Jim Verburg
Director, Fuels

October 19, 2022

Sent via website upload at: https://aq.ecology.commentinput.com/?id=NGd7e

Mr. Adam Saul
Department of Ecology
Air Quality Program
P.O. Box 47600
Olympia, WA 98504-7600

Re: WSPA Comments on Washington Clean Vehicles Program (WAC 173-423) CR-102 Proposed Rule - Proposed Adoption of California's Advanced Clean Cars II (ACC II)

Dear Mr. Saul:

The Western States Petroleum Association (WSPA) appreciates the opportunity to provide input regarding the Advanced Clean Cars II (ACC II) element of the Washington Department of Ecology (Ecology) proposed rule update to Clean Vehicles (WAC 173-423) and the General Regulations for Air Pollution Sources (WAC 173-400), as announced in the September 7, 2022 CR-102 notice of proposed rulemaking.[1] 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 Washington and four other western states.

In addition to the WSPA comments submitted to Ecology on June 21, 2022 regarding the proposed WAC 173-423[2], incorporated herein by reference, WSPA offers the following additional comments:

Insufficient Analysis Required by SEPA and APA

Ecology is proposing to adopt the California Air Resources Board (CARB)-developed ACC II regulation which seeks to increase the sale of zero emission vehicles in California to 100% by 2035.[3] The CARB Governing Board adopted ACC II on August 25, 2022. It now appears that Ecology is rushing to finalize WAC 173-423 and adopt the flawed California ACC II before the end of the calendar year to meet the federal Section 177 requirements.

WSPA believes that this action by Ecology continues to raise serious concerns about whether Ecology has performed sufficient due diligence and required analysis under the State Environmental Policy Act (SEPA) as well as analysis of the proposed regulations as they would be uniquely applied to Washington under the Washington Administrative Procedures Act (APA). A detailed assessment of the SEPA and APA compliance concerns resulting from the proposed Ecology regulatory action regarding WAC 173-423 is presented in Attachment A. We offer the following specific comments.

[1] https://ecology.wa.gov/Asset-Collections/Doc-Assets/Rulemaking/AQ/WAC173-423_400-21-12/Rulemaking-Proposal-WAC-173-423;-WAC-173-400-9-7-2 -Accessed 10-10-2022.
[2] https://scs-public.s3-us-gov-west-1.amazonaws.com/env_production/oid100/did1008/pid_202698/assets/merged/1202i7t_document.pdf?v=GRBN6WH5M – Accessed 10-12-2022.
[3] Advanced Clean Cars II | California Air Resources Board – Accessed 10-10-2022

CARB ACC II ISOR Deficiencies

We note, as we have in previous comment letters[4], that WSPA provided written comments[5] and oral testimony during the June 9, 2022 CARB Governing Board hearing on California's ACC II Initial Statement of Reasons (ISOR). Those comments would extend to Washington's adoption of California's ACC II and are incorporated by reference. In the May 31st 2022 comment letter to CARB provided as Attachment B (specifically in Section A-7 of Attachment A titled "Legal Comments"[6]) we point out that ACC II Program is preempted by Federal Law. These federal preemption arguments would extend to Washington's adoption of ACC II. With respect to the Energy Policy and Conservation Act (EPCA) we stated the following:

> *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, 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.*

WSPA's comments also pointed out several deficiencies in CARB's ISOR including insufficient/incomplete technical analyses and inconsistencies with state and federal laws. The ACC II regulation does not attempt to address vehicle emissions by way of technology neutral emissions standards but is instead a sweeping mandate about what kind of vehicles consumers are allowed to purchase.

Inadequate Cost-Benefit Analysis

During the staff presentations in the February and June webinars, Ecology was asked if it planned to issue a cost-benefit analysis under the Washington APA. The Ecology staff response was the same in both instances. The response during the February 28th meeting was as follows:

> *"Because the Legislature specifically directs Ecology to adopt California's motor vehicle emission standards, we do not evaluate the economic impacts of those rules. So, what we will be evaluating is the cost of the credit system and the cost of fleet reporting [under the proposed rule]. The other actions we're taking through this rulemaking are not subject to an economic analysis."*[7]

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[4] https://scs-public.s3-us-gov-west-1.amazonaws.com/env_production/oid100/did1008/pid_202698/assets/merged/1202i7t_document.pdf?v=YNQCE938T
[5] https://www.arb.ca.gov/lists/com-attach/477-accii2022-AHcAdQBxBDZSeVc2.pdf - Accessed 10-10-2022
[6] Id. at A-20.
[7] https://www.youtube.com/watch?v=ixh5MvEWlOw (beginning at 38:41) – Accessed 6-17-2022.

This response indicated that Ecology did not plan to perform a cost-benefit analysis under the Washington APA[8] which sets forth specific requirements governing state agency rulemaking processes, including preparing a cost-benefit analysis of the proposed rule.[9] Indeed, both the CR-102 document[10] and Preliminary Regulatory Analysis (PRA)[11] show that Ecology made good on that promise and their approach was to hide the true cost of the regulation to Washington residents and businesses by including the costs of implementation of ACC II as part of the baseline. As such, the only cost reflected by Ecology in the PRA was the cost of reporting for approximately 2,226 entities under the rule. Page 10 of the PRA states:

> *"We estimated the total cost range for all entities affected by the proposed change is between $445,200 and $890,400."*

And further:

> *"We do not expect other costs associated with other sections of the proposed rule amendments."*

It is WSPA's belief that Ecology is misreading the APA's clear intent and direction. Ecology's approach has disregarded potentially significant costs that could run into the billions if not hundreds of billions of dollars of fleet electrification and its impact on Washington residents and businesses. The potential costs ignored by Ecology include the required build out of electrical transmission and distribution infrastructure, charging infrastructure, future increased utility rates and electric procurement costs, and higher incremental purchase costs of EV's just to name a few.

Nothing under the APA expressly exempts Ecology from preparing a robust cost-benefit analysis of its proposed rules adopting California's emission standards. Chapter 173-423 is a significant legislative rule that must be adopted through the proper APA rulemaking process. This is particularly true when adopting a rule with such expansive impact and costs to the entirety of the state in terms of infrastructure build out, electricity needs, and whether or not the vehicles will be available in the proposed time frame. Attachment A (Sections IV and V) provide further details regarding APA applicability.

WSPA appreciates the opportunity to comment on the proposed rulemaking. If you have any questions regarding these comments, please contact me at (360) 296-0692 or via email at jverburg@wspa.org.

Sincerely,

James Verburg
Director, Fuels
WSPA

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[8] RCW 34.05.328.
[9] RCW 34.05.328(1)(c)-(d).
[10] https://ecology.wa.gov/Asset-Collections/Doc-Assets/Rulemaking/AQ/WAC173-423_400-21-12/Rulemaking-Proposal-WAC-173-423;-WAC-173-400-9-7-2 – Accessed 10-10-2022.
[11] https://apps.ecology.wa.gov/publications/SummaryPages/2202030.html - Accessed 10-10-2022.

Attachment A: WSPA Concerns with SEPA and APA Compliance for the Proposed Revisions to WAC 173-423, Clean Vehicles Program

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

ATTACHMENT A

WSPA Concerns with SEPA and APA Compliance for the Proposed Revisions to WAC 173-423, Clean Vehicles Program

Attachment A

WSPA Concerns with SEPA and APA Compliance for the Proposed Revisions to WAC 173-423, Clean Vehicles Program

I. Introduction

On September 7, 2022, the Washington Department of Ecology ("Ecology") issued a determination of nonsignificance[1] under the State Environmental Policy Act ("SEPA") for the proposed revisions to WAC 173-423, Clean Vehicles Program. This includes the Advanced Clean Cars II rule ("ACC II rule"). Ecology's flawed threshold determination is based on the following inadequate and limited analysis:

- "Although some adverse environmental conditions could potentially result from implementation of conditions specified in the law, these conditions are not within the scope of this rule. Any such impacts would be identified, considered and mitigated (if appropriate) at the time specific projects are proposed."
- "Transitioning to battery electric vehicles and other zero emission vehicles will reduce greenhouse gas and criteria pollutant emissions, as well as the extraction, refinement, and transport of oil and gas products."
- "Ecology is also adopting California's battery warranty and labeling requirements that will decrease battery waste and limit additional mining of lithium, cobalt, nickel, and other minerals. State energy policies will also decrease the GHG emissions associated with additional electricity production for vehicle charging."

Ecology's determination of nonsignificance fails to meet SEPA's requirements under RCW 43.21C.030(2) and WAC 197-11-340 in the following ways.

First, Ecology failed to meet SEPA's provisions requiring a detailed statement discussing: 1) the numerous environmental impacts of the proposed ACC II rule, 2) any adverse environmental effects that cannot be avoided due to the ACC II rule, and 3) alternatives to the proposed rule.[2]

Second, Ecology's rationale that any future "impacts would be identified, considered and mitigated (if appropriate) at the time specific projects are proposed" fails to conform with SEPA provisions. Ecology must prepare an environmental impact statement (EIS) when significant adverse environmental impacts are probable following the government action, even in the absence of immediate and specific proposals.[3] Thus, Ecology incorrectly claims that SEPA does not require the agency to address the probable significant and adverse impacts caused by the ACC II rule, even if those impacts are not immediate.

Third, Ecology focused solely on the purported beneficial aspects of the proposed rule while neglecting to discuss any probable significant, adverse environmental impacts. Specifically, in making its threshold determination, Ecology determined that "transitioning to battery electric vehicles and other zero emission vehicles will reduce greenhouse gas and criteria pollutant emissions" which it then claimed outweighed any adverse impacts. However, SEPA regulations make clear that a "threshold determination shall <u>not</u> balance whether the beneficial aspects of a

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[1] https://apps.ecology.wa.gov/separ/Main/SEPA/Record.aspx?SEPANumber=202204495&utm_medium=email&utm_source=govdelivery.

[2] RCW 43.21C.030(c)(i)-(iii).

[3] *See* WAC 197-11-055 (i) (The fact that proposals may require future agency approvals or environmental review shall not preclude current consideration, as long as proposed future activities are specific enough to allow some evaluation of their probable environmental impacts.).

proposal outweigh its adverse impacts, but rather, shall consider whether a proposal has any probable significant adverse environmental impacts…"[4]

For these reasons, Ecology's threshold determination does not comply with SEPA.

II. Ecology's Determination of Nonsignificance for the ACC II Rule Does Not Comply with SEPA

A. Ecology's Determination of Nonsignficance Does Not Properly Address the Significant and Adverse Environmental Impacts of the ACC II Rule

Ecology failed to comply with SEPA by issuing a determination of nonsignificance for the proposed changes to WAC 173-423, Clean Vehicles Program. This includes the language adopting California's ACC II rule, which mandates the sale of zero emission vehicle sales of passenger cars,[5] light-duty truck and medium-duty vehicles in Washington. The rule requires automobile manufacturers to increase sales of these vehicles every year until 2035 when all new vehicles sold in Washington must be zero emission vehicles.

Washington's SEPA statutes and regulations provide detailed requirements that Ecology must follow when determining whether an EIS should be issued on "proposals for legislation" or "other major actions having a probable significant, adverse environmental impact."[6] Specifically, SEPA requires preparation of an EIS for any "major action significantly affecting the quality of the environment."[7] If an agency determines an action will not have a significant adverse effect upon the environment, it issues a determination of nonsignificance (DNS).[8]

However, if an agency determines an action will have a significant adverse effect upon the environment, the agency must issue an EIS.[9] An EIS shall include a "detailed statement" discussing: 1) the environmental impact of the proposed action; 2) any adverse environmental effects which cannot be avoided should the proposal be implemented, and 3) alternatives to the proposed action.[10]

As discussed above, Ecology provides only three reasons for its DNS without explaining the reasoning behind the determination. Ecology fails to address the numerous environmental impacts that will result with implementation of the proposed rule, including:

- **Lifecycle Emissions from "Zero Emission Vehicles":** Despite SEPA's requirement to consider all potential significant and adverse environmental impacts associated with the ACC II rule, Ecology minimizes the environmental impacts while highlighting potential decreases in greenhouse gas emissions associated with zero emission vehicles. Ecology fails to discuss the greenhouse gas emissions associated with building out the electric grid, or the emissions

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[4] WAC 197-11-330 (emphasis added).
[5] The rule defines these vehicles as "zero emissions," however, as discussed in these comments, said vehicles are not "zero emission" vehicles. *See* 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.
[6] RCW 43.21C.031(1).
[7] RCW 43.21C.030(c).
[8] WAC 197-11-340.
[9] RCW 43.21C.031.
[10] RCW 43.21C.030(c)(i)-(iii).

caused by the mining of minerals for battery production, or the transport, disposal, or recycling of batteries. Instead, Ecology makes the [unsupported] assertion that the benefits of zero emission vehicles outweigh any environmental impacts caused by the transition from internal combustion vehicles. However, as discussed in further detail below, SEPA does not allow Ecology to ignore the environmental impacts even if the proposed rule may decrease overall emissions.

Ecology specifically fails to address the lifecycle emissions from electric vehicles. SEPA mandates that Ecology consider the impacts that "are likely to arise or exist over the lifetime of a proposal, or, depending on the particular proposal, longer."[11] Additionally, Ecology is required to consider "direct and indirect impacts caused by a proposal."[12]

Moreover, Ecology cannot ignore the indirect emissions that occur outside of the state caused by the proposed ACC II rule. SEPA regulations provide that in "assessing the significance of an impact, a lead agency shall not limit its consideration of a proposal's impacts only to those aspects within its jurisdiction, including local or state boundaries []."[13] The ACC II rule will have probable significant, adverse impacts through mining of the necessary minerals needed for the manufacture of "zero emission" vehicle batteries.

- **Adverse Environmental Impacts Due to Battery Disposal:** Ecology tacitly acknowledges in the threshold determination that the ACC II rule will cause environmental impacts associated with battery waste. However, it tries to minimize the significant adverse environmental impacts associated with disposal of batteries of electric vehicles by stating that it is "adopting California's battery warranty and labeling requirements" which will "decrease battery waste and limit additional mining…" This brief discussion of significant environmental impacts caused by battery waste exemplifies Ecology's blatant disregard of the significant adverse environmental impacts that will result from the ACC II rule.

- **Increased Demand for Electricity:** Ecology only briefly references the significant increased electricity demand that will occur due to the proposed rule. According to Ecology, "[w]hile the proposal may increase electricity [usage] statewide, current state policies to replace fossil fuels with clean electricity will drastically reduce the amount of greenhouse gases emitted from electric generation over the next two decades." Ecology is wrong that statewide electricity demand *may* increase due to the proposed rule. It is an absolute certainty that shifting to all electric vehicles in Washington will substantially increase electricity demand. Ecology fails to adequately consider the increased demand on the electric grid due to the significantly increased amount "zero emission" vehicles. Nor does Ecology properly consider the impacts caused by the necessary buildout of the electric grid, which will likely include gas units [or additional batteries][?] 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 adversely affect the environment, including biological resources, increased greenhouse gas emissions, and criteria pollutants.

- **Increased Potential of Wildfire Ignition:** In 2021, the Washington Legislature enacted Second Substitute House Bill 1168 (Chapter 298, Laws of 2021),[14] relating to long-term forest

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[11] WAC 197-11-060(4)(c).
[12] WAC 197-11-060(4)(d).
[13] WAC 197-11-060(4)(b).
[14] https://lawfilesext.leg.wa.gov/biennium/2021-22/Pdf/Bills/Session%20Laws/House/1168 S2.SL.pdf?cite=2021%20c%20298%20%C2%A7%202.

health and the reduction of wildfire dangers. The legislation created a wildfire response, forest restoration, and community resilience account to address the increase of wildfires in Washington state. Additionally, the legislation provides that the legislature intends to "take immediate action to fully fund the wildland fire protection 10-year strategic plan." The legislation further states that one of the strategies is to "work[] with each state utility, local publicly owned electric utility, and electrical cooperative to reduce wildfire risk and develop consistent approaches and shared data related to fire prevention, safety, vegetation management, and energy distribution systems."[15] Despite this clear legislative priority and concerns regarding increased potential of wildfires in Washington state caused by electric utilities, Ecology fails to address how the proposed rule will affect wildfire resilience. Nowhere in its DNS does Ecology address how the inevitable build-out of electricity infrastructure will exacerbate the risk of wildfires in Washington state. The environmental impacts from the significant buildout of the electrical grid to meet the demand for electric vehicles will be significant and adverse. This is yet another example of how Ecology has failed to comply with SEPA.

- **Increased Cost of Vehicles Resulting in Consumers Keeping Internal Combustion Vehicles Longer**: One of the unintended consequences of the proposed ACC II rule is that it will lead to significantly more expensive vehicles. The rule will cause many middle- and lower-income individuals to hold on to their internal combustion vehicles as long as possible, thereby foregoing opportunities to replace their aging vehicles with more efficient models. With many individuals retaining older, less efficient vehicles longer, the ACC II rule may lead to more greenhouse gas emissions. Ecology fails to acknowledge or analyze this possible consequence in its DNS.

- **Increased GHG Emissions Caused by Consumers Purchasing Vehicles from Other States:** Ecology also fails to address how the proposed ACC II rule may lead to higher greenhouse gas emissions caused by Washington consumers traveling to and purchasing traditional internal combustions engine vehicles in surrounding states. This is yet another unintended consequence of the ACC II rule that will result in additional greenhouse gas emissions and criteria pollutants.

These are just a few of the probable significant, adverse environmental impacts Ecology fails to acknowledge in its threshold determination. Based on its failure to address these (and other) probable significant, adverse impacts the ACC II rule will cause, Ecology's threshold determination does not comply with SEPA.

B. Ecology is Required to Issue an EIS Even in Situations When Future Developments and Actions are Not Certain

Despite Ecology's acknowledges that "some adverse environmental conditions could potentially result" from implementation of the rule, the agency claims that an environmental impact statement is not necessary because some of the "conditions" will occur at an unspecified time in the future. Specifically, Ecology claims that "such impacts would be identified, considered and mitigated (if appropriate) at the time of specific projects."

Ecology's position that future impacts will be considered and mitigated at the time specific projects are proposed is erroneous and a clear violation of SEPA's requirements. SEPA requires lead

[15] Id.

agencies to address all significant and adverse environmental impacts early in the process, irrespective of whether those adverse impacts are to occur in the future.

The SEPA regulations explicitly address future impacts. The SEPA "process shall be integrated with agency activities at the earliest possible time to ensure that planning and decisions reflect environmental values, to avoid delays later in the process, and to see to resolve potential problem."[16] The lead agency "shall prepare its threshold determination and EIS (EIS), if required, at the earliest possible point in the planning and decision-making process, when the principal features of a proposal and its environmental impacts can be reasonably identified."[17]

Importantly, the "fact that proposals may require future agency approvals or environmental review shall not preclude current consideration, as long as proposed future activities are specific enough to allow some evaluation of their probably environmental impacts."[18]

Additionally, SEPA makes clear that a "proposal's effects include direct and indirect impacts caused by a proposal. Impacts include those effects resulting from growth caused by a proposal, as well as the likelihood that the present proposal will serve as a precedent for future actions."[19] The rule further explains that "[f]or example, adoption of a zoning ordinance will encourage or tend to cause particular types of projects or extension of sewer lines would tend to encourage development in previously unsewered areas." [20] Ecology must "carefully consider the range of probable impacts, including short-term and long-term effects. Impacts shall include those that are likely to arise or exist over the lifetime of a proposal or, depending on the particular proposal, longer."[21]

The Washington Supreme Court has made clear that lead agencies must address environmental impacts at the earliest stages even if future adverse impacts are to occur later in the process:

> *"One of SEPA's purposes is to provide consideration of environmental factors at the earliest possible stage to allow decisions to be based on complete disclosure of environmental consequences." Stempel v. Department of Water Resources*, 82 Wash.2d 109, 118, 508 P.2d 166 (1973); *664 *Loveless v. Yantis*, 82 Wash.2d 754, 765–66, 513 P.2d 1023 (1973).
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> *"Even if adverse environmental effects are discovered later, the inertia generated by the initial government decisions (made without environmental impact statements) may carry the project forward regardless. When government decisions may have such snowballing effect, decisionmakers need to be apprised of the environmental consequences before the project picks up momentum, not after." King County v. Washington State Boundary Review Bd.*, 122 Wn. 2d 648, 860 P.2d 1024 (1993) (emphasis added).

As discussed above, the adoption of the ACC II rule will have significant, adverse environmental impacts. Although many of the adverse impacts will occur in the future, Ecology is not absolved from discussing and addressing those impacts at the rulemaking stage through an EIS. Indeed, SEPA requires Ecology to discuss such adverse impacts early in the rulemaking process to

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[16] WAC 197-11-055(1) (emphasis added).
[17] WAC 197-11-055(2) (emphasis added).
[18] WAC 197-11-055(2)(a)(i).
[19] WAC 197-11-060(4)(d) (emphasis added).
[20] Id.
[21] WAC 197-11-060(4)(c).

ensure that any policy changes can occur at the outset before such adverse impacts occur in the future. As discussed below, one such alternative policy change involves enforcement of Washington's low carbon fuel standard instead of creating unnecessary adverse environmental impacts caused by the new electric vehicle mandate.

Ecology may argue that it is required by law to adopt California's ACC II rule with no changes. However, Ecology must also comply with Washington statutes and regulations, including SEPA's requirement to issue an EIS and take affirmative steps to mitigate adverse environmental impacts. This may require Ecology to scale back its rulemaking as it relates to the ACC II rule and instead comply with the low carbon fuel standards that were recently enacted.

Ecology's threshold determination fails to comply with SEPA when it determines that an EIS is not necessary because adverse environmental impacts will occur in the future.

C. SEPA Does Not Permit Ecology to Only Consider a Rule's Benefits and Ignore Probable, Significant Adverse Impacts

Ecology also argues that an EIS is not required because the proposed ACC II rule will have positive environmental impacts. Specifically, Ecology states that "[t]ransitioning to battery electric vehicles and other zero emission vehicles will reduce greenhouse gas and criteria pollutant emissions, as well as the extraction, refinement, and transport of oil and gas products." In addition, Ecology states the rule "adopt[s] California's battery warranty and labeling requirements that will decrease battery waste and limit additional mining of lithium, cobalt, nickel, and other minerals. State energy policies will also decrease the GHG emissions associated with additional electricity production for vehicle charging."

This suggests that Ecology believes it can forgo addressing the significant, adverse environmental impacts from the proposed ACC II because there will be some beneficial impacts.

SEPA explicitly disallows Ecology from issuing a DNS based on the beneficial aspects of a proposal potentially outweighing its adverse impacts. The SEPA rule provides in relevant part:

> A threshold determination <u>shall not</u> balance whether the beneficial aspects of a proposal outweigh its adverse impacts, but rather, <u>shall consider</u> whether a proposal has any probable significant adverse environmental impacts under the rules stated in this section. For example, proposals designed to improve the environment, such as sewage treatment plants or pollution control requirements, may also have significant adverse environmental impacts.[22]

Here, Ecology's threshold determination based on the beneficial aspects of the ACC II rule's potentially outweighing any adverse impacts of the rules is a clear violation of SEPA. Ecology must issue an EIS that addresses the numerous probable significant, adverse impacts caused by the ACC II rule regardless of the beneficial aspects of the rule.

III. Ecology Must Follow SEPA and Issue an EIS to Address Alternatives to the Advanced Clean Cars II Rule

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[22] WAC 197-11-330(5) (emphasis added).

Attachment A

WSPA Concerns with SEPA and APA Compliance for the Proposed Revisions to WAC 173-423, Clean Vehicles Program

A. SEPA Requires Ecology to Address Alternatives to the Proposed Rules in an EIS When There Are Probable, Significant Adverse Impacts

In failing to lawfully comply with SEPA and issuing a DNS, Ecology undermines a vital aspect of the SEPA process: addressing possible alternatives to the proposed ACC II rule with the potential for fewer significant adverse impacts.

SEPA explicitly states that once a determination of significance has been made and an EIS is required, the lead agency shall include a detailed statement discussing "alternatives to the proposed action."[23]

The SEPA regulations explain further that an "EIS shall provide impartial discussion of significant environmental impacts and shall inform decision makers and the public of reasonable alternatives, including mitigation measures, that would avoid or minimize adverse impacts or enhance environmental quality."[24]

Here, Ecology must address the alternatives to the ACC II rule may provide environmental benefits. This should include a discussion of how a technology neutral performance-based standard allowing low-carbon fuel and engine technologies could provide both environmentally beneficial and cost-effective alternatives to the prescriptive regulations contained in the proposed ACC II rule.

Ecology ignores this step and pretends that reasonable alternatives do not exist. But, as discussed below, such alternatives do exist and should be discussed in an EIS.

B. Ecology Should Consider Low Carbon Fuel Technology as An Alternative in the EIS for the Proposed Advanced Clean Cars II Rule

To comply with SEPA, Ecology must consider alternatives in the EIS. One obvious and reasonable alternative Ecology must include in the EIS is implementing the current Clean Fuels Program that was enacted in 2021.[25]

The law requires Ecology to develop rules that limit greenhouse gas emissions attributable to each unit of transportation fuel to 20 percent below 2017 levels by 2038. The Clean Fuels Program relies on market-based mechanisms that deliver sustainable greenhouse gas emission reductions without a technology-based mandate. Additionally, the low carbon fuel technology could lead to further reductions in carbon intensity through market incentives that produce opportunities for carbon capture and sequestration and numerous other novel low-carbon fuel pathways.

As discussed in the attached comments submitted by WSPA to the California Air Resources Board, in some instances when a lifecycle emissions analysis is applied to "battery electric

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[23] RCW 43.21C.030(c)(iii). See also *Brinnon Group v. Jefferson County*, 159 Wash.App. 446, 245 P.3d 789. (2011) ("For purposes of judicial review of the adequacy of an environmental impact statement under the State Environmental Policy Act, the required discussion of alternatives in an EIS is of major importance, because it provides a basis for a reasoned decision among alternatives having differing environmental impacts.").

[24] WAC 197-11-400(2).

[25] Engrossed Third Substitute House Bill 1091, Chap. 317, Laws of 2021, at https://app.leg.wa.gov/billsummary?BillNumber=1091&Year=2021&Initiative=false.

vehicles," the greenhouse gas emissions over the lifetime of the vehicle can be higher than those of internal combustion engine vehicles.[26]

The significant emission increases associated with the production of a battery electric vehicle, as compared to an internal combustion engine vehicle, must be included in an EIS to fully understand the impacts of the proposed ACC II regulation and to ensure that Ecology considers all reasonable alternatives.

IV. Washington APA Requires Ecology to Prepare an Economic Impact Analysis for the Proposed Rule Adopting California's Emission Standards

The Washington Administrative Procedure Act contains specific requirements state agencies must comply with during the rulemaking process, including preparing a cost-benefit analysis of the proposed rule. Specifically, the agency issuing the rule must "[d]etermine that the probable benefits of the rule are greater than its probable costs, taking into account both the qualitative and quantitative benefits and costs and the specific directives of the statute being implemented."[27] This includes: 1) a requirement to "provide notification in the notice of propose rule making…that a preliminary cost-benefit analysis is available," and 2) a "final cost-benefit analysis" when "the rule is adopted."[28]

The cost-benefit analysis, along with the other listed procedural requirements, must be performed for all "significant legislative rules of the department…"[29] There is no doubt that the proposed rule (Chapter 173-423 WAC) adopting California emission standards meets the statutory definition of a "significant legislative rule," which is defined as:

> *"[A] rule other than a procedural or interpretive rule that (A) adopts substantive provisions of law pursuant to delegated legislative authority, the violation of which subjects a violator of such rule to a penalty or sanction; (B) establishes, alters, or revokes any qualification or standard for the issuance, suspension, or revocation of a license or permit; or (C) adopts a new, or makes significant amendments to, a policy or regulatory program."*[30]

The only potential exception under the APA relieving Ecology of its duty to adopt a cost-benefit analysis is under RCW 34.05.328(5)(b). This provision provides that the above-listed procedural requirements are exempted for rules *"adopting or incorporating by reference without material change federal statutes or regulations, Washington state statutes, rules of other Washington state agencies, or, as referenced by Washington state law, national consensus codes that generally establish industry standards if the material adopted or incorporated regulates the same subject matter and conduct as the adopting or incorporating rule."*

Ecology may argue the proposed rules here are adopting or incorporating by reference RCW 70A.30.010, which directs Ecology to adopt California's emission standards. However, the statute itself recognizes that Ecology must adopt rules to "implement the motor vehicle emission standards of the state of California, including the zero emission vehicle program." Thus, the rule

[26] "Comments on Advanced Clean Cars II Regulation Initial Statement of Reasons (ISOR) Documents, Western States Petroleum Ass'n, American Fuel & Petrochemical Manufacturers, and California Independent Petroleum Association, May 31, 2022.
[27] RCW 34.05.328(d).
[28] RCW 34.05.038(c).
[29] RCW 34.05.328(a).
[30] RCW 34.05.328(5)(c)(iii).

is not incorporating by reference specific statutory language. Instead, RCW 70A.30.010 explicitly directs Ecology to adopt the standards through rulemaking. The legislature drafted the statute in this manner recognizing that California's regulations would change over time, thus requiring Ecology to update its regulations through the rulemaking process.

Nothing under the APA exempts Ecology from preparing a cost-benefit analysis of the entire proposed rules adopting California's emission standards, including the ACC II rule. Chapter 173-423 is a significant legislative rule that must be adopted through the proper APA rulemaking process.

Based on the foregoing, Ecology has the authority to adopt California's emission standards by rule. Ecology is not, however, exempt from having to comply with the Washington APA's procedural requirements, including preparing a cost-benefit analysis.

V. Ecology Fails to Comply with the Regulatory Fairness Act by Ignoring the Costs of the Advanced Clean Cars II Rule on Small Businesses

In 1994, the Washington Legislature enacted the Regulatory Fairness Act (RFA). The RFA's legislative finding states that "administrative rules adopted by state agencies can have a disproportionate impact on the state's small businesses because of the size of those businesses," and "this disproportionate impact reduces competition, innovation, employment, and new employment opportunities, and threatens the very existence of some small businesses."[31]

The statute mandates that a state agency that adopts a "rule under chapter 34.05 RCW…shall prepare a small business economic impact statement."[32] The small business EIS "must include a brief description of the reporting, recordkeeping, and other compliance requirements of the proposed rule, and the kinds of professional services that a small business is likely to need in order to comply with such requirements."[33]

Additionally, the small business EIS "shall analyze the costs of compliance for businesses required to comply with the proposed rule," including "costs of equipment, supplies, labor, professional services, and increased administrative costs."[34] It must also consider "whether compliance with the rule will cause businesses to lose sales or revenue."[35]

To determine whether the proposed rule will have a disproportionate cost impact on small businesses, "the impact statement must compare the cost of compliance for small business with the cost of compliance for the ten percent of businesses that are the largest businesses required to comply with the proposed rules using one or more of the following as a basis for comparing costs:

- Cost per employee;
- Cost per hour of labor; or
- Cost per one hundred dollars of sales.

[31] RCW 19.85.011.
[32] RCW 19.85.030.
[33] RCW 19.85.040.
[34] Id.
[35] Id.

A small business EIS must also include a "statement of the steps taken by the agency to reduce the costs of the rule on small businesses," or "reasonable justification for not doing so."[36] The EIS must also include an "estimate of the number of jobs that will be created or lost as the result of compliance with the proposed rule."[37]

Despite these clear requirements, Ecology's small business EIS prepared for the proposed changes to WAC 173-423 and 173-400 disregards the costs associated with the ACC II rule. Instead, Ecology's small business EIS focuses solely on the reporting requirements of the proposed rule. Ecology incorrectly believes it can neglect to discuss the costs of the ACC II rule to all small businesses because it is required by law to implement the rule. However, that is a misreading of the statute. The RFA does not allow Ecology to ignore the costs associated with implementation of the ACC II rule. Based on the plain language of the RFA, Ecology must go back to analyze the "costs of compliance for businesses required to comply with the proposed rule," including the ACC II rule language.

Even the California Air Resources Board issued cost estimates (albeit rather sloppily) in its rulemaking. Here, Ecology completely sidesteps the most obvious aspect of the ACC II rule, which is the increased costs of the vehicles and the disproportionate impact those costs will have on small businesses, especially in rural parts of the state. For example, a study performed by Capitol Matrix Consulting analyzing the impact of the ACC II regulation on California businesses found that businesses will incur $5,000 to $8,000 per small vehicle in 2026. For larger pickup trucks with towing capacity, small businesses will incur an increase of $12,000 to $16,000 per vehicle.

Other costs will no doubt be incurred due to the ACC II. Such costs include higher fuel costs for companies that maintain internal combustion engine vehicles, higher utility rates, exposure to greater electrical power disruptions and thus reduction in business productivity, and lower spending by consumers caused by increased transportation costs.

In summary, Ecology's small business EIS does not comply with the RFA. Therefore, Ecology should not move forward with the proposed ACC II rule until it issues a small business economic impact statement that complies with the RFA.

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[36] Id.
[37] Id.

ATTACHMENT B

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

Tanya DeRivi
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Western States Petroleum Association

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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.

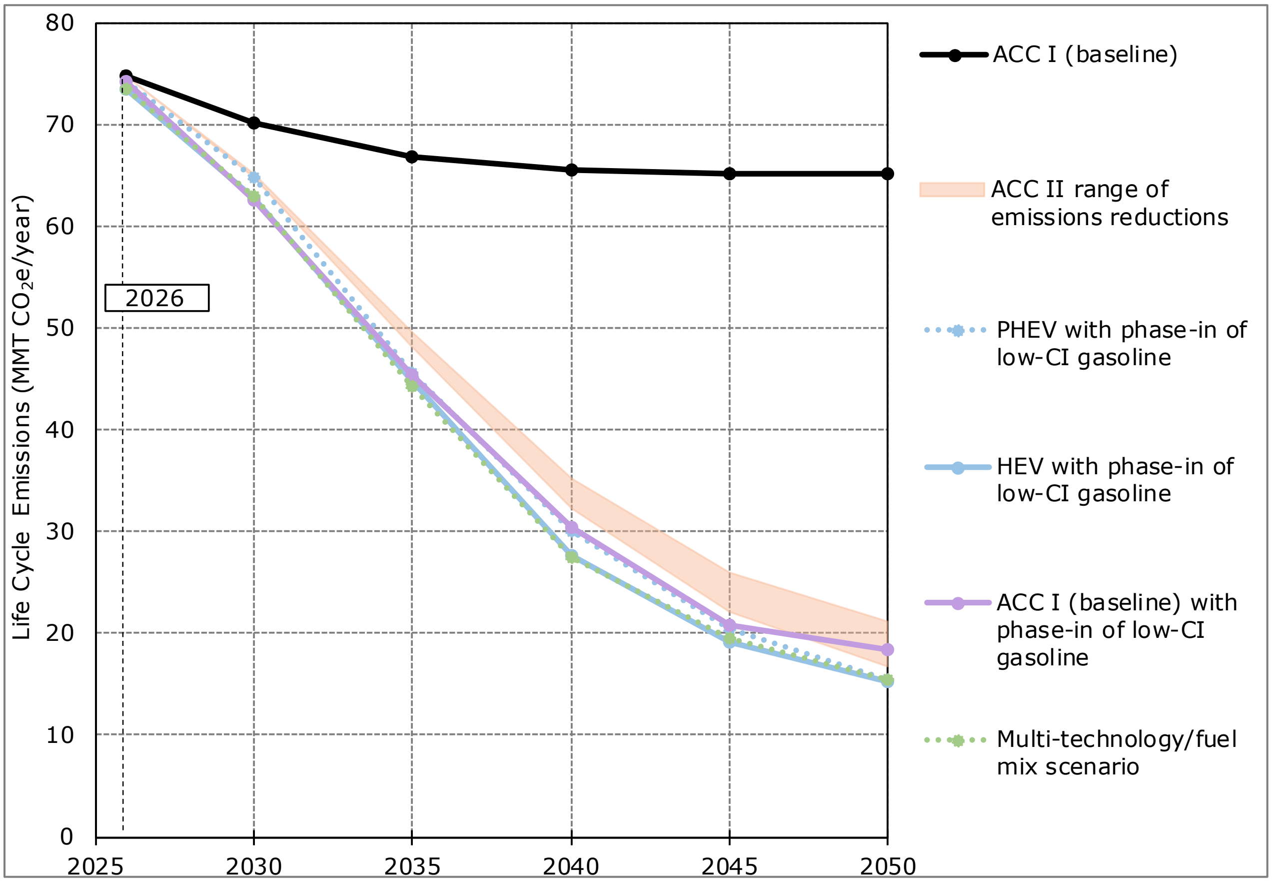
Despite multiple comments by many stakeholders, including the Associations, over the last two years, CARB has explicitly included ZEV technology mandates in its ACC II and Advanced Clean Fleets (ACF) proposals, without the necessary analyses to justify the choice of a sales mandate over a performance-based 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]

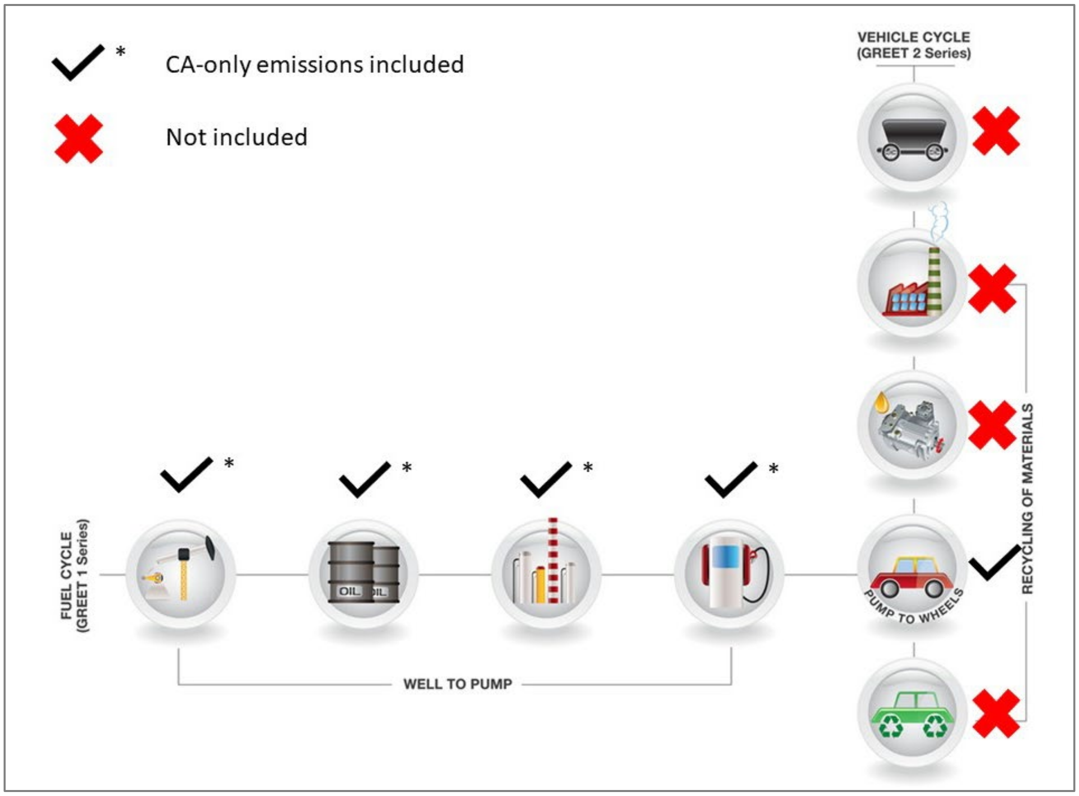
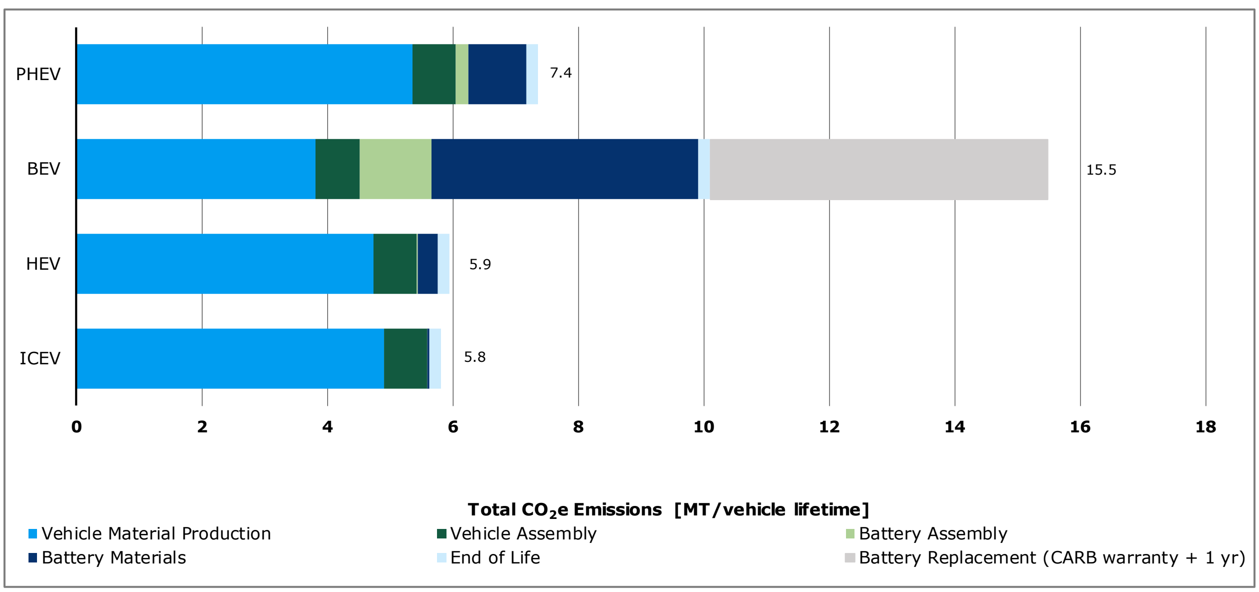


Figure 3: Vehicle Cycle GHG Emission Factors for Different Vehicle Technologies



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,

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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.

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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.

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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

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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.

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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.

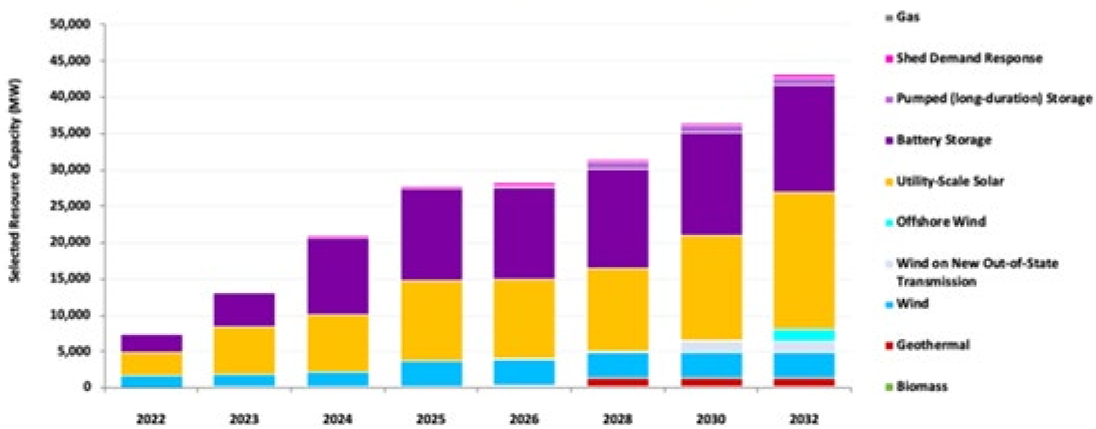
23 Further, the North American Electric Reliability Corporation's (NERC) draft 2022 Summer Reliability Assessment determined that extreme weather creates an elevated reliability risk in the western United States. NERC, *2022 Summer Reliability Assessment* (May 2022). Available at: https://www.nerc.com/pa/RAPA/ra/Reliability%20Assessments%20DL/NERC_SRA_2022.pdf.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

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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

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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

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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 S*ee* 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

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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.

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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

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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,

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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

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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.

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[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

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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.

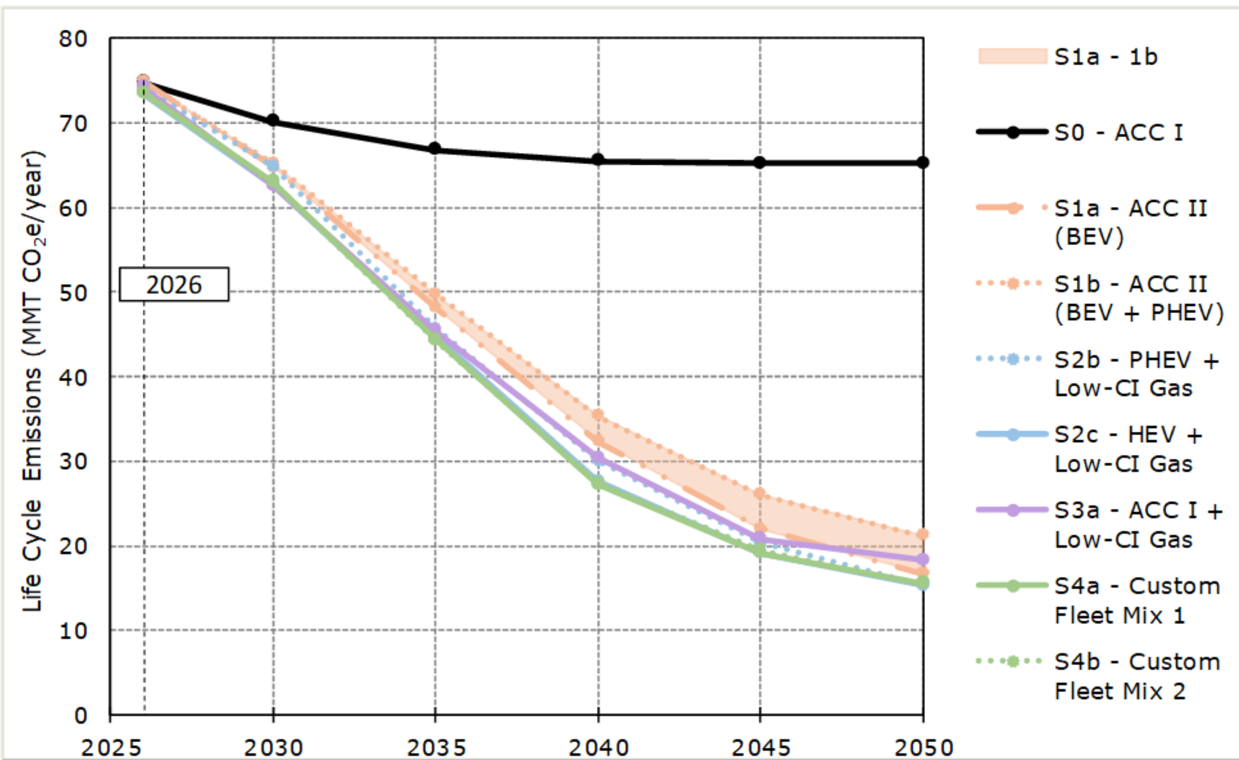
ATTACHMENT B
Technical Comments

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

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[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

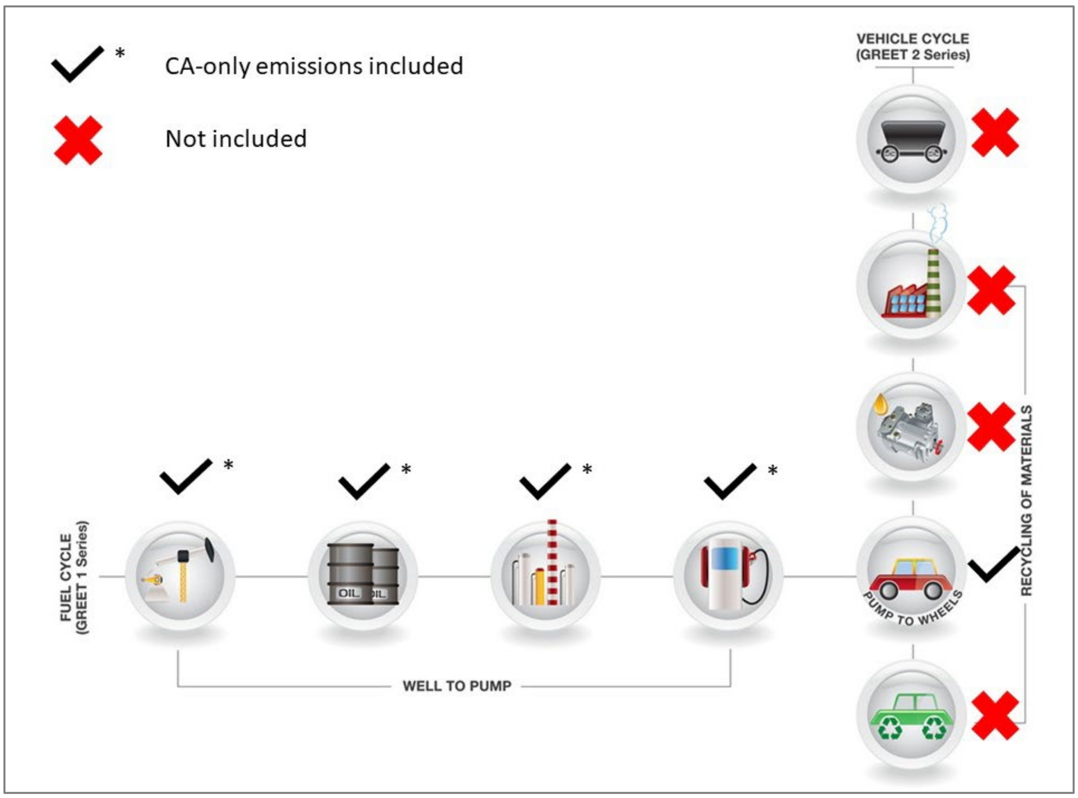
[121] Cleaner fuels have now replaced more than 3 billion gallons of diesel fuel under the LCFS. Available at: https://ww2.arb.ca.gov/news/cleaner-fuels-have-now-replaced-more-3-billion-gallons-diesel-fuel-under-low-carbon-fuel. Accessed: May 2022.

[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]

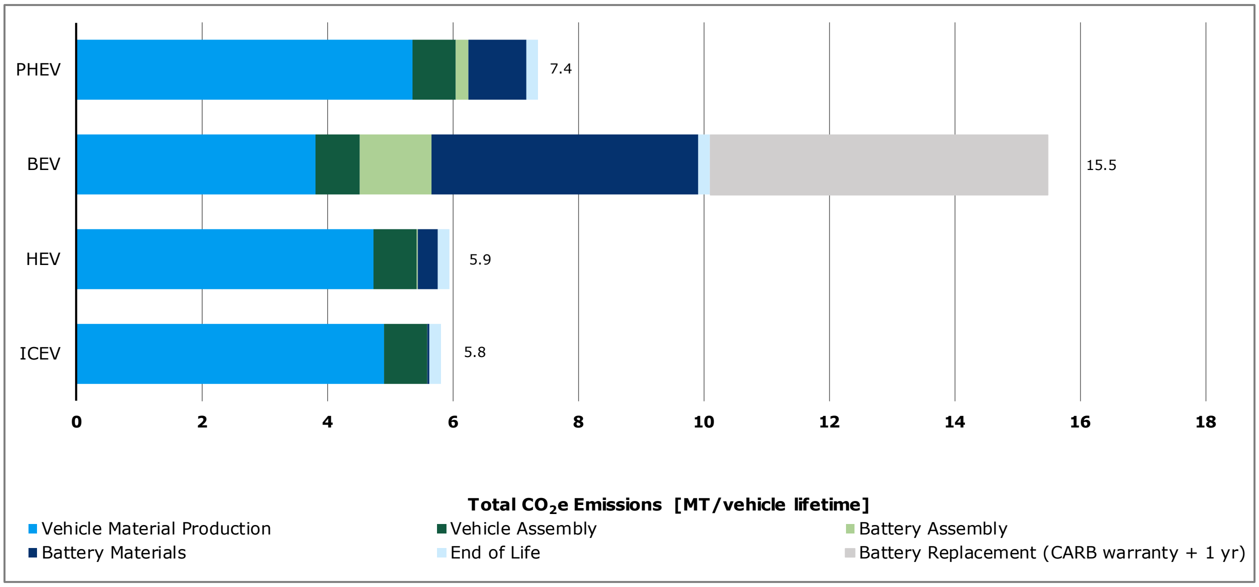


Ramboll conducted an analysis of California's light-duty auto (LDA) fleet to evaluate whether alternative vehicle technology and fuel pathways could achieve life cycle GHG emission reductions similar or greater than the ACC II proposal ("Ramboll LDA Study", included in **Attachment D**). Unlike the ISOR 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



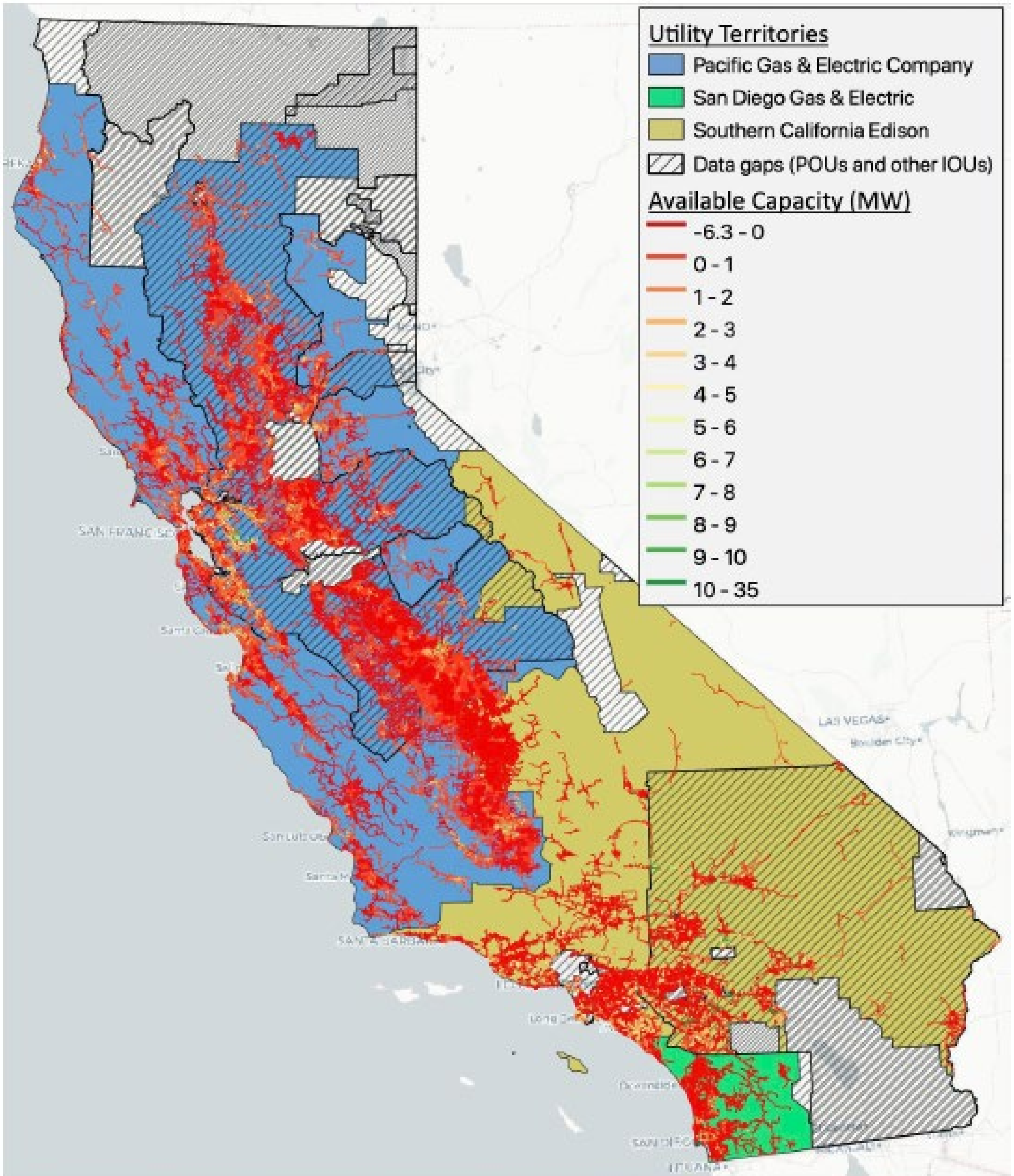
B.4 CARB does not discuss the potential impact to the California electric grid from this regulation including requirements for new and upgraded generation, transmission, and distribution.

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)

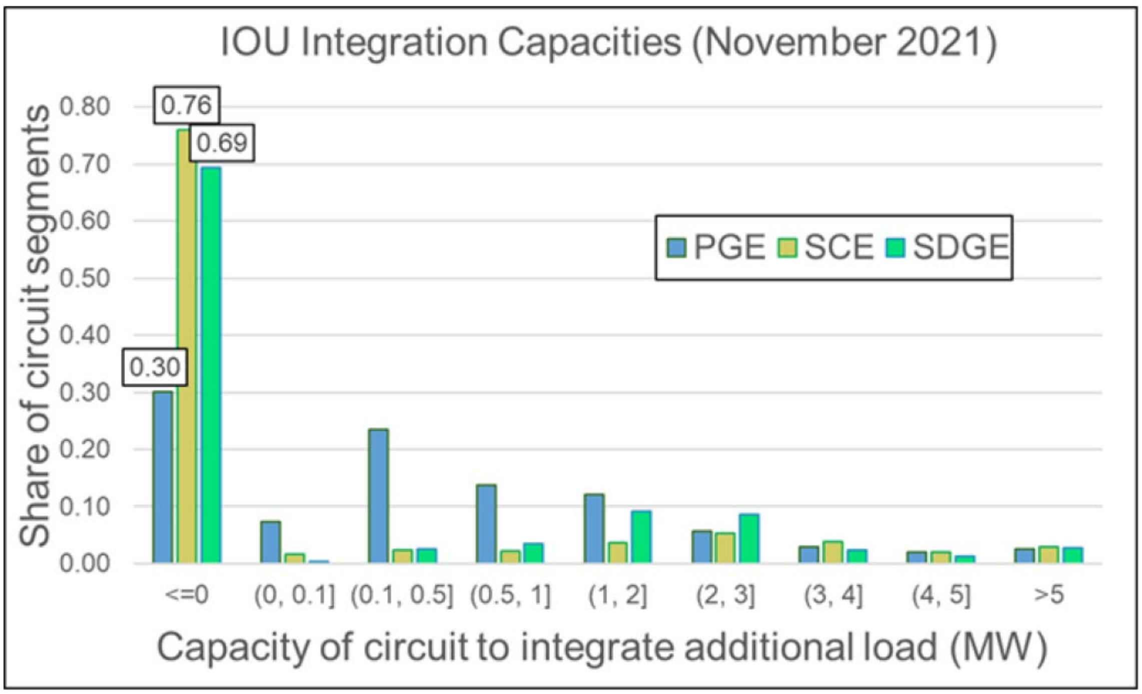


[126] Draft Environmental Analysis (EA) for the Proposed ACC II Program. Available at: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/accii/appe1.pdf. Accessed: May 2022.

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

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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] ($/charger) Low Estimate	Cost Range[2] ($/charger) 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

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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

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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

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[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

<u>October 27, 2021 Comments</u>[152]

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

<u>September 1, 2021 Comments</u>[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.

<u>June 11, 2021 Comments</u>[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)

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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

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RAMBOLL

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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.

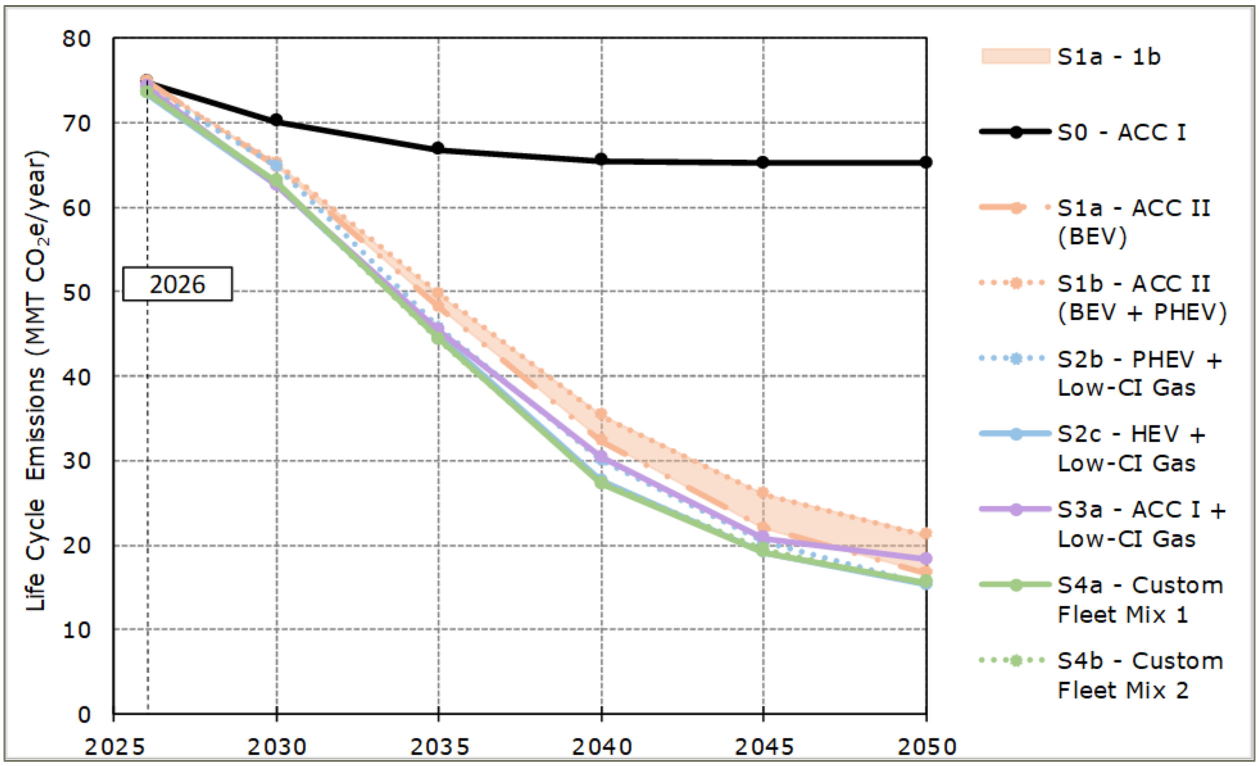
The main conclusions of our analysis are:

- 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

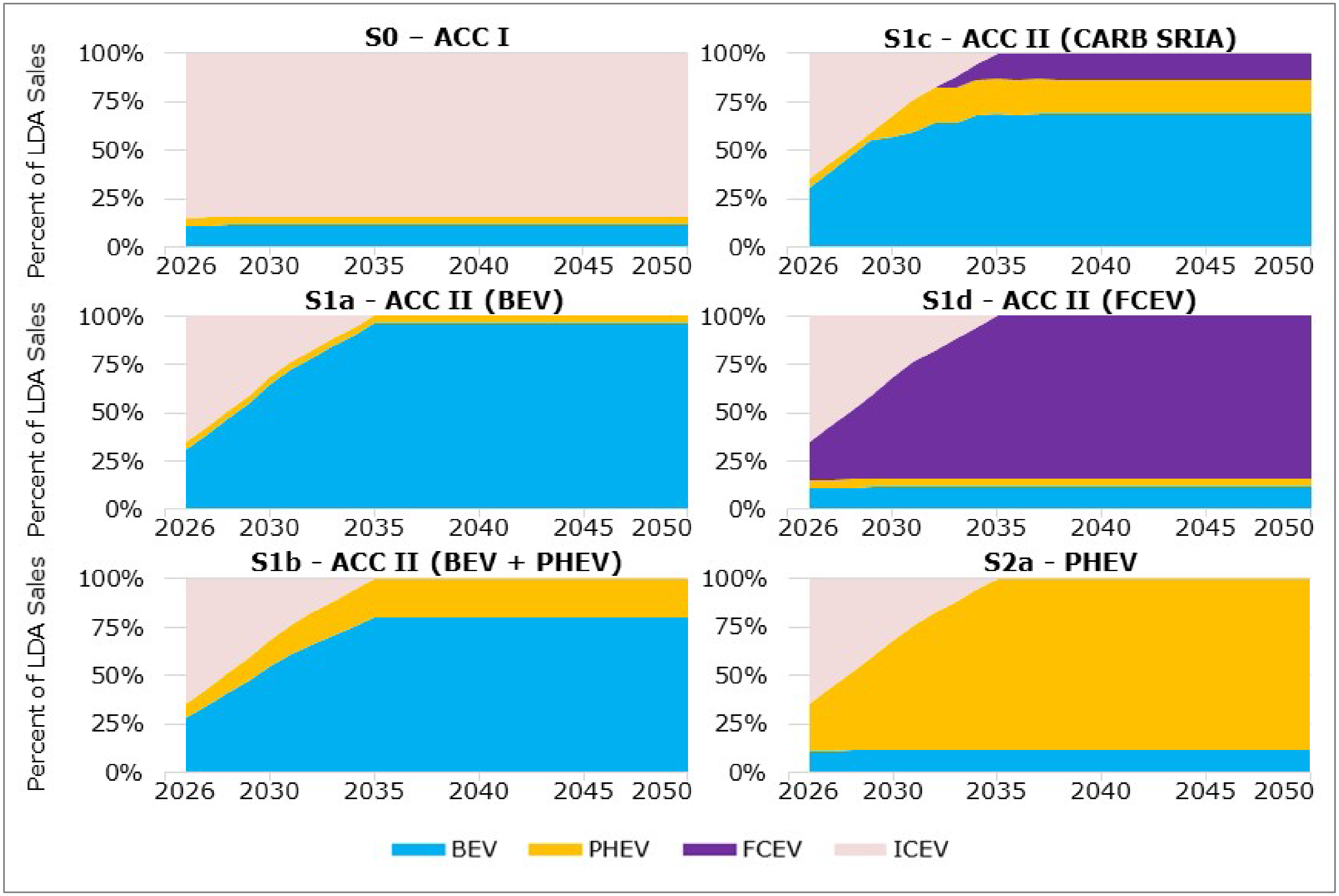


Figure 2-2. LDA New Vehicle Sales Fractions for Scenarios 2b, 2c, 3a, 4a, 4b, and 4c

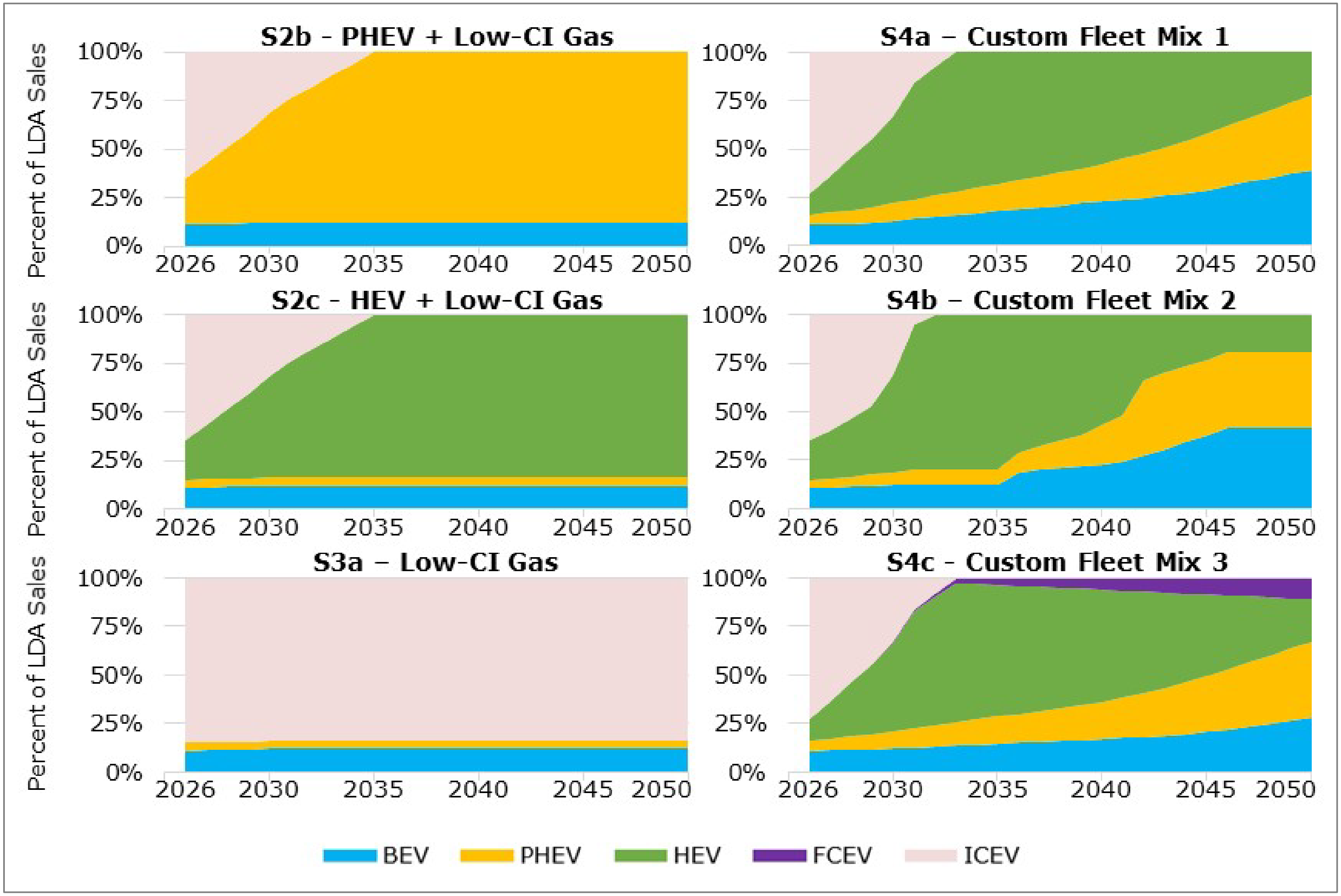


Figure 2-3. LDA Fleet Mixes for Scenarios 0, 1a, 1b, 1c, 1d, and 2a

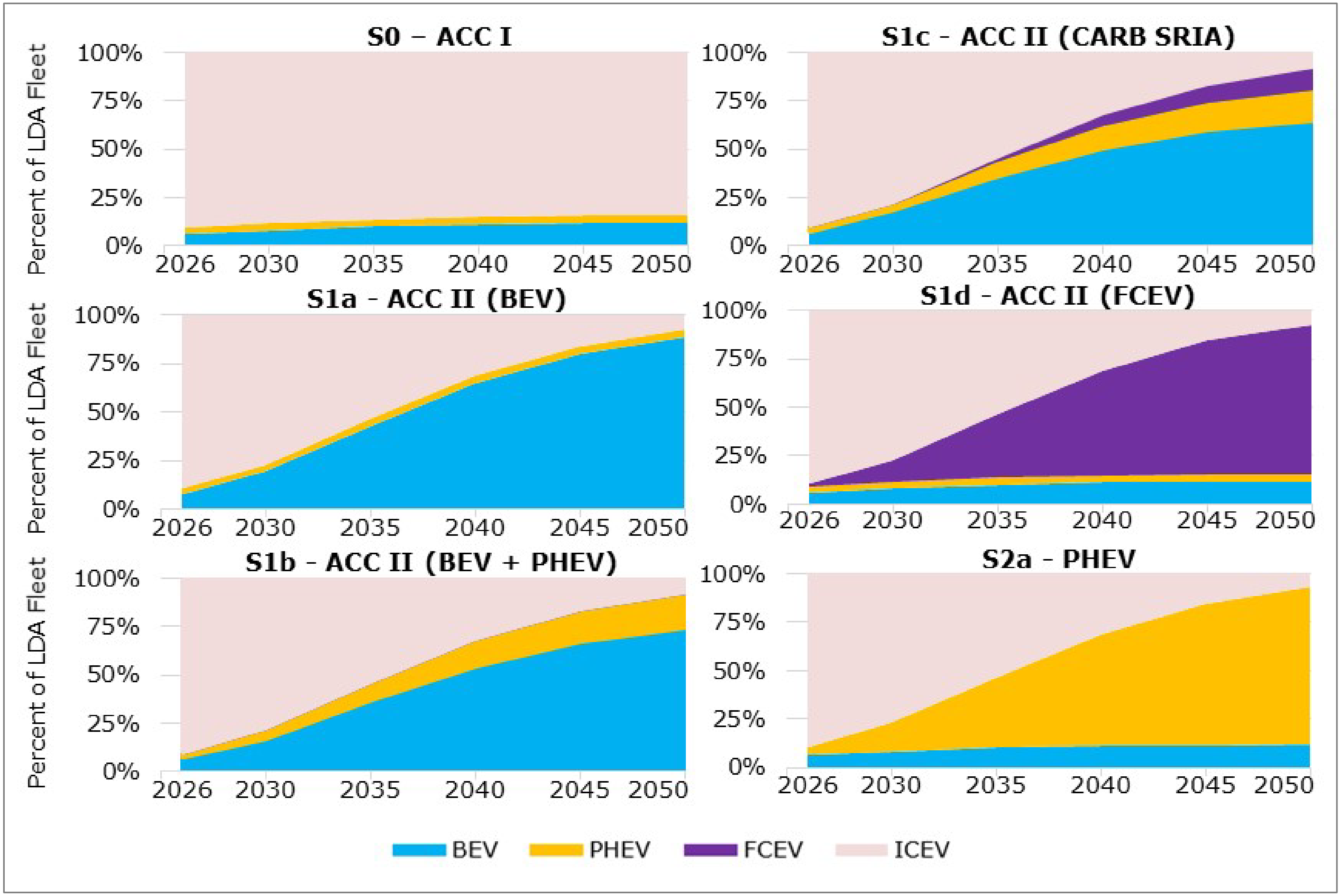


Figure 2-4. LDA Fleet Mixes for Scenarios 2b, 2c, 3a, 3b, 4a, 4b, and 4c

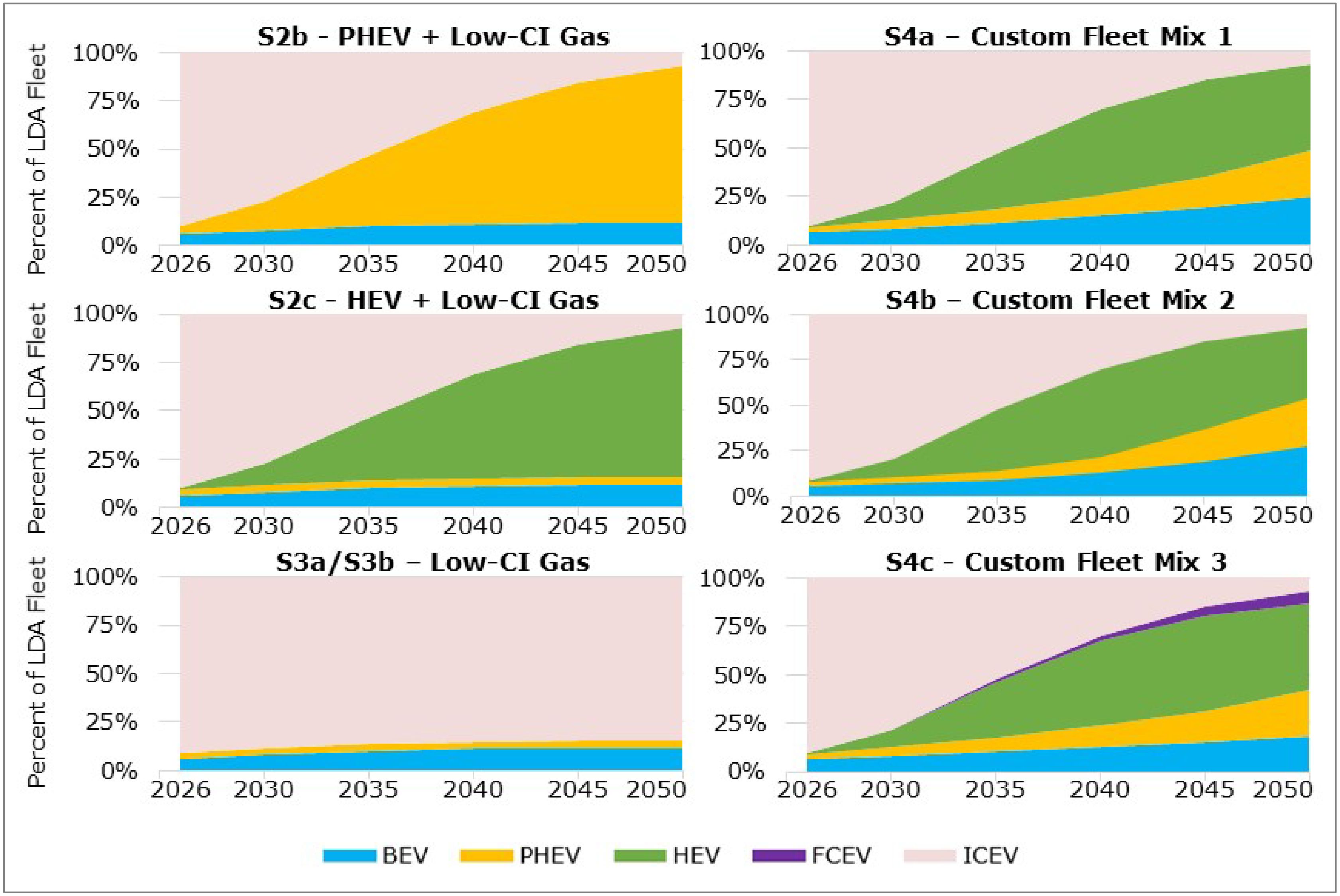


Figure 2-5. Fuel Usage Fractions for Scenarios 0, 1a, 1b, 1c, 1d, and 1d-1

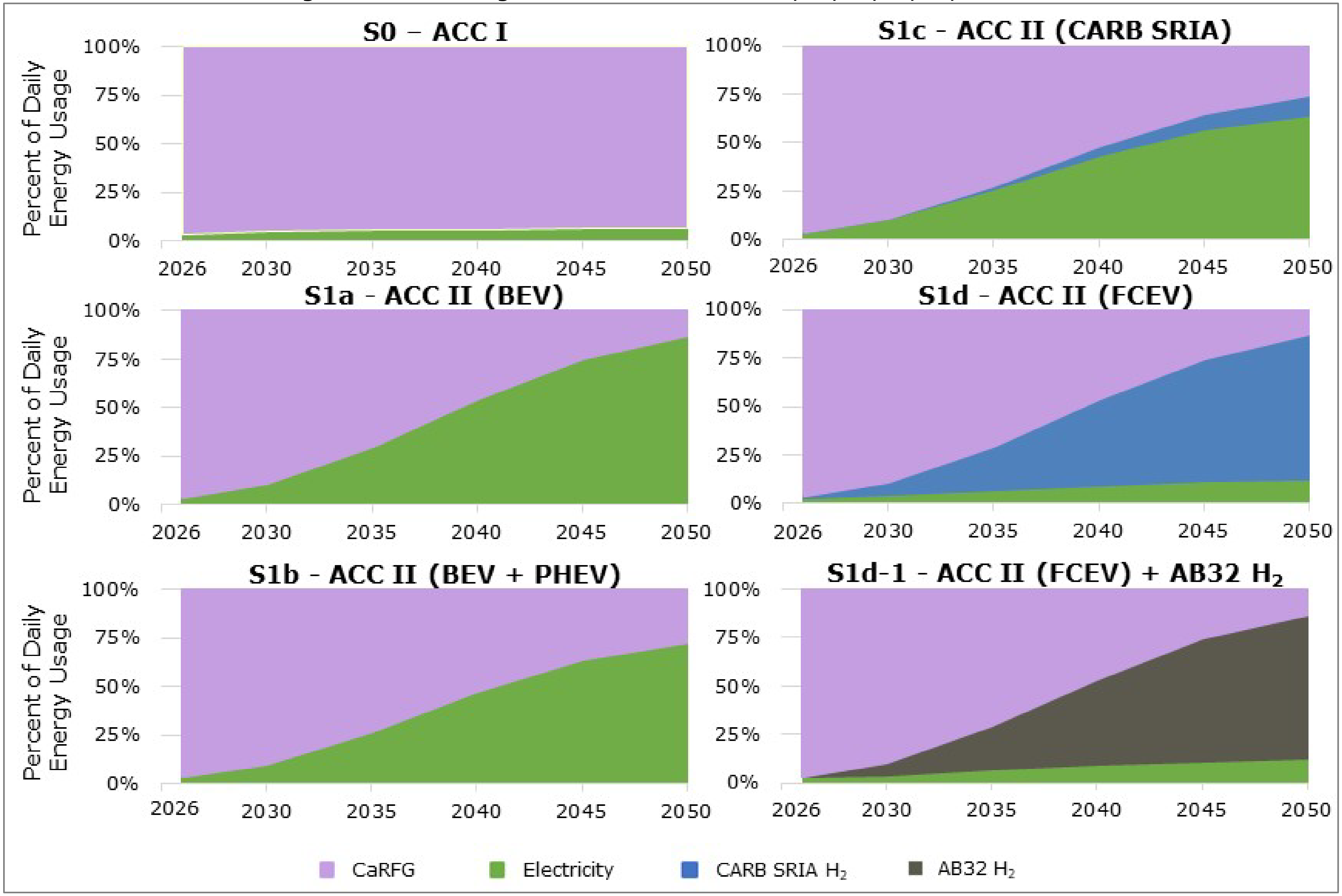


Figure 2-6. Fuel Usage Fractions for Scenarios 2a, 2b, 2c, 3a, 3b, and 4a

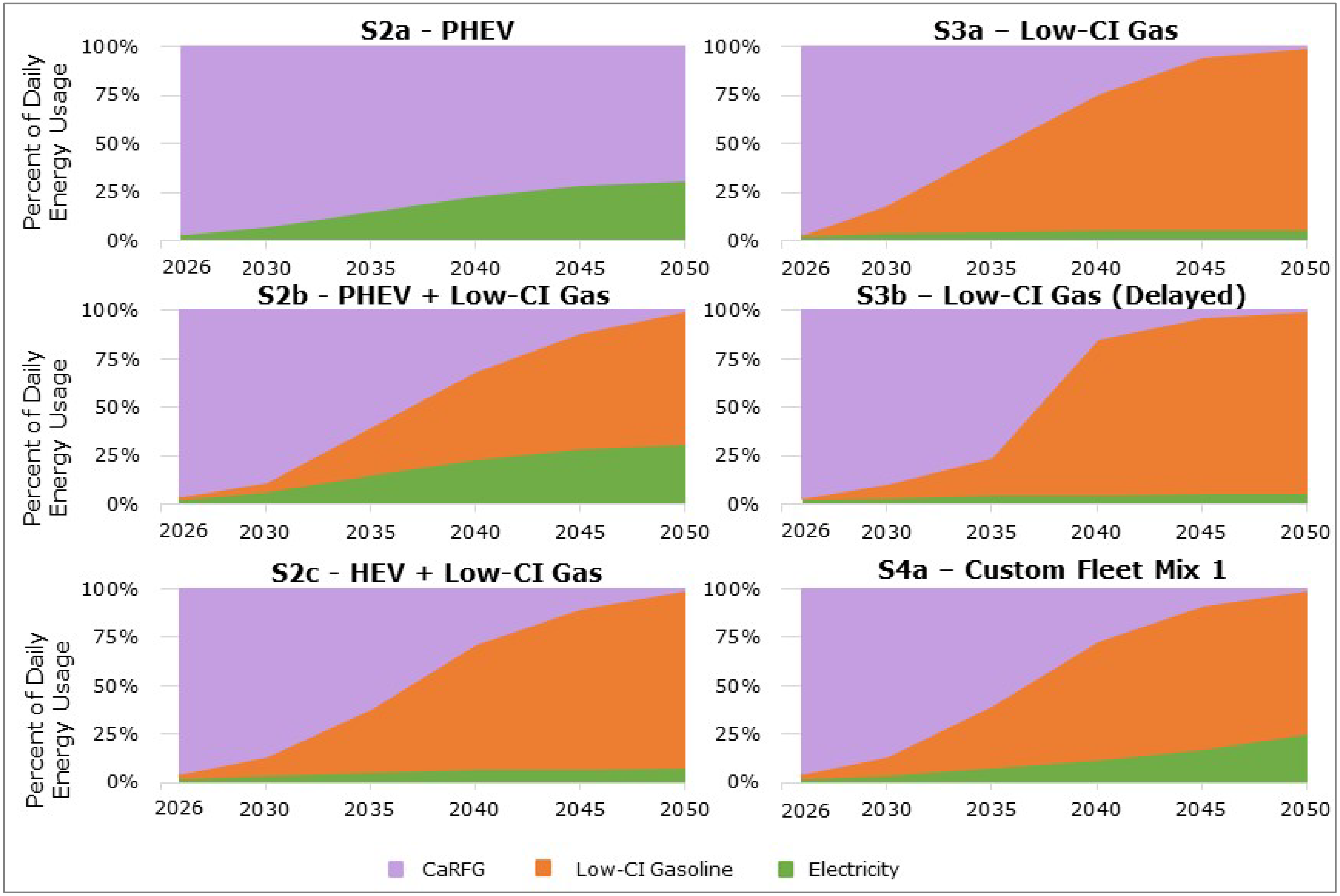
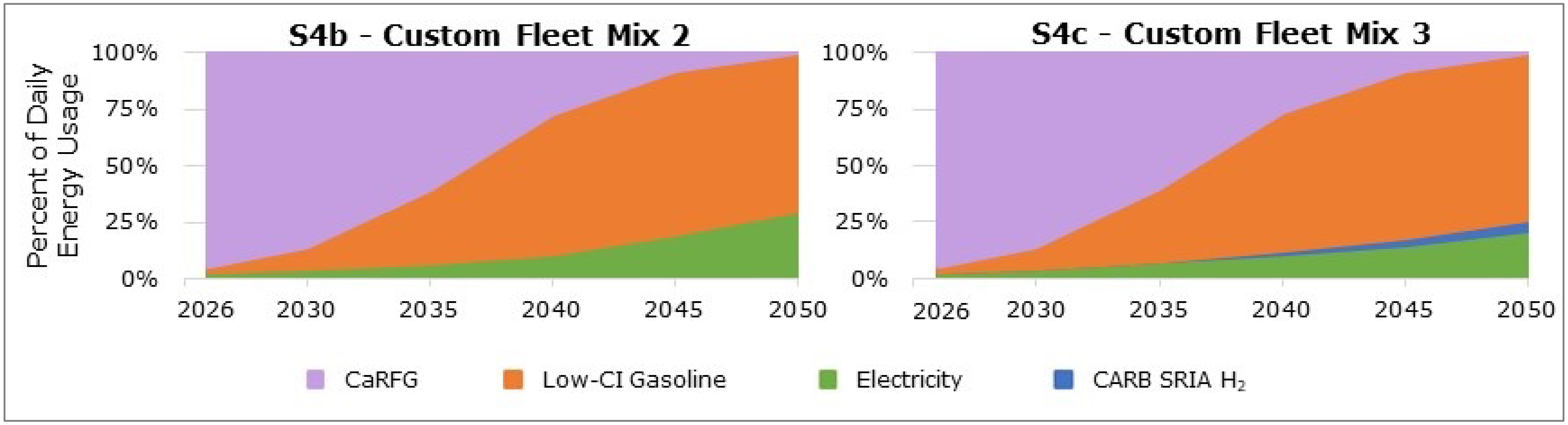


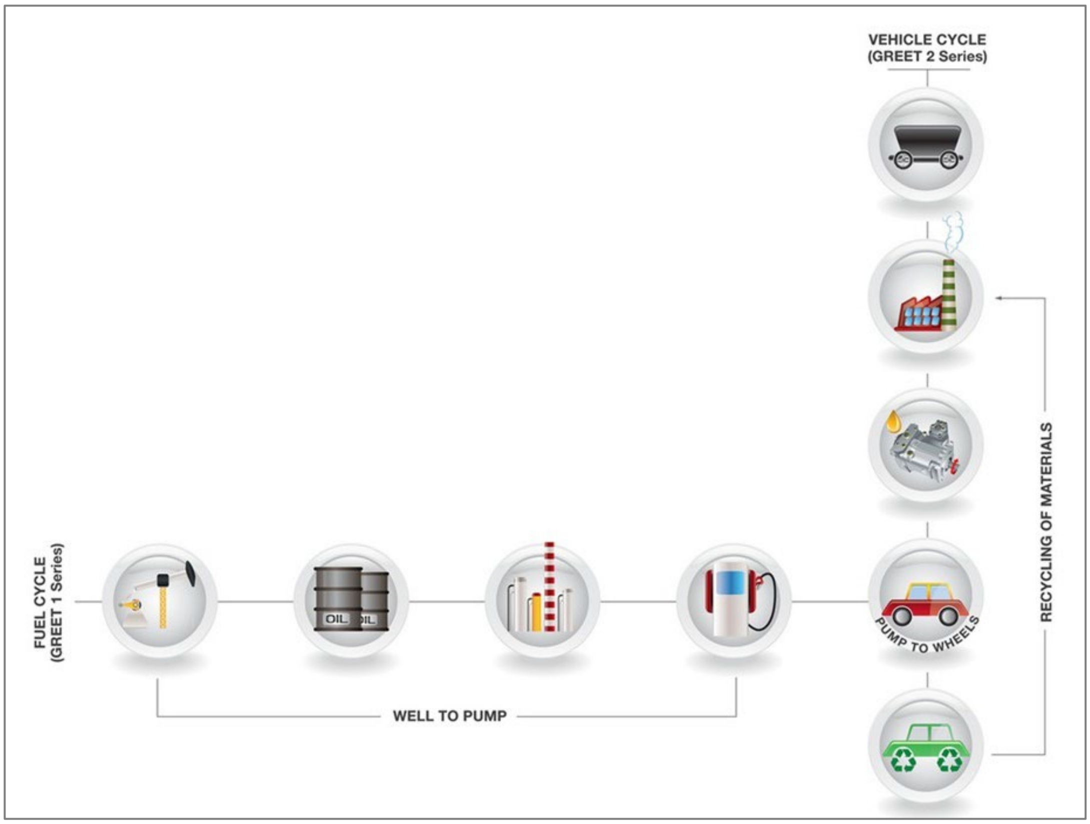
Figure 2-7. Fuel Usage Fractions for Scenarios 4b and 4c



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]

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[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.

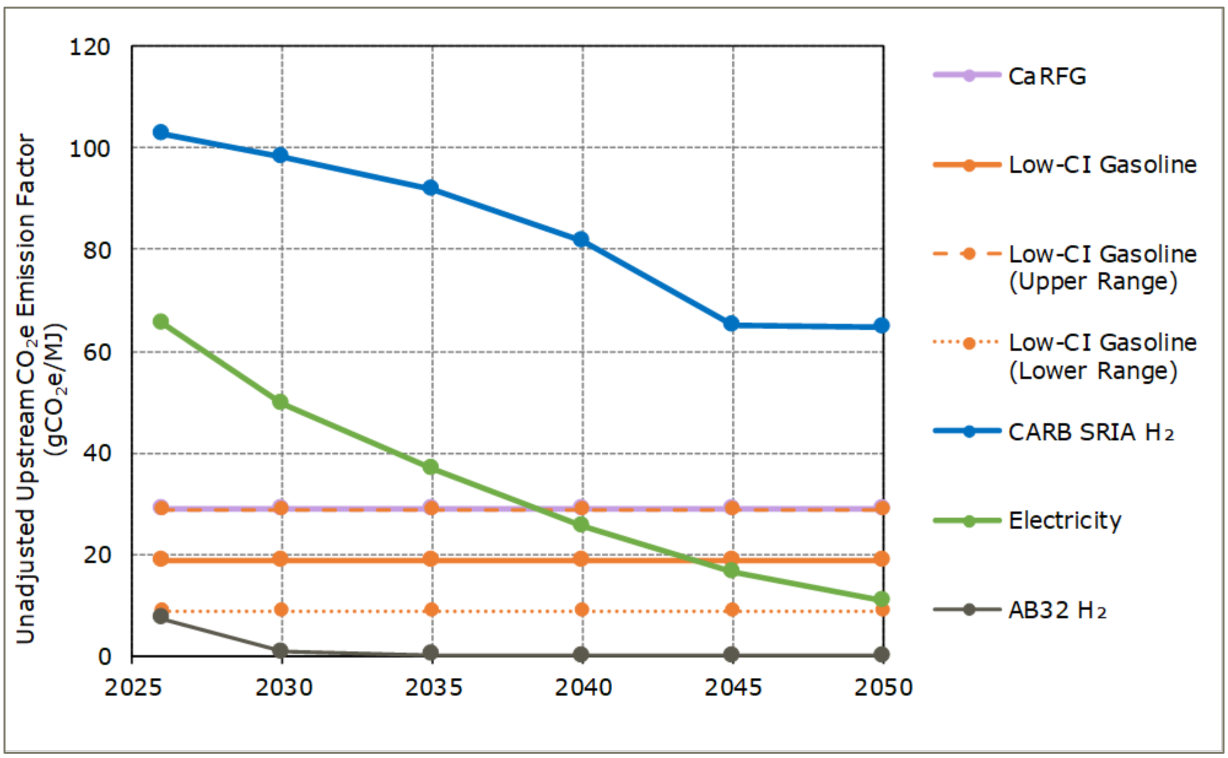
[25] CARB. 2018. CA-GREET3.0 Lookup Table Pathways Technical Support Documentation. August 13. Available at: https://ww2.arb.ca.gov/sites/default/files/classic/fuels/lcfs/ca-greet/lut-doc.pdf. Accessed: May 2022.

[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.

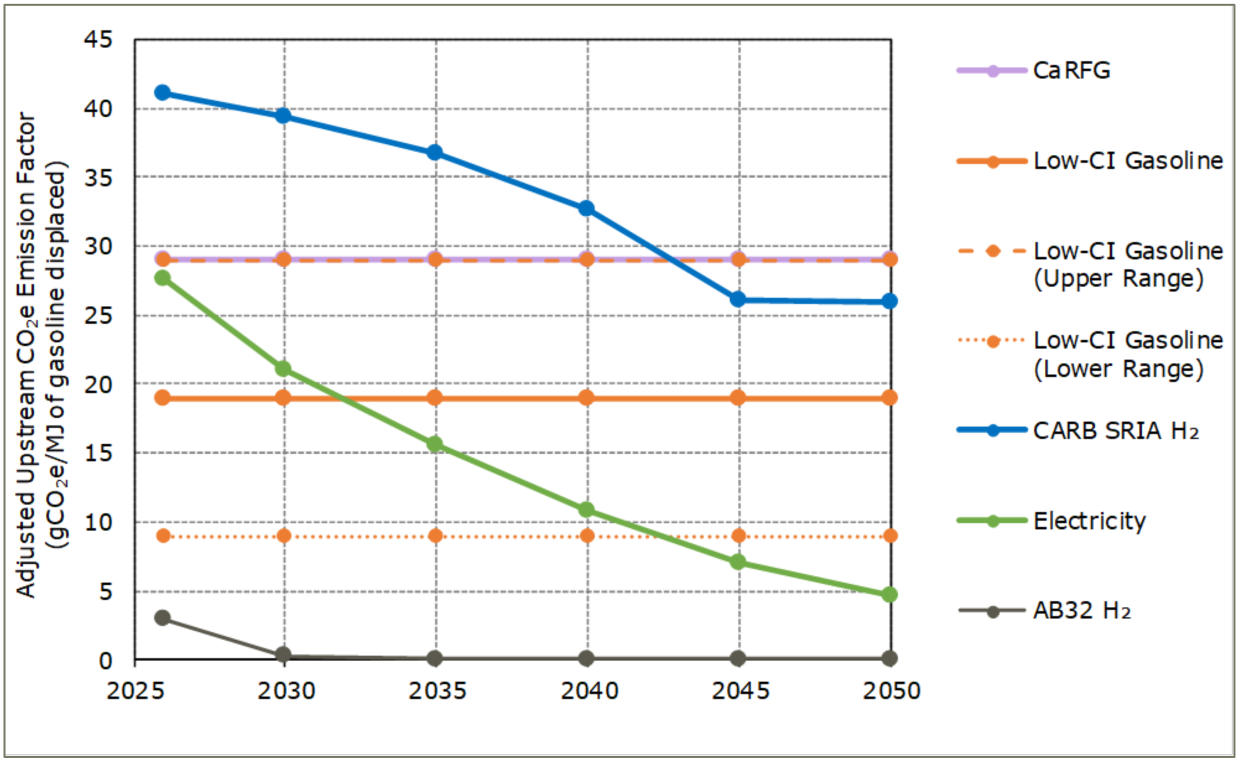
Figure 3-2. Upstream (EER-unadjusted) GHG Emission Factors by Fuel Type



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.

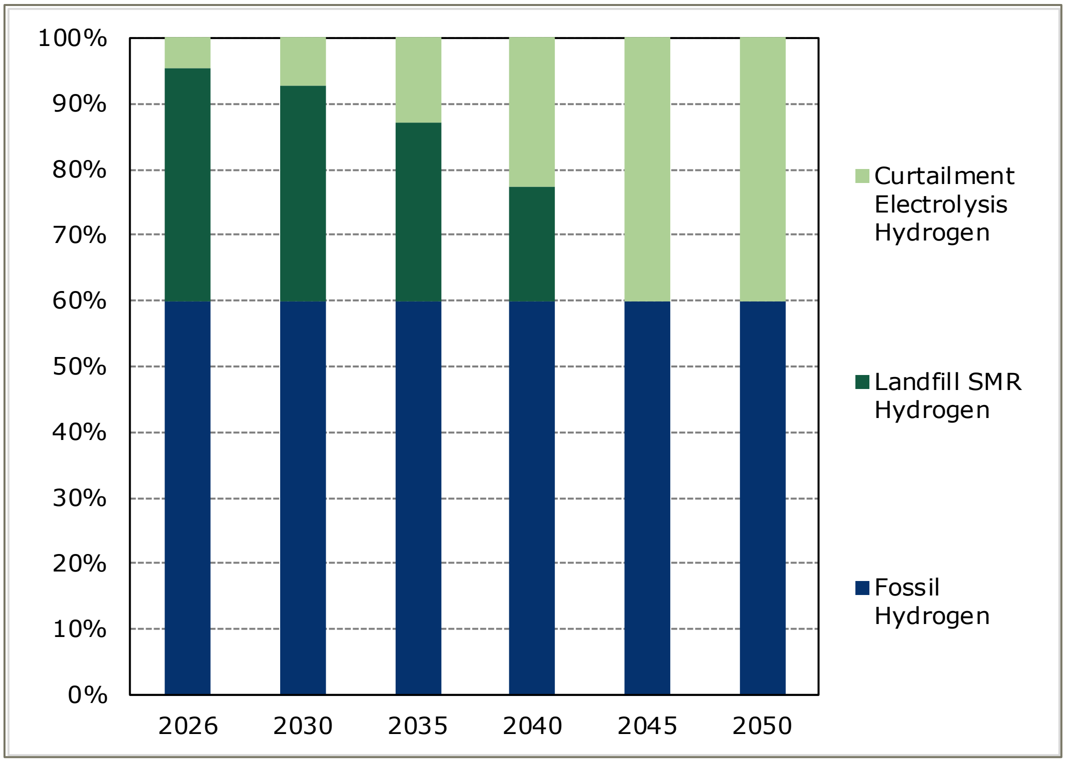
[34] CEC 2018. Deep Decarbonization in a High Renewables Future - Implications for Renewable Integration and Electric System Flexibility, Docket 18-IEPR-06 - 223869, Slide 10. Available at: https://efiling.energy.ca.gov/GetDocument.aspx?tn=223869&DocumentContentId=54081. Accessed: January 2021.

[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.

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[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.

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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.
  - Adjustments for Tailpipe GHG Emissions Associated with CaRFG: 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.
  - Adjustments for Tailpipe GHG Emissions Associated with Low-CI Gasoline: 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

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[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.

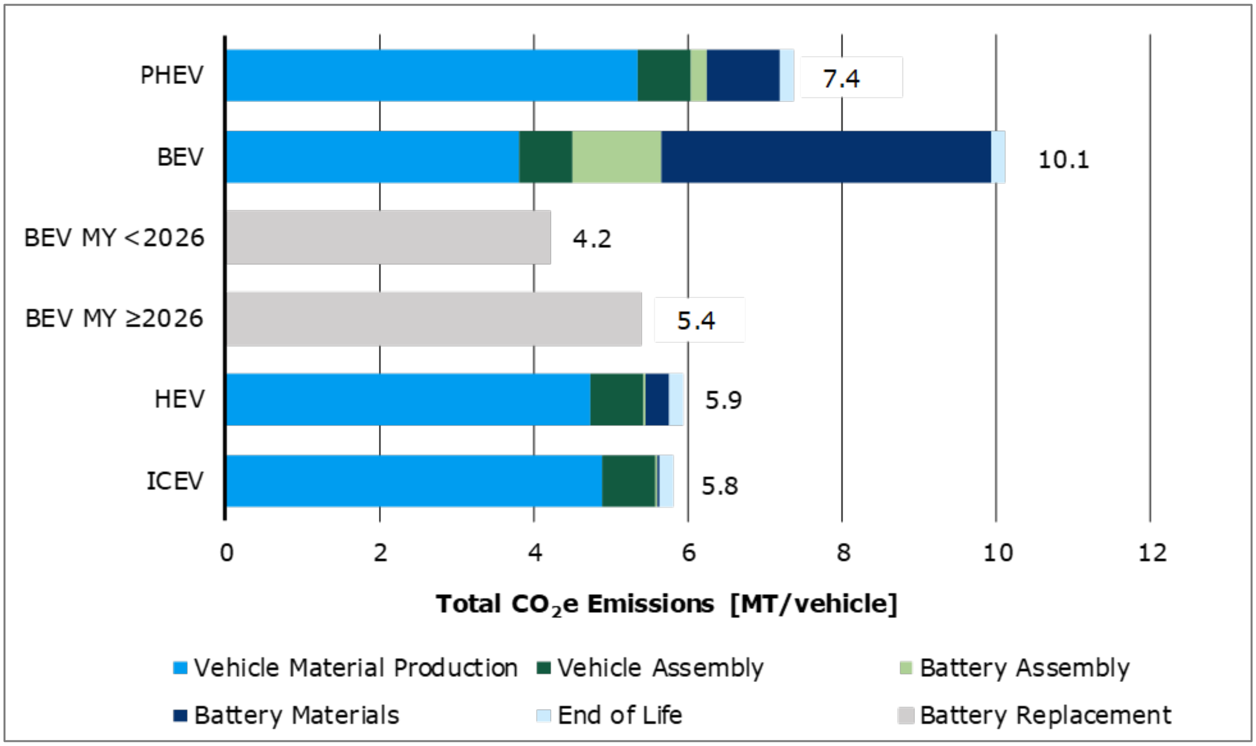
The resulting vehicle cycle emission factors in metric tons of CO_2e per vehicle for PHEVs, BEVs, HEVs, and ICEVs are shown in **Figure 3-5**. Additional details on the GREET model inputs used to estimate these emissions are described in the following sub-sections.

[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

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[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:

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[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.

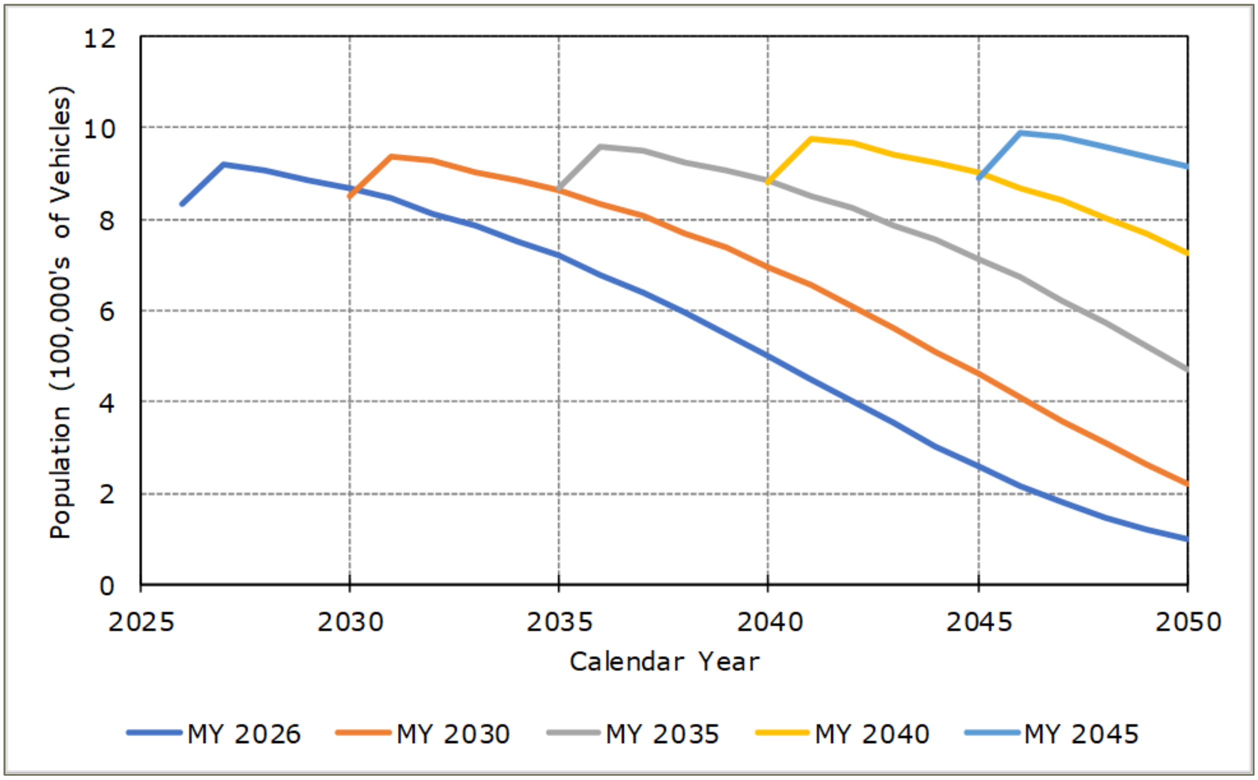
[65] CARB. 2021. ZEV Cost Modeling Workbook October 2021. Available at: https://ww2.arb.ca.gov/sites/default/files/2021-11/ZEV_Cost_Modeling_Workbook_Update_October2021.xlsx. Accessed: January 2022.

[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

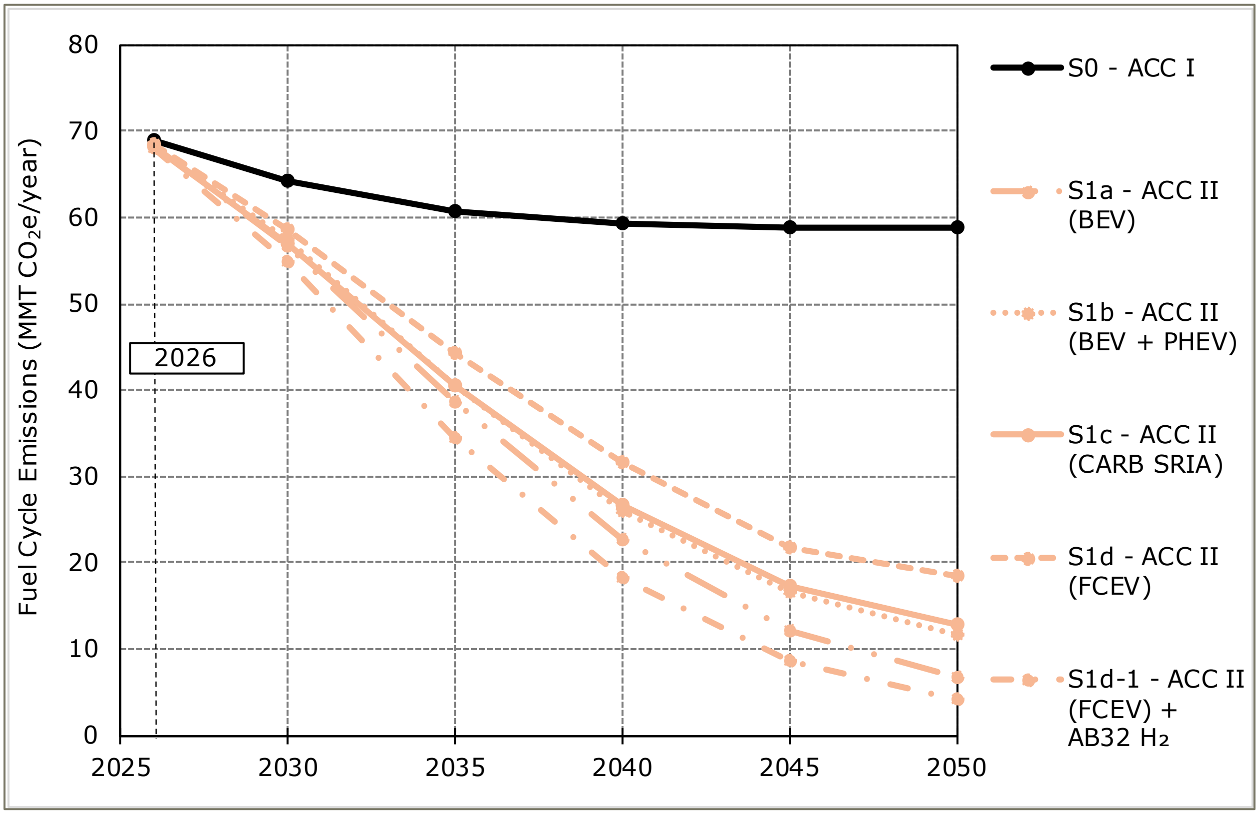
4.1 Fuel Cycle (Well-to-Wheel) Emissions

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

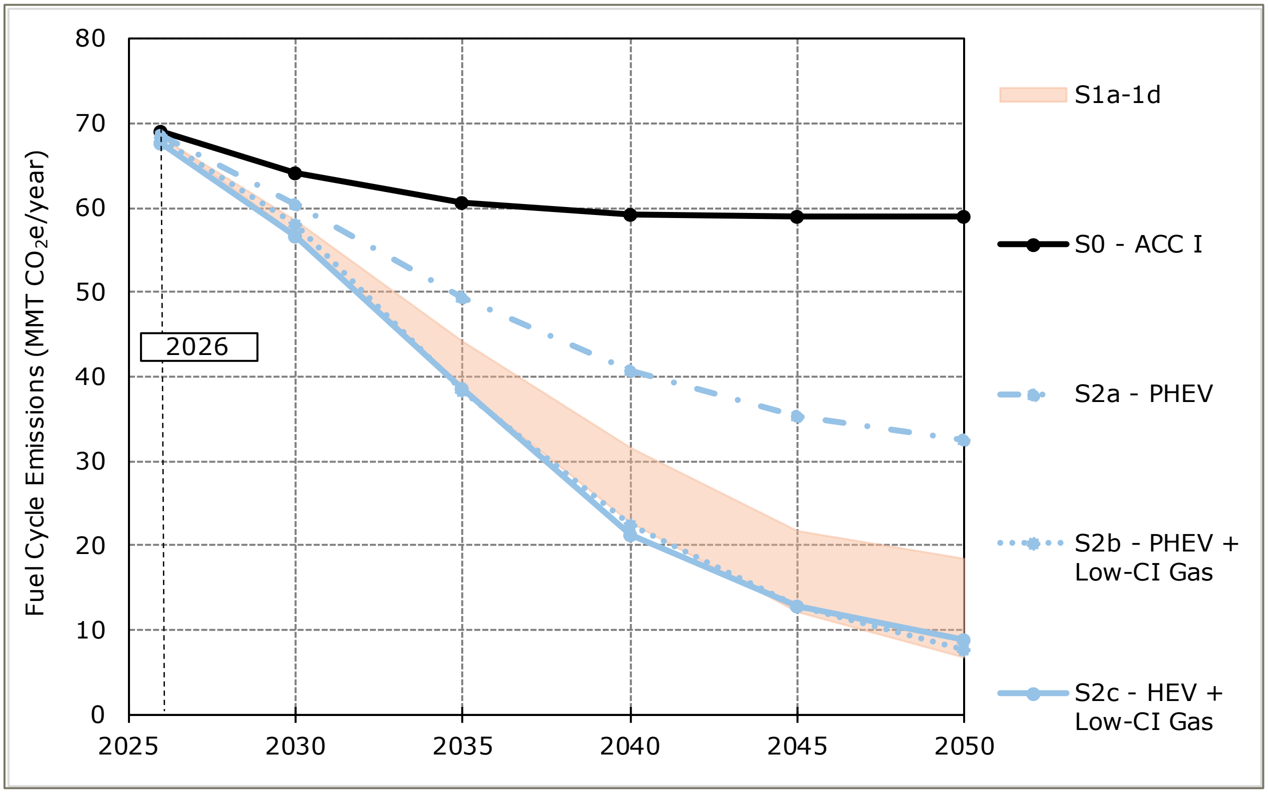
Figure 4-1: Fuel Cycle Emissions for Baseline Scenarios



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



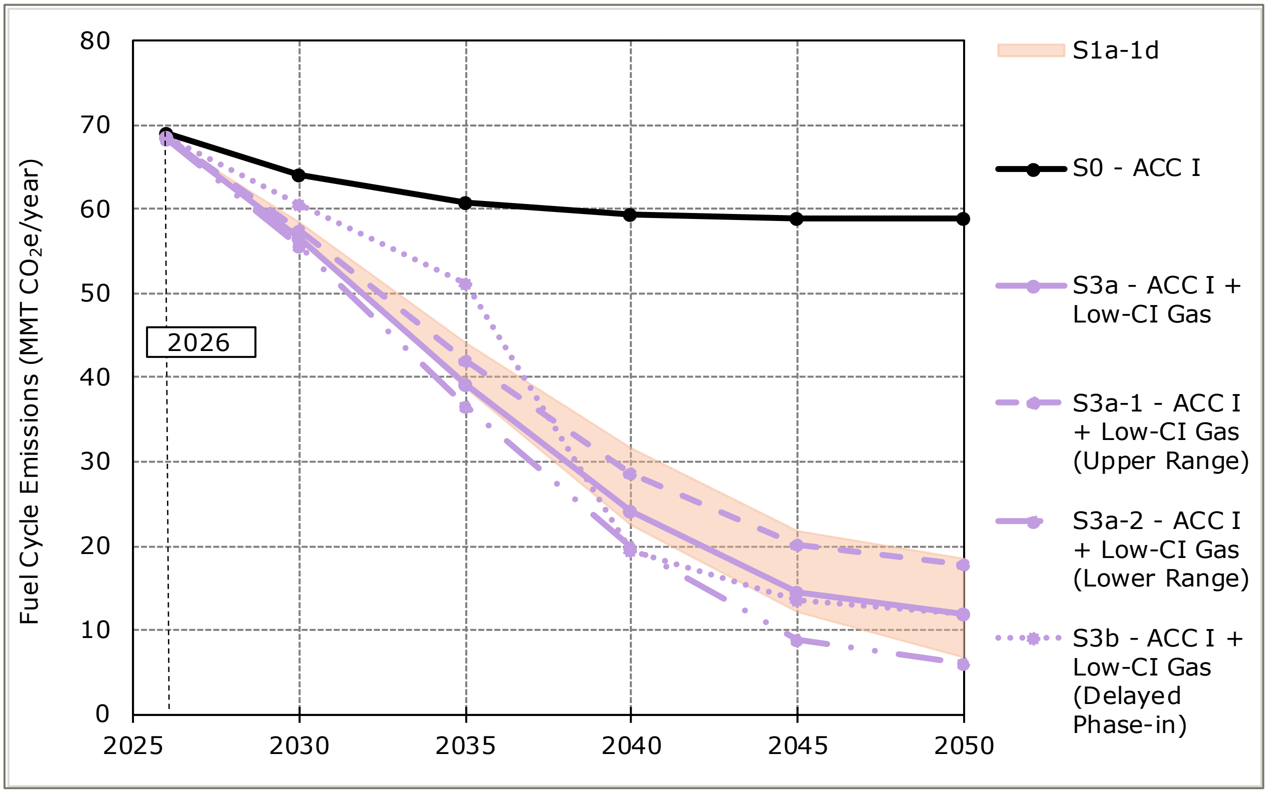
These results (**Figure 4-2**) show that we can achieve >50% of the estimated GHG reductions from the draft ACC-II proposal (scenarios S1a-1d, represented by the shaded pink region) as compared to S0 – ACC I (represented by the black solid line), by using PHEVs sales[71] to meet the ACC II ZEV sales 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

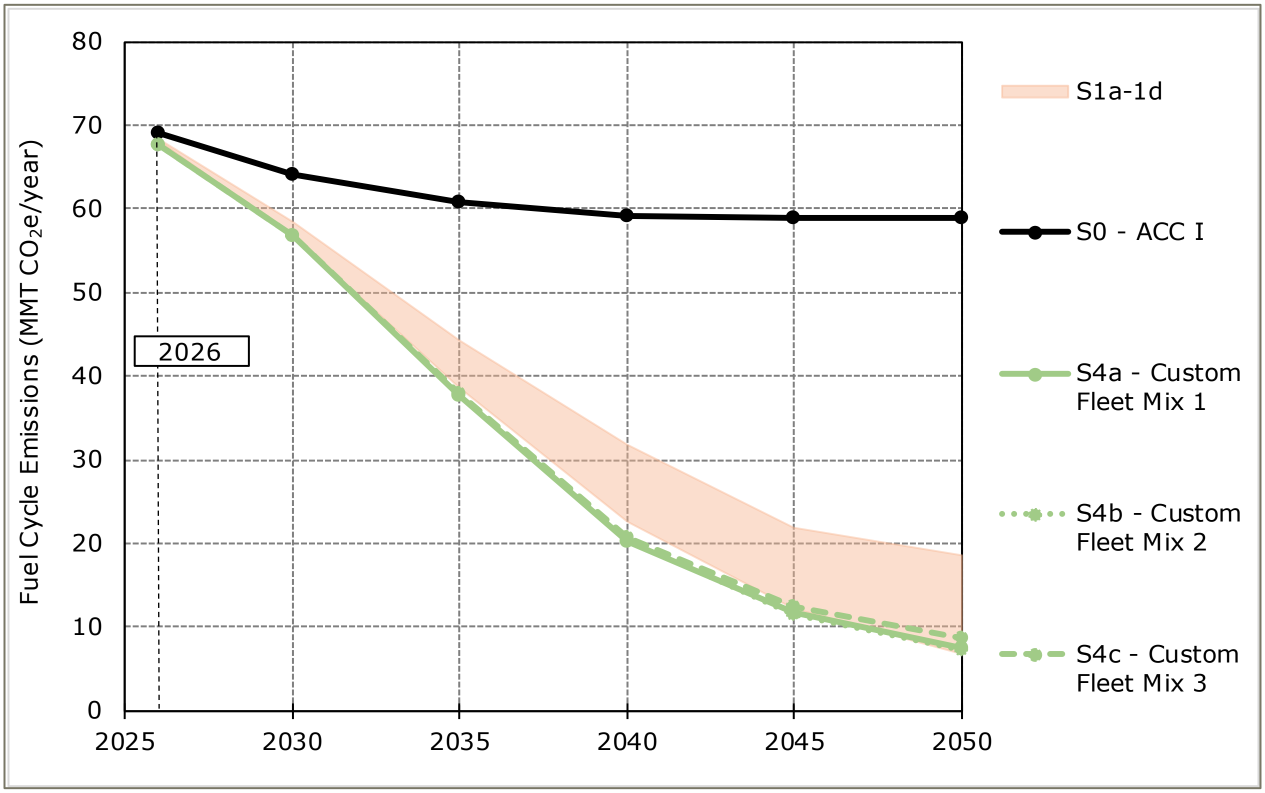


These results (**Figure 4-3**) show that a phase in of low-CI gasoline alone (represented by the purple lines) with no additional ZEV sales beyond those included in scenario S0 – ACC I (represented by the solid black line) can achieve fuel cycle GHG reductions similar to those achieved in the baseline 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

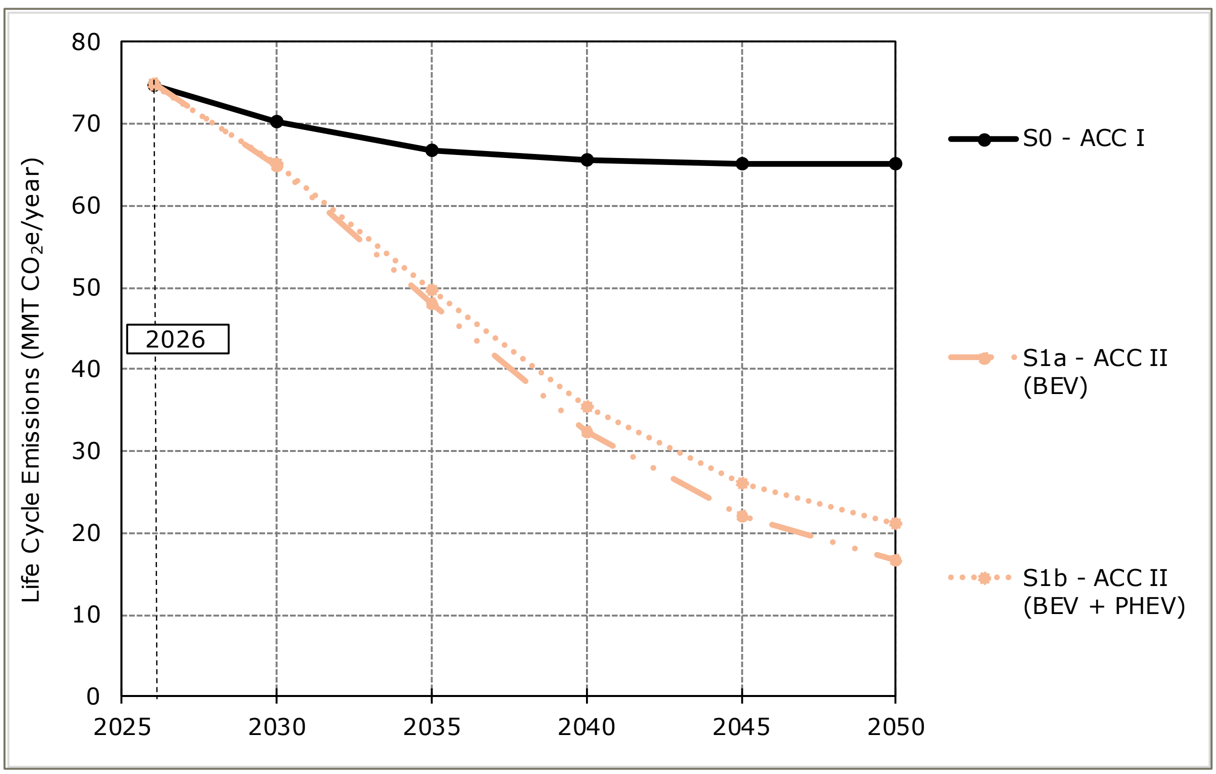


Figure 4-6: Life Cycle Emissions for Alternative Scenarios Part 1

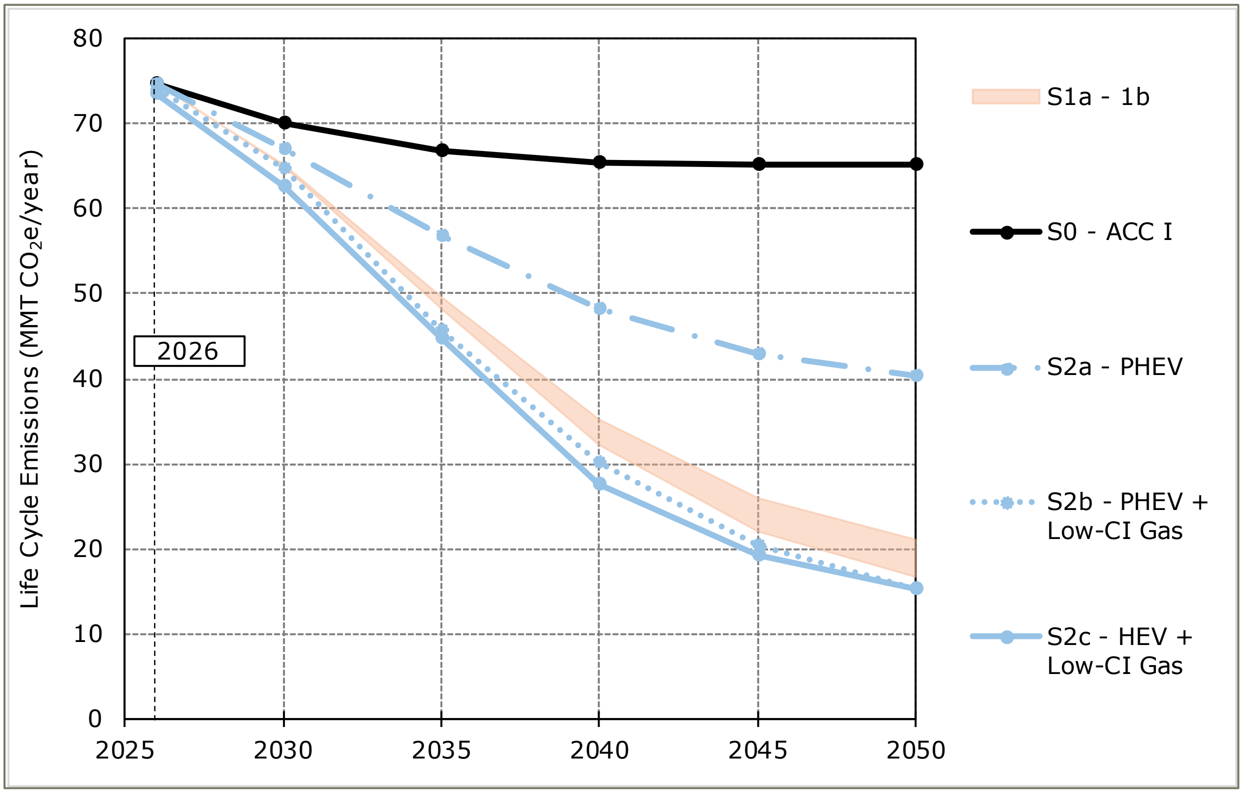


Figure 4-7: Life Cycle Emissions for Alternative Scenarios Part 2

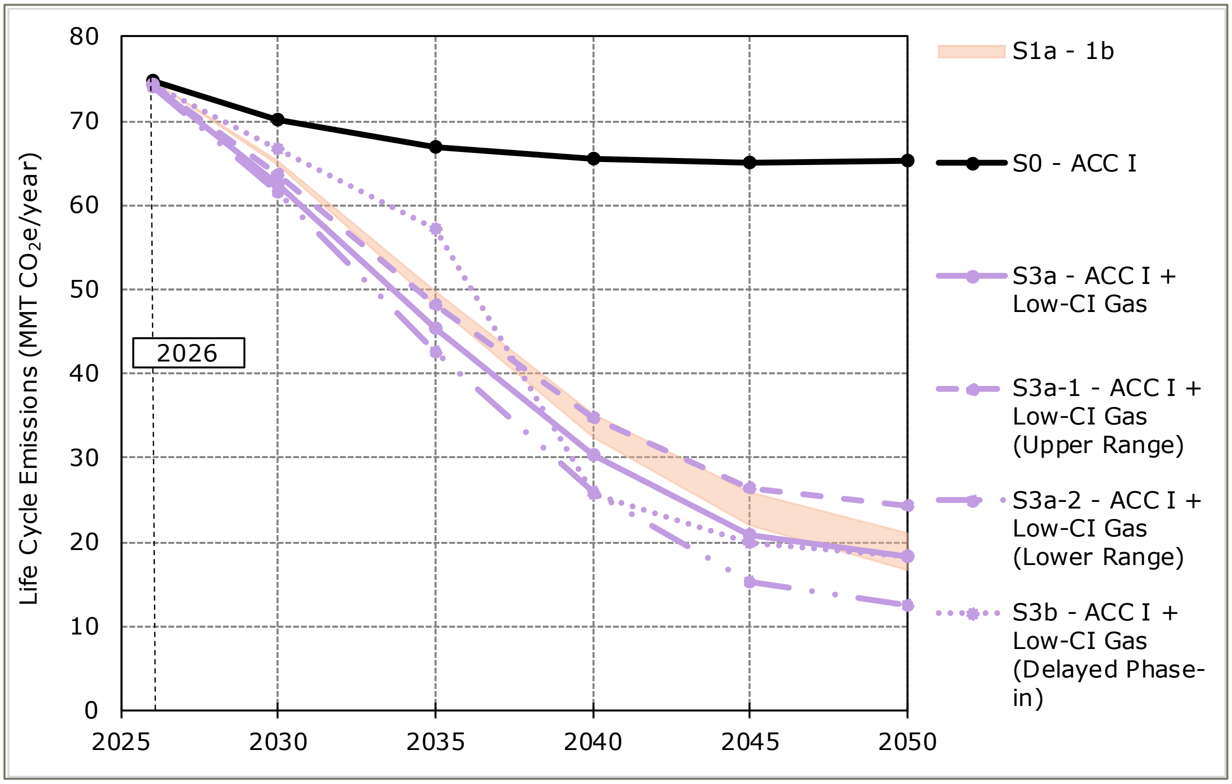
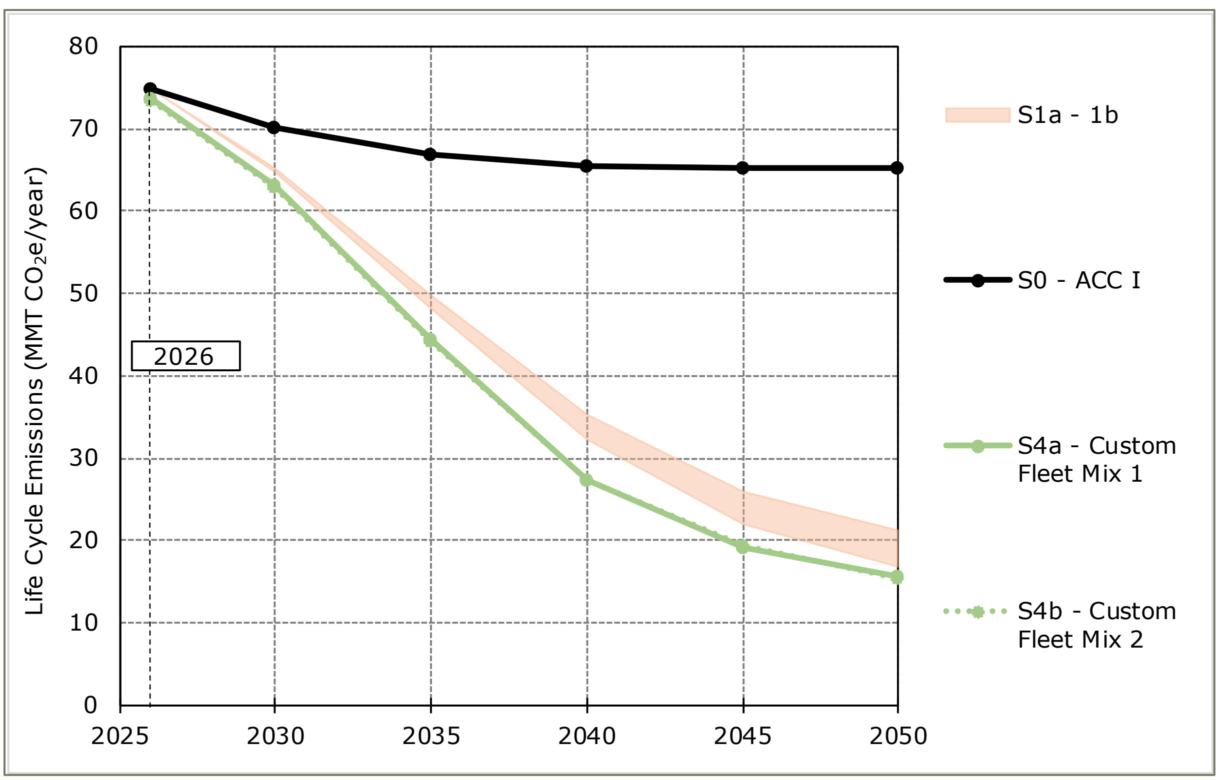


Figure 4-8: Life Cycle Emissions for Alternative Scenarios Part 3



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

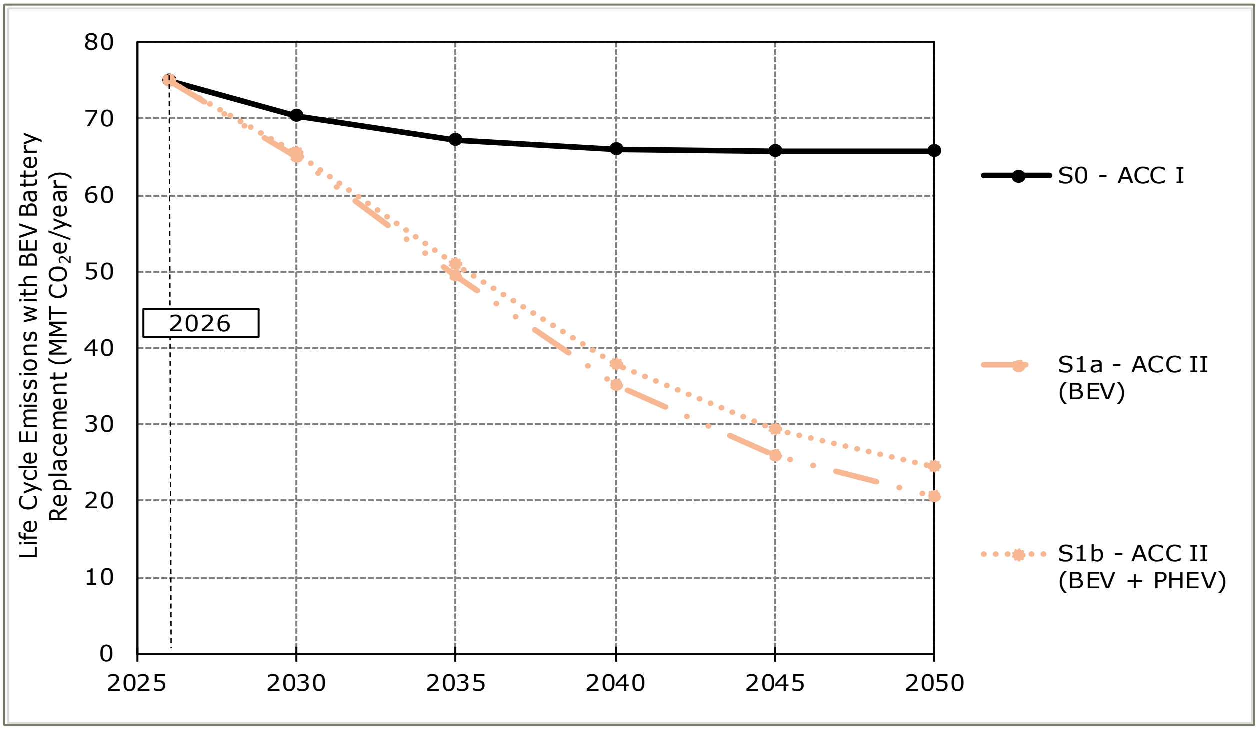


Figure 4-10: Life Cycle Emissions with BEV Battery Replacement for Alternative Scenarios Part 1

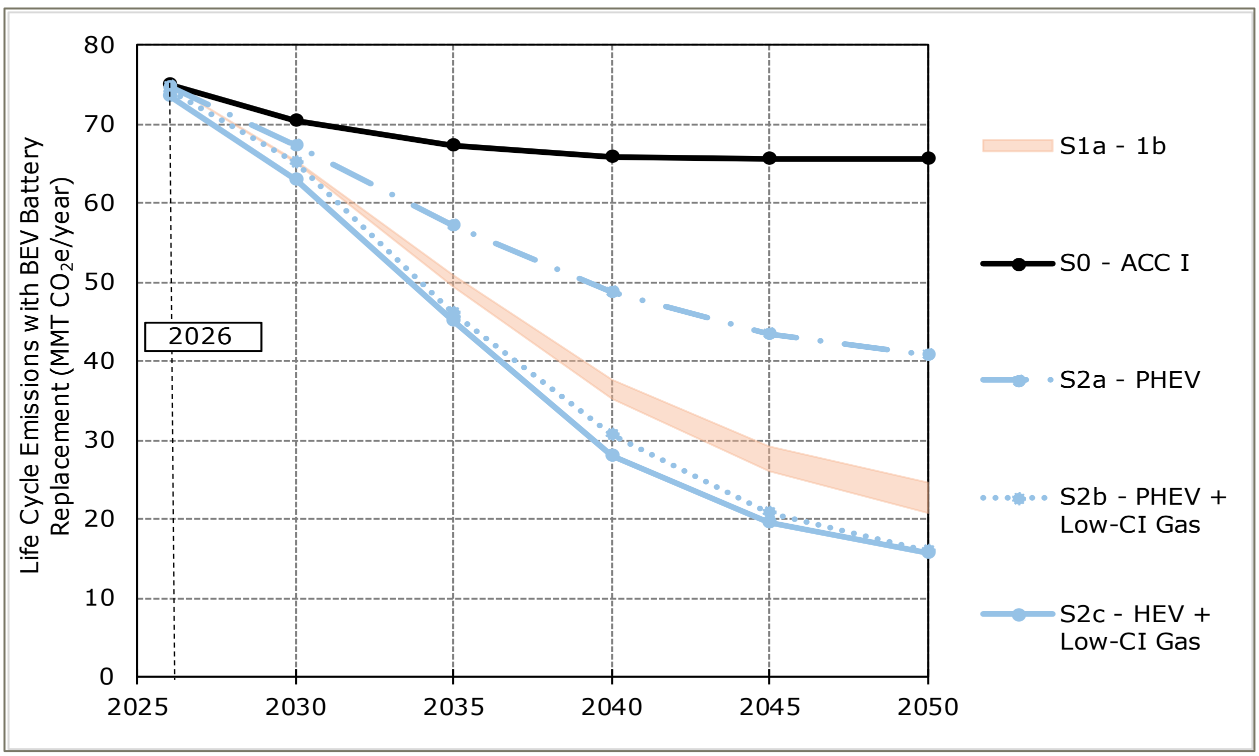


Figure 4-11: Life Cycle Emissions with BEV Battery Replacement for Alternative Scenarios Part 2

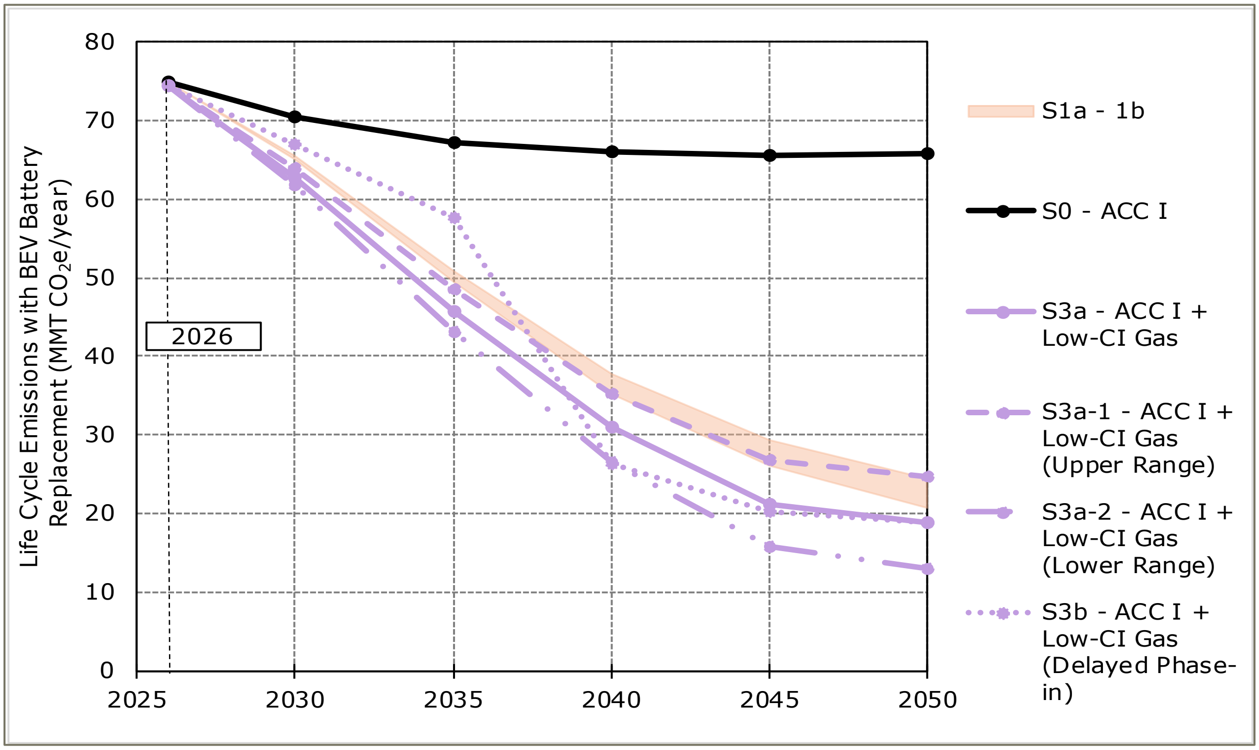
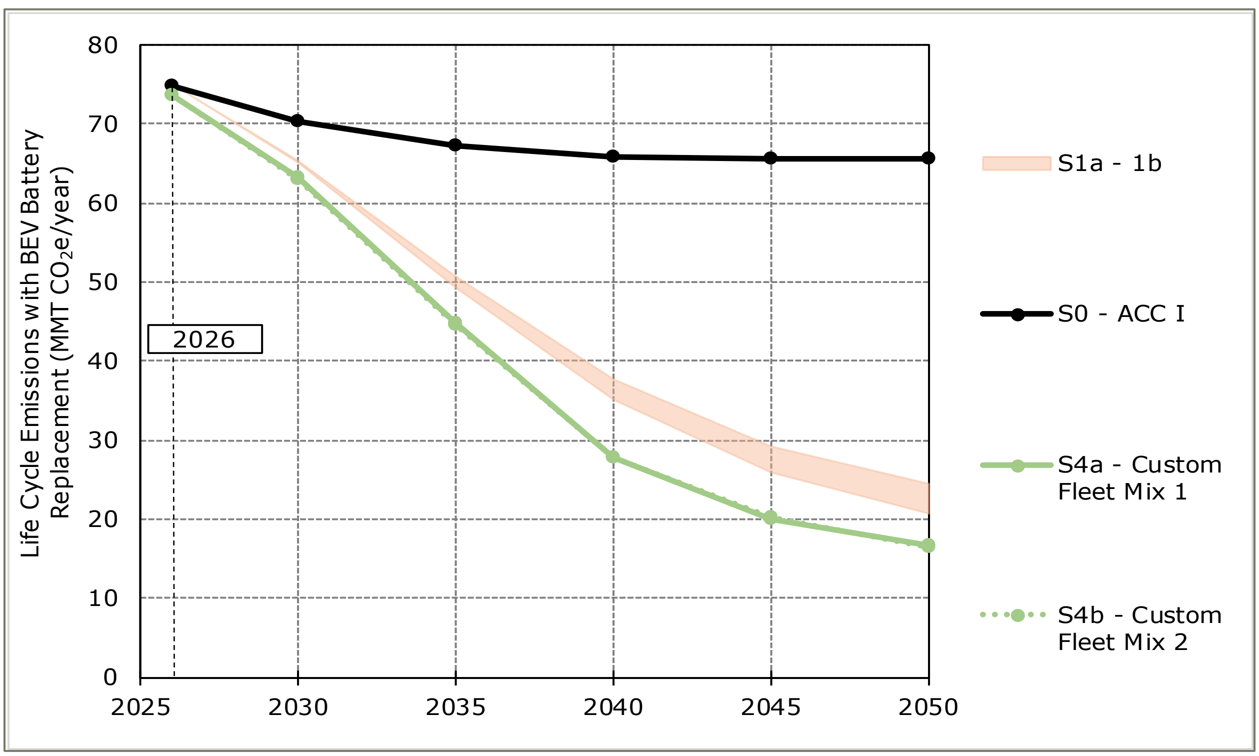


Figure 4-12: Life Cycle Emissions with BEV Battery Replacement for Alternative Scenarios Part 3



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.

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. 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**.

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** 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.

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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.

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.[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**.

Hydrogen

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

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[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

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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

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[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.

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[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

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[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**.

<u>Vehicle Cycle GHG Emissions in Scenario Analysis</u>

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:

- <u>Run Mode</u>: Emissions
- <u>Region Type</u>: Statewide
- <u>Region</u>: California
- <u>Calendar Year</u>: 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
- <u>Season</u>: Annual

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[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

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 that 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 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
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

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
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

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

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)
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] (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	0.028	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

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)
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
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-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

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

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

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

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)
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

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)
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

	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)
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

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)
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	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-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)
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

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	0.029	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] (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)
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

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

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

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

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)
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	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-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

	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-26. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 0 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	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

	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-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

Table A-28. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 0 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	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
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	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

	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

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	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

	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

	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

Table A-33. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 1a 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	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
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
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

	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	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

	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	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
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	1,176	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

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

Table A-38. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 1b 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	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
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	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

	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

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	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

	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

	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	2,927	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

	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	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

	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

	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

	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	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

	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

Table A-45. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 1c 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	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
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
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

	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	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

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	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
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	1,176	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

	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

	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

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	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-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

	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

	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

	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-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

	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	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
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	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
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	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

Table A-58. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenarios 2a and 2b 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	5,879	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

	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	3,297	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

	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	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

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

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
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

	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-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	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

	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

	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	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
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

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

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

	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

	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%	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

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-66. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 2c 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	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

	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	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
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	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
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	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

	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-69. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenarios 3a, 3a-1, 3a-2 and 3b 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	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
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
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

	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-71. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenarios 3a, 3a-1, 3a-2 and 3b 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-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

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-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

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

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	1,528	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

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	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

	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

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	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

Table A-75. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 4a 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	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

	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	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
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	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

	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

Table A-78. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 4a 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	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
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	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

	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	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

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

	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

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%	166,194	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
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%	562,951	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

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

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	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

Table A-83. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 4b 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	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

	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

	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	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

Table A-85. Light Duty Auto Fleet Mix and Tailpipe GHG Emissions for Scenario 4b 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	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

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	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

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	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

	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	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

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

	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

	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

	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

	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	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

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

		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)				
Country	**Year**	**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
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

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

Capitol Matrix Consulting
Analysis, Advice, Advocacy

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

Capitol Matrix Consulting
Analysis, Advice, Advocacy

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.

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[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.

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[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-

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[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.