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THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION
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October 18th, 2022
Re: Comments on the proposed changes to the Clean Vehicles Program

The International Council on Clean Transportation (ICCT) appreciates the opportunity to comment on the Washington Department of Ecology's proposed changes to the Clean Vehicles Program.

The ICCT was established in 2001 as an independent source to provide unbiased research and technical and policy expertise for motor vehicle regulators working to improve the environmental performance and energy efficiency of road, marine, and air transportation, in order to benefit public health and mitigate climate change. Our work supports the development and implementation of advanced vehicle regulations in the world's largest markets. In the United States, the ICCT has been highly engaged with federal and state-level vehicle regulations, participating in expert working groups, submitting public comments on regulations' technical designs, and regularly publishing research on vehicle regulations and standards.

The ICCT commends the Washington Department of Ecology on its continuing effort to reduce vehicle emissions and to support the state's growing zero-emission vehicle (ZEV) market. We welcome the opportunity to provide comments on the proposed ACC II rulemaking which sets increasingly stringent emissions standards for internal combustion engine (ICE) vehicles and requires an increasing number of ZEV sales to meet the state's goal of transitioning entirely to zero-emission vehicles, as well as the proposed adoption of Low NOx Omnibus Rules. The comments below offer our support for the proposed regulation, provide international context for Washington's proposed ZEV sales targets relative to global developments, and include some technical observations on ZEV and low NOx compliance costs.

We are happy to clarify or elaborate on our comments. Washington Department of Ecology staff can feel free to contact ICCT staff Pete Slowik (peter.slowik@theicct.org) or Dr. Stephanie Searle (stephanie@theicct.org) with any questions.

Stephanie Searle, PhD
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SUPPORT FOR THE PROPOSED ADVANCED CLEAN CARS II REGULATION

ICCT strongly supports Washington's proposal to adopt California's Advanced Clean Cars II rulemaking and recommends doing so. This rulemaking is critical to achieving the pace and scale of needed transportation emission reductions in Washington. There is a clear and urgent need to rapidly transition the transportation sector to zero-emission vehicles. Continued and strengthened standards are important to protect public health and deliver on the state's air quality and climate change obligations. We support the proposed Advanced Clean Cars II rulemaking. While Washington has a target for 100% of new light-duty vehicle sales to be electric by 2030,[1] which is more ambitious than the ACC II requirements for 68% ZEV sales in 2030 and 100% ZEV sales in 2035, adopting ACC II now is an important first step in putting Washington on an early path towards its ZEV goals.

As a member of the International ZEV Alliance, Washington joins several of the world's major vehicle markets with the shared commitment to accelerate a global transition to ZEVs. This transition is crucial for decarbonizing road transport and meeting global climate goals. Specifically, ICCT's modeling shows that limiting global warming to below 2°C as targeted in the Paris Agreement will require that leading markets including Washington reach 100% zero-emission new light-duty vehicle sales no later than 2035.[2] Achieving the annual ZEV requirements outlined in the proposed ACC II rulemaking would put Washington's light-duty vehicle fleet on track to deliver deep greenhouse gas emissions reductions in line with a below-2°C goal. Still, our analysis shows that to maintain a chance of limiting warming to 1.5°C, governments will need to consider even earlier transitions to 100% ZEV sales and complementary measures to halve global vehicle fleet emissions by 2030, which is aligned with Washington's target. Such actions could include accelerating replacement of the existing vehicle fleet with ZEVs, maximizing uptake of efficiency technologies for conventional vehicles and ZEVs, and large-scale avoid-and-shift measures.[3]

INTERNATIONAL CONTEXT

Washington is not alone in its commitment to transition entirely to ZEVs. The number of national and subnational governments around the world committing to phase out the sale or registration of new internal combustion engine passenger vehicles continues to rise. Table 1 below highlights countries, provinces, and state governments that have announced an intention to phase out new sales of internal combustion vehicles (ICEs) by some future date.[4] It does not include announcements that signal an intent to phase out new gasoline and diesel cars but still

[1] Washington Senate Bill 5974 of 2022. https://lawfilesext.leg.wa.gov/biennium/2021-22/Pdf/Bills/Session%20Laws/Senate/5974-S.SL.pdf

[2] Sen, A., and Miller, J. Emissions reduction benefits of a faster, global transition to zero-emission vehicles. *International Council on Clean Transportation.* https://theicct.org/publication/zevs-global-transition-benefits-mar22/

[3] Sen, A., and Miller, J. Emissions reduction benefits of a faster, global transition to zero-emission vehicles. *International Council on Clean Transportation.* https://theicct.org/publication/zevs-global-transition-benefits-mar22/

[4] Based on Wappelhorst (2021) with updates through March 2022. See https://theicct.org/publication/update-on-government-targets-for-phasing-out-new-sales-of-internal-combustion-engine-passenger-cars/ and https://zevtc.org/tracking-progress/light-duty-vehicle-map/

permit the sale or registration of other new vehicles using fossil fuels, such as hybrid electric, compressed natural gas, or liquefied petroleum gas vehicles. Globally, there are 15 national and 3 subnational governments that have committed to phase out the sale or registration of new internal combustion engine passenger vehicles. The details of the targets vary; some phase-outs will only allow for battery electric vehicles (BEVs) and fuel cell electric vehicles (FCEVs) while others also allow for plug-in hybrid electric vehicles (PHEVs).

Table 1. Government targets to 100% phase out the sale or registration of new internal combustion engine light-duty vehicles (passenger cars and vans/light trucks) as of March 2022

Region	Jurisdiction	ICE phase-out year	Source
Africa	Cape Verde	2035	Electric Mobility Policy Charter
Asia-Pacific	Singapore	2030	Singapore Green Plan 2030
Europe	Austria	2030	Austria's 2030 Mobility Master Plan
Europe	Denmark	2030	Climate and Air Plan
Europe	France	2040	Mobility Guidance Law
Europe	Greece	2030	Draft Climate Law
Europe	Iceland	2030	Iceland's 2020 Climate Action Plan
Europe	Netherlands	2030	Looking out for each other, looking ahead to the future, 2021-2025 Coalition agreement
Europe	Norway	2025	National Transport Plan 2022-2033
Europe	Slovenia	2030	Market Development Strategy for the Establishment of Adequate Alternative Fuel Infrastructure in the Transport Sector in the Republic of Slovenia
Europe	Spain	2040	Law on Climate Change and Energy Transition
Europe	United Kingdom	2035	Transitioning to zero emission cars and vans: 2035 delivery plan
Central America	Costa Rica	2050	National Decarbonization Plan
North America	California	2035	Executive Order N-79-20
North America	Canada	2035	2030 Emission Reduction Plan
North America	New York	2035	Assembly Bill A4302
North America	Washington	2030	Senate Bill 5974
South America	Chile	2035	National Electromobility Strategy

As shown, 10 countries in Europe have announced ICE vehicle phase out targets. These phaseout timelines vary by jurisdiction and range from 2025 (Norway) to 2040 (France, Spain). In North America, Canada has a national ICE phaseout target for new sales by 2035. In the United States, three states have announced combustion vehicle phaseouts: California (2035), New York (2035), and Washington (2030). There are 8 jurisdictions with phaseout targets from sooner than 2035 (i.e., from 2025-2030, including Austria, Denmark, Greece, Iceland, Netherlands, Norway, Singapore, Slovenia, Washington), and 9 jurisdictions with phaseout targets by 2035 or later. In the United States, several additional states are likely to adopt California's ACC II regulation and join the list of governments with ICE phase-outs by 2035.[5]

Based on our review of global phase-out developments, Washington's target for 100% of new vehicles sold being zero-emission or plug-in hybrid electric vehicles by 2030 appear to be well-aligned with those of other jurisdictions that have similarly high levels of climate and clean

[5] Northeast States for Coordinated Air Use Management. (2022). Re: Proposed Amendments to the Proposed Advanced Clean Cars II Regulations. Retrieved from https://www.nescaum.org/documents/nescaum-final-comments-carb-accii-15-day-amends-20220727.pdf/

transportation leadership and ambition. More details about the various phaseout targets can be found in Wappelhorst (2021) and on the ZEV Transition Council phase-out tracker website.[6]

ZERO-EMISSION VEHICLE COSTS

There are clear and significant benefits associated with transitioning the state new passenger vehicle market to 100% ZEVs. New ICCT analysis from October 2022 shows that battery electric vehicle purchase price parity is coming before 2030 for BEVs with up to 300-miles of range across all light-duty vehicle classes in the United States.[7] And because of their lower per-mile fuel and maintenance costs, BEVs provide significant cost savings to drivers several years before purchase price parity is reached. By 2025, BEVs with up to 300 miles of range have a six-year cost of ownership that is less than comparable gasoline models in every light-duty vehicle class. The longest-range 400-mile range pickups are last to reach ownership parity and do so in 2027.

Clean vehicle regulations and ZEV targets can only be as ambitious as they are feasible, and feasibility relies heavily on costs and benefits. ICCT's new research that BEVs with up to 400 miles of range in every light-duty vehicle class will reach purchase price parity with conventional light-duty vehicles by 2033 and ownership parity several years sooner shows that strong ZEV regulations and performance standards in this time frame can be implemented and lead to billions of dollars in consumer savings. On average, the individual first-owner consumer savings for new 300-mile range BEVs purchased in 2030 is about $9,000. The Advanced Clean Cars II rulemaking will be critical to ensure that continued industry investments are made and consumer benefits are realized.

SUPPORT FOR LOW NOX OMNIBUS RULES

ICCT strongly supports Washington's proposal to adopt California's Low NOx Omnibus Rule and recommends doing so. ICCT estimates that adoption of this rule will avoid 16,800 cumulative tons of NOx emissions by 2040 and 35,640 cumulative tons by 2050.[8]

Table 1. Tank-to-wheel NOx emissions with HDV Omnibus implementation in 2026 (annual short tons)

YEAR	BUSINESS-AS-USUAL	HDV OMNIBUS ADOPTION
2020	29,360	29,360
2021	27,770	27,770
2022	26,180	26,180
2023	24,580	24,580

6 See https://theicct.org/publication/update-on-government-targets-for-phasing-out-new-sales-of-internal-combustion-engine-passenger-cars/ and https://zevtc.org/tracking-progress/light-duty-vehicle-map/

7 Slowik, P., Isenstadt, A., Pierce, L., and Searle, S. Assessment of light-duty electric vehicle costs and consumer benefits in the United States in the 2022-2035 time frame. *International Council on Clean Transportation*. Retrieved from https://theicct.org/publication/ev-cost-benefits-2035-oct22

8 ICCT (2022). Benefits of adopting California medium- and heavy-duty regulations. Washington, DC: International Council on Clean Transportation. Fact sheet and detailed spreadsheet for Washington State available at https://theicct.org/benefits-ca-multi-state-reg-data/.

2024	22,990	22,990
2025	21,400	21,400
2026	20,510	20,320
2027	19,610	19,240
2028	18,720	18,160
2029	17,820	17,080
2030	16,930	16,000
2031	16,350	15,330
2032	15,760	14,650
2033	15,180	13,980
2034	14,590	13,300
2035	14,010	12,630
2036	13,640	12,180
2037	13,270	11,740
2038	12,890	11,290
2039	12,520	10,850
2040	12,150	10,400
2041	11,940	10,160
2042	11,720	9,920
2043	11,510	9,680
2044	11,290	9,440
2045	11,080	9,200
2046	11,000	9,100
2047	10,920	9,000
2048	10,840	8,900
2049	10,760	8,800
2050	10,680	8,700

Note: Business-as-usual assumes ACT implementation in 2025.

These rules are critical to reducing health-harming air pollution from heavy-duty vehicles in Washington. Diesel vehicles are the largest contributor to health impacts from transportation-related air pollution nationally, responsible for more than 9 thousand premature deaths in 2015 and these impacts disproportionately affect disadvantaged communities. Previous ICCT research has shown that achieving a 90% NOx reduction for model year 2027 and later diesel engines could avoid more than $1 trillion nationally in air pollution-related health damages cumulatively from 2027–2050.

We believe that compliance with these regulations, including in the early years, is technologically feasible and cost effective. Below, we include excerpts from our comments submitted in 2022 to the United States Environmental Protection Agency (EPA) on its proposed heavy-duty vehicle air pollution proposal and its consideration of California's waiver request on its Omnibus Low NOx rules. These excerpts provide technical observations and evidence on the costs to comply with and health benefits of Low NOx requirements, necessary lead time for manufacturers, and cost and technology readiness of zero-emission heavy duty vehicles with zero tailpipe emissions.

ICCT also supports the adoption of the one-time fleet reporting requirement for owners and operators of large vehicle fleets. This measure is important to laying the groundwork for possible adoption of California's proposed Advanced Clean Fleets rule, which will accelerate adoption of zero-emission medium- and heavy-duty vehicles beyond what is required by the existing Advanced Clean Trucks regulation in Washington.

Excerpts from ICCT's comments on EPA's Opportunity for Public Comment on California's Request for Waiver of Preemption for the Advanced Clean Trucks and "Omnibus" Low NOx regulations

In 2020, EMA submitted to the California Air Resources Board (CARB) estimates of the additional cost of meeting CARB's proposed Low NOx regulation, based on research by ACT Research.[9] Those comments reported cost estimates from $17,000 to $65,000 for Model Year 2027 and $26,000 to $80,000 for MY2031; these estimates were based on a survey of engine manufacturers. The survey was anonymous and confidential, and its details have not been disclosed. The 2022 Ricardo study[10] uses the same general methodology, an anonymous and confidential survey of engine and component manufacturers, supplemented with Ricardo's own technology assessment knowledge. Ricardo's cost estimates range from $18,000 to $35,000 for MY2031.

These cost estimates are sums of direct manufacturing costs (DMC) and indirect costs. Ricardo's DMC estimates are lower than those from ACT Research but in our view remain overestimated. For example, we compare Ricardo's DMC estimate for a Cylinder DeActivation (CDA) system with an EPA estimate. EPA estimated the cost of CDA for heavy duty engines using a detailed, tear-down study of heavy-duty diesel valvetrains, which was later published as the Heavy Duty Engine Valvetrain Technology Cost Assessment.[11] The study was conducted by FEV North America, Inc. under a contract with EPA and was submitted to independent peer review. The FEV Valvetrain Study investigated the design modifications on a production Cummins X15 engine cylinder head, a broadly commercially available model. The detailed and peer-reviewed study found that the CDA would add between $153 to $215 in DMC to the engine. In contrast, the EMA-Ricardo report estimated a DMC of $1512 for EPA's proposed Option 1 in 2031 and $1249 for Option 2.

A larger source of the difference in total cost estimates between the Ricardo study and others is the assessment of indirect costs. Indirect costs cover warranty, R&D, profit, and other cost elements. A comparison of indirect cost estimates between the EMA-ACT Research report and other literature is provided in Section 2.2 of ICCT's comments on EPA's proposed rule below. The EMA-Ricardo study similarly overestimates indirect costs. The main assumption both EMA studies make is that a truck would experience a complete system replacement during the warranty period covering the useful life (UL) of the vehicle. The implication is that manufacturers would just as well maintain current system design rather than invest in its useful life and durability. By oversimplifying, this approach implies thousands of dollars of additional increased warranty costs per vehicle that exceed other estimates.

For instance, the EMA-Ricardo report shows that warranty cost for a Heavy Duty Vehicle (HDV) under proposed Option 1 requirements for MY 2031 would reach $14,655, and that the UL requirements would add $11,721. EMA-Ricardo warranty costs are 3.4x higher than the

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[9] EMA (2020). Comments of The Truck and Engine Manufacturers Association. https://www.arb.ca.gov/lists/com-attach/8-hdomnibus2020-1jACGvmafqDgElXk.pdf

[10] Ricardo (2022). Review of EPA NRPM and Compliance Cost Assessment. http://www.truckandenginemanufacturers.org/file.asp?F=Exhibit+B+Ricardo%2Epdf&N=Exhibit+B+Ricardo%2Epdf&C=documents

[11] Mamidanna, S. 2021. Heavy-Duty Engine Valvetrain Technology Cost Assessment. U.S. EPA Contract with FEV North America, Inc., Contract No. 68HERC19D0008, Task Order No. 68HERH20F0041.Submitted to the Docket.

manufacturing costs of the parts to be replaced in case of a malfunction as required under warranty. Ricardo thus essentially assumes that all components would need to be replaced under warranty several times over the lifetime of a vehicle. Typical warranty claim rates are reported to range between 1.3% for Selective Catalytic Reduction (SCR) systems to 5.3% for dosing systems and can reach 15% for a NOx sensor according to CARB warranty claims data.[12]

High failure rates may be expected for some types of new technology. For example, close-coupled SCR and some sensors may have higher risks, perhaps similar to the 8.1% warranty claim rate of Diesel Oxidation Catalysts (DOCs), which are exposed to higher temperature peaks. However, other components should be expected to operate at the same conditions as EPA 2010 equipment.

To illustrate, we estimate the probability-adjusted average warranty cost for a NOx sensor. CARB cost data shows the individual instance of replacing a NOx sensor, including parts and labor, costs $670. Given the warranty claim rate above of 15%, the average cost of the replacement of a NOx sensor is $102. Following this approach, the average warranty costs to replace a DOC (in leu of a close-coupled SCR) would be $310. Ricardo's warranty cost estimates are much higher than would be expected using this kind of probability-adjusted approach.

Ricardo also estimates high costs imposed by the UL requirements of $11,000. We expect the UL requirements to be addressed by manufacturers in modifying component sizes, not by planned obsolescence or replacements (which should be accounted for in warranties). Thus, EPA's estimate of around $1,000 for the incremental cost added due to UL in its NPRM is a more reasonable estimate.

[12] The warranty claim rates data comes from ARB, using information from the warranty claims-related data and sales data from the engine certification applications. As an example, around 11,000 Heavy-heavy duty engines were sold in MY2013 with 138 instances of warranty claims related to that model year, resulting in a warranty claim rate of 1.3% for that technology.

Excerpts from ICCT's comments on EPA's proposed rule, titled "Control of Air Pollution from New Motor Vehicles: Heavy-Duty Engine and Vehicle Standards" (EPA-HQ-OAR-2019-0055):

We recommend EPA adopt a strengthened Option 1 to fully align with a 90% NOx reduction in MY2027

Option 1 is technically feasible and cost-effective.
Technical feasibility. EPA has provided a comprehensive analysis of the feasibility of the proposed Option 1 NOx standards in its technical support document. Its conclusion is clear: The standards proposed for all three test cycles for large, long-life engines are feasible. "*When taking into consideration the proposed Option 1 longer useful life (UL) and the anticipated additional degradation in SCR NOX reduction between 600,000 miles and 800,000 miles, when taking lead time into consideration to 2027 and 2031, the proposed Option 1 MY 2031 and later emissions standards of 40 mg/hp-hr for FTP composite and SET, 100 mg/hp-hr for the LLC, and the respective off-cycle standards are feasible at a useful life of 800,000 miles beginning in MY 2031."* TSD page 130.

The Stage 3 SWRI test programs sponsored by California Air Resources Board (CARB) and EPA demonstrate that the NO_x standards can be met with available technologies, using optimized SCR aftertreatment and cylinder deactivation. EPA has provided proof of feasibility that goes far beyond that provided in previous rulemakings, such as the rulemaking for the current 2010 NO_x and PM standards. The remaining issues are proof of emission durability beyond 600,000 miles to the full useful life of 800,000 miles, with early results showing NO_x levels below the standard at 800,000 miles, and the emission margin available to assure production and in-use compliance.

Regarding durability beyond 600,000 miles, an EPA test program with aftertreatment aged to full useful life is nearing completion. The proposed 2031 NOx standard for 800,000 miles is double the mid-life standard at 435,000 miles, providing room for emission deterioration as the engine ages. Projecting the data at 600,000 miles to full useful life, EPA shows that the demonstration engine will emit below the full life standard on the FTP (Figure 3-16, EPA TSD). The projected 2031 NO_x emissions for the new, low-load cycle are about 25% below the proposed mid-life standard and more than 50% below the proposed full life standard (Figure 3-17, EPA TSD), suggesting adequate margin for compliance. The EPA figures are reproduced below.

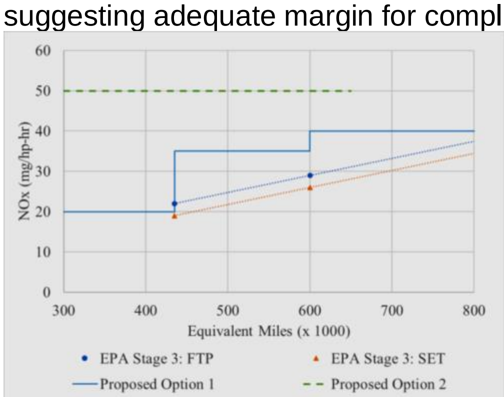

Figure 1. FTP and SET Emission Deterioration (EPA TSD)

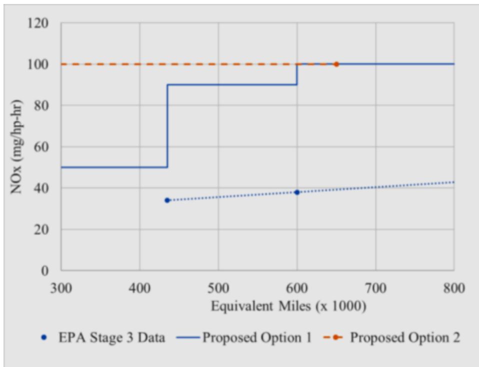

Figure 2. LLC Emission Deterioration (EPA TSD)

Major suppliers continue to develop and test technologies that can be used to simultaneously achieve lower NOx emissions and reduced CO_2/fuel consumption. An example is the Eaton Corp development of a 48-volt electric heater to increase catalyst inlet temperatures at low loads. The heater combined with cylinder deactivation cut low load NOx emissions in half compared to cylinder deactivation alone, while reducing CO_2 and fuel consumption by nearly 2 percent. FTP CO_2/fuel consumption was reduced by slightly less than 1 percent.[13] Another example is use of an EGR pump to optimize turbocharger and EGR flow. Testing at SwRI indicates a fuel consumption reduction of approximately 3 percent on the hot FTP.[14]

Another promising option for compliance with the proposed Option 1 standards is the opposed piston diesel engine being developed by Achates Power in San Diego, CA. On the dynamometer the demonstration engine met the proposed 2031 NOx standards using a current, conventional aftertreatment system. More importantly, this 400 hp, 10.6-liter diesel engine has been installed in a Peterbilt class 8 tractor and placed into fleet service by Walmart. Recent PEMS testing of this truck performed by UC Riverside demonstrated NOx emissions over 50 percent below the proposed in-use limits. Walmart also compared fuel consumption of the Achates/Peterbilt truck to a comparable truck with a Detroit Diesel 15-liter engine. The Achates-powered truck had 10 percent better fuel economy. An independent study showed the cost of volume production of the opposed piston engine including compliance with the proposed standards will cost no more and possibly less than current diesel engines.[15] This technology provides a second feasible pathway for engine manufacturers to meet the proposed standards.

Another consideration that supports the feasibility of the proposed NOx standards is that once the engine begins in-use operation, off-cycle, in-use compliance standards become numerically less stringent than the certification standards. The in-use standards provide extra margin to account for unexpected emission deterioration and engine-to-engine variability, compared to the certification standards. The proposed off-cycle in-use emission standards for non-idle Bins 2 and 3 are two times the certification standards for 2027-30, and 1.5 times the certification standards for 2031+. The 150 mg in-use standard for the 2031 LLC cycle for HHD engines between 435K and 800K miles is particularly generous, when compared to the projected SWRI data indicating less than 50 mg at full useful life (see EPA's Figure 3-17 from the TSD, reproduced above). These generous in-use standards support the feasibility of the proposed

[13] SAE paper 2021-01-0211, Tables 8 and 17a, April 6, 2021.
[14] Int'l Vienna Engine Symposium 2022 – Session: Latest results in engine and component development
[15] https://achatespower.com/wp-content/uploads/2022/04/Achates-Power-Heavy-Duty-Diesel-In-Use-Testing-Results.pdf

standards by reducing in the initial years the compliance risk that engines have higher emissions than anticipated.

Manufacturer concerns regarding compliance margin are premature.
The technical concerns expressed by the manufacturers that the proposed standards cannot be met, in part due to a lack of compliance margin, are not warranted as the latest research by SwRI shows that with the remaining lead time the proposed emission standards can be met.

SwRI provides an example of compliance for both the traditional FTP cycle as well as the much-needed LLC, with ample compliance margin for an 800,000-mile useful life. The past manufacturer comments present an incomplete picture of the technical analysis performed by SwRI to evaluate the EPA proposal, specifically at the extended UL requirements. Manufacturers claim that the basis of the current evaluation was the previous research work for ARB's Low NOx omnibus rule, which included the technical package known as "Stage 3" aged to 435k miles. They claim that EPA contracted with SwRI to *"perform an aged demonstration with a technical solution very similar to the CARB "Stage 3" technology package. Thus, the SwRI system is the principal basis for the purported feasibility of the 0.02 g/bhp-hr NOx standard"*.

What the manufacturer comments fail to mention is that aftertreatment aging was extended by SwRI to cover the 800,000 miles for the proposed UL. Moreover, the Stage 3 demonstration is only one potential pathway to meet the standards. European manufacturers are exploring other technology options (e.g., heated catalysts) to meet planned Euro VII standards.

The manufacturers claim that EPA has not demonstrated the technical feasibility of the standards, however, their claims are unfounded.

First, manufacturers claim that the Stage 3 aged-engine NOx emissions results do not demonstrate feasibility across all required certification cycles and extended UL. This is not up to date with the latest information. The latest SwRI update from April 2022 demonstrated composite FTP results of 27 mg/bhp-hr at 600k miles, which demonstrates feasibility for the 2027-2030 proposal with a margin of 23%; and 37 mg/bhp-hr at 800k, which demonstrates feasibility for the MY2031 and beyond with 8% margin.[16]

[16] Chris Sharpe et al. (2022). An Update on Continuing Progress Towards Heavy-Duty Low NO_X and CO_2 in 2027 and Beyond. Southwest Research institute. SAE World Congress Experience (April 5-6 2022).

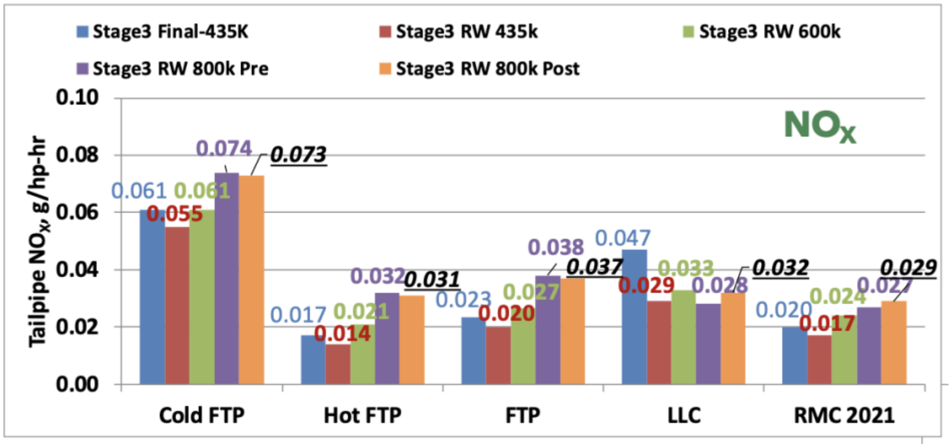

Figure 3. Summary of engine emission test results presented at SAE World Congress by SwRI in April 2022. Latest Stage 3RW Results at 800,000 Equivalent Miles. Source: Sharpe et al. (2022)]

LLC compliance is also achieved with even larger margins. The LLC standard under EPA Option 1 calls for 90 mg/bhp-hr at 600k miles for MY2027-2030. The latest results from SwRI show 33 mg/bhp-hr or a 60% compliance margin. For MY 2031 and beyond the LLC Option 1 standard is listed as 50 mg/bhp-hr @ 435k miles and 100 mg/bhp-hr at 800k miles. SwRI results show LLC emissions at 30-40 mg/bhphr at 435k miles, at least a 20% margin, and 30mg/bh-hr @800k miles, which provides a 70% compliance margin.

The industry has many years to improve the first-ever emission compliance design to reach the final level of emissions of the proposed Option 1 standards, and 8 years to assure its performance at 800k miles. These results also indicate that LLC standards can be tightened even further.

Manufacturers also claim that the Stage 3 aged-engine does not consistently meet the in-use NOx standards when laboratory tested on “road-cycles” that mimic real-world operation.

The latest SwRI results from April 2022 demonstrated excellent and consistent performance with respect to the proposed off-cycle NOx standards. For bin 1, the idle bin, the Option 1 proposal is 10 gr/hr for MY2027-2030 and 7.5 g/hr after that. The SwRI off-cycle NOx results demonstrate compliance below the standards with a margin of 60%, even at 800k miles with an aged system. For bin 2, the low load operation bin, the results demonstrate a 70% compliance margin, even at 800k miles of aging. For bin 3, the middle to high load operating bin, the aged system performs well at 800k miles, achieving compliance margins between 25-50%. For bin 3 the results are better at 800k miles than at 435k miles. Thus, SwRI results indicate that even more stringent limits can be adopted for off-cycle NOx compliance, especially at idle and low load.

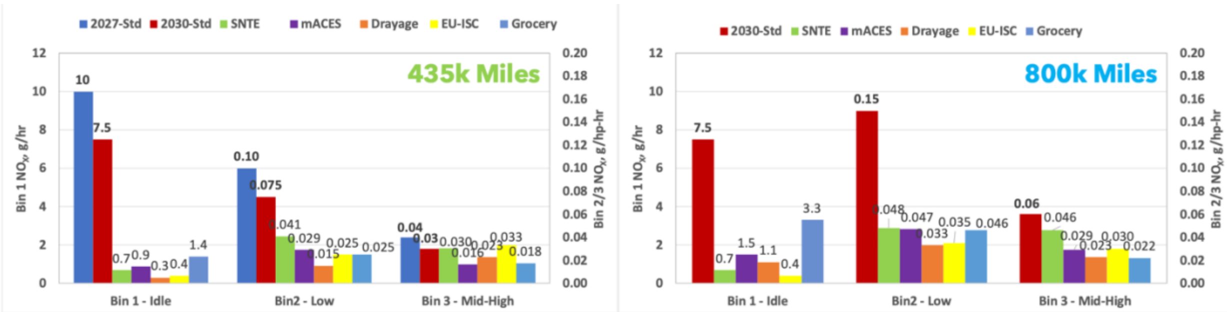

Figure 4. Summary of engine emission test results presented at SAE World Congress by SwRI in April 2022. Field Duty Cycle Results (3B-MAW). Stage 3RW 800k vs 435k Miles Source: Sharpe et al. (2022)]

Based on a thorough review of the EPA proposal and the most recent findings from SwRI, we draw the following conclusions:

- The research conducted by SwRI provides compelling evidence of the feasibility of achieving the EPA proposed Option 1 FTP emission standards for both MY2027-2030 and MY2031 and later models. Compliance margins are sufficient for Option 1, especially given the 8 years remaining to increase margins if needed.
- Adoption of a supplemental low-load cycle with corresponding emission standards is necessary to assure emission reductions during urban driving, and the SwRI data show emission levels well below the proposed standards throughout the full useful life.
- A highly capable single research group with limited funding and only a few years working with a suitable technology package (Stage 3) was able to demonstrate emission levels at or below the EPA's most stringent proposed standards. Based on its results, SwRI has pointed out additional possible advancements that could result in further reduction in NOx emissions, such as catalyst size increases and reformulations, and control algorithm improvements. EPA has provided proof of feasibility that goes far beyond that provided in previous rulemakings, such as the rulemaking for the current 2010 NO_x and PM standards. It is reasonable to conclude that the industry as a group, with their enormously greater resources and 8 more years of time before the final standards and useful life go into effect, will be able to produce durable engines with even lower emissions and greater emission compliance margins both in certification and in-use over the future extended UL.
- By law, heavy-duty engine standards must reflect "the greatest degree of emission reduction achievable through the application of technology which the Administrator determines will be available for the model year to which standards apply". The technologies developed by SwRI and their demonstrated ultra-low NOx emissions are consistent with the technology-forcing statutory requirements and the EPA proposed Option 1 standards for 2027 and 2031. The statutory requirement would not be met if EPA chose to adopt less stringent standards.

The cost of compliance is reasonable.
The implementation of the proposed standards and new certification and in-use NOx requirements will require technology changes in HDVs sold in MY2027 and beyond. These technologies would have an impact on costs. For the past 10 years, the ICCT has been publishing detailed cost information to ensure that national regulators in countries where we work can have access to that type of information. EPA's NPRM presents a careful revision and update of emission control technologies for diesel and gasoline HDVs in the U.S., and the

proposal presents a detailed analysis of the expected cost to meet the proposed targets. The draft RIA often refers to ICCT's work as the basis for its cost assessment. Our detailed review of the cost numbers shown in the draft RIA agrees with our own analysis. The RIA provides an even deeper look into the cost elements that influence the total incremental cost to meet the proposed standards.

The California Air Resources Board (CARB) recently adopted a new rule, referred throughout this document as the HDV omnibus, to significantly reduce real-world nitrogen oxide (NO_x) emissions from new on-road heavy-duty engines sold in the state beginning in 2024. The cost information from that process is relevant in this discussion as the current EPA NPRM is closely linked to the CARB regulation.

Six studies were published that analyzed the cost to manufacturers of the low-NO_x regulation between 2019 and 2021: one by the ICCT, one from the Manufacturers of Emissions Control Association (MECA); one by the California Air Resources Board; one by the National Renewable Energy Laboratory (NREL); and two by the Truck and Engine Manufacturers Association (EMA).

The table below shows what each of the six studies found to be the incremental 12L–13L engine cost to the manufacturer of full compliance with the final step of CARB's regulation and EPA's NPRM. The estimates range from $2,200 (the lowest, from ICCT's study) to $80,821 (the highest, from EMA-ACT Research)—a huge difference. These can be compared to EPA's estimated $3,200 to $3,900 compliance cost to meet the HHDV regulatory requirements for MY 2031, depending on the regulatory option adopted. We find that the highest estimates are inaccurate largely due to their overestimation of indirect costs, as discussed below. For reference, the MSRP of a leading MY2022 Class 8 tractor-trailer model, the Freightliner Cascadia, is listed today at $168,274. [17]

Table 2. Published estimates of incremental cost of new heavy-heavy-duty diesel 12-13L engines to meet low-NOx standards in the United States

Study	Incremental cost	Description
ICCT [18]	$2,200 to $3,200 MY31	ARB Low NOx Omnibus. Bottom-up analysis based on data from emission control technology manufacturers plus desk research. Warranty costs not included.
MECA [19]	$3,500 to $4,800 MY31	ARB Low NOx Omnibus at 1 MM mile FUL, 800k mile warranty included
CARB [20]	$6,000 to $6,700	ARB Low NOx Omnibus. Range MY27/MY31. Accounting for ACT regulation
NREL[21]	$10,000 to $50,000	Survey. Four anonymous respondents plus EMA

[17] Source: Price Digests https://app.pricedigests.com/login. Accessed 4 May 2022.
[18] Francisco Posada et al. (2020). Estimated Cost of Diesel Emissions-Control Technology To Meet Future California Low NOx Standards In 2024 and 2027. https://theicct.org/wp-content/uploads/2021/06/HDV-emissions-compliance-cost-may2020.pdf
[19] MECA Comments to ARB Low NOX Omnibus ISOR.
[20] ARB's Staff Report Initial Statement of Reasons. https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2020/hdomnibuslownox/isor.pdf
[21] NREL (2020). On-Road Heavy-Duty Low-NOx Technology Cost Study. https://www.nrel.gov/docs/fy20osti/76571.pdf

EMA - ACT Research[22]	$17,000 to $65,000 MY27 $26,000 to $80,000 MY31	Confidential industry input. Range represents low-volume California sales and high-volume federal sales at extended UL and warranties
EMA - Ricardo[23]	$18,000 to $35,000 MY31	Prepared in October 2021 for Potential Next-Tier EPA HDOH Emission Regulations. Data from engine and component manufacturers plus Ricardo's own technology assessment knowledge. Low/high range for different levels of extended UL and warranties

The total cost to meet a standard is traditionally split between direct and indirect cost of manufacturing. Direct manufacturing cost (DMC) covers in broad terms the hardware; indirect costs (IMC) cover warranty, R&D, profit, and other cost elements that would impact the cost depending on how many units are sold. Figure 5 shows estimates of the incremental direct manufacturing costs derived from meeting the standards, including estimates from ARB's Low NOx Omnibus and EPA's NPRM (Option 1). The deviation is relatively small compared to the deviation found in the total costs table. The DMC values are close to $2,000 for EPA NPRM and ICCT costs. ARB's cost for the Low NOx Omnibus rule is based on NREL's OEM survey, which explains the agreement in values. ARB's values corrected by volume to better represent national HDV sales reduce DMC by ~30% and are close to DMC values reported by Ricardo under contract for EMA in 2021. However, EMA-Ricardo's values and NREL values were obtained from surveying vehicle manufacturers and provide few details to explain how the numbers were derived. Cost surveys among regulated entities tend to generate values well above those found via bottom-up cost analysis, as detailed by ICCT and EPA.

Additional sources from the industry also confirm the DMC range. Eaton's analysis shows that the total incremental cost to meet the proposed regulation while reducing GHG emissions ranges from $1,700 to $2,900 and includes cylinder deactivation, e-heater, LO-SCR, and a 48V, and supports a 25-35% full-time NOx compliance margin to 435k miles useful life.

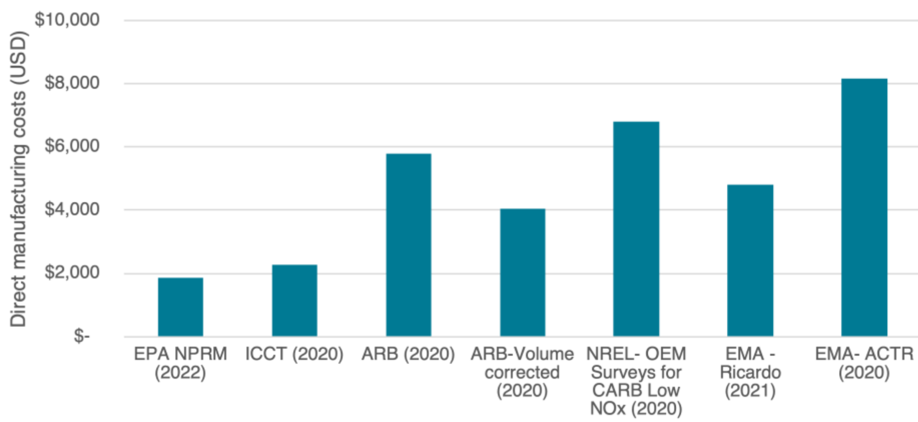

Figure 5. Direct manufacturing costs from different sources that provided public comments to HDV NO_x emission regulatory processes in California and at the Federal level. Dates represent the publication date for each report.

[22] EMA (2020). Comments of The Truck and Engine Manufacturers Association. https://www.arb.ca.gov/lists/com-attach/8-hdomnibus2020-1jACGvmafqDgElXk.pdf

[23] Ricardo (2021). Cost Impact Study for Potential Next-Tier EPA HDOH Emission Regulations.

The largest source of cost variability comes from indirect cost assessments. The values reported on indirect costs from each study are summarized in Figure 6. The root of this wide range of values are assumptions and methods to evaluate the cost impact of increasing emission control system useful life (UL) and warranty requirements.

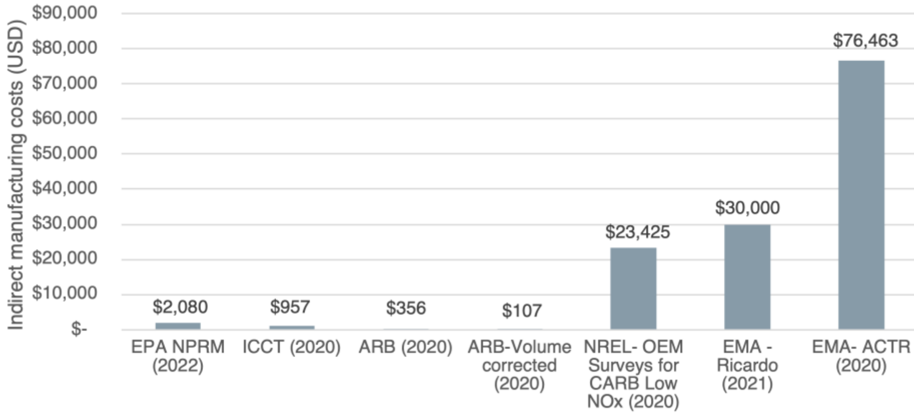

Figure 6. Indirect manufacturing costs from different sources that provided public comments public comments to HDV NOx emission regulatory processes in California and at the federal level. Dates represent the publication date for each report

Two different UL and warranty requirement evaluation methodologies were used by the different authors of the reports presented here. The first group (EPA, ICCT and ARB) assumed that suppliers and manufacturers have several years to make production-ready the next generation of control technology to comply with the CARB proposal for NOx limits, UL and warranties. Most would increase the size of some components to meet the new requirements. As the cost impact of the size increases is already accounted for in the DMC values, the impact on IMCs is minimized.

In addition, EPA reflected the warranty and UL costs in the IMC by including Retail Price Equivalent (RPE) multipliers. RPEs are one of the main methods EPA has used to estimate IMCs. Warranty costs that traditionally have a RPE of 0.02 were increased by a factor derived from the mileage increase to meet the MY2027 and MY2031 warranty, i.e., a VMT-based scaling factor. The warranty-RPE scaling factor ranged from 4.5 to 6.0. The UL requirement costs were accounted for in the R&D component of the IMC. RPEs for R&D were increased by a VMT-based scaling factor of 1.33 to 1.38.

The second group relied on surveys of engine and truck manufacturing OEMs. This approach was adopted by NREL under contract to ARB, and by Ricardo under contract to EMA. The main assumption these make is that an average truck would experience a complete system replacement during the warranty period covering the useful life of the vehicle. By oversimplifying, this approach implies thousands of dollars of additional increased warranty costs per vehicle that exceed those over other estimates.

Given that emission control system manufacturers have historically been able to meet their UL and warranty requirements since the inception of emission standards in the 70’s, that the bulk of the technology required is an incremental improvement on existing technology, and that the industry still has 8 years to develop durable and reliable technology, it would be wrong to assume that complete system replacements would be required to meet more ambitious UL and warranty requirements.

Public health benefits of Option 1 outweigh costs by a factor of 5.3.
The EPA analysis shows the adoption of Option 1 will result in substantial air quality benefits. Annual NOx reductions in 2030 and 2040 are 16.4 and 55.9 percent. $PM_{2.5}$ emissions are reduced 3.4 and 23.7 percent. And benzene, an air toxic, is reduced 4.1 and 23.1 percent. Reducing the health impacts of exposure to these pollutants is especially important to residents of communities located close to high truck traffic.

EPA's analysis of health benefits indicates the proposed Option 1 standards when fully implemented in 2045 will reduce premature deaths by about 3,000 per year. The average monetized value of all health benefits of Option 1 (at a 7 percent discount) is 5.3 times the total cost of compliance. Option 2 provides lower benefits and higher costs with a less favorable benefit/cost ratio of 3.8.

The NO_x benefits of EPA's proposal are determined, in part, by the degree of future ZEV uptake. To understand this relationship, we modeled several scenarios for ZEV uptake under both proposed Options for new NOx engine standards. More detailed modeling methodology and scenario descriptions can be found in Attachment 1 – Appendix A.

We find that EPA Option 1 and 2 standards combined with faster future ZEV deployment can lower overall NOx emissions, as shown in
Table 3. We estimate EPA's Option 1 would reduce NOx emissions by 0.4 to 5.1 million tonnes over the period 2027–2050 compared to EPA 2010 standards. Strengthening EPA's Option 1 to align with state HDV Omnibus rules would increase NOx emission benefits by an additional 0.1-0.5 million tonnes over this period. We find the greatest NOx reductions - up to 5.9 million tonnes - would come from both accelerating ZEV uptake in line with the most ambitious *Alternative 3* scenario and adopting requirements similar to state HDV Omnibus rules (compared to *Baseline EPA 2010)*.

Table 3: Cumulative NOx emissions from model year 2027-2050 heavy-duty vehicles over the period of 2027-2050 under different NOx standard options and ZEV sales shares.

NOx standard	ZEV pathway	Cumulative NOx emissions for the period 2027–2050, thousand tonnes			% change from EPA 2010 Baseline
		MY 2027–2030	MY 2031+	MY 2027–2050	
EPA 2010	Baseline	1,808	5,889	7,696	**0.0%**
	MOU	1,770	5,564	7,334	**-4.7%**
	Alternative 1	1,751	2,703	4,454	**-42.1%**
	Alternative 2	1,505	1,546	3,051	**-60.4%**
	Alternative 3	1,022	322	1,344	**-82.5%**
EPA Option 2	Baseline	495	1,599	2,094	**-72.8%**
	MOU	521	1,630	2,151	**-72.1%**
EPA Option 1	Baseline	350	819	1,169	**-84.8%**
	MOU	400	965	1,366	**-82.3%**
	Alternative 1	429	727	1,156	**-85.0%**
	Alternative 2	519	477	996	**-87.1%**
	Alternative 3	723	107	830	**-89.2%**
EPA Option 1 with lower FEL cap	Baseline	344	808	1,152	**-85.0%**
	MOU	360	846	1,206	**-84.3%**
	Alternative 1	406	718	1,124	**-85.4%**
	Alternative 2	466	478	944	**-87.7%**
	Alternative 3	290	96	386	**-95.0%**
EPA Option 1 with no ZEV credits	Baseline	331	769	1,100	**-85.7%**
	MOU	330	739	1,069	**-86.1%**
	Alternative 1	327	377	704	**-90.9%**
	Alternative 2	268	218	486	**-93.7%**
	Alternative 3	167	47	214	**-97.2%**
Federal omnibus	Baseline	260	769	1,029	**-86.6%**
	MOU	252	720	972	**-87.4%**
	Alternative 1	246	369	615	**-92.0%**
	Alternative 2	213	218	431	**-94.4%**
	Alternative 3	134	47	181	**-97.7%**

Option 2 does not reflect the greatest degree of emission reduction achievable
The Clean Air Act requires heavy-duty standards for new engines to "reflect the greatest degree of emission reduction achievable through the application of technology which the Administrator determines will be available for the model year which the standards apply, …" (section 202(a)(3)(A) of the Act). EPA has clearly stated its finding (see quote from the NPRM in the section of our comments on Technical Feasibility) that Option 1 standards are technically feasible within the lead time provided. The Option 2 proposed NO_x standards are much less stringent than Option 1: 1.4 times higher in 2027 and 2.5 times higher in 2031+ for the FTP cycle. Clearly Option 2 standards do not meet the Clean Air Act definition of the greatest degree of emission reduction achievable, given EPA's definitive statement that Option 1 standards are technically feasible.

Under a scenario in which 17 states adopt and implement an Advanced Clean Trucks Rule, we estimate that Option 2 standards will result in nearly 1 million additional cumulative tonnes of NOx emitted from 2027 through 2050, compared to Option 1, as shown in Figure 7. EPA estimates Option 1 will deliver over 1.25 million additional tons of NOx reductions when compared with Option 2 (Table 5-34, EPA RIA). The additional health damages of Option 2 are $9–$16 billion (Table 8-8, EPA RIA).

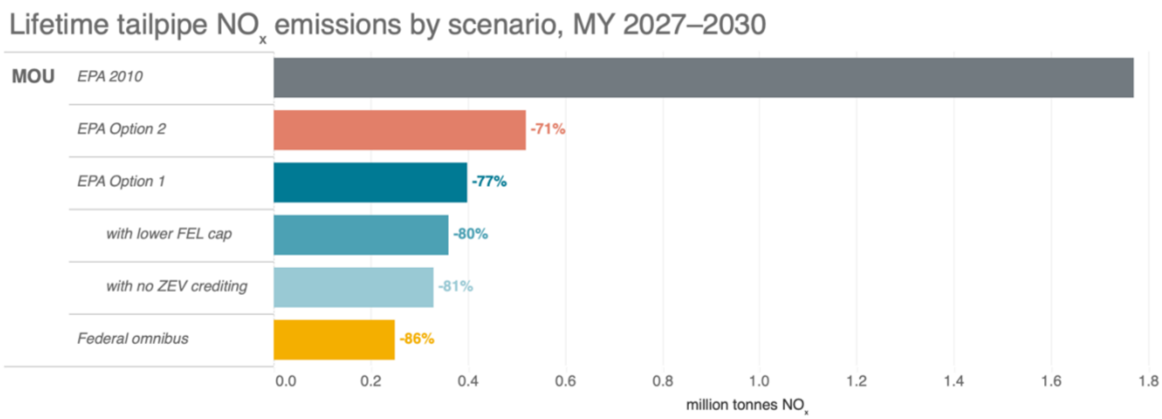

Figure 7. Lifetime tailpipe NOx emissions of MY2027–2030 vehicles for the period 2027–2050.

Assumes a degree of ZEV uptake equivalent to adoption of the California Advanced Clean Trucks rule among all states who are signatories to the multi-state memorandum of understanding as of May 2022. See Attachment 1 – Appendix A for a description of scenarios.

Less stringent emission standards proposed in Option 2 higher proposed FEL caps explain the emission differences with Option 1. For example, the highest allowed 2031+ FTP FEL in Option 2 is 150 mg NOx for HHD engines —3 times the proposed standard of 50 mg and only 25 percent below the current standard. By comparison, the highest 2031+ HHD FTP FEL under Option 1 is 70 mg at full useful life—only 1.75 times the proposed standard of 40 mg and less than half the Option 2 FEL. These are shown in the table below.

Table 4. Maximum allowable NO_x Family Emissions Level (FEL) in model year 2031 and later.

Engine class	Option 1 mg/bhp-hr.		Option 2 mg/bhp-hr.	
	NOx Std.	FEL	NOx Std.	FEL
HHD[1]	20/40	35/70	50	150
MHD[2]	20	50	50	150

[1] @ 435/800K mi. for Option 1, and @650K mi. for Option 2
[2] @ 350K mi. for Option 1, and 325 mi. for Option 2

One implication of low FELs under Option 2 is many trucks that operate in or near disadvantaged communities could be allowed to achieve only a 25% NOx reduction compared to the current standards. Residents living in these communities are already exposed to a higher air pollution burden. The results of EPA's analysis indicates that environmental justice would not be served by adoption of Option 2, with its laxer standards, much higher FELs, shorter useful life and a warranty more than 40% shorter in mileage coverage and 50% lower in years compared to Option 1.

For the above reasons, ICCT recommends Option 2 be dismissed.

Underpinning of our views on this opportunity to address diesel exposure disparities

A combined strategy to reduce HDV tailpipe NO_x emissions by at least 90% and accelerate ZEV uptake is crucial to addressing exposure disparities

Combination long-haul trucks, combination short-haul trucks, and single unit short-haul trucks are the segments with the greatest potential NO_x emissions reductions from strengthened policies.

These 3 segments account in our modeling for nearly 89% of estimated NO_x reductions in 2035, assuming adoption of EPA's Option 1. (Table 5) These segments also account for more than 85% of the additional NO_x reduction potential we assume is still available. Compared to EPA's Option 1, a strategy to reduce HDV tailpipe NO_x emissions by at least 90% via NO_x engine standards and increase ZEV uptake in line with reaching 100% zero-emission HDV sales by 2035 via GHG standards, could reduce NO_x emissions across all vehicle segments by 46,400 tonnes in 2035—a 15% increase in NO_x benefits compared to EPA Option 1.

Table 5. Modeled NO_x emission reductions by vehicle segment in 2035 under EPA's proposed Option 1 and additional reductions under ICCT's recommended Federal omnibus + Alternative 3 ZEV pathway

Vehicle segment	EPA Option 1 reductions compared to baseline		Federal omnibus + Alternative 3: additional reductions compared to EPA Option 1	
	Thousand tonnes	% of total	Thousand tonnes	% of total
Combination Long-haul Truck	192.3	61.1	13.8	29.8
Combination Short-haul Truck	49.7	15.8	12.4	26.8
Single Unit Short-haul Truck	37.7	12.0	13.2	28.5
Single Unit Long-haul Truck	2.4	0.8	0.5	1.1
Transit Bus	7.3	2.3	1.0	2.2
School Bus	6.3	2.0	0.6	1.4
Other Buses	14.8	4.7	3.7	8.0
Refuse Truck	1.8	0.6	0.7	1.6
Motor Home	2.9	0.9	0.2	0.5
Total	**315.0**	**100%**	**46.4**	**100%**

Note: EPA Option 1 total reduction compared to baseline is sourced from EPA Draft Regulatory Impact Analysis Table 5-34. See Attachment 1-Appendix A for a description of modeling scenarios.

EPA's Option 1 will especially benefit communities living near interstates and highways in all states.

More than 60% of the NOx benefits of EPA's Option 1 are expected to come from combination long-haul trucks; these emission reductions are estimated to be concentrated on major roads across the U.S. Securing these benefits is especially important to reduce the impacts of transportation pollution in communities living near interstates and highways (Figure 8). EPA's Option 1 would also significantly reduce emissions from combination unit short-haul and single unit short-haul trucks; the latter are especially concentrated in densely populated areas.

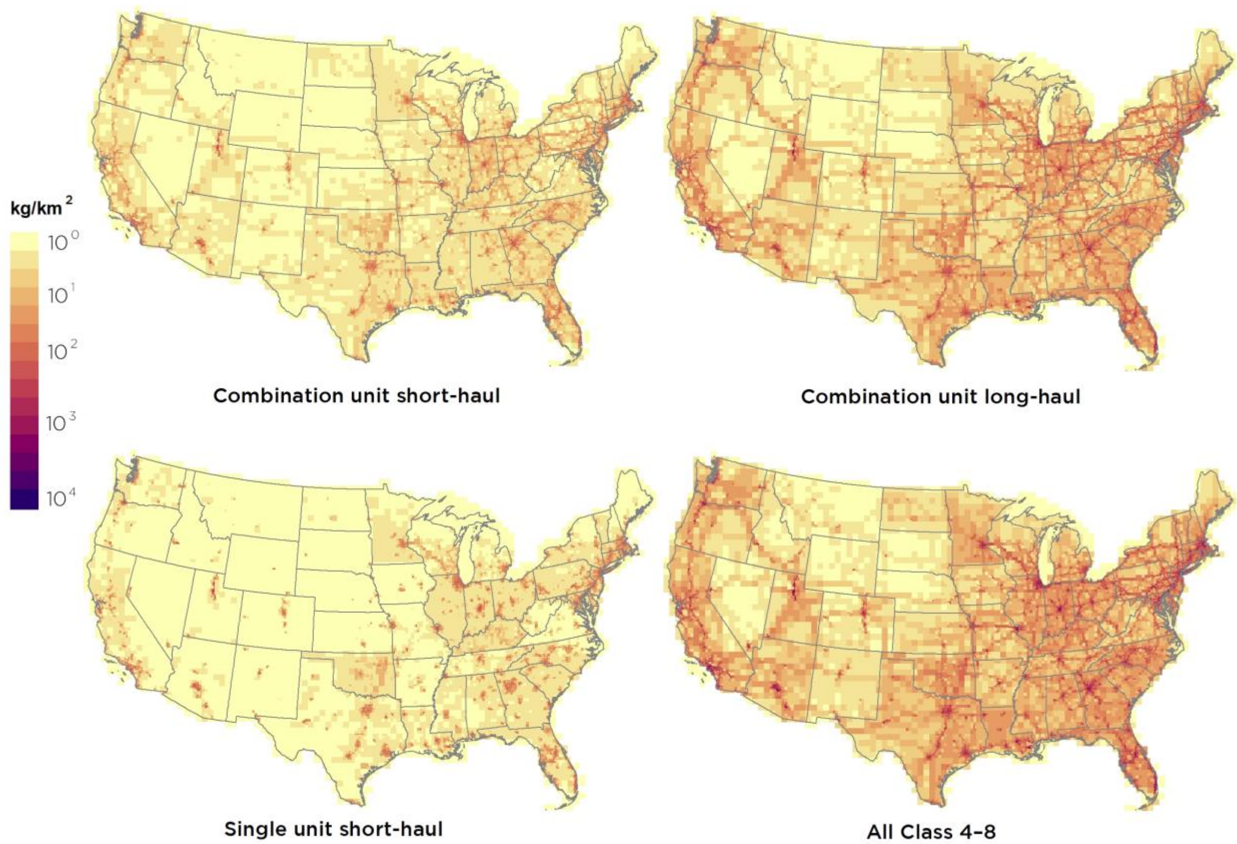

Figure 8. Area density (kg/km^2/year) of NO_x reductions in 2035 under EPA Option 1 compared to baseline

Adopting requirements similar to state HDV Omnibus rules and accelerating ZEV uptake would further benefit communities all over the U.S., including in densely populated areas and communities near interstates and highways.
Compared to EPA's Option 1, the additional benefits of EPA action represented by our modeling scenarios *Federal omnibus + Alternative 3* are approximately evenly divided among combination unit long-haul trucks, combination unit short-haul trucks, and single-unit short-haul trucks. Since each of these segments have distinct spatial patterns, these combined emission reductions would benefit communities across the U.S., especially population centers and areas near major freight corridors (Figure 9).

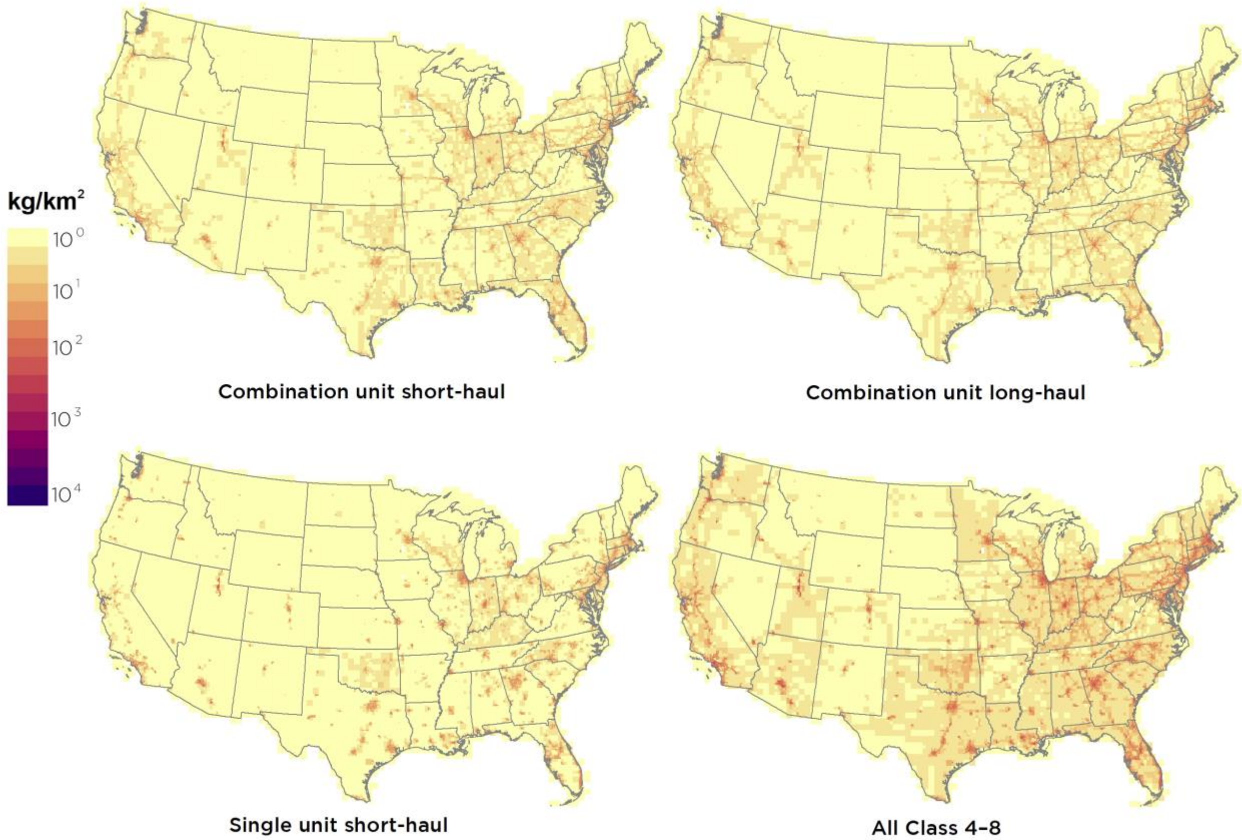

Figure 9. Area density (kg/km^2/year) of additional NO_x reductions in 2035 under ICCT's recommended scenario Federal omnibus + Alternative 3 compared to EPA Option 1. See Attachment 1-Appendix A for a description of modeling scenarios.

We analyzed health benefits at a census tract level for communities meeting select environmental justice criteria versus all others. The definitions of these groups of census tracts are mostly based on criteria in EPA's Climate and Environmental Justice Screening tool[24]:

1. **Disadvantaged**: Communities designated as disadvantaged are considered overburdened both in terms of environmental or climate indicators and underserved socioeconomically. This definition is not limited to impacts from transportation;

[24] *Methodology*. Climate and Economic Justice Screening Tool. https://screeningtool.geoplatform.gov/en/methodology

2. **High diesel particulate exposure (diesel PM)**: Communities at or above the 90th percentile for diesel particulate matter exposure, or the top 10% that are adversely impacted by diesel particulate matter exposure in the U.S., and above the threshold for socioeconomic indicators;
3. **High traffic (traffic)**: Communities at or above the 90th percentile for traffic proximity and volume and above the threshold for socioeconomic indicators;
4. **High ambient $PM_{2.5}$ exposure (PM)**: Communities at or above the 90th percentile for $PM_{2.5}$ in the air on an annual average basis and above the threshold for socioeconomic indicators;
5. **High rates of air pollution related diseases (disease)**: Communities at or above the 90th percentile for asthma OR diabetes OR heart disease OR low life expectancy and above the threshold for socioeconomic indicators;
6. **High proportion of low-income households (income)**: Communities at or above the 65th percentile for low income versus all others. Low income is defined as 'Percent of a census tract's population in households where household income is at or below 200% of the Federal poverty level';
7. **High proportion of people of color (POC)**: Communities at or above the 65^{th} percentile for percent people of color, people of color defined as Latinos of any race and any non-Latino, non-white people;
8. **Meets any criteria (any)**: Communities that meet any of the criteria above. This group represents 47.3% of total population in 48 states and the District of Columbia as shown in Table 6.

Table 6. Population of communities meeting select environmental justice criteria (48 states + D.C.)

Indicator	Total population (millions)		Share of population	
	Meets criterion	All others	Meets criterion	All others
Disadvantaged	90.0	232.5	27.9%	72.5%
High ambient $PM_{2.5}$ exposure	12.3	310.2	3.8%	96.2%
High diesel particulate exposure	12.3	310.3	3.8%	96.2%
High traffic	11.1	311.4	3.4%	96.6%
High rates of air pollution related disease	42.6	279.9	13.2%	86.8%
High proportion of low-income households	100.3	222.2	31.1%	68.1%
High proportion of people of color	112.8	209.7	35.0%	65.0%
Meets any criteria	152.4	170.1	47.3%	52.7%

Nearly half of the health benefits of aligning federal NOx engine standards with state Omnibus rules and accelerating ZEV uptake would occur in EJ communities.
Our modeling results show that a scenario represented by *Federal omnibus + Alternative 3* could avoid an additional $753 million in health damages annually in 2035 compared to EPA's

Option 1; 47% of these benefits ($350 million) are projected to occur in communities that meet at least one of the selected environmental justice criteria, which represent over 150 million people. Communities with high proportions of people of color and low-income households, two of the most populous groups we identified, are projected to benefit the most from accelerating ZEV uptake, followed by disadvantaged communities and those that experience high rates of air pollution related disease. Those that experience high rates of air pollution related disease are also the group that experience the largest benefits relative to their population, benefitting 13% more than average on a per-capita basis.

Table 7. Benefits of EPA's Option 1 compared to Federal omnibus + Alternative 3 in 2035, in million US$

Indicator	**EPA Option 1**		**Federal omnibus + Alternative 3**		**Incremental benefits**	
	Meets criterion	All others	Meets criterion	All others	Meets criterion	All others
disadvantaged	1,440	3,540	1,660	4,070	219	534
high ambient $PM_{2.5}$ exposure	195	4,780	225	5,510	30.3	723
high diesel particulate exposure	158	4,820	183	5,550	25.1	728
high traffic	178	4,800	206	5,530	28.0	725
high rates of air pollution related disease	741	4,240	852	4,880	111	642
high proportion of low-income households	1,630	3,350	1,870	3,860	246	507
high proportion of people of color	1,540	3,440	1,780	3,950	238	515
meets any criteria	2,300	2,680	2,650	3,080	350	403
Total (48 states + D.C.)	**4,980**		**5,730**		**753**	

Note: Values in table are rounded. Only three significant digits are shown. See Attachment 1-Appendix A for a description of modeling scenarios.

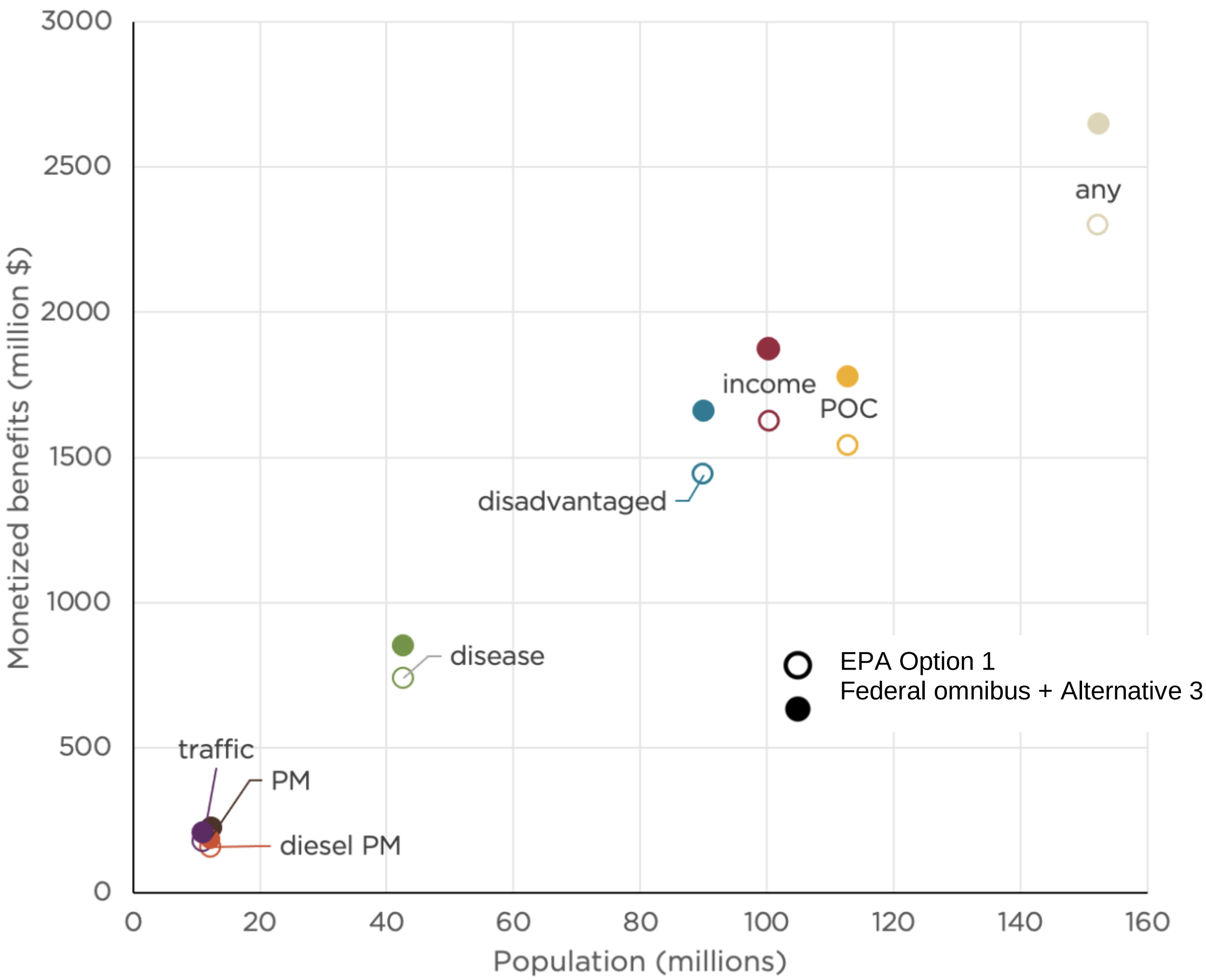

Figure 10. Monetized health benefits of EPA Option 1 vs. the scenario Federal omnibus + Alternative 3 in 2035 for communities meeting select environmental justice criteria. See Attachment 1-Appendix A for a description of modeling scenarios.

EPA's Option 1 will benefit communities in all states; adopting requirements similar to the scenario represented by *Federal omnibus* + *Alternative 3* would further increase benefits by approximately 15% across U.S. states.

The most populous states, such as California and Texas have among the highest potential health benefits in absolute terms from heavy-duty vehicle emission regulations. Yet multiple states are projected to experience outsized benefits compared to their population, such as Pennsylvania and Delaware, as well as Midwest and Southern states, including Indiana, Arkansas, Ohio, Missouri, North Carolina, and Georgia.

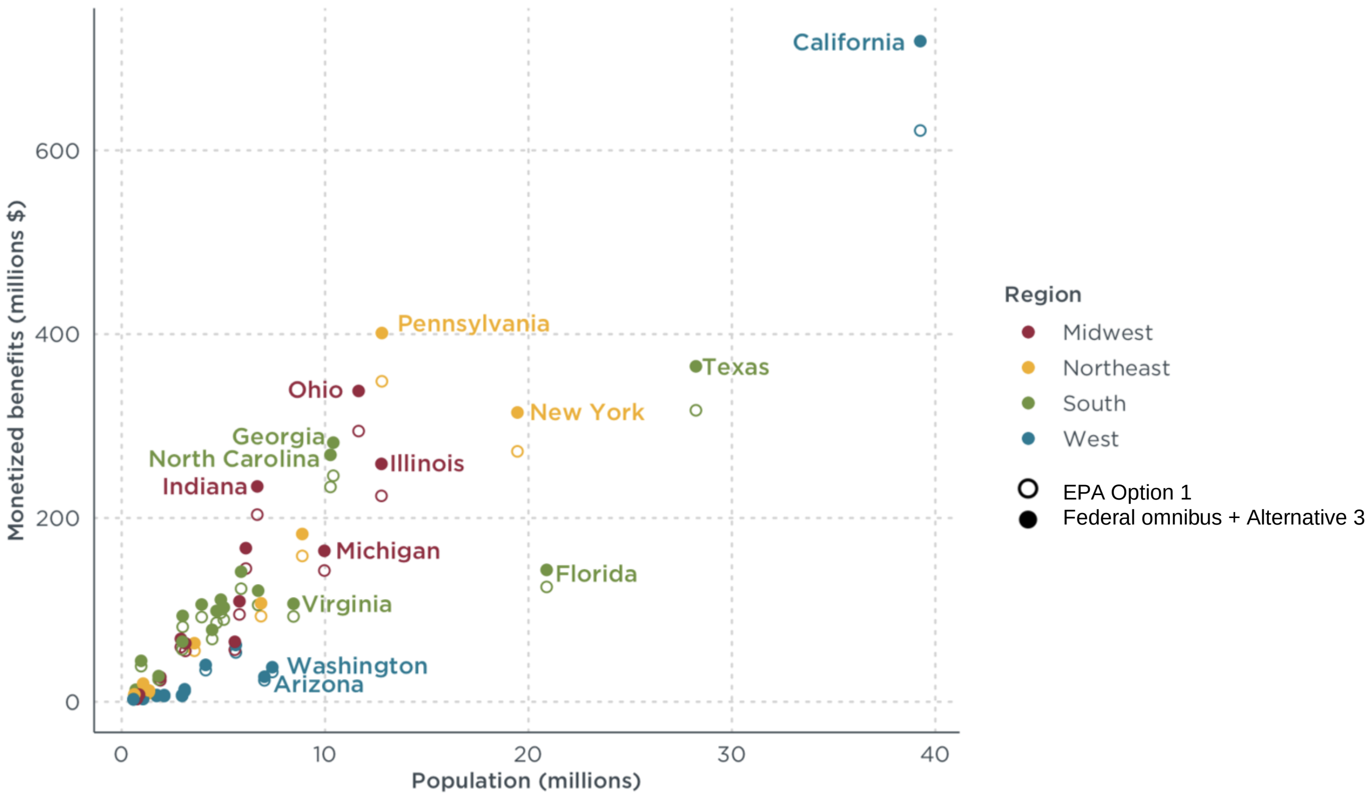

Figure 11. Monetized benefits of all populations by state for EPA Option 1 compared to the scenario Federal Omnibus + Alternative 3. See Attachment 1-Appendix A for a description of modeling scenarios.