs.

NHTSA must also consider realistic retail fuel costs for EVs as compared to liquid fuels. EV owners will not pay the national average residential electricity price to charge their vehicles. The majority of EVs in the U.S. are located in utility service territories with some of the highest electricity rates in the country such that the average EV owner currently pays a much higher price to charge their EV at home than the national average residential electricity rate. Given that EV penetration has varied widely across the U.S., it would be arbitrary to assume that EVs will, unlike in the past, penetrate uniformly across the U.S. and thus that the average electricity price would be representative of the actual cost of electricity. For example, California, which has roughly 40 percent of all registered EVs in the U.S., has a residential electricity rate that is roughly double the national average. Moreover, the assumed EV penetration rates will necessarily require exponential increases in commercial EV charging at rates that are significantly higher than the current national average residential electricity rate, depending on location and charging speed. Those customers who are not homeowners and not able to install their own charging stations and take advantage of charging at low-cost times will be adversely impacted. A true assessment of fuel costs must consider both commercial and residential rates for electricity, as well as peak power or time of use charges. For example, California electric prices rose 42 percent - 78 percent between 2010 and 2020 and are projected to rise an additional 50 percent by 2030 as shown in Figure 17.

Figure 17: Historical and Forecasted Electricity Rates for California[229]

For example, California's ZEV mandates have contributed to the inflationary impacts on energy prices and on jobs in certain industries related to traditional fuels and vehicles. According

229 Michael Shellenberger, Twitter (citing California Public Advocate's Office data), *April 27, 2021*.

to a 2021 California Public Advocates Office presentation to the California Public Utilities Commission, "it is already cheaper to fuel a conventional internal combustion engine (ICE) vehicle than it is to charge an EV" in the San Diego Gas & Electric Co. service area.[230] This is astonishing given that gasoline prices in California are the second highest in the nation, averaging approximately $4.01 per gallon of gasoline at the time in 2021. According to an Anderson Economic Group article, entry-priced, gas-powered cars were significantly more affordable to fuel at $9.78 per 100 "purposeful miles" compared to the $12.55 at-home charging costs for an entry-priced EV. Future projections afford consumers no relief, as the California Energy Commission projects that both commercial and residential electricity prices will continue to rise, reaching nearly $7 per gasoline-gallon equivalent for the commercial sector. Similarly, many in the Boston-Cambridge-Newton area paid $0.34 per kWh in April 2023, which was nearly 107% higher than the national average.[231]

Heaping additional demand for EV charging into this market could exacerbate already high electricity prices. This will be especially impactful to lower-income homeowners who may not be able to install dedicated charging units, forcing them to pay more out of pocket for charging during peak demand periods.[232]

Finally, charging pricing has been unpredictable, with some stations charging by the minute instead of charging for electricity consumed.[233] Other charging stations offer multiple subscription plans or charge different rates at various times of day, resulting in significant price increases over the past few months.[234] Boston charging companies raised charging fees in response to New England utilities increasing their rates to 39 cents per kilowatt-hour in February 2023, from 27 cents a year earlier.[235] Additionally, many ZEV owners will be forced to install their own residential charging stations, which have significant upfront costs (not to mention the added ongoing electrical costs to actually charge the vehicle).

NHTSA must revise its analysis to account for realistic electricity prices. NHTSA's underlying EV assumptions will require an enormous investment in power generation and distribution, resulting in nationwide increases in electricity bills that NHTSA has not considered. Of course, considering the additional trillions of dollars in costs would paint a clear picture that the costs of the Proposal far exceed its inflated benefits (see Section III.B.2.d below).

---

230 California Public Utilities Commission, "Utility Costs and Affordability of the Grid of the Future" (May 2021). Presentation from Mike Campbell, Public Advocates Office at 116-117 available at https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/office-of-governmental-affairs-division/reports/2021/senate-bill-695-report-2021-and-en-banc-whitepaper_final_04302021.pdf.
231 U.S. Bureau of Labor Statistics, Northeast Information Office, Average Energy Prices, Boston-Cambridge-Newton—April 2023, available at https://www.bls.gov/regions/northeast/news-release/averageenergyprices_boston.htm#:~:text=Source%3A%20U.S.%20Bureau%20of%20Labor,of%2016.5%20cents%20per%20kWh.
232 Hardman, Scott, et al., "A Perspective on Equity in the Transition to Electric Vehicles." *MIT Science Policy Review*, (Aug. 20, 2021), *available at* https://sciencepolicyreview.orq/2021/08/equity-transitionelectric-vehicles/ (accessed June 29, 2023).
233 Aaron Pressman, "Inside the crazy, mixed-up world of electric-vehicle charger pricing," The Boston Globe, March 27, 2023. Available at https://www.boston.com/news/the-boston-globe/2023/03/27/electricvehicle-charger-pricing.
234 *Id.*
235 *Id.*

iii. NHTSA's Proposal will lead to cross-subsidization, shifting costs associated with increased EV penetration rates to those purchasing ICEVs.

While the purchase price differential between comparable ICEVs and EVs may be relevant for forecasting consumer demand, it does not reflect the true costs of the ZEVs required under the Proposed Rule. A ZEV typically costs tens of thousands of dollars more to produce than a comparable ICEV due primarily to the surging costs of critical minerals and resulting high costs of batteries.[236] McKinsey & Company found that EV manufacturers "do not make a profit from the sale of EVs. In fact, these vehicles often cost $12,000 more to produce than comparable vehicles powered by internal-combustion engines (ICEs) in the small- to midsize-car segment and the small-utility-vehicle segment. What is more, carmakers often struggle to recoup those costs through pricing alone. The result: apart from a few premium models, OEMs stand to lose money on almost every EV sold, which is clearly unsustainable."[237] Additionally, the practical effect of NHTSA's Proposed Rule will force manufacturers to sell increasing numbers of ZEVs each year that goes far beyond the consumer demand for the product at its true cost. Manufacturers will be forced to incentivize ZEV purchases through a practice called cross-subsidization.

Automobile cross-subsidization is a pricing strategy to spread the high cost of ZEVs across a manufacturer's other product offerings. Under this pricing convention, manufacturers set the prices of certain ICEVs higher than their production costs to generate additional profits that can then be used to offset losses incurred by selling ZEVs below their actual production costs. This operates as a hidden tax on ICEVs and results in the purchasers of ICEVs subsidizing the sale of ZEVs. Without cross-subsidies, manufacturers simply cannot achieve the assumed ZEV penetration rates. This means that even those who are completely unwilling to pay for EVs still pay for them in part by absorbing a markup on ICEV costs. These cross-subsidies are effectively a tax imposed on all those choosing not to purchase electrified vehicles.

While opaque, the magnitude of ZEV cross-subsidies is significant.[238] Ford's decision to report ZEV financial information separately beginning in 2023 provides an additional glimpse into

---

[236] *See* PCMag, Profit vs. the Planet, (Sept. 26, 2022), Profit vs. the Planet: Here's Why US Automakers Are All-In on Electric Vehicles I PCMag *last accessed* July 3, 2023 ("EVs are currently more expensive to manufacture than gas-powered vehicles because of spiking battery costs. The cost of lithium, the main ingredient, has skyrocketed since demand far exceeds the number of working mines that can supply it.").

[237] McKinsey & Company. March 2019. https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/making-electric-vehicles-profitable.

[238] NHTSA's methodology ignores current EPA, DOE, NHTSA, and state regulations that add hundreds of billions of dollars in costs of ICEVs to cross-subsidize buyers of ZEVs. These cost transfers are in the form of: (1) state-mandated ZEV credit payments from ICEV manufacturers (i.e., ICEV buyers) to ZEV manufacturers (i.e., ZEV buyers); (2) current and future potential EPA GHG ZEV multiplier credit payments from ICEV manufacturers (i.e., ICEV buyers) to ZEV manufacturers (i.e., ZEV buyers); and, (3) NHTSA-mandated fuel economy ZEV multiplier credit payments from ICEV manufacturers (i.e., ICEV buyers) to ZEV manufacturers (i.e., ZEV buyers). A NHTSA presentation suggests that NHTSA EV multiplier credits alone subsidize each EV by more than $25,000, increasing the true average cost of every EV sold to over $90,000. See https://www.nhtsa.gov/sites/nhtsa.gov/files/2015sae-powellaltfuels cafe. pdf; https://www.nhtsa.gov/sites/nhtsa.gov/files/2022-04/Model-Documentation CAFE-MY-2024-2026 v1-tag.pdf; https://one.nhtsa.gov/cafepic/home/ldreports/manufacturerPerformance. Per the NHTSA information above, since MY2017 standards were -35mpg and MY2017 Tesla FE performance (with multipliers) was 518.7 mpg, and since Tesla sold -46,979 MY2017 vehicles in the U.S., then Tesla in

the magnitude of cross-subsidization. Ford lost approximately $58,000 for each ZEV car it sold during the quarter.[239] While cross-subsidization, tax credits, emissions trading, and other ZEV subsidies may hide the true costs of a ZEV mandate from consumers, NHTSA has a duty to quantify and present those costs that are attributable to the Proposed Rule. Pursuant to Executive order 12866:

> NHTSA must "assess all costs and benefits of available regulatory alternatives, including the alternative of not regulating. Costs and benefits shall be understood to include both quantifiable measures (to the fullest extent that these can be usefully estimated) and qualitative measures of costs and benefits that are difficult to quantify, but nonetheless essential to consider.[240]

Ignoring actual ZEV production costs, including credit trading costs, is unreasonable.

NHTSA ignores this real-world regulatory compliance pricing scheme. As noted above, E.O. 12866 requires NHTSA to be a neutral decisionmaker and to fairly assess the costs and benefits of this Proposal. The Agency has not met its obligations under relevant Executive Orders, the Administrative Procedure Act, or EPCA, which requires NHTSA to consider "economic practicability" when deciding maximum feasible average fuel economy standards. NHTSA has instead understated the costs of this Proposal.

NHTSA must account for these real-world costs and communicate to the public that these cross-subsidies must be paid for by a shrinking number of ICEV buyers and, therefore, must significantly increase the average price of EVs. As ZEV prices rise, their sales and ICEV fleet turnover will slow, reducing fuel efficiency benefits and creating a significant drag on the economy.

d) NHTSA failed to adequately account for the total cost required to upgrade and expand the grid.

Notably absent from NHTSA's analysis is any demonstration that sufficient utilities and other infrastructure needed to support the EV penetration assumptions in NHTSA's baseline calculation and its modeling considerations will actually be available. In fact, grid resiliency is at risk of further deterioration due to increasing power demand from electrification, not just in transportation.

As described in more detail in Section III.B.1.b.i, significant regional power demands resulting from increased EV penetration rates will greatly stress the U.S. energy and transmission

---

MY2017 generated 227 million excess credits. If the market-value of these credits is -$5.50 per 0.1 mpg shortfall per vehicle under the MY2017 CAFE standard of-35 mpg, then these credits were worth approximately $1.25 billion, or $26,600 per EV that Tesla sold. [Calculation of estimated value: Credits= (518. 7 - 35) x 46979 x 10 x CAFE Penalty of $5.50 per 0.1 mpg shortfall per vehicle]. Tesla may have banked, traded, or sold these credits. Tesla MY2022 sales in the U.S. were 484,351 and the CAFE civil penalty is now $15 per 0.1 mpg shortfall per vehicle.

[239] *See* Luc Olinga, TheStreet, *Ford Loses Nearly $60,000 for Every Electric Vehicle Sold*, (May 2, 2023) *available at* Ford Loses Nearly $60,000 for Every Electric Vehicle Sold - TheStreet (last accessed July 3, 2023).

[240] E.O. 12866, Section 1(a), Sept. 30, 1993.

grid. There is insufficient time and inadequate materials supply to expand and upgrade the grid as needed to support these rates. Even if such upgrades were possible, doing so would be cost prohibitive. NTHSA has not accounted for the significant costs associated with expanding and upgrading the grid in light of these significant materials and timing constraints. NHTSA must consider the increase in the cost of electricity to consumers (whether EV owners or others) associated with the Proposed Rule. The U.S. needs to invest an estimated $4.5 trillion to fully transition the U.S. power grid to renewables during the next 10-20 years.[241] The cost of grid upgrade projects needed to support the incremental electricity demand growth from transportation is significant and can be quite variable. A particular case study of Northern California illustrated in 10P Science notes: "[T]he total cost of these upgrades will be at least $1 billion and potentially more than $10 billion" for a service area of 4.8 million electricity customers.[242] These costs need to be taken into consideration with expected demand growth, within detailed rate base calculations, and in concert with appliance upgrade costs to fully understand their ultimate impact on annual ratepayer expenditures.

Even where energy expansion and upgrade projects are contemplated or proposed, these complex projects often fail to materialize. While the Lawrence Berkley National Laboratory reports strong interest in clean energy, increasing delays in studying, building, and connecting new energy projects to the grid means that "much of this proposed capacity will not ultimately be built."[243] The high-rate project withdrawal is reflected in the fact that only 21 percent of the projects (representing 14 percent of capacity) seeking connection from 2000 to 2017 were constructed as of the end of 2022.[244] Other challenges cited by the Berkeley National Lab that prevent timely operation of new renewable energy projects include increased interconnection wait times, reaching agreements with landowners and communities, power purchasers, supply chain constraints, and financing.[245] In sum, NHTSA has given insufficient consideration to the significant cost barriers to the grid updates that would be required by the Proposed Rule.

e) NHTSA overlooks the significant costs of installing required charging capacity.

NHTSA must also consider the costs to build the charging infrastructure required to support the assumed EV penetration rates. Even as new EVs are ready to enter into production, auto industry representatives have acknowledged the necessary infrastructure for electric vehicles continues to lag.[246] In 2020, there were a total of 103,582 publicly available non-proprietary charging outlets in U.S. (30 percent of which are located in 14 counties) for 3.04 million EVs on the road, a ratio of 29 EVs per charger.[247] In 2022, 51 percent of all new chargers were added in 2 percent of U.S. counties, with California adding 25 percent of the 2022 new charging

[241] Dan Shreve and Wade Schauer, *Deep decarbonization requires deep pockets* (June 2019), https://www.decarbonisation.think.woodmac.com/.
[242] Salma Elmallah et al., IOP SCIENCE, "Can distribution grid infrastructure accommodate residential electrification and electric vehicle adoption in Northern California?" (Nov. 9, 2022), *available at* https://iopscience.iop.org/article/10.1088/2634-4505/ac949c.
[243] Berkeley Lab, *Electricity Markets and Policy: Queued Up: Characteristics of Power Plants Seeking Transmission Interconnection*, https://emp.lbl.gov/gueues (last visited June 9, 2023).
[244] *Id*.
[245] *Id*.
[246] ALLIANCE FOR AUTOMOTIVE INNOVATION, "Get Connected Electric Vehicle Quarterly Report" (Fourth Quarter 2022).
[247] *Id.*

capacity and 160 counties adding only one charger.[248] And the pace of installing new public chargers is not keeping up with current and projected EV sales, as the ratio of registered EVs to new chargers in 2022 was 38 to one.[249]

A 2023 EV Charging Station Report based on DOE's Alternative Fuel Data Center data highlights as the number of ZEVs in the U.S. increased by 42 percent, but the growth in public charging outlets increased by only 12 percent during the same time.[250] According to S&P Global's Mobility Special Report, U.S. charging infrastructure is not nearly robust enough to fully support a maturing electric vehicle market, and ZEV charging stations will need to quadruple between 2022 and 2025 and grow more than eight-fold by 2030.[251] There is lower investment into charging systems outside of major metro markets.[252] Of the 3,100 counties and city-counties in the U.S., 63 percent had five or fewer chargers installed; 39 percent had zero; and 53 percent of counties added no new chargers in 2022.[253]

NHTSA must also consider the cost of power distribution upgrades needed for EVSE installation. The National Renewable Energy Laboratory ("NREL") published new estimates of the need for ZEV charging infrastructure investment that finds:

> A cumulative national capital investment of $53—$127 billion in charging infrastructure is needed by 2030 (including private residential charging) to support 33 million PEVs. The large range of potential capital costs found in this study is a result of variable and evolving equipment and installation costs observed within the industry across charging networks, locations, and site designs. The estimated cumulative capital investment includes:
>
> - $22—$72 billion for privately accessible Level 1 and Level 2 charging ports

---

248 Id.
249 Id.
250 ZUTOBI, "2023 EV Charing Station Report: State-by-State Breakdown" (June 16, 2023) *available at* https://zutobi.com/us/driver-guides/the-us-electric-vehicle-charging-point-report.
251 S&P Global Mobility. "EV Chargers: How Many Do We Need?" *News Release Archive*, (Jan. 9, 2023), https://press.spglobal.com/2023-01-09-EV-Chargers-How-many-do-we-need (accessed June 28, 2023).
252 S&P Global Mobility. "EV Chargers: How Many Do We Need?" *News Release Archive*, (Jan. 9, 2023), https://press.spglobal.com/2023-01-09-EV-Chargers-How-many-do-we-need, (accessed June 28, 2023). Currently EV charging is concentrated in high-income urban areas in California, Colorado, Massachusetts, Maryland, New Jersey, New York, and Oregon. Phillipp Kampshoff, et al., McKinsey & Co., "Building the electric-vehicle charging infrastructure America needs" (Apr. 18, 2022) *available at* https://www.mckinsey.com/industries/public-sector/our-insights/building-the-electric-vehicle-charginginfrastructure-america-needs.
253 Alliance for Automotive Innovation. *Get Connected Electric Vehicle Quarterly Report, Fourth Quarter 2022*. *See also* S&P Global Mobility. "EV Chargers: How Many Do We Need?" *News Release Archive*, 9 Jan. 2023, https://press.spglobal.com/2023-01-09-EV-Chargers-How-many-do-we-need. Accessed 28 June 2023 (Texas currently has about 5,600 Level 2 non-Tesla and 900 Level 3 chargers, but by 2027 S&P Global Mobility forecasts the state will need about 87,500 Level 2 and 7,800 level 3 chargers – more than ten times the current number of Level 2 and 3 chargers - to support an expected the expected 1.1 million EVs at that time).

- $27—$44 billion for publicly accessible fast charging ports
- $5—$11 billion for publicly accessible Level 2 charging ports.[254]

Given a general linear relationship between EV charging infrastructure costs and the number of registered ZEVs, it is reasonable to estimate (using the DOE numbers) a cost added for charging infrastructure to each EV of (at least) $1,606 to $3,848.

The BIL provides up to $7.5 billion to install 500,000 public chargers nationwide by 2030. “However, even the addition of half a million public chargers could be far from enough. In a scenario in which half of all vehicles sold are EVs by 2030—in line with federal targets—McKinsey estimates that America would require 1.2 million public ZEV chargers and 28 million private EV chargers by that year.[255] All told, the country would need almost 20 times more chargers than it has now.”[256] NHTSA must address charger investment and reliability by more than just referencing EV subsidies in recent legislation.

Moreover, NTHSA must consider the costs to businesses to install and operate such chargers. Current office buildings, parking lots, apartment buildings, municipal buildings, and town centers will need to be retrofitted with adequate charging stations.

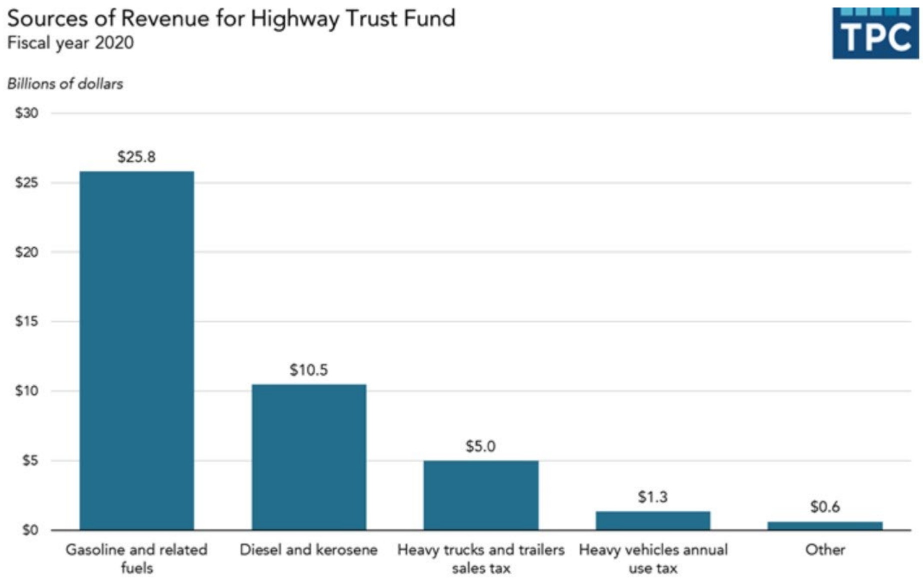
f) NHTSA does not adequately evaluate the Proposal’s impact on fuel tax revenue (Highway Trust Fund).

NHTSA does not adequately account for infrastructure impacts from increased operation of heavier EVs on the road including road and bridge deterioration and commensurate reduced funding for infrastructure from fuel tax collections. The Highway Trust Fund (HTF), established by the Highway Revenue Act of 1956, is the source of federal revenue for the construction and maintenance of our nation’s roads and bridges. The HTF is primarily funded by a federal fuel tax on each gallon of gasoline and diesel fuel. See Figure 18.

---

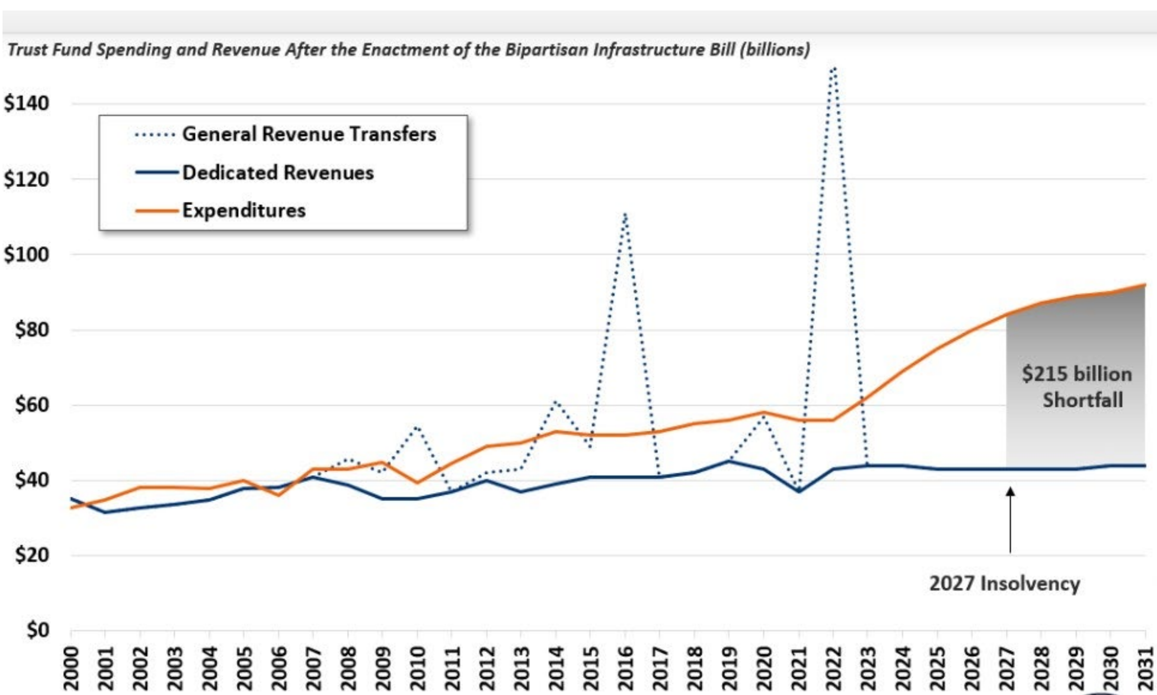
[254] National Renewable Energy Laboratory, *The 2030 National Charging Network: Estimating U.S. LightDuty Demand for Electric Vehicle Charging Infrastructure*, June 26, 2023, at vii. *Available at* https://www.nrel.gov/docs/fy23osti/85654.pdf.
[255] McKinsey, “Building the Electric Vehicle Charging Infrastructure America Needs,” (Apr. 18, 2022), *available at* America’s electric-vehicle charging infrastructure I McKinsey: *see also* S&P Global, “EV Chargers: How Many Chargers DO We Need?, (Jan. 9, 2023) (millions of chargers are needed).
[256] *Id*.

Figure 18: Revenue Sources for Highway Trust Fund[257]



Although the Bipartisan Infrastructure Law (BIL) included a one-time deposit into the HTF, the fact remains that spending dramatically outpaces revenue, calling into question the HTF's solvency past 2027.

Figure 19: HTF Spending and Revenue after the BIL[258]



---

[257] Congressional Budget Office, The Budget and Economic Outlook 2020 to 2030, January 2020.

[258] Committee for Responsible Federal Budget, based on Congressional Budget Office data. Available at https://www.crfb.org/blogs/infrastructure-bills-impact-highway-trust-fund.

As of July 2023, taxes and other fees on retail gasoline and diesel fuel, in cents per gallon, are:

	Gasoline[259]	Diesel
Federal	18.40	24.40
Average of total state taxes	32.26	34.20

Because EVs are heavier than ICEVs of similar size and class, they can have a greater impact on road wear.[260] Yet, because they do not consume liquid fuel, EV drivers do not pay a tax that contributes to the HTF. According to NHTSA, the proposed CAFE standards, if implemented, would reduce gasoline consumption by "88 billion gallons relative to baseline levels for passenger cars and light trucks, and by approximately 2.6 billion gallons relative to baseline for HDPUVs through calendar year 2050."[261] Applying the current fuel tax rates to NHTSA's estimated reduction in fuel consumption for passenger cars and HDPUVs, the HTF would lose $16.192 billion dollars in lost gasoline tax revenue, and $634 million in lost diesel fuel revenue between 2027-2050. Any economic assessment must factor in the significant financial loss. The vast economic and political impact of NHTSA's Proposal triggers the major question doctrine.

g) NHTSA lacks authority to mandate EVs

For all the reasons described above, NHTSA's fails to adequately consider the true costs of its Proposal and seeks to force a transformational shift to electric vehicles despite clearly lacking the authority to do so. NHTSA's Proposed Rule amounts to a *de facto* electric vehicle mandate since automakers will be forced to produce more electric vehicles in order to meet the proposed standards. The forced electrification of the Nation's vehicle fleet would have vast economic and political significance, triggering the major-questions doctrine. NHTSA must therefore point to clear congressional authorization to effectively mandate electric vehicles, which it cannot do.

The question of whether this shift is necessary and, if so, how to accomplish this shift, is a "major question" reserved for Congress, not NHTSA. The "major questions doctrine" holds that Congress must "speak clearly when authorizing an agency to exercise [such] powers" of "vast economic and political significance."[262] This doctrine applies in the context of environmental regulation. Last year, in *West Virginia v. EPA*, the Supreme Court relied on the major questions doctrine in holding that the EPA exceeded its statutory authority in adopting its Clean Power Plan.

---

[259] U.S. Energy Information Agency, Frequently Asked Questions: "How Much Tax Do We Pay on a Gallon of Gasoline and a Gallon of Diesel Fuel? Available at https://www.eia.gov/tools/faqs/faq.php?id=10&t=10.

[260] Low, J.M., Haszeldine, R.S. & Harrison, G.P. The hidden cost of road maintenance due to the increased weight of battery and hydrogen trucks and buses—a perspective. *Clean Techn Environ Policy* 25, 757–770 (2023), accessed at https://doi.org/10.1007/s10098-022-02433-8.

[261] 88 Fed. Reg. at 56,132.

[262] *Nat'l Fed. Of Indep. Bus. v. Dep't of Labor*, 142 S. Ct. 661 ,665 (2022); see also *Ala. Assoc. of Realtors v. Dep't of Health & Human Servs.*, 141 S. Ct. 2485, 2489 (2021); *Utility Air Regulatory Group v. EPA*, 573 U.S. 302, 324 (2014); *U.S. Telecom Assoc. v. FCC*, 855 F.3d 381, 419-21 (D.C. Cir. 2017) (Kavanaugh, J., dissenting from denial of rehearing *en banc*) (explaining provenance of "major rules doctrine").

That regulation sought to impose caps on GHG emissions by requiring utilities and other providers to shift electricity production from coal-fired power to natural gas and then to renewable energy in place of imposing source-specific requirements reflective of the application of state-of-the-art emission reduction technologies.[263] As noted by the Court, EPA "announc[ed] what the market share of coal, natural gas, wind, and solar must be, and then require[d] plants to reduce operations or subsidize their competitors to get there."[264] EPA's attempt to devise GHG emissions caps based on a generation-shifting approach would have had major economic and political significance impacting vast swaths of American life and substantially restructured the American energy market; however, EPA's purported authority was only based on a "vague statutory grant" within Section 111(d) of the Clean Air Act—far from the "clear authorization required by [Supreme Court] precedents.[265] The need for clear congressional authorization for such sweeping regulatory programs is nothing new —the Supreme Court recently reaffirmed the major questions doctrine "as an identifiable body of law that has developed over a series of significant cases spanning decades."[266]

NHTSA's Proposed Rule here presents an analogous situation, albeit one with substantially greater costs. A *de facto* EV mandate that requires a rapid shift from ICEV to EV will reshape the American automotive market with profound collateral effects, making clear that NHTSA is encroaching upon an issue of "vast economic and political significance." As discussed throughout this comment, the Proposal's direct compliance costs are enormous—even in the face of numerous errors and oversights in its analysis that materially understate these costs.

NHTSA has proposed this de facto mandate despite lacking statutory authorization to do so. As described above in Section III.A, Congress specifically prohibited NHTSA, the agency tasked with setting fuel-economy standards, from even considering electric vehicles when setting those standards. In addition to protecting Congress's incentives, Section 32902(h)(1) also prevents NHTSA from seizing authority over a major policy issue that Congress has not given it. Indeed, Congress has not only failed to clearly authorize NHTSA to set fuel-economy standards that effectively mandate electric vehicles; Congress has expressly forbidden NHTSA to do so. Yet NTHSA seeks to bake these ultra vires electric vehicle mandates into federal fuel-economy standards by incorporating them into the "baseline" fleet it uses to assess the average level of fuel economy that manufacturers can feasibly achieve and incorporating them into the modeling used for setting the proposed standards.

As described in Section III.3.a, relying on other state and federal electric-vehicle mandates is unlawful, and it's arbitrary and capricious because it puts NHTSA's rulemaking in a tenuous position. If a party successfully challenges any one of those laws, then NHTSA's rule will fail to reflect "reality," as it will have been set based on manufacturers' presumed compliance with unlawful standards. This practical problem further confirms that Congress did not permit NHTSA to incorporate other entities' electric-vehicle mandates into fuel economy rules. And it provides an

[263] *West Virginia v. EPA*, 142 S. Ct. 2587 (2022).
[264] *Id*. at 2613, n4.
[265] *Id*. at 26,14.
[266] *Biden v. Nebraska*, No. 22-506, slip op. at 23 (June 30, 2023) (internal quotations omitted) (applying major questions doctrine to strike down student loan repayment program that will cost taxpayers approximately $500 billion and affects nearly every student loan borrower). Just as the trade-offs inherent in a mass debt cancelation program are ones that Congress would likely have reserved for itself, *id*., slip op. at 25, so too are those that must be considered for the mass adoption of electric vehicles.

independent ground for invalidating NHTSA's rule in the event that California's zero-emission-vehicle mandate, or its adoption by one or more of the Section 177 States, is determined to be unlawful. If some of the electric-vehicle-forcing laws incorporated into NHTSA's baseline are overturned, then even NHTSA's "reality" rationale would evaporate: it would be NHTSA's fuel-economy standards themselves, and not just preexisting state standards, that would require additional electrification of the Nation's vehicle fleet.

There are several issues included in the Proposed Rule with impacts that go well beyond NHTSA's expertise, and the Agency is not positioned to fully grapple with the consequences that such a rapid push for EVs will have across the nation. Beyond the obvious impacts to consumer automotive markets, the Proposed Rule will also eliminate American jobs in the refining sector and significantly strain the electric grid, requiring utilities to rapidly increase generation, transmission, and distribution capacity to a degree not fully contemplated by NHTSA. And it will have profound impacts on national security by forcing the American automotive industry and a large share of the domestic transportation market to depend on critical minerals from foreign suppliers—most notably, China—rather than a domestically-abundant and secure resource. NHTSA's rule goes beyond its statutory authority to propose standards that would require drastic changes that were not contemplated or provided for by Congress. Because the Proposed Rule raises a major question, NHTSA can only proceed if Congress clearly authorized it to do so. However, Congress has explicitly prohibited NHTSA from doing so.

3. The proposed standards do not adequately or correctly consider other government standards impacting motor vehicles.

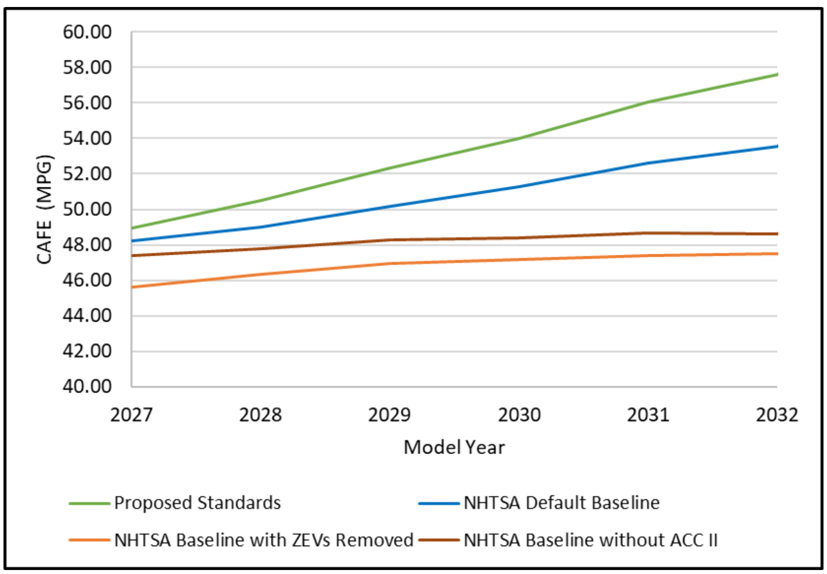
In determining maximum feasible fuel economy standards, NHTSA must also consider "the effect of other motor vehicle standards of the Government on fuel economy."[267] NHTSA has conveniently interpreted this statutory directive in a manner that allows the Agency to include overinflated EV penetration rates in the baseline and modeling while simultaneously ignoring the significant challenges and costs associated with doing so. This interpretation runs contrary to the clear prohibition contained in the very same statute that expressly forbids NHTSA from considering EVs when setting fuel economy standards,[268] which applies throughout the standard-setting process and thus expressly applies to NHTSA's consideration of other motor vehicle standards of the Government[269] If this were not clear enough, in statutory interpretation, the specific provision governs over the general one. NHTSA cherry picks when and how it considers other government standards, conveniently doing so when it would support NHTSA's Proposal, but failing to consider the implications of such standards where they would weigh against NHTSA's Proposal. If NHTSA had adequately considered the cumulative impacts of other government standards, as required under EPCA when determining the maximum feasible standard, then it would become clear that significant additional lead time is needed to meet these proposed standards.

[267] 49 U.S.C. 32902(f).
[268] 49 U.S.C. 32902(h) ("In carrying out subsections (c), ***(f)***, and (g) of this section, the Secretary of Transportation— (1) may not consider the fuel economy of dedicated automobiles." (emphasis added)).
[269] *See* Final Reply Br. of Pet'r American Fuel & Petrochemical Manufacturers and State Petitioners, Doc. #2000037, *Nat. Res. Def. Council v. EPA*, No. 22-1080 (D.C. Cir.), pp. 6-9.

a) NHTSA improperly considered CARB's ZEV regulations and EPA's existing GHG standards.

Despite a clear congressional directive that NHTSA "shall not" consider the fuel economy of EVs when determining the maximum feasible fuel economy standards, NHTSA openly acknowledges that it did exactly what it is forbidden to do. For example, in describing how it considered other government standards, NHTSA states that it "considered EPA's standards for this proposal by including the baseline (i.e., the MYs 2024-2026) GHG standards in [the] analytical baseline for the main analysis.[270] Similarly, NHTSA included "anticipated manufacturer compliance with California's ZEV mandate (and its adoption by the Section 177 states)" by incorporating the corresponding ZEV penetration rates into the baseline and modeling for the Proposed Rule. Figure 20 below demonstrates the magnitude of this assumption. As described in more detail in Section III.A, NHTSA's consideration of EVs in this manner is contrary to its statutory authority and Congressional intent. NHTSA should not rely on regulatory programs that have not received final approval, as California's ACC II program has not yet received a Clean Air Act waiver from EPA. Moreover, as described in more detail above, CARB's ACC I, ACC II, and ACT programs are preempted and are subject to significant ongoing legal challenges and could be invalidated by courts. Relying on preliminary and legally-tenuous programs makes NHTSA's own Proposed Rule significantly vulnerable to legal challenges, particularly in the event that the underlying programs on which NHTSA's standards are premised are deemed invalid.

Figure 20: Impact of Eliminating ACC II Regulations NHTSA's Baseline Fleet Fuel Economy 2027 to 2032



Even worse, while assuming that manufacturers will achieve ZEV penetration rates that are not grounded in reality, NHTSA fails to adequately incorporate the significant challenges facing the industry with achieving those rates. As described throughout this document, these challenges include material supply limitations, manufacturing and supply-chain constraints, grid availability and reliability, insufficient charging infrastructure, and significantly lagging consumer demand, which make it highly unlikely that automakers will meet these assumed penetration

[270] 88 Fed. Reg. 56,315.

rates. As a threshold matter, NHTSA should not consider the fuel economy of EVs when determining fuel economy standards. However, if NHTSA chooses to ignore its clear statutory boundaries, it must at least consider the true costs and challenges associated with those assumptions.

4. The proposed standards do not appropriately address the need to conserve energy.

NHTSA is also required to consider "the need of the United States to conserve energy" in its standard setting process.[271] This includes, among other considerations, the cost to consumers and the environment as well as national security and foreign policy considerations.[272] NHTSA consistently underestimates or wholly fails to account for these costs in its Proposal.

a) NHTSA underestimates the energy consumption of EVs and overestimates the energy consumption of ICEVs.

NHTSA's Proposal unreasonably relies on comparing ICEV's and ZEV's performance based on vastly different fuel economy testing procedures for these two different technologies and incorrectly assumes it is an apples-to-apples comparison. This error significantly undermines NHTSA's estimates of potential environmental and energy conservation benefits. NHTSA has cherry-picked the data underlying its analysis to boost the estimated energy conservation benefits from EVs compared to ICEVs by a significant percentage. In particular, NHTSA (via EPA's testing procedures for determining fuel economy) assesses ICEV fuel economy differently than ZEVs. Specifically, EPA uses performance data estimates of ICEV fuel economy using EPA's '5-cycle method', i.e., Federal Test Procedure-75 ("FTP") at regular and cold temperatures, Highway Fuel Economy Test (HWFET) and High-Speed Driving (US06) and Use of Air Conditioning (SC03). In contrast, performance data estimates of ZEV fuel economy (unlike the testing for ICEVs) never account for EVs operating: above a top speed of 60 mph (whereas ICEVs are tested at 80 mph), above an acceleration rate of 3.2 mph/sec (whereas ICEVs are tested at 8.46 mph/sec); in real world temperatures (ZEVs are tested at optimal battery performance temperatures of approximately 75 degrees F, while ICEVs are tested at 20 degrees F and 95 degrees F); with air conditioning and heating (EPA assumes ZEVs never used air conditioning or heating).

These discrepancies are unreasonable and arbitrary. If NHTSA's analysis were based on real-world fuel economy testing of ZEVs, it would show they use vastly higher amounts of electricity to travel the same distance, with a corresponding increase in power sector emissions and ZEV maintenance and battery replacement and associated environmental and energy impacts. NHTSA must account for these differences.

NHTSA must also account for research that shows that EVs are driven substantially less than their ICEV counterparts. Without considering this real-world implication, the Agency arbitrarily overstates potential fuel savings. EVs drive fewer miles than ICEVs. One study suggests that a newer ICEVs accumulate 40% more miles than a comparable EV,[273] and a recent

---

[271] 49 U.S.C. 32902(f).
[272] See Section II above for a more fulsome discussion of energy security and national security and geopolitical considerations.
[273] iSeeCars, *The Most and Least Driven Electric Cars* (May 22, 2023), https://www.iseecars.com/mostdriven-evs-study.

National Bureau of Economy Research study finds that EVs are being driven less than half the annual miles of the average ICEV, which undermines assumptions that the technology will replace a vast majority of trips currently using gasoline.[274] This single omission could result in the Agency arbitrarily doubling any estimated avoided emissions. Assuming reductions in emissions based on the faulty premise that EVs are driven the same distance as ICEVs distorts the cost-benefit analysis, including total carbon emissions reductions and the fuel savings calculations. Policymakers must have a more complete picture about EVs before costly and irreversible commitments are made to the technology.[275]

Further research shows ZEV-owning consumers tend to buy larger second cars, potentially wiping out substantial fuel efficiency savings (and carbon reductions).[276] According to recent research by professors from Yale, MIT, and the University of California-Davis (UC-Davis), even consumers who have already bought ZEVs are less likely to choose another ZEV as an additional car.[277, 278] The Yale, MIT, and UC-Davis study used long-term data, tracking households over several vehicle replacements, and found that "attribute substitution" is a common phenomenon where households buy an additional vehicle with very different attributes than the first vehicle (the "kept vehicle").[279] For example, a household may choose to prioritize cargo space or the need to be able to travel long distances over fuel economy if it already owns an electric car. Attribute substitution has a large countervailing effect on the fuel economy of the newly purchased vehicle. For example, in the preferred specification, increasing the fuel economy of the kept vehicle by 10% results in a 4.8% decrease in the fuel economy of the purchased vehicle.[280]

The authors observed "significant changes in usage patterns that further reduce the net fuel savings" through increases in mileage for both vehicles that "erodes over 60% of the fuel savings from the fuel economy increase of the kept vehicle on net…."[281] The idea is that because

---

[274] Burlig, F., Bushnell, J., Rapson, D., Wolfram, C., "Low Energy: Estimating Electric Vehicle Electricity Use," National Bureau of Economic Research Working Paper 28451, http://www.nber.org/papers/w28451.
[275] Moreover, it is notable that the above-referenced study evaluates EVs in the State of California (where more than 50% of U.S. EVs are located). Because the study does not include any colder climates, where ZEV performance degrades materially during winter months, it likely overestimates the average miles driven per ZEV in the U.S. Other studies that claim to show higher ZEV miles traveled include ZEVs used for commercial business and cannot be considered by EPA as representative of the typical EV.
[276] Archsmith, Gillingham, Knittel & Rapson. (2017). "Attribute Substitution in Household Vehicle Portfolios," NBER Working Paper No. 23856, https://www.nber.org/system/files/working_papers/w23856/w23856.pdf.
[277] *Id.*
[278] *See also*, Strategic Vision, "BEVS: THE CUSTOMER STORY," January 2019, Prepared for U.S. Department of Transportation (finding a repurchase rate of BEVs of 54%, meaning nearly half of BEV purchasers bought a gasoline powered vehicle. A full 31% chose an ICEV without any hybrid component, "which is more than three times more than what they stated they believed they would do." It also found that only 9% of plug-in hybrid owners chose a BEV for their next vehicle.)
[279] Archsmith, Gillingham, Knittel & Rapson. (2017). "Attribute Substitution in Household Vehicle Portfolios," NBER Working Paper No. 23856, https://www.nber.org/system/files/working_papers/w23856/w23856.pdf, at 2, 4-5.
[280] *Id.* at 5.
[281] *Id.* at 5-6; see also Laura Bliss, Why Gas-Efficient Cars Can't Save the Climate: New Research Reveals Unintended Consequences, City Lab (Oct. 5, 2017), available at, https://www.citylab.com/transportation/2017/10/why-gasefficient-cars-cant-save-the-climate/541992/ ("In a new white paper, scientists at Yale University, University of California, Davis, and the Massachusetts Institute of Technology reveal an unintended consequence of tighter fuel standards: When a two-car

these drivers already own a small car, they'll seek out a vehicle with the opposite attributes when it comes time to replace the car. Attribute substitution introduces a new and previously unaccounted for phenomenon that reduces the effectiveness of higher fuel economy standards or ZEV mandates.

b) NHTSA overstates the environmental benefits of the Proposed Rule.

NHTSA's cost-benefit analysis is lopsided in favor of the Administration's preferred technology – EVs. In analyzing environmental costs and benefits, NHTSA conveniently overlooks negative environmental consequences of ZEVs, including from fleet turnover, increased power generation required to support these vehicles, increased emissions due to heavier vehicles, development of electric vehicle and battery manufacturing supply chain, life-cycle considerations including battery replacements and disposal, and assumptions regarding vehicles miles traveled (VMT).

i. Increased vehicle costs associated with the Proposed Rule will reduce fleet turnover.

NHTSA did not fully consider the impact of the rule on fleet turnover. The higher purchase price of new ZEVs will keep older cars and trucks on the road longer. A further increase above all-time highs in the price of new and used vehicles will further slow vehicle replacement. Additionally, as described above in Section III.B.2.c.iii, NHTSA's Proposal will lead to price increases not only of ZEVs but also of ICEVs via cross-subsidization practices, which force ICEV consumers to bear the additional costs associated with increased ZEV penetration rates. As prices increase, sales and fleet turnover decrease, meaning the Proposal will result in older vehicles that are designed to meet less stringent safety standards, emissions standards, and fuel economy standards than newer ones remaining on the road for longer periods of time. The negative effects of this phenomenon are far-reaching and disadvantages emissions reduction, vehicle safety, and the economy.

New CAFE standards may have the unintended consequence of deterring consumers from purchasing new cars because the standards make cars more expensive.[282] NHTSA accounts for this effect by using "scrappage rate" models that estimate how vehicle prices might affect consumers' decisions to discard an older vehicle and buy a new one.[283] Yet, in Section 4.2 of the TSD where NHTSA addresses vehicle life and scrappage rates, there is no discussion of differences between EVs and other types of vehicles.[284] Specifically, NHTSA neglects to mention the need to potentially replace a costly battery in a ZEV at a mileage long before the assumed

---

household goes to replace one of its vehicles, a household that already owns a fuel-efficient car tends to buy a gas hog for its second car. This decision-making erodes more than 60% of the fuel savings that first car should have yielded, they found.").

[282] *See*, e.g., Sanya Carley, et al., A Macroeconomic Study of Federal and State Automotive Regulations, Indiana University School of Public and Environmental Affairs (Mar. 2017) at 71, available at, https://spea.indiana.edu/doc/research/working-groups/auto-report-032017.pdf (estimating that CAFE standards would impose between $1,226 and $2,468 in direct manufacturing costs on new cars and trucks by 2025).

[283] This is also sometimes referred to as "fleet turnover" in the economics literature and regulatory documents.

[284] See Appendix B Trinity Technical Review at 12.

average vehicle life of more than 200,000 miles or extremely high costs for accident repairs. The agency simply assumes BEV lifetimes will be the same as other vehicles, which is not realistic in light of AFPM's prior comments to NHTSA,[285] and automaker comments expressing concerns with EPA's proposed battery durability standards.[286] Failure to adequately consider scrappage rates likely leads to a significant overestimation of the existing standard's benefits with respect to fuel conservation and air pollutant emission reductions, and an underestimation of safety risks and societal costs.

The used car market represents 94% of the U.S. vehicle fleet. In addition to the all-time high prices for both new and used vehicles previously mentioned, it is well established that increased new car prices, in turn, lead to higher used car prices.[287] When both new and used car prices increase, the scrappage rate of used cars decreases and older, less fuel-efficient vehicles stay on the road longer.[288] Jacobsen and van Benthem estimated that increased car prices create a 13% to 16% loss of expected gasoline savings.[289]

Moreover, vehicle reliability has increased over recent decades. Therefore, vehicles are being kept on the road for longer periods of time. Longer vehicle retention delays the impact of gasoline efficiency standards. The car market has shown an increase in average age of the U.S. fleet, which is approaching 12 years.[290] Overall, the average vehicle lifetime has increased by over 29% from 1995 to 2017.[291] The reduced fleet turnover resulting from this Proposal further adds to the uncertainty of the Proposal's net benefits and slows the introduction of safety technologies.

ii. Increased roadway emissions due to heavier vehicles.

New ZEVs will increase particulate matter ("PM") emissions through increased tire and road wear. EPA's National Emissions Inventory shows that roadway dust contributes more PM2.5 emissions than the tailpipe. Roadway dust emissions, including particles from tire wear, are correlated with vehicle weight, so increases in fleet average vehicle weight would be expected to increase roadway dust PM2.5 emissions.[292] Converting ICEs to ZEVs would significantly increase the average vehicle weight on U.S. roadways, which in turn would increase highway wear and entrained road dust emissions. Additionally, more limited carrying capacity of HDPUVs could require a greater number of ZEVs to move the same tonnage of cargo, thus increasing the number

[285] AFPM, Comments to the Environmental Protection Agency, Multi-Pollutant Emissions Standards for Model Years 2027 and Later Light-Duty and Medium-Duty Vehicles, Proposed Rule, Docket No. EPA-HQ-OAR-2022-0829-0714 at 48-53.
[286] AAI Comments at 195-204.
[287] Jacobsen, M. and van Benthem, A., "Vehicle Scrappage and Gasoline Policy," American Economic Review (2015) Vol. 105, No. 3, 1312-1338 ("Vehicle Scrappage").
[288] Gruenspecht, Howard "Differentiated Regulation: The Case of Auto Emissions Standards", American Economic Review, (1982) Vol. 72(2):328-31.
[289] Jacobsen and van Benthem, "Vehicle Scrappage."
[290] Average Age of Automobiles and Trucks in Operation in the United States | Bureau of Transportation Statistics. (2021). Retrieved 15 October 2021, from https://www.bts.gov/content/average-age-automobiles-and-trucks-operation-united-states.
[291] *Id.*
[292] EPA, "2020 National Emissions Inventory (NEI) Data," *available at* https://www.epa.gov/air-emissionsinventories/2020-national-emissions-inventory-nei-data.

of vehicles needed to haul the same amount of cargo, vehicle miles traveled, and resulting PM emissions.

iii. Impact of additional electrical generation needed.

NHTSA's assumed ZEV penetration rates and resulting proposed standards will require significant expansion of the electrical grid and energy sources to power these vehicles. This drastic expansion is likely lead to the degradation of air quality in areas in the direct vicinity of existing or new power plants.[293] As described elsewhere in this comment, if NHTSA is going to consider the environmental impacts of this proposal, it must also evaluate the overall increase in critical minerals demand for electrical grid expansion and how that compounds the stress on critical minerals required to produce the ZEVs themselves.[294] Expansion of electrical grids also requires a large amount of earth minerals and metals. Copper and aluminum, which are both needed for ZEVs, are also the two main materials in wires and cables and higher prices could have a major impact on future grid investments and ZEV costs.[295] The need for expanded grid capabilities simultaneous to expanded ZEV production places a more pressing demand on materials like copper and aluminum thereby increasing extraction and refining efforts throughout the global market. These added electricity and material demands would be directly caused by this rule and will have real environmental costs that must be addressed.

iv. Mining sector environmental impacts.

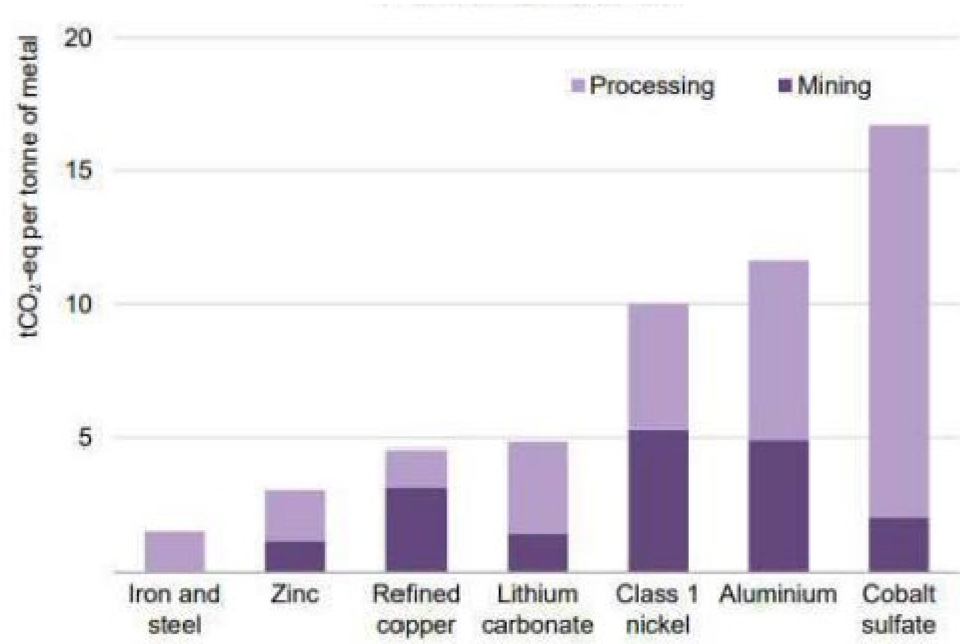
The mining sector will also need to grow significantly to meet the EV penetration assumptions of the Proposed Rule. Mining is an energy- and environmental resource-intensive activity. Critical minerals for electric batteries such as lithium and copper are particularly vulnerable to water stress given their high-water usage.[296] And more than 50 percent of today's lithium and copper production is concentrated in areas with high water stress levels. Several major producing regions such as Australia, China, and Africa are also subject to extreme heat or flooding, which pose greater challenges in ensuring reliable and sustainable supplies. Strong focus on environmental best practices in this sector are needed to safeguard natural lands, biodiversity, and sustainable water use. Similarly, focus on ethical best practices is needed to protect indigenous peoples' rights, and to provide better child labor protections. These challenges call for sustainable and socially responsible producers to lead the industry. The accelerated EV technology penetration rate necessary to meet NHTSA's proposal poses significant challenges for the timely and widespread implementation of best practices to be developed, implemented, and ensure oversight mechanisms are working.[297]

---

293 *Id*. at 29,379 (noting that although "[e]missions from upstream sources would likely increase in some cases (e.g., power plants) and decrease in others (e.g., refineries), EPA projects that the Proposed Rule will result in a total decrease in emissions of certain pollutants").
294 EPCA does not include environmental impacts as a criterion for establishing fuel economy standards, and AFPM reserves the right to challenge any standard set using extra-statutory criteria.
295 IEA Report 2022.
296 *See* EIA 2022 Report.
297 For example, the United Nations Environment Programme is advising the Global Investor Commission on Mining 2030 to identify best practice standards for responsible mining. *See* Mining 2030 at https://mining2030.org/new-global-commission-launched-to-raise-mining-sustainability-standards-by-2030/.

In addition, activities associated with mining produce GHG emissions, particulate matter emissions, nitrogen oxide emissions, and other air pollutant emissions from mining equipment. As shown in Figure 21, mining and processing several minerals and metals used for EV production are carbon intensive.

Figure 21: Average GHG emissions intensity for production of selected commodities.[298]



The process for extracting and processing critical minerals can be responsible for approximately 20 percent of the lifecycle GHG emissions from battery production.[299] NHTSA failed to weigh any of these consequences appropriately in the Proposed Rule.

v. In considering environmental impacts associated with the Proposal, NHTSA should conduct a full life-cycle analysis for EVs to account for their true environmental costs.

To the extent NHTSA is considering environmental costs and benefits, it must not ignore known consequences of the Proposal, including the emissions caused by the manufacture of batteries, and charging-caused upstream emissions. NHTSA should consider the environmental profiles of both EVs and ICEVs in light of the production, operation, and disposal of the vehicle and its components (its useful life). Such a life-cycle analysis would account for the increased environmental costs associated with the reduced lifespan of these vehicles and their material-intensive components. For example, recycling of the battery and related electrical components of EVs is in a state of infancy and poses unique materials handling and safety challenges. The following list provides just some of the electric battery disposal-related issues that are likely to impact the environment and need to be addressed by NHTSA in the Proposed Rule:

---

298 IEA Report 2022 at 17.

299 H.C. Kim, et al., ENVIRONMENTAL SCIENCE AND TECHNOLOGY (Vol. 50) “Cradle-to-Gate Emissions from a Commercial Electric Vehicle Li-Ion Battery: A Comparative Analysis,” (2016), pp. 7715-22.

- Battery packs could contribute 250,000 metric tons of waste to landfills for every 1 million retired ZEVs.[300]
- Less than five percent of Li-ion batteries, the most common batteries used in ZEVs, are currently being recycled "due in part to the complex technology of the batteries and cost of such recycling."[301]
- Economies of scale will play a major role in improving the economic viability of recycling, for which currently cost is the main bottleneck. Increasing collection and sorting rates is a critical starting point.[302]
- The cathode is where most of the material value in a Li-ion battery is concentrated. Currently, there are numerous cathode chemistries being deployed. Each of these chemistries needs to be known, and then the appropriate method of recycling identified, which poses a challenge, as batteries pass through a global supply chain and all materials are not well tracked.
- Lithium can be recovered from existing Li-ion recycling practices but is not economical at current lithium prices.
- BMI forecasts that near-term recyclers are likely to use scrap material from the increasing number of gigafactories coming online versus used electric vehicle batteries. Scrap is anticipated to account for 78 percent of recyclable materials in 2025.[303]
- In 2022, BMI expected over 30 gigawatt hours of process scrap to be available for recycling, growing ten-fold across the next decade. Loss rates vary by region and tend to be higher in earlier years of a gigafactory.[304]
- Many 'spent' EV batteries still have 70-80 percent of their capacity left, which is more than enough to be repurposed into other uses such as energy storage and other lower-cycle applications for approximately another 10 years.[305] This will extend the time that batteries and raw materials remain in use and therefore increase the demand for virgin critical minerals.
- Clear guidance on repackaging, certification, standardization, and warranty liability of spent ZEV batteries would be needed to overcome safety and regulatory challenges reuse poses at scale.[306]
- Recycling ZEV batteries to recover high-value metals has not been proven to a commercial scale. The majority of analysts are aligned that recycling will not become an integral supplier of raw materials until the 2030s, and at that point, only will provide approximately 20 percent of demand.[307]

---

300 Kelleher Environmental, "Research Study on Reuse and Recycling of Batteries Employed in Electric Vehicles: The Technical, Environmental, Economic, Energy and Cost Implications of Reusing and Recycling EV Batteries", (September 2019) *available at* https://www.api.org/oil-and-natural-qas/wellstoconsumer/fuels-and-refininq/fuels/vehicle-technoloqy-studies.

301 Gavin Harper, Roberto Sommerville, et al., NATURE, "Recycling lithium-ion batteries from electric vehicles" (Jan. 21, 2020) *available at* https://www.nature.com/articles/s41586-019-1682-5.

302 IEA Report 2022.

303 Benchmark Minerals Intelligence, "Battery production scrap to be main source of recyclable material this decade" (Sept. 5, 2022) available at https://source.benchmarkminerals.com/article/battery-productionscrap-to-be-main-source-of-recyclable-material-this-decade.

304 *Id*.

305 Pagliaro, M. and Meneguzzo, F., "Review Article: Lithium battery reusing and recycling: A circular economy insight," *Heilyon* 5: E01866 (June 15, 2019) *available at* https://doi.org/10.1016/j.heliyon.2019.e01866.

306 IEA Report 2022.

307 Benchmark Minerals Intelligence, *supra* at n. 105.

- Unlike ICEVs, EPA has recently stated that ZEV batteries may need to be handled as hazardous waste, further driving up the cost of such recycling efforts.[308]
- Whether sufficient recycling capacity can be permitted and constructed to facilitate the Proposal.

NHTSA must, therefore, conduct a full life-cycle analysis to compare all environmental impacts to reasonably conclude that the Proposal will decrease environmental impacts.

Finally, NHTSA's unrealistic assumptions regarding EV efficiency and cost result in overstated environmental benefits and understated costs. According to NHTSA, the physical and environmental impacts are the result of either fuel consumption and VMT, with the product of on-road fuel economy (or fuel efficiency) and VMT determining fuel consumption of each vehicle.[309] Yet, as Trinity Consultants points out, in Section 4.3 of the TSD, NHTSA baselessly concludes EVs will be driven more than other types of vehicles.[310] There is no debate that EVs have a more limited range, need charging infrastructure, and cost more than ICEVs and hybrid vehicles. But Section 4.3 of the TSD makes no mention of EVs' limited range or the need for recharging when discussing how the VMT input was derived. Instead, after ignoring the impacts of limited range and charging infrastructure, NHTSA assumes without any evidence that lower operating costs will result in EVs being driven more than other types of vehicles. There is simply no basis for the conclusion that EV VMT will increase, thereby resulting in fewer emissions. In fact, the data shows that individuals drive EVs fewer miles than their ICEV counterparts (see Section III.B.4.b.v above). This information was previously presented to NHTSA and is well known. NHTSA is acting arbitrarily and capriciously in continuing to rely on this known inaccuracy.

IV. THE PROPOSED RULE VIOLATES NHTSA'S STATUTORY AUTHORITY BY FAILING TO ESTABLISH MAXIMUM CRITICAL AVERAGE FUEL ECONOMY STANDARDS FOR HEAVY DUTY PICKUP TRUCKS AND VANS (HDPUVS)

Similar to the determination for passenger cars and light trucks, for commercial medium-duty and heavy-duty vehicles and work trucks, including HDPUVs, NHTSA must set "maximum feasible" fuel economy standards that are "appropriate, cost-effective, and technologically feasible."[311] While these factors have previously been treated broadly and not well-interpreted, NHTSA's proposed standards fail to meet this requirement. Under NHTSA's Proposal (the "HDPUV10" Alternative), fuel efficiency stringency would increase, on average, 10 percent per year, year over year, for MY 2030–2035 HDPUVs. NHTSA has done little to evaluate that such stringency increase is "appropriate, cost-effective, and technologically feasible" for the commercial HDPUV fleet and in fact has abrogated its responsibility to do so by assuming, erroneously, that the majority of the HDPUV fleet would have largely become compliant by 2030 under the "No Action" alternative. In other words, NHTSA has declined to comprehensively evaluate the appropriateness, cost-effectiveness and technological feasibility of its Proposed Rule.

---

[308] Letter from Carolyn Hoskinson, Director, EPA Office of Resource Conservation and Recovery, "Lithium Battery Recycling Regulatory Status and Frequently Asked Questions," (May 24, 2023).
[309] PRIA at 4-4
[310] See Appendix B Trinity Technical Review at 12.
[311] 49 U.S.C. § 32902(k)(2).

NHTSA failed to address any of the unique statutory factors for HDPUVS. For example, Section 3902(k)(1) directs NHTSA to rely on a National Academy of Sciences Study and consult with DOE and EPA to "examine the fuel efficiency of commercial medium and heavy-duty on highway vehicles and work trucks." and determine: (1) "the appropriate test procedures and methodologies for measuring the fuel efficiency of such vehicles and work trucks," (2) the appropriate way to measure the "fuel efficiency performance" of those vehicles, (3) the range of factors that affect their "fuel efficiency," (e.g., design, functionality, use, duty cycle, infrastructure, total overall energy consumption, operating costs) and (4) "other factors and conditions that could have an impact on a program to improve" their "fuel efficiency."[312] With that determination, NHTSA was to consult with DOE and EPA to "determine in a rulemaking proceeding how to implement a commercial medium- and heavy-duty on-highway vehicle and work truck fuel efficiency improvement program designed to achieve the maximum feasible improvement."[313]

Nor has NHTSA adequately explained its authority to include BEVs in its HDPUV standards. Section 32902(k) directs NHTSA to determine how to implement a "fuel efficiency improvement program" for commercial medium and heavy-duty vehicles that would achieve the "maximum feasible improvement" that is "appropriate", "cost-effective", and "technologically feasible" for this category of vehicles. Such an improvement program is necessarily less prescriptive than the passenger vehicles and light trucks standards, and it would make no sense for Congress to have excluded BEV's from its more prescriptive standard setting directive for passenger vehicles and light trucks and include them in an "improvement program." Moreover, it is unclear how forcing increased electrification of HDPUVs would improve the fuel economy of any ICE HDPUVs, as it is just a displacement. That has no basis in the statute, and to the extent there is any question, the authority to require displacement of ICE vehicles presents a major question of vast economic and political significance that would require a clear statement from Congress (which is not present).

A. Appropriateness

As described in the Proposed Rule, NHTSA suggests that the "appropriate" factor is the "kitchen sink" of HDPUV standard setting and interprets it broadly to include, among other things, energy conservation, fuel savings, and energy security, environmental benefits and emissions avoided, possible safety effects, effects on the industry that do not directly relate to cost effectiveness including on sales and employment, as well as effects in the industry that may be happening for reasons unrelated to NHTSA.[314]

NHTSA's projections of a rapid transition to electric vehicles warrants an evaluation of whether it is appropriate to measure ICE and BEV with the same measuring stick. EVs and ICEVs both generate emissions of CO2 and other pollutants. NHTSA places a significantly greater regulatory burden on ICEVs. NHTSA should have considered whether separate emissions standards for ICEs and BEVs are appropriate. HDPUVS fuel efficiency does not have a PEF factor that sets equivalency from EVs and ICEs as with passenger vehicles. And Congress could not have anticipated when electric vehicles would become competitive in the marketplace when

[312] 49 U.S.C. § 32902(k)(1).
[313] 49 U.S.C. § 32902(k)(2).
[314] "NHTSA interprets 'appropriate' broadly, as not prohibiting consideration of any relevant elements that are not already considered under one of the other factors." 88 Fed. Reg. at 56,320.

it tasked NHTSA with setting fuel efficiency standards, which therefore were clearly intended to address vehicles operating with liquid fuels.

All of the same concerns about NHTSA's Proposal for passenger cars and light trucks, including that the proposal exceeds NHTSA's statutory authority and raise major questions of economic and political significance that would require a clear statement from Congress, the proposed standards are not being feasible and security concerns related to relying on electrification, as described above in Sections II and III.B, are relevant in the HDPUV context and are incorporated here by reference.

1. National security and energy security considerations are largely ignored

The comments above in Sections II and III regarding national and energy security considerations are applicable in the HDPUV context as well and are incorporated here by reference. In particular, NHTSA largely ignores important considerations, including the scarcity of critical minerals required to produce ZEV batteries as described above in Section III.B.1.a and insufficient grid and charging infrastructure as described in Sections III.B.1.b-c. In fact, the scarcity of critical minerals and electric charging infrastructure is much more impactful in the HDPUV context since, as NHTSA acknowledges, there are so few HDPUV manufacturers and the market is much smaller than passenger cars and light trucks and much less diverse. "The nature of this fleet—smaller, with fewer models—and the nature of the technologies that this fleet will be applying leading up to and during the rulemaking time frame, means that the analysis is very sensitive to changes in inputs, and the inputs are admittedly uncertain."[315] Forcing a substantial portion of the commercial HDPUV fleet to electrify with an implicit ZEV mandate, will make the fleet reliant on these scare minerals and beholden to the unstable countries that control them, thereby further reducing our energy security and impacting the stability of our commercial fleet operations using HDPUV class vehicles.

2. The Proposal over-estimates the amount of energy conservation for HDPUV EVs

The comments above in Section III.B.4 regarding NHTSA's estimates of energy conservation are applicable in the HDPUV context as well and are incorporated here by reference. As described above in Section III.B.4.a, NHTSA consistently underestimates the energy consumption of EVs and overestimates the energy consumption of ICEVs, and therefore erroneously considers ZEVs as conserving greater energy than ICEVs. In reality, ZEVs use significant amounts of electricity and result in a corresponding increase in power sector emissions. ZEV maintenance and battery replacement, as well as potentially shorter useful lives, also have associated environmental impacts. NHTSA must account for these differences and environmental impacts. Until the agency fully accounts for the true energy consumption and environmental impacts of ZEVs, NHTSA cannot support its "appropriate" determination of its proposed standards.

[315] 88 Fed. Reg. at 56,358.

3. The environmental benefits of HDPUV EVs are over-estimated and HDPUV ICEVs are under-estimated

The comments above in Section III.B.4 regarding NHTSA's estimates of environmental benefits of EVs (and impacts of ICEVs) are applicable in the HDPUV context and are incorporated here by reference.

In particular, to support a viable HDPUV ZEV fleet, significant upgrades and expansion of energy and charging infrastructure will be necessary. NHTSA ignores the significant environmental impacts associated with such expansion, including the impact of additional electrical generation and mining as described in Sections III.B.4.b.iii-iv. As noted above in Section III.B.4.b.ii, ZEVs are typically heavier than their ICEV counterparts, thereby resulting in increased PM emissions through increased tire and road wear. This is particularly true in the HDPUV context.

Additionally, NHTSA ignores the fact that due to higher purchase and lifetime costs associated with HDPUV ZEVs, many commercial fleet operators may choose to either keep their older vehicles on the road longer (thereby reducing fleet turnover) or purchase a larger vehicle that is not subject to the proposed HDPUV standards (resulting in greater emissions from a larger vehicle than would have otherwise been purchased in the absence of the proposed standards).

Finally, similar to the discussion in Section III.B.4.b.v above, in order to fully account for the true environmental impacts of its Proposal, NHTSA should conduct a full life-cycle analysis for HDPUV ZEVs, which would account for cradle-to-grave considerations associated with ZEVs (including significant concerns related to disposal of batteries as hazardous waste, among others).

4. Important regulatory effects to consumers and commercial operators, including on employment, are ignored

Equally importantly, in considering whether its proposed HDPUV standards are "appropriate," NHTSA must consider the significant costs to commercial fleet operators associated with purchasing, using and maintaining HDPUV ZEVs. For example, as described above in Sections III.B.2.b-c, HDPUV ZEV owners will be faced not only with higher costs to purchase these vehicles, but also to maintain them. While conventional ICEV HDPUVs can be refueled in a matter of minutes, HDPUV ZEVS will require significant time to accommodate charging needs, which results in costly vehicle down-time and increased labor expenses. As described above in Section III.B.1.c, the electrical grid and charging infrastructure would need to be significantly upgraded and expanded to support HDPUV ZEV commercial fleets. Dual charging installations to enable the flexibility of passenger car, light truck, and HDPUV charging will become increasingly important, and direct current fast charging equipment ("DCFCs") will enable broader market coverage. However, the same supply, timeline, and cost constraints described above in Sections III.B.1.d and III.B.2.e also apply to HDPUV ZEVs. All of these impacts will inevitably increase the cost of new, electrified HDPUVs for consumers and commercial fleet operators and reduce consumer operator demand for HDPUV ZEVs. Consequently, commercial operators may choose not to purchase or operate as many vehicles, which could reduce the number of employees and drivers across the commercial fleet. NHTSA appears to have declined to review such possibility or even consider potential impacts on commercial operator businesses and employees.

B. Cost-Effectiveness

As NHTSA acknowledges, "Congress' use of the term 'cost-effective' in 32902(k) appears to have a more specific aim than the broader term ''economic practicability'' in 32902(f)."[316] NHTSA interprets this factor as a cost/benefit balancing, and has previously considered the ratio of estimated technology (or regulatory costs) to estimated value of GHGs emissions avoided and estimated fuel savings or the consumer costs and benefits.

For all the reasons described above in Section III.B.2 and III.B.4, incorporated here by reference, NHTSA has overestimated the value of GHG emissions avoided and estimated fuel savings for ZEVs, in particular for HDPUVs.[317] Moreover, NHTSA also has woefully underestimated the regulatory costs of HDPUV electrification. Amazingly, NHTSA has assumed the vast majority of regulatory costs for HDPUV manufacturers will occur in the No Action alternative—in large part as a result of compliance with EPA requirements—and has failed to assess any significant costs in connection with NHTSA's own proposed standard alternatives.[318] Accordingly, NHTSA's cost-effective determination is skewed and unreliable.

C. Technical Feasibility

NHTSA interprets technological feasibility in the HDPUV context similar to the passenger car and light truck context. Importantly, in the HDPUV context NHTSA stresses "that a technology does not necessarily need to be currently available or already in use for all regulated parties to be 'technologically feasible'" under the statute.[319] NHTSA stresses this point because it is keenly aware that even though ZEV technology is available, large-scale deployment for HDPUVs is questionable and speculative at best. Currently ZEV HDPUV production is miniscule and unlikely to reach the necessary scale in the timeframe proposed, in particular given the significant costs and trade-offs associated with ZEV technology in HDPUVs.

Yet, in the Proposed Rule NHTSA assumes significant increases in electrification, including BEV, SHEV, and PHEV HDPUVs by MY 2038,[320] despite acknowledging that zero PHEV HDPUVs currently exist or are planned,[321] that only 6 percent of the HDPUV baseline fleet was projected to be BEV, and that no other electrification technologies were present in the baseline fleet.[322] Moreover, NHTSA assumes this leap to scale of electrified HDPUVs mostly as

---

[316] 88 Fed. Reg. at 56,320.
[317] "NHTSA regulations currently grant BEVs (and the electric-only operation of PHEVs) an HDPUV compliance value of 0 gallons/100 miles" 88 Fed. Reg. at 56,283.
[318] 88 Fed. Reg. at 56,283-84.
[319] 88 Fed. Reg. at 56,320-21.
[320] 88 Fed. Reg. at 56,283.
[321] Draft TSD at 3-75. "There are no PHEVs in the baseline HDPUV fleet and there are no announcements from major manufacturers that indicate this a pathway that they will pursue in the short term." NHTSA believes "this is in part because PHEVs, which are essentially two separate powertrains combined, can decrease HDPUV capability by increasing the curb weight of the vehicle and reducing cargo capacity. A manufacturer's ability to use PHEVs in the HDPUV segment is highly dependent on the load requirements and the duty cycle of the vehicle." *Id*.
[322] Draft TSD at 3-75-3-79.

part of its No Action alternative, thereby minimizing the costs and impacts analyzed for the imposition of NHTSA's proposed HDPUV standards.

NHTSA's assumptions regarding the feasibility and projected availability of HDPUV ZEVs are not sufficiently supported—and, frankly, are *unsupportable*. Among other things, NHTSA's Proposal and CAFE Model do not distinguish between the less costly lower range BEV1 and BEV2 options, and the much more costly and virtually unavailable higher range BEV3 and BEV4 options. This is based on an assumption that that "BEV HDPUVs are often used as delivery fleet vehicles or utility/service vehicles, and require less range capability compared to light-duty vehicles."[323] To support this assumption, NHTSA relies on press articles quoting dealer opinions, along with a review of less than 100 delivery vehicles conducted by the National Renewable Energy Laboratory from 2014.[324] This is tragically insufficient. Since the COVID pandemic and corresponding shutdowns, delivery services and consumer expectations have undergone a complete transformation and delivery fleets have experienced significant and unprecedented increases in demand. NHTSA should coordinate with others within the Department of Transportation as well as the commercial fleet operators to fully analyze—rather than assume or guess—the range needs for HDPUV commercial delivery and service/utility vehicles, and then NHTSA should adjust its modeling to fully assess the real feasibility (and cost) of the BEVs that commercial HDPUV fleet operators really need.

In addition, NHTSA's assessment largely ignores important considerations, including the scarcity of critical minerals required to produce batteries as described above in Section III.B.1.a, insufficient grid and charging infrastructure as described in Sections III.B.1.b-c, insufficient time to facilitate such a drastic fleet transition and infrastructure expansion as described in Section III.B.1.d, and unrealistic assumptions regarding consumer adoption rates as described in Section III.B.1.e, which also apply for HDPUVs and are incorporated here by reference.

V. THE DRAFT ENVIRONMENTAL IMPACT STATEMENT IS INADEQUATE

As detailed in our comments on the Draft Environmental Impact Statement (see Appendix C AFPM Comment on NHTSA's Draft Environmental Impact Statement (AFPM DEIS Comment)) and incorporated herein by reference, NHTSA's alternatives are inadequate. First, all CAFE alternatives for the light duty vehicle fleet and alternatives reflecting the combined impact of proposed standards for CAFE and HDPUV include BEVs in violation of EPCA. Specifically, two passenger car and light tuck alternatives (PC3LT5 and PC6LT8) and one heavy duty alternative (HDPUV14) are so infeasible that NHTSA could not adopt them. Moreover, as articulated in Section III.B.2.f above, NHTSA's Proposal implicates the major questions doctrine and, therefore, NHTSA lacks the authority to adopt the proposed standard. Finally, NHTSA's alternatives do not address reasonably available, cost-effective mitigation measures reflecting the use of improved technologies for internal combustion engine vehicles and liquid fuels.

The DEIS also understates the environmental consequences of the proposed standards, most notably because it does not conduct a full life cycle assessment of mandating EVs. In a rule that compares the relative GHG emissions of two distinct technologies that can be used to

---

[323] Draft TSD at 3-77.
[324] Id. (citing National Renewable Energy Laboratory. NREL Fleet DNA: Commercial Fleet Vehicle Operating Data (Fleet DNA Project Data Summary Report prepared by K. Walkowicz et al. (Aug. 1, 2014), available at: https://www.nrel.gov/transportation/fleettest-fleet-dna.html).

meet an average standard, the agency must fairly characterize the emissions resulting from each technology option. In the context of this rulemaking, where ICEVs emit most of their carbon from the tailpipe and EVs emit them mostly during the vehicle production and recharging phases, lifecycle analyses of each technology are critically important and the only way of ensuring an apples-to-apples comparison. For individual project permitting, such as for pipelines, these projects are unlikely to cause any foreseeable upstream impacts because the products they transport exist in a global market and would likely reach the market anyway; but here, where you have a forced transition of an *entire industry*, and a rulemaking that creates new demand for critical minerals, the upstream impacts are well known. Ignoring GHG emissions from battery production and replacement, vehicle charging operations, and a grid buildout, necessitated by this rulemaking would be arbitrary and capricious and contrary to NEPA.

NHTSA's analyses of the ability of the proposed CAFE standard to conserve energy, air quality impacts, and direct and indirect impacts on climate change and GHG emissions are based on faulty assumptions. Additionally, NHTSA must conduct a systemic, interdisciplinary evaluation of the economic (*e.g.*, impact on jobs and worker wages), safety considerations, and the proposed standard's impact on fleet turnover and quality. Finally, the DEIS is devoid of any discussion regarding the conflict between these proposed standards and Congressional objectives as expressed in the Energy Independence and Security Act and the Renewable Fuel Standard. For these reasons and the numerous deficiencies identified in AFPM's comments, NHTSA should withdraw its proposed standards.

VI. THE PROPOSAL FAILS TO PROVIDE MEANINGFUL OPPORTUNITY FOR PUBLIC COMMENT

AFPM welcomes the opportunity to meaningfully engage with regulators to discuss cost-effective, efficient, and feasible measures to improve the fuel efficiency of the transportation sector. Unfortunately, the comment period for this rule (which runs concurrently with the comment period on the accompanying DEIS) is insufficient to provide fully informed comments on the Proposal.

Although AFPM was one of several entities requesting that NHTSA extend the comment period, the agency declined, claiming in part that its pre-publication release of material meant that the public in fact had 19 additional days to comment on the Proposed Rule.[325] This ignores the fact that not all supporting material was available the same day as the pre-publication copy, as well as the sheer volume of material NHTSA released. In addition to the Proposed Rule itself, the rulemaking docket comprises a significant quantity of additional material subject to review and comment, including various modeling scenarios and technical analyses. In total, commenters are expected to review and comment on over 5,000 pages of technically complex materials that affect many industries and segments of the economy beyond auto manufacturing. In addition, NHTSA released a technical correction twelve days after the NPRM publication,[326] a fact also overlooked by the denial of extension.

---

[325] Letter from R. Ryan Posten, Associate Administrator for Rulemaking, U.S. Department of Transportation National Highway Traffic Safety Administration, received September 29, 2023.
[326] NHTSA, Notice of proposed rulemaking correction, 88 Fed. Reg. 58,229 (Aug. 25, 2023).

NHTSA's refusal to grant additional time to respond to the NPRM denied the public ample time to formulate meaningful comments responsive to the underlying information in support of the Agency's Proposal. The Agency's action is an arbitrary departure from its typical practice of granting reasonable extensions of time—often thirty days, but frequently sixty or even ninety—to provide meaningful input from the public on proposed rules.

The Administrative Procedure Act requires opportunity for meaningful public input, and Executive Order 12866 states that, in most cases, agencies should provide a comment period "of not less than 60 days." In other words, a 60-day comment period is the minimum expected. Even counting the handful of additional days afforded by NHTSA's pre-publication release of the preamble, this period is not sufficient to adequately address the sweeping scope of NHTSA's Proposal, particularly coming on the heels of multiple other sweeping federal and state proposals that would interact in complicated ways to completely transform the U.S. transportation industry.[327] Considerable time is required simply to read and respond to the sheer volume of material covered in the rulemaking docket, let alone to analyze the impacts of the Proposed Rule within the context of other recent federal and state proposals. Moreover, as illustrated in these comments, our review identified numerous instances in which NHTSA's analysis is inaccurate, incomplete, or misleading. Thus, to meaningfully respond to NHTSA's Proposal, the public must fact-check NHTSA's work.

Further, the short comment period is exacerbated by NHTSA's unduly narrow identification of industries affected by this rule. Under the heading "Does this action apply to me," NHTSA limits its identification of affected industries to entities with direct compliance obligations: motor vehicle manufacturers, commercial importers of vehicles and vehicle components, and alternative fuel vehicle convertors.[328] Although NHTSA notes that "[t]his list is not intended to be exhaustive," NHTSA understands many entities necessarily rely on regulatory screening tools based on search terms tied to their own NAICS codes to alert them to new proposed rules that may impact them. Moreover, NHTSA is well-aware, given other current contexts outside the agency, that fuel producers and manufacturers, including AFPM members, are interested and affected stakeholders.

By narrowly limiting the identification of industries affected based on this extremely short and incomplete list of NAICS codes and by its arbitrary refusal to extend the comment periods, NHTSA has unreasonably constrained the number and types of entities that will find out about these proposed actions in time to comment. This is at odds with NHTSA's responsibility under the Administrative Procedures Act and the Due Process clause of the U.S. Constitution.

---

[327] *See e.g.,* Environmental Protection Agency, Multi-Pollutant Emissions Standards for Model Years 2027 and Later Light-Duty and Medium-Duty Vehicles, Proposed Rule, 88 Fed. Reg. 29,184 (May 5, 2023); Department of Energy, Petroleum-Equivalent Fuel Economy Calculation, Notice of Proposed Rulemaking; Request for Comment, 88 Fed. Reg. 21,525 (April 11, 2023); Environmental Protection Agency, Greenhouse Gas Emissions Standards for Heavy-Duty Vehicles—Phase 3, Notice of Proposed Rulemaking, 88 Fed. Reg. 25,926 (April 27, 2023); and California Air Resources Board, Advanced Clean Cars (ACC) II standards (see rulemaking documents at https://ww2.arb.ca.gov/rulemaking/2022/advanced-clean-cars-ii) and corresponding section 177 state adoption proposals.

[328] 88 Fed. Reg at 56,131.

VII. CONCLUSION

Rather than secure our nation's energy and national security, NHTSA departed from Congressional intent by proposing standards that do not meet statutory requirements. NHTSA exceeded its legal authority by setting the fuel economy standards at a level that is not feasibly achievable by ICEVs, effectively establishing a de facto EV mandate. Despite EPCA's explicit instruction, NHTSA improperly considered EVs when setting CAFE standards for passenger cars and light-duty trucks. NHTSA failed to set "maximum feasible" fuel economy standards that ICEVs can achieve based on the four statutory factors, Similarly, the proposed fuel efficiency standards for commercial medium-duty and heavy-duty vehicles and work trucks, including HDPUVs are not (i) appropriate, (ii) cost-effective, and (iii) technologically feasible. For these reasons, NHTSA should withdraw the Proposed Rule.

* * *