American Petroleum Institute

Will Hupman
Vice President - Downstream
202-682-8463
HupmanWR@api.org

September 16, 2024

Ms. Sarah Dunham
Director, Office of Transportation and Air Quality
U.S. Environmental Protection Agency
1200 Pennsylvania Avenue NW
Washington, DC 20460

Filed electronically: https://www.regulations.gov

Re: American Petroleum Institute Comments on the State of California's Request for a Clean Air Act Waiver for the Advanced Clean Fleets Regulation (Docket ID No. EPA–HQ–OAR–2023–0589)

Dear Ms. Dunham:

The American Petroleum Institute ("API") appreciates the opportunity to submit comments in response to the notice entitled "California State Motor Vehicle Pollution Control Standards; Advanced Clean Fleets Regulation; Request for Waiver of Preemption and Authorization; Opportunity for Public Hearing and Public Comment" ("Notice").[1] In the Notice, the U.S. Environmental Protection Agency ("EPA") solicits public comments on a request from the State of California for a waiver of preemption under Clean Air Act § 209(b) for recently "adopted Advanced Clean Fleets (ACF) regulations, applicable to affected state and local government fleets, drayage truck fleets, federal agency fleets, and large commercial fleets that own, lease, or operate on-road medium-duty and heavy-duty vehicles, and light-duty package delivery vehicles, to incorporate zero-emitting vehicles beginning in 2024." *Id*. Those regulations are known as the Advanced Clean Fleets ("ACF") program.

API represents all segments of America's natural gas and oil industry, which supports nearly 11 million U.S. jobs and is backed by a growing grassroots movement of millions of Americans. Our approximately 600 members produce, process and distribute the majority of the nation's energy, and participate in API Energy Excellence®, which is accelerating environmental and safety progress by fostering new technologies and transparent reporting. API was formed in 1919 as a standards-setting organization and has developed more than 800 standards to enhance operational and environmental safety, efficiency and sustainability.

API members will be adversely affected if EPA grants the waiver of preemption requested by California. According to the California Air Resources Board ("CARB"), ACF[2] requires fleet

---

[1] 89 Fed. Reg. 57151 (Jul. 12, 2024).
[2] https://ww2.arb.ca.gov/resources/fact-sheets/advanced-clean-fleets-regulation-overview.

owners and operators to begin acquiring zero emission vehicles[3] (ZEVs) as early as 2024 and removing ICE vehicles or agree to a transition schedule by 2025. The 100% ZEV mandate in 2036 for new vehicle sales plainly will have a significantly adverse effect on the market for liquid transportation fuels, including renewable fuels, produced and marketed by API members and ignores other approaches that can result in emissions reductions, on a faster timeline, and at a lower cost.

Our comments are organized into two sections: Policy Concerns and Legal Arguments.

POLICY CONCERNS

API appreciates the opportunity to engage on EPA's efforts to address transportation sector greenhouse gas (GHG) emissions and has submitted comments[4,5] to the agency in response to recent proposals and rulemakings. API's *Climate Action Framework*[6] reflects our policies and goals, which are incorporated in our comments below. The challenge of meeting the world's growing need for energy while simultaneously ushering in a lower-carbon future is massive, intertwined, and fundamental. It is the opportunity of our time – governments, industries, and consumers must act to solve it together. Our industry is at the center of this challenge. We share the goal of reduced emissions across the broader economy and, specifically, those from energy production, transportation, and use by society.

API submitted comments to CARB[7] that strongly supported the comments submitted by Western States Petroleum Association (WSPA) and the American Fuel & Petrochemical Manufacturers (AFPM) and has been an active participant in the ACF rulemaking process. Despite this engagement, CARB's ACF program remains narrowly focused and overly stringent. The ACF is poorly drafted, relies most heavily on ZEV technology, and if granted the waiver of preemption, would allow other states to choose to adopt the ACF program through Clean Air Act Section 177.

API strongly believes in an "all-of-the-above" strategy to reduce emissions in the heavy-duty transportation sector and is concerned that the ACF program is a severe constraint on the "all-of-the-above" approach to reducing emissions. In addition to the concerns identified in the Legal Arguments section, the following policy discussion demonstrates that California's assessment of ACF is arbitrary and capricious[8] and if EPA grants the waiver to CARB for the ACF program it would have negative impacts for consumers, be impractical for the medium-duty and heavy-duty fleets, put increased reliance on critical

---

[3] Zero emission vehicles have carbon emissions associated with their production, usage, and disposal throughout their lifetime which CARB should incorporate in its analysis.

[4] https://www.regulations.gov/comment/EPA-HQ-OAR-2022-0829-0641.

[5] https://www.regulations.gov/comment/EPA-HQ-OAR-2022-0985-1617.

[6] https://www.api.org/climate.

[7] https://www.arb.ca.gov/lists/com-attach/589-acf2022-UzJVIwdvV1sHYgdo.pdf.

[8] Clean Air Act § 209(b)(1)(A).

minerals sourced from other countries, and consequently negatively impact the energy security of the United States.

Technology-neutral policies are critical to efficiently reducing carbon emissions in transportation

API supports technology-neutral policies at the federal level that drive GHG emissions reductions in the transportation sector, taking a holistic “all-of-the-above” approach to fuels, vehicles, and infrastructure systems. Such policies include: 1) federal fuel standards, 2) a full lifecycle approach to vehicle standards, 3) optimization of fuel/vehicle systems to improve efficiency, and 4) supportive infrastructure measures. We are concerned that the ACF program would work at cross purposes to these goals and, in any event, does not qualify for a waiver of preemption under § 209(b) of the Clean Air Act (“CAA”).

API’s members are committed to delivering solutions that reduce the risks of global climate change while meeting society’s growing energy needs. API members work to advance the development, transmission, and use of cleaner fuels and technologies to provide lower-carbon choices for consumers. Specifically, API members have made, and continue to make, significant investments in new technologies that reduce carbon emissions in transportation, including:

- Stand-alone production and coprocessing of bio-feedstocks to make renewable fuels.
- Manufacturing of low-carbon ethanol.
- Manufacturing of renewable natural gas from wastewater, landfill gas, and biodigesters at farms as fuel for compressed natural gas (CNG) vehicles.
- Production of lower carbon intensity hydrogen for transportation and stationary applications including building infrastructure.
- Direct air carbon capture.
- Carbon capture and sequestration of CO_2.
- Development of advanced plastics to meet auto industry standards and consumer expectations while mitigating environmental impact through emissions reduction and improved vehicle efficiency by light-weighting.
- Installation of electric vehicle charging stations.
- Installation of hydrogen fueling stations.

To achieve meaningful emissions reductions that meet the global climate challenge, it will take a combination of policies, innovation, industry initiatives and a partnership of government and economic sectors. The objective is large enough that relying only on so-called zero emission vehicles and trucks as the single solution will not achieve the goals of reducing transportation GHG emissions.

Practical use and availability of heavy-duty ZEVs is problematic

There is significant uncertainty regarding CARB's expectation for rapid availability of ZEV powertrains. For example, ZEV powered trucks have practical limitations, including but not limited to, 1) there are a small number of the vehicles available for purchase, 2) some are not able to perform the work that a comparable internal combustion engine vehicle (ICEV) would perform (due to time required to charge, range limitations due to terrain and weather, and duty-cycle constraints), 3) cost can be two times that of an ICEV, and 4) the vast majority of long-haul ZEVs are in the pilot stage and have significant challenges. Further, it will be extremely challenging to meet the ACF's ZEV requirements that increase at a faster rate than the expected ZEVs produced for compliance with the EPA's HD-Phase 3 requirements.

HD ZEVs are currently not available in sufficient quantities or at affordable levels to significantly displace ICEVs. Further, the cost to purchase a heavy-duty ZEV is currently prohibitive – not only is the purchase price currently higher than that of an ICEV, but fleet owners and operators are finding that HD ZEVs result in more work or trips needed to accomplish the same task as with an ICEV. For battery electric vehicles (BEV), this is largely due to battery range and charging, but can also be affected by temperature, road grade, and other factors. A study by ATA noted vehicle and fleet owner concerns regarding total cost of ownership, despite IRA and BIL funding.[9, 10]

The average cost of a HD tractor is about $180,000, while the electric version of the same vehicle can be nearly $400,000.[11] Expending this additional capital for a vehicle that may not meet the duty-cycle, is significantly heavier (and thus reduces the payload of the vehicle) and may require additional vehicles or work trips to achieve the same job[12], creates massive challenges that cannot be overcome in the short time frame contemplated by ACF, and may never be able to be overcome.

The practicality and availability of ZEVs required to comply with the ACF program will ripple into direct and indirect impacts that will negatively affect consumers as illustrated below.

---

[9] Advanced Clean Transportation (ACT) Expo 2023 Mainstage - Monday - 2023 State of Sustainable Fleets: https://vimeo.com/824774094.

[10] Advanced Clean Transportation (ACT) Expo 2023 Keynote Address: https://vimeo.com/824772504.

[11] https://nmfta.org/newsroom-articles/1-trillion-price-tag-report-details-cost-of-electrifying-u-s-trucks/#:~:text=For%20example%2C%20a%20diesel%20Class,electric%20truck%20costs%20over%20%24400%2C000.

[12] Testimony of Andrew Boyle, First Vice Chair of the American Trucking Associations and Co-President, Boyle Transportation, before the U.S. Senate Environment and Public Works Committee's Subcommittee on Clean Air, Climate, and Nuclear Safety, April 18, 2023: https://www.epw.senate.gov/public/_cache/files/0/d/0d62639d-9821-4f0c-b4f5-166ab4e7fb06/8BD123C841C5F59806D852155EE981FFC282647F860583FE863FEEF9C7A57FD1.04-18-2023-boyle-testimony.pdf.

Consumer impacts

The upfront purchasing costs of ZEVs are projected by CARB to exceed ICEVs into the foreseeable future.[13] Increased costs attributed to the purchase of ZEVs and the associated infrastructure could have negative impacts including 1) forcing companies out of business, leading to less competition and higher costs for consumers, and/or 2) driving companies to retain their older vehicle as long as possible to avoid the costs and limitations of the new technology. For example, a BEV compared to an ICE truck has reduced capacity, shorter range, and may require more work trips, duty cycles, or vehicles to accomplish the same task. Each of these results in increased costs that will likely result in upward pressure on costs of delivered goods and services that would be seen by the consumer. CARB's economic analysis of impacts of the ACF program support these concerns as they conclude that the cost of the ACF program would "cascade through the economy and affect individuals".[14]

Critical minerals / energy security / energy diversity issues

Reliance on a limited number of technologies (e.g., ZEVs) on the timeline required by the ACF program will likely result in a non-resilient transport sector that is vulnerable to unexpected disruptions. Both the federal government and the private sector have recognized that critical minerals are essential to the future of ZEV technology, and likewise, that unstable critical mineral supply chains could disrupt this future.

BEV battery supply chains, including both raw material extraction and processing of critical minerals and manufacturing battery components, are controlled by a small number of countries, some with questionable environmental and human rights practices and geopolitical stability concerns.[15] Exacerbating these concerns, the raw material extraction sector will need to grow exponentially to meet demand, and mining is an energy- and environmental-intensive activity. The accelerated ZEV technology penetration rate required under the ACF program poses significant challenges for best practices to be widely and fully deployed in the timeframe of the rule.

Five critical minerals are needed to manufacture lithium-ion batteries whose domestic supply is potentially at risk of disruption including lithium, cobalt, graphite, manganese and nickel. [16] Further, significant amounts of additional aluminum and copper are needed for ZEVs beyond what is needed for ICE cars and trucks. While there is a move to modify and change battery chemistry, time is needed to develop the technology, improve

---

[13] CARB, Staff Report: Initial Statement of Reasons, Public Hearing to Consider the Proposed Advanced Clean Fleets Regulation (2022), Executive Summary, Section C. Staff Report.

[14] CARB, Staff Report: Initial Statement of Reasons, Public Hearing to Consider the Proposed Advanced Clean Fleets Regulation (2022), Executive Summary, Section F. Staff Report.

[15] https://www.sciencedirect.com/science/article/abs/pii/S0016328723000058.

[16] Congressional Research Service, "Critical Minerals in Electric Vehicle Batteries," August 29, 2022, https://crsreports.congress.gov/product/pdf/R/R47227.

manufacturing processes and overcome some limitations of the technologies to make the new chemistries practical.

Three countries – Australia, Chile and China – dominate the supply of lithium accounting for nearly 90 percent of the global market. While 70% of global cobalt production comes from the Democratic Republic of Congo[17], most of the mines are owned/operated by China and more than 60 percent of cobalt processing is in China. China produces 67 percent of the world's graphite.[18] The U.S. imports most of its manganese from Gabon, a less geopolitically stable country, providing 65 percent of the United States' supply.[19] Electricity networks need a large amount of copper and aluminum. China possesses over half of the entire world's aluminum smelting capacity.

There are sources[20] that indicate a shortage of critical minerals as well as volatility in critical mineral prices. U.S. energy security would also undergo a dramatic paradigm shift if vehicle technologies were shifted from ICEVs to ZEVs in the rate that the ACF program requires. Domestic production of critical minerals required for battery production is insufficient to meet the projected demands. Although Congress and the Administration have taken steps to accelerate this activity by funding, facilitating, and promoting the rapid growth of U.S. supply chains for these products through the IRA, BIL, and numerous Executive Branch initiatives, more will still be needed if EPA grants a waiver for the ACF program. Further, CARB dismissed considering all the complexities, such as federal permitting, National Environmental Protection Act reviews, and the supply chains for these critical materials in their technology feasibility assessment.

In contrast, the U.S. is the world's largest producer of oil and natural gas and is a major manufacturer of biofuels consumed in on-road transportation. Over 70 countries supply petroleum feedstocks and multiple others supply biofuels to the world compared to a small handful of countries that supply critical minerals needed for BEVs. The combined oil production capacity has changed the geopolitical fabric of the world to the benefit of the U.S. and its allies.

Lifecycle Emissions of ZEVs

ZEVs do not produce tailpipe emissions, but they do have significant lifecycle emissions at other stages of the process: extracting the minerals needed to produce the batteries, producing the large batteries or fuel cells required for HDVs, and recycling at the end of a vehicle's useful life. Likewise, producing the electricity needed to power a BEV fleet releases emissions, and much electricity production in California and across the country is powered by carbon-intensive energy sources. ACF failed to consider these lifecycle

---

[17] "The Role of Critical Minerals in Clean Energy Transitions", International Energy Agency World Energy Outlook Special Report: https://iea.blob.core.windows.net/assets/ffd2a83b-8c30-4e9d-980a-52b6d9a86fdc/TheRoleofCriticalMineralsinCleanEnergyTransitions.pdf.

[18] "Graphite," Professional Paper 1802-J, US Geological Survey: https://pubs.usgs.gov/publication/pp1802J.

[19] https://oec.world/en/profile/bilateral-product/manganese-ore/reporter/usa.

[20] "Global Critical Minerals Outlook 2024", International Energy Agency, May 2024, www.iea.org.

emissions, instead focusing exclusively on tailpipe emission. In doing so, CARB has failed to consider the true emissions from ZEVs.

Lower-carbon intensity fuels teamed with existing vehicle technology can provide competitive reductions in GHG emissions more cost efficiently. It is not necessary to focus solely on ZEV technology, and to not consider the benefits of existing technologies to achieve the goals of the administration.

LEGAL ARGUMENTS

There are six major legal issues with CARB's waiver request that require EPA to deny it. First, EPA should not grant a preemption waiver because the ZEV component of the ACF program is not consistent with CAA § 202(a). Second, a ZEV mandate is not an emissions "standard" under the Clean Air Act. Third, EPA should not grant a preemption waiver because California has not demonstrated that it needs the ACF program to address any "compelling and extraordinary conditions." Fourth, California has arbitrarily failed to consider lifecycle emissions of ZEVs. Fifth, CAA § 209(b) is invalid because it violates the Constitutional guarantee of equal sovereignty among the states. And finally, the ACF program violates the Dormant Commerce Clause.

I. The ZEV component of the ACF program is not consistent with CAA § 202(a).

CAA § 209(b)(1)(C) provides that EPA may not grant a preemption waiver to California if "such State standards and accompanying enforcement procedures are not consistent with section 7521(a) [CAA § 202(a)] of this title." CAA § 209(b)(1)(C).[21] In its waiver petition, California argues that the inquiry under CAA § 209(b)(1)(C) should be very limited:

> Under the third waiver criterion, Section 209(b)(1)(C), EPA may deny a waiver if it finds that the additional or amended standards for which the waiver is requested would render California's new motor vehicle emission program inconsistent with Section 202(a) of the Clean Air Act. "[I]n the waiver context, section 202(a) relates ... to technological feasibility."99 EPA has long understood the reference to Section 202(a) in Section 209(b)(1)(C) as referring to Section 202(a)(2)'s requirement that EPA's federal standards provide "such period as ... necessary to permit the development and application of the requisite technology, giving appropriate

---

[21] We note that a waiver decision for the nonroad component of the ACF program must be considered under the criteria established in CAA § 209(e) rather than the criteria in CAA § 209(b). However, as California correctly asserts in its waiver application, CAA § 209(e) requires that "California's nonroad standards and enforcement procedures must be consistent with section 209(b)(1)(C)" and that "[u]nder section 209(b)(1)(C), the Administrator shall not grant California's motor vehicle waiver if she finds that California 'standards and accompanying enforcement procedures are not consistent with section 202(a)' of the [CAA]…." CARB Support Document at 16-17 (quoting 65 Fed. Reg. 69763, 69764 n. 5 (Nov. 20, 2000). Thus, the following analysis of the requirement for consistency with CAA § 202(a) applies equally to the onroad and nonroad components of California's waiver request.

> consideration to the cost of compliance within such period." Under this long-standing, traditional interpretation, EPA can deny a waiver under Section 209(b)(1)(C) only if "the state's regulations ... provide 'inadequate lead time to permit the development of the technology necessary to implement the new procedures, giving appropriate consideration to the cost of compliance within the time frame.'"[22]

Applying that interpretation, California asserts that the ZEV component of the ACF program satisfies CAA § 209(b)(1)(C) "because the technology required to demonstrate compliance with the emissions standards and accompanying enforcement procedures already exists." *Id*. at 31-2.

But California misunderstands the requirement of technological feasibility. And technological feasibility is not the only requirement of section 202(a).

A. ACF is not consistent with section 202(a) of the Clean Air Act because it is not technologically feasible.

California may receive a waiver only if its proposed standards are "consistent with" section 202(a) of the Clean Air Act. 42 U.S.C. § 7543(b)(1)(C). Section 202(a), in part, requires that any federal emission standard take effect only "after such period as the Administrator finds necessary to permit the development and application of the requisite technology, giving appropriate consideration to the cost of compliance within such period." 42 U.S.C. § 7521(a)(2). Section 209(b) imposes this same requirement on California's standards. *Id.* § 7543(b)(1). In other words, section 202(a) requires that "California's standards ... be technologically feasible within the lead time provided, giving due consideration to costs." 89 Fed. Reg. 57,153.

According to California, ACF is technologically feasible because ZEV trucks exist in every weight class. "Over the last decade, advancements in battery technology have occurred, and the number of manufacturers of both battery electric and fuel cell electric vehicles have increased, which has accordingly resulted in the commercial availability of ZEVs in every weight class of medium- and heavy-duty vehicles, including the heaviest vehicle weight class of Class 7 and Class 8 vehicles. Specifically for that weight class, CARB is currently aware of 28 models, 8 of which are tractors, and anticipates that an additional 5 models of tractors will be commercially available by 2023." CARB Support Document at 32. Moreover, California asserts "that although the costs to acquire medium- and heavy-duty ZEVs are higher than the costs to acquire their conventional counterparts, ZEVs have lower operational costs than conventional vehicles, and will accordingly incur lower TCOs than conventional vehicles over their operational lives." *Id*. at 43.

---

[22] *Clean Air Act § 209(b) Waiver and § 209(e) Authorization Request Support Document Submitted by the California Air Resources Board*, Docket No. EPA-HQ-OAR-2023-0589-0004 (November 15, 2023) at 30 (internal quotes and cites omitted) ("CARB Support Document").

But showing technological feasibility requires more than just identifying models available on the market. Rather, the technology mandated must also be capable of meeting market needs and “feasible within economic parameters,” so as to “avoid undue economic disruption in the automotive manufacturing industry” and “to avoid doubling or tripling the cost of motor vehicles to purchasers.” *Motor and Equip. Mfrs. Ass’n, Inc. v. EPA*, 627 F.2d 1095, 1118 (D.C. Cir. 1979). ACF does not meet that standard, as ZEV trucks do not come close to meeting market needs at a remotely reasonable price.

To start, certain models of ZEV trucks may be available on the market, but the technology still falls far short of being able to replace ICE fleets. For example, BEVs can travel a mere 150 to 300 miles on a single charge, while a diesel truck can drive about 1,200 miles on a full tank. Am. Trucking Ass’n, *California’s Dream Is Becoming America’s Supply Chain Nightmare* (June 12, 2023),[23] and that diesel tank only takes about 15 minutes to fill, whereas a full charge for a comparable BEV can take 10 hours. *Id.* Beyond charging, the additional weight from the battery decreases the weight that a truck can carry, meaning that a fleet must put more trucks on the road to transport the same amount of cargo. And as fleets must switch over to ZEVs on California’s accelerated timeline, there is no guarantee that there will be a sufficient supply of BEV trucks to satisfy the country’s trucking needs, for example because of the resource limitations on battery production or limited vehicle production capacity.

Further, the charging infrastructure is insufficient. Many fleets do and will have problems with on-site charging, as fleets must negotiate with utilities for power from already strained grids. Those problems are even greater on the road, as “[t]here is currently no U.S. network where over-the-road trucks can stop for rest breaks and recharging at the same time.” Am. Transp. Research Inst., *Understanding the CO2 Impacts of Zero-Emission Trucks* at 15 (May 2022).[24]

Finally, the costs are exorbitant. As one recent study conducted by Ryder concluded based on real-world experience, the total annual extra cost to convert to a BEV in California—accounting for all relevant factors, like the truck itself and fuel and labor costs—was $5,000 for a class 4 van, $48,000 for a class 6 truck, and a whopping $314,000 for a class 8 tractor trailer. Ryder, Electric Vehicle Total Cost to Transport Analysis at 4–6 (May 2024). For a mixed fleet of 25 vehicles, those costs would result in a 56% increase in total costs. *Id.* at 7. Trucking companies already operate on thin margins, meaning that the fleets that cannot shoulder these extra costs will pass them on to consumers, increasing the price of consumer goods across the country.

Recognizing those serious barriers, California did include certain purported exceptions for technological feasibility. For instance, the ZEV Purchase Exemption allows a fleet to seek permission to purchase an ICE truck if a needed vehicle configuration is not available as a ZEV. But those exceptions will offer little to no meaningful relief for fleet owners. For one,

---

[23] https://tinyurl.com/29pe4yzf.

[24] https://tinyurl.com/by43r7bt.

the exemptions apply only where it is physically impossible for a fleet to comply—not where it would be operationally or financially difficult (or even infeasible). And it is left to CARB's discretion whether the exemption is met. That is a cold comfort for any fleet.

For all these reasons, ACF is not technologically feasible.

B. ACF is not consistent with section 202(a) because it exceeds EPA's own statutory authority to set emission standards.

Moreover, even if ACF were technologically feasible, it still would not be consistent with CAA § 202(a). The words "consistent with [CAA § 202(a)]" plainly require a showing that California's rules are consistent in all respects with CAA § 202(a). California has not attempted to make that broader showing, and could not do so even if it tried.

i. To satisfy CAA § 209(b)(1)(C), California must demonstrate not just that its regulations are technologically feasible, but that they are consistent in all respects with CAA § 202(a).

For its assertion that CAA § 209(b)(1)(C) is limited to an assessment of the technological feasibility of its standards, California relies primarily on *Motor & Equip. Mfrs. Ass'n v. Nichols*, 142 F. 3d 449 (D.C. Cir. 1998) ("*MEMA II*"),[25] and in particular on its statement that "[i]n the waiver context, section 202(a) 'relates in relevant part to technological feasibility and to federal certification requirements.'" *Id*. at 463 (quoting *Ford Motor Co. v. EPA*, 606 F.2d 1293, 1296 n. 17 (D.C. Cir.1979) ("*Ford*"), and citing *Motor and Equipment Mfrs. Ass'n, Inc. v. EPA*, 627 F. 2d 1095, 1101, 1111 (D.C. Cir. 1979) ("*MEMA I*")). *MEMA II* is inapposite for two reasons.

First, its asserted interpretation of CAA § 209(b)(1)(C) is dicta and does not constitute controlling precedent because the meaning of CAA § 209(b)(1)(C) was not at issue in that case. *MEMA II*, 142 F.3d at 463 ("Petitioners do not contend that California's OBD II regulations directly violated section 202(a)."). The relevant part of that case dealt instead with the question of whether CAA § 202(m) was incorporated by reference into CAA § 202(a), thus requiring (according to the petitioners there) that California's program be consistent with CAA § 202(m). The court rejected that contention on the grounds that California should have broad discretion to adopt alternative motor vehicle standards, CAA § 209(b) "does not require California to establish perfect compliance with the CAA to obtain a waiver," and "it would appear virtually impossible for California to exercise broad discretion if it had to comply with every subsection of section 202 that cross-referenced subsection (a)." *Id*. at 463-64. The court's reasoning did not depend on its observation that CAA § 209(b)(1)(C) has been interpreted to relate to "technological feasibility and to federal certification requirements."

---

[25] CARB Support Document at 30.

In support of its suggestion that CAA § 209(b)(1)(C) should be limited to consideration of technological feasibility, *MEMA II* quoted *Ford*, 606 F. 2d at 1296 n. 17, and cited *MEMA I*, 627 F. 2d at 1111. Neither of those decisions, however, establishes controlling precedent on the meaning of CAA § 209(b)(1)(C).

Ford dealt with "only one question: whether vehicles which conform to [California] standards but not to the applicable federal ones may be sold outside of California." 606 F.2d at 1294-95. The court's decision did not rely on the meaning of CAA § 209(b)(1)(C). In note 17, the court stated that the pre-1977 version of the CAA expressly required consideration of "technological feasibility" in the waiver provision and that that provision "was transferred in [the 1977 CAA Amendments] to [CAA § 202(a)]." *Ford*, 606 F.2d at 1296 n. 17. However, that observation was made in passing and played no part in the court's decision. Moreover, the *Ford* court did not conclude that, because the express "technological feasibility" provision was carried forward into CAA § 202(a), CAA § 209(b)(1)(C) should be construed as being limited to consideration of technological feasibility. And, even if the lone footnote in *Ford* mentioning the issue were meant to suggest that interpretation, the court provided no analysis or explanation as to how the generic requirement in the current CAA § 209(b)(1)(C) to consider consistency with CAA § 202(a) can or should be interpreted to be limited to consideration of technological feasibility. Thus, for multiple reasons, that lone footnote in *Ford* cannot represent binding precedent as to the meaning of CAA § 209(b)(1)(C).

As for *MEMA I*, it involved a challenge to an EPA preemption waiver for California in-use maintenance regulations and, in particular, whether those regulations are emissions standards or enforcement procedures. Petitioners contended that the in-use maintenance regulations were emissions standards, for which EPA was required to consider all three criteria specified in CAA § 209(b)(1)(A), (B), and (C). EPA, by contrast, contended that the regulations were enforcement procedures, for which only CAA § 209(b)(1)(C) had to be considered in granting the waiver. *MEMA I*, 627 F.2d at 1111-14. The meaning of CAA § 209(b)(1)(C) was thus not at issue in the case. Instead, the controversy centered on whether EPA had to consider just one or all three of the CAA § 209(b)(1) criteria. In that context, the court observed in passing that EPA shall not grant a waiver if "the standards and accompanying enforcement procedures are inconsistent with section 202(a) of the Clean Air Act, which as indicated requires the Administrator's standards to be technologically feasible." *Id*. at 1111. That statement provided context for the decision but had no direct bearing on the issue being litigated or on the court's resolution of that issue—and in any event, that statement does not assert that the requirements of CAA § 209(b)(1) are *limited* to technological feasibility. That dictum was also purely conclusory, with no supporting legal analysis or any explanation as to how the generic obligation in CAA § 209(b)(1)(C) for an inquiry into consistency with CAA § 202(a) can or should be construed as being limited to an inquiry into technical feasibility (if that meaning was even intended). *MEMA I* therefore likewise does not establish that CAA § 209(b)(1)(C) is limited to technological feasibility.

Regardless, construing CAA § 209(b)(1)(C) to be limited to consideration of only technical feasibility is not the best interpretation of that provision. The text of CAA § 209(b)(1)(C) facially requires an inquiry into whether the proffered California standards "are not consistent with [CAA § 202(a)]." The technical feasibility requirement appears in CAA § 202(a)(2), but Congress required that California comply with all of 202(a), not just part of 202(a)(2). If Congress wanted to limit the inquiry to technical feasibility, it knew how to say that. Thus, while technological feasibility is one factor that EPA must consider when setting standards under CAA § 202(a), that section prescribes numerous additional obligations with which EPA must also comply. One obvious example is the obligation in CAA § 202(a)(1) for EPA to set standards for the full useful life of affected engines or vehicles. The phrase "not consistent with [CAA § 202(a)]" cannot and should not be interpreted to encompass technological feasibility and to exclude other CAA § 202(a) requirements, such as the obligation to set standards "applicable to such vehicles and engines for their useful life." CAA § 202(a)(1).

In sum, California's contention that the scope of EPA's inquiry under CAA § 209(b)(1)(C) is limited to technological feasibility is incorrect. The cases that California cites do not authoritatively interpret the scope of CAA § 209(b)(1)(C), and that provision on its face cannot and should not be interpreted to have such a limited scope.

ii. The ZEV component of the ACF program is not consistent with CAA § 202(a) because a ZEV mandate is not authorized under CAA § 202(a).

The most fundamental authority afforded to EPA under CAA § 202(a) and that section's principal function is to allow the Agency, under prescribed circumstances, to set emissions standards for new motor vehicles and motor vehicle engines. EPA's obligation to ascertain whether a state rule for which California seeks a preemption waiver is "consistent with" CAA § 202(a), must accordingly include an assessment of whether the rule exceeds the limited authority to set emissions standards that CAA §202(a) contemplates. If so, the California rule cannot be determined to be "consistent with" CAA § 202(a) and a preemption waiver must be denied. While California may certainly prescribe motor vehicle emissions standards that differ from those promulgated by EPA, it cannot obtain a preemption waiver for motor vehicle emissions standards that would exceed the carefully delineated authority to set emissions standards that CAA §202(a) affords, as such standards are necessarily inconsistent with the limitations that CAA §202(a) imposes.

As a simple example, CAA § 202(a)(2) requires EPA to consider the "cost of compliance" when setting motor vehicle emissions standards. A failure by California to consider the cost of compliance when establishing a given motor vehicle emissions standard would disqualify that standard from obtaining a preemption waiver because EPA could not conclude that the standard is consistent with the express CAA § 202(a) requirement that costs must be considered.

Applying that principle to the ACF program, EPA cannot grant the requested preemption waiver for the program because one of the core components of the program – the ZEV mandate – is not consistent with CAA § 202(a). In its comments on EPA's recently promulgated GHG emissions standards for model year 2027 and later light- and medium-duty vehicles and in its comments on EPA's latest proposed standards for medium and heavy-duty trucks, API provided detailed analyses as to why a ZEV mandate is impermissible under CAA § 202(a).[26] API respectfully incorporates those analyses here. In simple terms, the ZEV component of the ACF program—like the ZEV mandate in EPA's GHG emissions standards—would effectively mandate a fundamental transformation of the affected vehicle fleet from ICE powertrain technology to BEVs or, to a far lesser extent, other ZEV technologies (such as vehicles powered by certain fuel cells). That mandate vastly exceeds the limited authority to set emissions standards that Congress envisioned in CAA § 202(a)(1).

To be clear, requiring a shift from ICE powertrains to ZEV powertrains would be truly transformative.[27] For example, BEVs require fundamentally different vehicle technologies than those used in conventionally fueled vehicles – e.g., electric motors instead of internal combustion engines, batteries to store power rather than on-board fuel tanks, etc. BEVs also rely on a wholly different infrastructure (e.g., electric power generation and distribution, charging stations, battery manufacturing) – much of which does not yet exist or exists only in limited form. And switching to BEVs will fundamentally change the way that vehicles are used, such as by requiring careful scheduling of vehicle operations to accommodate the relatively long periods needed to adequately charge the vehicles. Lastly, a ZEV mandate would produce widespread effects on the national economy, such as the reduced need for oil and gas production and gas processing, and changes to petroleum refining and distribution. Such changes are extraordinary and far more expansive than those required by prior medium and heavy-duty vehicle standards, which could be met by properly designed ICE vehicles.

The U.S. Supreme Court has concluded that such an "extraordinary" claim of agency authority can be supported only when there is "clear congressional authorization." *West Virginia v. EPA*, 142 S.Ct. 2587, 2609 (2022). CAA § 202(a) contains no such clear authorization. At its core, CAA § 202(a) authorizes EPA to establish "standards applicable to the emission of any air pollutant from any class or classes of new motor vehicles or new

---

[26] Letter from W. Hupman, Vice President – Downstream, API, to The Honorable Michael Regan, Administrator, U.S. Environmental Protection Agency, Re: Multi-Pollutant Emissions Standards for Model Years 2027 and Later Light-Duty and Medium-Duty Vehicles (Docket ID No. EPA-HQ-OAR-2022-0829) (July 5, 2023) ("API LDV Comments"), docketed at EPA-HQ-OAR 2022-0829-0641; Letter from W. Hupman, Vice President – Downstream, API, to The Honorable Michael Regan, Administrator, U.S. Environmental Protection Agency, Re: Greenhouse Gas Emissions Standards for Heavy-Duty Vehicles – Phase 3 (Docket ID No. EPA-HQ-OAR-2022-0985-1617) (June 16, 2023) ("API HD 3 Comments"). See, also, Brief for Private Petitioners, *Western States Trucking Ass'n, Inc., et al. v. EPA*, No. 23-1143 (D.C. Cir.) at 28-34. We incorporate by reference all elements of those documents into these comments.

[27] Indeed, that is a driving purpose of California's efforts. See, e.g., Building the Electricity Grid of the Future: California's Clean Energy Transition Plan ("California is focused on transforming the transportation sector" by ending "sales of new gasoline powered vehicles by 2035") https://www.gov.ca.gov/wp-content/uploads/2023/05/CAEnergyTransitionPlan.pdf.

motor vehicle engines, which in [the Administrator's] judgment cause, or contribute to, air pollution which may reasonably be anticipated to endanger public health or welfare." Because that provision includes no statement—clear or otherwise—that EPA may mandate a fundamental shift in propulsion technology, it does not afford EPA the authority to impose emissions limitations that effectively will require manufacturers to replace ICE vehicles with electric vehicles. And for the same reason, CAA §209(b)(1)(C) prevents California from obtaining a preemption waiver for its own ZEV mandate, because allowing that kind of transformative regulation would be inconsistent with the limited scope of emissions regulation that CAA §202(a) contemplates.

Other longstanding tools of statutory construction confirm that CAA § 202(a) cannot be reconciled with regulations that would mandate a market-wide shift from ICE vehicles to ZEVs. First, EPA may regulate a class of motor vehicles under CAA § 202(a)(1) only if emissions from that class of vehicles "cause, or contribute to, air pollution which may reasonably be anticipated to endanger public health or welfare." Because ZEVs have zero tailpipe emissions of any regulated air pollutant, CAA § 202(a) does not afford EPA any authority to regulate the production and use of ZEVs, let alone their sale, and does not authorize EPA to waive preemption of California regulations with the same effect.[28] For the same reason, the statute does not afford EPA any authority to include ZEVs as part of a class of regulated vehicles that have tailpipe emissions and to regulate them as part of that class, or to waive preemption of California regulations that take that approach.

Second, CAA § 202(e) – entitled "New power source or propulsion systems" – prescribes additional requirements that EPA must meet when regulating new motor vehicles employing a new power source or propulsion system. EPA first must determine whether emissions from the new power source or propulsion system cause or contribute to air pollution that endangers public health or welfare. If the answer is yes, EPA must then establish new emissions standards for the new power source or propulsion system or, alternatively, determine that appropriate standards have already been established. ZEVs clearly constitute a new power source or propulsion system. But because ZEVs in and of themselves do not have tailpipe greenhouse gas emissions, neither EPA nor California can reasonably conclude that greenhouse gas emissions from ZEVs cause or contribute to the endangerment finding that authorizes the regulation of greenhouse gases under CAA § 202(a) in the first instance. EPA accordingly has no need or authority to impose emissions standards on ZEVs prior to certifying them and cannot find that a California program that mandates ZEVs is consistent with CAA § 202(a).

Third, given the fundamental differences between ICE vehicles and ZEVs, it would be arbitrary and capricious for EPA to conclude that those two types of vehicles belong to the same class of vehicles for purposes of establishing appropriate standards under CAA § 202(a). By the same token, EPA may not approve a preemption waiver for a program that

---

[28] To be sure, ZEV's are not emissions free. Their production, use, and disposal generate emissions. So does the generation of electricity used to power them. But California does not purport to regulate those emission through ACF.

inappropriately regulates ICE vehicles and ZEVs as part of the same class, as any such program is contrary to the regulatory scheme that CAA § 202(a) contemplates.

Lastly, ACF (like EPA's latest LDV and HDV rules) treats ZEVs as if their powertrain were an emissions control technology and then mandates the use of that purported emissions control technology to control air pollutant emissions from ICE vehicles. That is contrary to CAA § 202(a), which authorizes EPA to set emissions standards but does not authorize EPA to mandate the use of any particular emissions control technology in meeting those standards.

As noted above, a fuller explanation of these legal principles and the limits of EPA's authority under CAA § 202(a) is included in API's comments on EPA's GHG emissions standards for model year 2027 and later light- and medium-duty vehicles and in its comments on the "Heavy-Duty Phase 3" rule, and those comments are incorporated by reference here and attached. In sum, EPA may not grant a preemption waiver to California for a program that would exceed EPA's own regulatory authority under CAA § 202(a).

C. ACF is not consistent with section 202(a) because CARB has failed to provide the four-years' lead time required to adopt emission standards for HDVs.

Section 202(a)(3)(C) of the Clean Air Act provides that "[a]ny standard . . . shall apply for a period . . . beginning no earlier than the model year commencing 4 years after such revised standard is promulgated." California failed to provide that lead time here, as ACF's requirements began in 2024, the year after its promulgation. CARB reasons that this lead time is unnecessary for regulations promulgated by California, rather than the federal government. But that conclusion contradicts the plain text of the Clean Air Act. Section 209(b) provides that a waiver cannot be granted if the "State standards and accompanying enforcement procedures are not consistent with" §202(a). 42 U.S.C. § 7543(b)(1)(C). And to be "consistent with" a statutory provision means to comply with that provision.

II. The ZEV mandate is not an emissions "standard" under the Clean Air Act.

Just as the EPA may not promulgate an ZEV mandate under section 202(a) of the Clean Air Act, so too California cannot pass off an ZEV mandate as an emissions standard. California may impose a "standard relating to the control of emissions from new motor vehicles or new motor vehicle engines"—but not a wholesale ban on an engine type. 42 U.S.C. § 7543(a). "[O]f course almost anything could constitute" a standard; "shorn of all context, the word is an empty vessel." *West Virginia v. EPA*, 597 U.S. 697, 732 (2022). But properly understood in context, an emission standard is a regulation that requires engines "to operate more cleanly" —not a regulation that "forc[es] a shift throughout [the trucking industry] from one type of energy source to another." *Id.* at 728. The "major-questions doctrine" demands that "standard" be read more narrowly. A ZEV mandate would reshape the trucking industry, forcing fleets to use fundamentally different technologies and to rely on a fundamentally different infrastructure. Given the extraordinary breadth and importance of the claimed assertion of power, CARB "must point to clear congressional authorization for the power it claims." *Id.* at 723. But the "vague statutory grant" conferred by the term "standard" in the Clean Air Act "is not close to the sort of clear authorization required by [the Supreme Court's] precedents." *Id.*

III. California has not demonstrated that the 100% ZEV mandate is "needed" to address any "compelling and extraordinary conditions" in California.

CAA § 209(b)(1)(B) instructs EPA that it shall not grant a preemption waiver if it determines that California "does not need such State standards to meet compelling and extraordinary conditions." CAA § 209(b)(1)(B).[29] California presents two alternative arguments as to why it believes the ZEV component of the ACF program is needed to meet compelling and extraordinary conditions.

First, California argues that the inquiry under CAA § 209(b)(1)(B) requires "an inquiry regarding California's need for separate new motor vehicle and nonroad engine and equipment emissions control ***programs***, respectively, to meet compelling and extraordinary conditions, and not whether any given standard is necessary to meet such conditions." CARB Support Document at 24 (emphasis added). Under that whole-program approach, California argues that the state "continues to struggle with the severe air pollution conditions that Congress considered "compelling and extraordinary" when it enacted the waiver provision in 1967." *Id*. at 25. California asserts that "particularly in the South Coast and San Joaquin Valley Air Basins, [it] continues to experience some of the worst air quality in the nation" and that "EPA has always agreed that California needs a separate program to address these compelling and extraordinary conditions." *Id*. at 25-6.

Second, and alternatively, California argues that "[e]ven if EPA applies a narrower, standards-specific inquiry (as some waiver opponents may argue is required), the record demonstrates that California 'needs' the ACF regulation to address California's compelling and extraordinary conditions." *Id*. at 26. California asserts that "the motor vehicles and off-yard trucks regulated by the ACF regulation are significant sources of harmful air pollutants, especially oxides of nitrogen (NOx), fine particulate matter (PM2.5) and greenhouse gases." *Id*. at 26-7. California further asserts that "[t]he ACF Regulation is projected to cumulatively reduce statewide emissions by approximately 146,872 tons of oxides of nitrogen (NOx), 6,875 tons of fine particulate matter (PM2.5), and 327,000 million metric tons of greenhouse gases (GHGs) from 2024 to 2050." *Id*. at 27. California concludes that "EPA has consistently found that California "needs" emissions standards to address the compelling and extraordinary conditions resulting from criteria pollutants described above, and has also found that this includes emissions standards that limit emissions of GHGs because of the connection between GHG emissions and the formation

---

[29] As noted above, a waiver decision for the nonroad component of the ACF program must be considered under the criteria established in CAA § 209(e) rather than the criteria in CAA § 209(b). CAA § 209(e)(2)(ii) states that a waiver should not be issued when "California does not need such California standards to meet compelling and extraordinary conditions." That criterium is identical to the criterion for motor vehicles at CAA § 209(b)(1)(C). Thus, the analysis presented here for CAA § 209(b)(1)(C) applies equally to CAA § 209(e)(2)(ii).

of harmful criteria pollution, and therefore has no basis to find that the ACF regulation is not needed under Section 209(b)(1)(B) or 209(e)(2)(A)(iii)." *Id*. (internal cites omitted).

With regard to GHG emissions and global climate change, California asserts that it faces compelling and extraordinary conditions because, among other things, "the existing and expected impacts of climate change specifically occurring in California, include[e] increases in ground-level ozone, sea-level rise and coastal erosion, variability in precipitation and reductions in water supply from reduced snowpack, increased frequency of droughts and land subsidence, lower agricultural crop yields, increased susceptibility of forests to wildfires, increased mortality risks to people due to extreme heat events, and flooding of California's coastal transportation infrastructure." *Id* at 29 (internal cites omitted). According to California, "[t]hese impacts constitute "compelling and extraordinary conditions" under any reasonable interpretation of Sections 209(b)(1)(B) and 209(e)(2)(A)(ii)." *Id*.

Even under a "narrower" standard-by-standard approach, California asserts that "medium- and heavy-duty vehicles and the fossil fuels that power them are the largest contributors to emissions greenhouse gases (GHGs), accounting for approximately 50 percent of statewide GHG emissions, when accounting for transportation fuel production." *Id.* at 29. Because "[t]he ACF regulation requires substantial reductions in those emissions, culminating in the elimination of tailpipe GHG emissions from new vehicles in the covered categories" California concludes that "[i]t cannot credibly argued that eliminating harmful emissions from sources that substantially contribute to California's compelling and extraordinary conditions are not needed." *Id*. at 29-30.

California's assertion that the ZEV component of the ACF program satisfies CAA § 209(b)(1)(B) is flawed for three reasons.

A. CAA § 209(b)(1)(B) must be applied to the particular standards for which a preemption waiver is sought, and not to California's motor vehicle emissions control program as a whole.

California's argument that CAA § 209(b)(1)(B) should be applied to the state's motor vehicle emissions control program as a whole and not to the ACF component of that program cannot be reconciled with the statutory text. The statute explicitly refers to "such State standards," CAA § 209(b)(1)(B), which plainly is a reference to the particular standards for which California seeks a preemption waiver. Congress understood when it enacted CAA § 209(b) that California's motor vehicle emissions control program would be an evolving program that would be revised as relevant factors (such as motor vehicle technology and California's air pollution problems) changed over time. The term "such State standards" thus naturally refers to the particular components of California's program that are being developed over time (and for which a preemption waiver is sought), not to the program as a whole.

CAA § 209(b)(1)'s requirement that California's standards must be "in the aggregate" at least as stringent as EPA's standards does not change that analysis. The "in the aggregate" requirement goes to the overall health and environmental protectiveness of California's program. It allows California to have standards that are different than EPA's but provides a backstop to make sure the differences are not so great as to compromise public health or welfare in California. By contrast, CAA § 209(b)(1)(B)'s requirement that the particular standards at issue must be needed "to meet compelling or extraordinary conditions" has nothing to do with the protectiveness of California's program as a whole. It would defy common sense to read the statute's whole-program effectiveness requirement to somehow also imply that the need for particular standards to address compelling and unique local conditions should also be evaluated on a program-wide basis. Indeed, a whole-program application of the CAA § 209(b)(1)(B) criteria would have the irrational effect of allowing California to implement certain program requirements that are not needed to address compelling and extraordinary local conditions as long as, on balance, the program as a whole could be described as necessary to address such conditions. That blank-check approach is not supported under the statute.

California's claim that "such State standards" refers to the program as a whole also conflicts with California's own interpretation of CAA § 209(b)(1)(C). Again, that subsection provides that EPA should not grant a preemption waiver when "such State standards and accompanying enforcement procedures are not consistent with [CAA § 202(a)]." CAA § 209(b)(1)(C). As explained in Section I above, California asserts that that provision should be narrowly interpreted to require showing only that California's standards are technologically feasible. CARB Support Document at 30.

For the reasons explained in Section I, that narrow interpretation is not supportable under the plain text of CAA § 209(b)(1)(C). But under either the plain meaning of the statutory text or California's incorrect interpretation, the term "such State standards" in CAA § 209(b)(1)(C) necessarily requires an assessment for *each new or revised standard* for which California seeks a preemption waiver of whether *that new or revised standard* is technologically feasible. In other words, even under California's understanding of CAA § 209(b)(1)(C), "such State standards" in that subsection plainly refers to the specific standards for which California seeks preemption, as it would make little sense to try to evaluate technological feasibility or adequate lead time for the entire program as a whole. So too for CAA § 209(b)(1)(B). In that subsection as in the following one, "such State standards" refers to the particular new or modified standard for which California seeks a waiver.

In the ongoing litigation in the D.C. Circuit over the validity of EPA's preemption waiver for California's ACC I program, a coalition of industry petitioners has likewise challenged EPA's "whole-program" interpretation of CAA § 209(b)(1)(B). API incorporates by reference the arguments on this issue that those petitioners have made in that litigation.[30] API also

---

[30] In particular, the following excerpt from the Industry Petitioner brief is incorporated by reference here: Brief for Private Petitioners, *State of Ohio v. EPA*, No. 22-1081 (D.C. Cir.) at 45-9.

incorporates similar arguments that it made in its amicus brief in support of industry petitioners' application for Supreme Court review of the D.C. Circuit's ACC I decision.[31]

B. California has not demonstrated that it "needs" the ZEV component of the ACF program to address its nonattainment problems.

In the alternative, California contends that even if CAA § 209(b)(1)(B) requires showing that California needs the particular new or revised standards at issue to address compelling and extraordinary conditions, California "needs" the ZEV component of the ACC II program because the program will produce reductions in the emissions of air pollutants that contribute to the state's ongoing nonattainment problems in the South Coast basin and other areas of the state.

But California has not shown that those emissions reductions are meaningful. For California to "need" a standard to address compelling and extraordinary conditions, that standard must meaningfully address those conditions. To need something means to "require" it.

CARB asserts that ACF will reduce statewide tailpipe emissions by 146,872 tons of NOx and 6,875 tons of fine particulate matter ($PM_{2.5}$) between 2024 to 2050. CARB Support Document at 27; Final Environmental Analysis at 40. Even taking those numbers on their face, that equates to a mere 5,615 fewer tons of NOx per year—or 5.7% of the 98,024 tons of NOx released in California by vehicles each year. For $PM_{2.5}$, that equates to 264 fewer tons per year—or 3% of the total 7,833 tons of $PM_{2.5}$ released in California by vehicles each year. [32] Notably, CARB fails to put these reductions in terms of total NOx or $PM_{2.5}$ concentrations or otherwise explain how these reductions would lead to a meaningful improvement in air quality in California. And these numbers do not account for the upstream emissions from, for example, the additional electricity generation required to support a BEV trucking fleet.

Either way, the mere fact that the ZEV component of the program will produce some emissions reductions is not sufficient to demonstrate that that part of the program is "needed" under CAA § 209(b)(1)(B). A program may not be "needed," for example, if there are other regulatory options that would achieve the same objective, but at lower cost.[33]

---

[31] Brief for *Amicus Curiae* American Petroleum Institute in Support of Petitioners, *Diamond Alternative Energy, LLC v. EPA*, No. 24-7 at 19-22.

[32] *See* CARB, *CEPAM2019v.103 – Standard Emission Tool*, https://ww2.arb.ca.gov/applications/cepam2019v103-standard-emission-tool. To obtain the total emissions for NOx and PM2.5, select "annual average," "2023," and "statewide." The tons per day for "total on-road motor vehicles" is multiplied by 312 operating days, the same assumption adopted by CARB in converting from tons per day into annual emissions. *See* Final Environmental Assessment at 40, n.32.

[33] "Multi-Technology Pathways To Achieve California's Greenhouse Gas Goals: Light-Duty Auto Case Study," prepared for Western States Petroleum Association by Ramboll US Consulting, Inc., May 31, 2022.

The ZEV program is a drastic regulatory action. It will ban the sale of new medium and heavy-duty vehicles powered solely by fossil-derived fuels and require a fundamental shift in drivetrain technology. As California has itself said, and as explained in Section I.B., above, the program would be truly transformative in several respects. It also would be unprecedented in scope. In fact, by imposing a zero-tailpipe emissions mandate, it represents the ultimate regulatory intervention with regard to air pollutant emissions from medium and heavy-duty vehicles.

But in its waiver application, California failed to identify other regulatory options to produce relevant criteria pollutant emissions reductions, nor has it attempted to weigh the advantages and disadvantages of such alternatives against the ZEV program or provide a reasoned explanation as to why the ZEV program should be implemented instead of available alternatives. In other words, California failed to show that the ZEV component of the ACC II program is "needed" to address the state's nonattainment problems.[34]

Because the record that California prepared in support of its proposed preemption waiver does not demonstrate that the ZEV program is needed, EPA must deny the state's waiver request pursuant to CAA § 209(b)(1)(B).

C. Any unique risks to California from global climate change do not constitute "compelling and extraordinary" conditions warranting a preemption waiver.

California also has not shown that the state faces "compelling and extraordinary" conditions that cause adverse effects to public health and the environment attributable to anthropogenic global climate change.

As an initial matter, the statutory term "extraordinary" refers to local pollution, not globalized issues like climate change. Extraordinary means, in simplest terms, not ordinary—"going beyond what is usual, regular, or customary." *Merriam Webster*. A condition is extraordinary only if it is different from that faced elsewhere. The Clean Air Act's structure and operation confirm that focus on local conditions. Congress enacted a baseline of preemption: "*No State or any political subdivision thereof* shall adopt or attempt to enforce any standard relating to the control of emissions from new motor vehicles." 42 U.S.C. § 7543(a). Against that baseline Congress adopted an exception for California to adopt more stringent standards. Implicit in that exception is the limitation that these standards be necessary to address local conditions. Otherwise, a single state could subvert federal efforts to address federal problems. Reflecting that local focus, section 177 allows other states to adopt California's standards to combat certain criteria pollutants as needed to address pollutants within their borders. 42 U.S.C. § 7507. History likewise affirms that understanding. At the time the Clean Air Act was passed, California suffered from serious smog problems due to localized pollution, and Congress recognized that

---

[34] We note that the lack of a comprehensive analysis of alternative regulatory approaches also renders the ACF program arbitrary and capricious, which is a separate and independent reason that EPA should not grant a preemption waiver. CAA § 209(b)(1)(A).

California may need different—but similarly protective—standards to respond to those local conditions.

Global climate change is not a localized condition but a global phenomenon, and worldwide greenhouse gas emissions are among the causes contributing to worldwide effects, regardless of where the emissions took place. While the effects of global climate change may not be identical from state to state or region to region, they are all a product of (among other things) the same global atmospheric pool of greenhouse gas emissions.

According to the IPCC, global anthropogenic greenhouse gas emissions in 2019 were 59±6.6 Gt CO2e, with global emissions continuing to rise on a year-to-year basis.[35] California predicts that the ACF program will result in 327,000 million metric tons of GHG emissions reductions from 2024 to 2050." *Id*. at 27 Even if accurate, that reduction cannot reasonably be expected to translate to a proportionate reduction to the effects of global climate change that California asserts it incurs as a result of global emissions. As a result, the estimated greenhouse gas emissions reductions resulting from the ACC II program cannot be described as "need[ed]" to address compelling and extraordinary conditions under CAA § 209(b)(1)(B), and so EPA must deny California's preemption waiver request.

Notably, it is implicit in the word "need" that the California standards for which the state seeks a preemption waiver would have some material effect in alleviating the claimed compelling and extraordinary conditions that the standards are designed to address. By no measure, including those set forth by California, would the ACF program have any such an effect on global climate change or its potential impacts on the State of California.

Indeed, EPA has previously recognized that California's standards "will not meaningfully address global air pollution problems posed by GHG emissions." 84 Fed. Reg. 51,342. GHGs "are well-mixed throughout the global atmosphere, such that their concentrations over California and the U.S. are substantially the same as the global average." *Id.* at 51,330. "The number of motor vehicles in California . . . is not a significant percentage of the global vehicle fleet and bears no closer relation to the levels of GHG in the atmosphere over California than any other comparable source or group of sources of GHG anywhere in the world." *Id.* Given the global nature of GHG emissions, California's attempts to reduce emissions on its roads would "likely [result in] no change in temperatures or physical impacts from anthropogenic climate change in California." *Id.* at 51,341.

IV. California has arbitrarily failed to consider the lifecycle emissions of ZEVs.

EPA may not waive preemption if California's determination that its standards are "at least as protective of public health and welfare as applicable Federal standards" is "arbitrary and capricious." 42 U.S.C. § 7543(b)(1). California has arbitrarily failed to consider the lifecycle emissions of ZEVs, fatally undermining its conclusion that a shift to ZEVs will protect public

---

[35] Climate Change 2023: Synthesis Report, United Nations Intergovernmental Panel on Climate Change, at 44.

health and welfare. CARB reasons that an ZEV mandate is "protective of public health and welfare" because ZEVs "emit no tailpipe pollution." CARB Support Document at 24. But significant emissions result from the production of ZEVs and the production of the electricity needed to power BEVs. Yet CARB utterly failed to "account for upstream emissions associated with producing and delivering the fuel or energy source to vehicles" or producing the ZEVs. Resolution 23-13 at 24. That failure makes California's assessment of ACF arbitrary and capricious.

V. CAA § 209(b) violates the Constitutional guarantee of equal sovereignty among the states.

The clear effect of CAA § 209(b) is to allow (in certain circumstances) only one state – California – to set motor vehicle standards. No other state is granted similar authority. In limited situations other states may adopt and implement motor vehicle standards that are "identical to the California standards" in lieu of otherwise applicable federal standards. CAA § 177(1). But California alone among the states has the authority to set such standards in the first instance. That disparate treatment of California renders CAA § 209(b) unconstitutional because it violates the "fundamental principle of equal sovereignty among the States." *Shelby County, Ala. v. Holder*, 570 U.S. 529, 544 (2013) (cleaned up). Put simply, the Constitution does not permit either Congress or the EPA to authorize one and only one state to set its own motor vehicle emissions standards.

That uneven treatment is exacerbated by an interpretation of section 209(a) that counts global climate change as a "compelling and extraordinary condition" that California can address with its own standards. Global climate change is a national and global issue, not one localized to California. Yet California seeks to be the only state that is allowed to adopt a special solution to this problem that affects all states. It is one thing for Congress to allow a single state, California, to address its own "extraordinary" local conditions. Whatever one might think about such a regime, it flies in the face of equal sovereignty to grant only a single state the authority to adopt regulations directed at a global issue. Consequently, EPA has no authority to waive the otherwise comprehensive federal preemption of state motor vehicle emissions standards under CAA § 209(a).

That constitutional flaw was previously raised by a coalition of state petitioners in the litigation in the D.C. Circuit over the validity of EPA's preemption waiver for California's ACC I program. While the D.C. Circuit rejected that challenge, the states have filed a pending petition for certiorari seeking Supreme Court review of the D.C. Circuit's erroneous decision. *See Ohio v. EPA*, 98 F.4th 288 (D.C. Cir. 2024), *pet. for cert. filed*, No. 24-13 (U.S. filed July 9, 2024). API endorses the equal sovereignty arguments presented by those state petitioners in the D.C. Circuit and in their petition for certiorari, and incorporates by reference their additional arguments in these comments.[36]

---

[36] In particular, the following excerpts from the state petitioners' D.C Circuit briefs are incorporated by reference here: (1) Brief for Petitioners States of Ohio, et al., State of Ohio v. EPA, No. 22-1081 (D.C. Cir.) at 11-

VI. ACF violates the Dormant Commerce Clause.

The Dormant Commerce Clause prohibits states from unduly burdening interstate commerce where "the burden imposed on [interstate] commerce is clearly excessive in relation to the putative local benefits." *Pike v. Bruce Church, Inc.*, 397 U.S. 137, 142 (1970); *see Nat'l Pork Producers Council v. Ross*, 598 U.S. 356, 403 (2023) (Kavanaugh, J., concurring in part) ("In today's fractured decision, six Justices of this Court affirmatively retain the longstanding *Pike* balancing test for analyzing dormant Commerce Clause challenges to state economic regulations.").

ACF unduly interrupts interstate commerce by significantly impeding the flow of interstate goods. Trucking is inherently an interstate industry, and California is a major port for goods set to be distributed across the country. ACF demands that all fleets operated in the state—even by out-of-state companies—be ZEVs. No other State imposes that same requirement. Under ACF, a company could transport cargo in an ICE truck all the way from Maine or Florida, only to have to switch that cargo to multiple ZEV trucks at the California border. That disruption is certain to significantly slow down fleets, reducing the amount of goods that can be transported and increasing prices for fleets and, in turn, consumers across the country. And the benefits are minimal. As explained above, ACF will not meaningfully remedy either global climate change or local pollution.

* * * * *

California seeks to go far beyond the onerous and unlawful standards promulgated by EPA. The State has not limited itself to regulating the types of trucks that manufacturers produce but the types of trucks that consumers are permitted to buy. And the State has imposed a 100% ZEV mandate that the EPA has rightly refused to implement. Those standards are a step too far.

RECOMMENDATIONS FOR EPA

EPA should not grant the 209(b) waiver of preemption from CARB as 1) the ZEV component of the ACF program is not consistent with CAA § 202(a), 2) a ZEV mandate is not an emissions "standard" under the Clean Air Act, 3) California has not demonstrated that it needs the ACF program to address any "compelling and extraordinary conditions," 4) California has arbitrarily failed to consider lifecycle emissions of EVs, 5) CAA § 209(b) is invalid because it violates the Constitutional guarantee of equal sovereignty among the states, and 6) the ACF program violates the Dormant Commerce Clause. Lastly, EPA should not grant the waiver of preemption as it would be arbitrary and capricious because CARB has not adequately addressed policy concerns in the design of the ACF program.

13, 16-33; and (2) Reply Brief for Petitioners States of Ohio, et al., *State of Ohio v. EPA*, No. 22-1081 (D.C. Cir.) at 10-15.

Thank you for this opportunity to comment on this proposed waiver of preemption. If you have any questions, please feel free to contact me.

Sincerely,

Will Hupman

Will Hupman

C: Karl Simon, Director, Transportation and Climate Division, U.S. EPA Office of Transportation and Air Quality
William Charmley, Director, Assessment and Standards Division, U.S. EPA Office of Transportation and Air Quality
David Dickinson, Transportation and Climate Division, U.S. EPA Office of Transportation and Air Quality

Attachments of comments, brief, and a study that API incorporates by reference:

1. API comments to EPA (dated July 5, 2023) on Multi-Pollutant Emissions Standards for Model Years 2027 and Later Light-Duty and Medium-Duty Vehicles
2. API comments to EPA (dated June 16, 2023) on Greenhouse Gas Emissions Standards for Heavy-Duty Vehicles – Phase 3
3. WSPA comments to CARB (dated October 17, 2022) in response to ISOR draft which references the Ramboll study
4. Ramboll study (dated Feb. 1, 2021) "Multi-Technology Pathways to Achieve California's Air Quality and Greenhouse Gas Goals: Heavy-Heavy-Duty Truck Case Study"
5. Brief for *Amicus Curiae* American Petroleum Institute in Support of Petitioners, *Diamond Alternative Energy, LLC v. EPA*, No. 24-7 at 19-22

Attachment 1:

API comments to EPA (dated July 5, 2023) on Multi-Pollutant Emissions Standards for Model Years 2027 and Later Light-Duty and Medium-Duty Vehicles

American
Petroleum
Institute

Will Hupman
Vice President - Downstream
202-682-8463
HupmanWR@api.org

July 5, 2023

The Honorable Michael Regan
Administrator
U.S. Environmental Protection Agency
1200 Pennsylvania Avenue, NW
Washington, DC 20460

Filed electronically: https://www.regulations.gov

Re: Multi-Pollutant Emissions Standards for Model Years 2027 and Later Light- Duty and Medium-Duty Vehicles (Docket ID No. EPA-HQ-OAR-2022-0829)

Dear Administrator Regan:

The American Petroleum Institute appreciates the opportunity to submit the following comments on the proposed rule entitled "Multi-Pollutant Emissions Standards for Model Years 2027 and Later Light-Duty and Medium-Duty Vehicles." API is a national trade association representing all aspects of America's oil and natural gas industry. Our industry supports nearly 11 million U.S. jobs and accounts for approximately 8 percent of U.S. GDP. API has nearly 600 members, from fully integrated oil and natural gas companies to independent companies, comprising all segments of the industry, including producers, refiners, suppliers, retail marketing, pipeline operators, and marine transporters, as well as service and supply companies that support all segments of industry. As producers, suppliers and retailers of transportation fuels that power the more than 99% of all vehicles covered by the proposed rule, API members have a significant interest in, and will be heavily impacted by, the vehicle emissions standards that would be imposed by the proposed rule.

API's *Climate Action Framework* reflects our policies and goals, which are incorporated in our comments below. The challenge of meeting the world's growing need for energy while simultaneously ushering in a lower-carbon future is massive, intertwined, and fundamental. It is the opportunity of our time – governments, industries, and consumers must act to solve it together. Our industry is at the center of this challenge. We share the goal of reduced emissions across the broader economy and, specifically, those from energy production, transportation and use by society.

API supports technology-neutral policies at the federal level that drive GHG emissions reductions in the transportation sector, taking a holistic "all-of-the-above" approach to fuels, vehicles, and infrastructure systems. Such policies include: 1) federal fuel standards, 2) a full lifecycle approach to vehicle standards, 3) optimization of fuel/vehicle systems to improve efficiency, and 4) supportive infrastructure measures. We have significant concerns that the proposed rule does not include many of these elements. A few of these concerns are summarized below and our detailed comments are attached.

a. *API Supports Emission Reductions in the Transportation Sector.*

API is aligned with EPA's goal to address emissions in the transportation sector, and API members have similarly been working to advance the development, transmission, and use of lower carbon intensity and lower criteria pollutant fuels and technologies to provide choices for consumers.

b. *API Supports the Concepts of a Lifecycle Approach to Emissions Reductions.*

EPA should employ a technology-neutral approach that holistically encompasses the lifecycle emissions of both the fuel and the vehicle, rather than narrowly focusing on tailpipe emissions only.

c. *Both this Proposal and the Heavy-Duty Vehicle Proposal Miss the Mark.*

EPA's focus on zero-emission vehicle (ZEV) solutions, and specifically battery electric vehicles (BEVs), ignores fuel- and vehicle-based options that could better accomplish the agency's objectives to expeditiously achieve greater transportation sector-related emission reductions from the entire vehicle fleet (both new and in-use) at lower cost.

d. *EPA is not Taking a Realistic Approach.*

API is concerned that there is significant uncertainty with regard to technology and infrastructure readiness for the proposed 2027-2032 timeframe; further, the transportation industry will be competing for the same resources to successfully implement both the light- and medium-duty and heavy-duty proposed programs on the same timeframe.

e. *API Supports Consumer Choice for Vehicles.*

API is concerned that consumer choice and impacts are not fully reflected in EPA's analysis.

f. *Critical Minerals, Energy Security, BEV Supply Chains, Feasibility and Modeling.*

API is concerned that the proposed rule could negatively impact U.S. energy security if vehicle technologies are shifted to ZEVs at the exponential rate that the proposal would likely entail, as it would increase the country's dependence upon foreign sources for needed minerals forgoing the use of existing U.S. resources.

g. *Program Review.*

API recommends that EPA consider incorporating pre- and mid-program assessments into its final program, with sufficient lead time following review to adjust the standards if needed.

h. *Legal Concerns.*

API is concerned that EPA is exceeding its statutory authority under the Clean Air Act by, among other things, mandating the production of ZEVs.

i. *Additional Concerns.*

EPA must address several aspects of their analysis of vulnerabilities associated with critical minerals as outlined in Appendix A and related to cost, modeling, and assumptions as outlined in Appendix B.

j. *Response to EPA Request for Information on Particulate Matter Fuel Controls.*

In Appendix C we respond to EPA's request to review the Agency's rationale for considering fuels controls in a future rulemaking to reduce PM emissions. API finds the Agency has not appropriately considered all data and issues raised by a potential rulemaking. Furthermore, EPA needs to reconsider their analytical conclusions, limitations of SimDis, refinery modeling specifications, and that tire wear and entrained road dust related PM emissions are significant. Please note that due to the compressed comment period for such a complex request for information, coupled with the lack of an extension, API may supplement the docket.

Thank you for the opportunity to provide our comments on this important rulemaking. If you have any questions, please do not hesitate to contact me.

Sincerely,

Will Hupman

c: Mr. Michael Safoutin, Office of Transportation and Air Quality, Assessment and Standards Division

Detailed Comments of API on “Multi-Pollutant Emissions Standards for Model Years 2027 and Later Light- Duty and Medium-Duty Vehicles” (Docket ID No. EPA-HQ-OAR-2022-0829)

a. API Supports Emission Reductions in the Transportation Sector.

API appreciates EPA’s efforts to address transportation sector emissions. As detailed in the API Climate Action Framework[1], we support technology-neutral policies at the federal level that drive GHG emissions reductions in the transportation sector and our members have committed to delivering solutions that reduce the risks of climate change while meeting society’s growing energy needs. API members work to advance the development, transmission, and use of lower carbon intensity and lower criteria pollutant fuels and technologies to provide choices for consumers. Specifically, API members have made, and continue to make, significant investments in new technologies that reduce emissions in transportation, including:

GHG Emission Reduction

- Stand-alone production and coprocessing of bio-feedstocks to make renewable fuels.
- Manufacturing of low-carbon ethanol.
- Manufacturing of renewable natural gas from wastewater, landfill gas, and biodigesters at farms as fuel for compressed natural gas (CNG) vehicles.
- Production of blue and green hydrogen for transportation and stationary applications including building infrastructure.
- Direct air carbon capture.
- Carbon capture and sequestration of CO_2.
- Development of advanced plastics to meet auto industry standards and consumer expectations while mitigating environmental impact through emissions reduction and improved vehicle efficiency by light-weighting.
- Installation of electric vehicle charging stations.
- Installation of hydrogen fueling stations.

Criteria Pollutant Reduction

- Tier 3 gasoline sulfur standards
- MSAT II gasoline benzene standards
- Lower vapor pressure reformulated gasoline

API shares the goal of reduced emissions across the broader economy and, specifically, those from energy production, transportation and use by society. To achieve meaningful emissions reductions that meet the climate challenge, it will take a combination of policies, innovation, industry initiatives and a partnership of government and economic sectors. The

---

[1] https://www.api.org/climate.

objective is large enough that no single approach can achieve it.

b. API Supports the Concepts of a Lifecycle Approach to Emissions Reductions.

i. EPA should use a lifecycle assessment (LCA) approach vs. tailpipe only.

To effectively achieve emissions reductions in the transportation sector, technology-neutral solutions are needed, utilizing an approach that addresses fuels, vehicles, and infrastructure systems. This is best accomplished through holistic policy that encompasses the lifecycle emissions of both the fuel and the vehicle. This combination makes for the most effective reduction of transportation GHG emissions, as emissions occur at multiple stages of the lifecycle of internal combustion engine vehicles (ICEVs) and battery electric vehicles (BEVs) and the fuels used in them. Further, utilizing a lifecycle approach would enable quantification of the emissions associated with light- and medium-duty vehicles (LMDVs), and allow technologies to be identified that provide more expeditious and robust GHG emissions reductions.

Use of a lifecycle approach would better achieve the goals of the proposed rule, as it would allow the agency and stakeholders alike to fully identify and reduce transportation sector emissions and to identify and develop meaningful solutions. The reductions achieved by EPA's existing programs – including the Tier 3 Motor Vehicle Emissions and Fuel Standards, Heavy-Duty (HD) GHG Phase 2 standards, and HD engine and vehicle criteria pollutant standards – are due in large part to addressing emissions holistically, and utilizing all available and emerging technology to do so. The myopic focus on tailpipe emissions in the proposed rule essentially means that the rule would only address certain transportation emissions, while ignoring other sources of emissions and potential emissions reduction solutions. A lifecycle approach would allow EPA to quantify all of the emissions associated with LMDVs, and to mitigate those emissions more effectively.

EPA has set the GHG emissions standards as attribute-based, using vehicle footprint as the attribute. As per EPA, "footprint is defined as a vehicle's wheelbase multiplied by its average track width—in other words, the area enclosed by the points at which the wheels meet the ground. The standards are therefore generally based on a vehicle's size." In Draft Regulatory Impact Analysis (DRIA) Section 1.1.2, EPA states that "footprint does not have any relationship with tailpipe emissions from BEVs or any other zero-emission vehicle." Yet, the proposed footprint-based standards are based on a projected penetration rate of BEVs of greater than 50%. A footprint-based tailpipe emission standard where, for the majority of the fleet, there is "no relationship" between footprint and tailpipe emissions could drive undesirable behaviors. For example, the weight of BEVs increases as the footprint is increased. This increase in weight impacts the efficiency of larger BEVs. With BEVs on the same footprint curve as internal combustion engines (ICEs) (with a positive slope) in a tailpipe emission banking and trading system, larger BEVs will generate a larger credit relative to their footprint. This could incentivize the production of larger more inefficient BEVs, increasing the upstream electricity generation emissions. The largest potential credit generator based on the proposal would be large BEV trucks which are the most inefficient BEVs. While BEVs have zero tailpipe emissions, the upstream electricity production does generate GHG emissions. Analysis by Argonne National

Laboratory[2] showed that a current midsize sedan with 200-mile range could achieve 124 mile per gallon gasoline equivalent (MPGge) while a heavier and larger 400-mile range small sport utility vehicle (SUV) could achieve 88 MPGge. This corresponds to cradle-to-grave lifecycle emissions of ~160 and 250 g CO_{2eq} / mile, respectively. For comparison, the same analysis found that a current midsize hybrid ICE would generate ~270 g CO_{2eq} / mile, similar to the 400-mile range SUV. The emissions from the hybrid ICE could be further reduced with lower-emission fuels. Under the current proposal, the hybrid ICE from this example would generate tailpipe emissions of 190 g CO_2 / mile, while the BEVs would generate zero tailpipe emissions. EPA should consider a rulemaking that accurately accounts for all emissions in the lifecycle of a vehicle.

By EPA's own account,[3] transportation pollution has been reduced significantly since the passage of the Clean Air Act – new passenger vehicles are 98-99% cleaner for most tailpipe pollutants compared to the 1960s, new vehicle estimated real-world CO_2 tailpipe emissions are at a record low,[4] and U.S. cities have much improved air quality, despite ever increasing population and increasing vehicle miles traveled. Criteria pollutant emissions have been mitigated via engine and after-treatment system improvements as well as through fuel quality improvements (e.g., low sulfur gasoline and ultra-low sulfur diesel). As noted in a study prepared for the Transportation Energy Institute, criteria pollutants are well controlled with the existing fleet, and ICEV emissions will continue to be reduced into the future as the ICEV fleet becomes more efficient (especially as high-emitting vehicles are replaced in the existing fleet).[5]

These reductions are due in large part to addressing emissions holistically and utilizing all available and emerging technology to do so. Use of a lifecycle approach would better achieve the goals of the proposed rule, as it would allow the agency and stakeholders alike to fully identify and reduce transportation sector emissions and to identify and develop meaningful solutions. The myopic focus on tailpipe emissions in the proposed rule essentially means that the rule would only address certain transportation emissions, while ignoring other sources of emissions and potential emissions reduction solutions. A lifecycle approach would allow EPA to quantify all emissions associated with light- and medium-duty vehicles[6] and more effectively mitigate those emissions.

---

[2] Kelly, J. et al., "Cradle-to-grave lifecycle analysis of U.S. light-duty vehicle-fuel pathways: a greenhouse gas emissions and economic assessment of current (2020) and future (2030-2035) technologies", June 2022, ANL-22/27. https://greet.es.anl.gov/publication-c2g_lca_us_ldv.

[3] https://www.epa.gov/transportation-air-pollution-and-climate-change/history-reducing-air-pollution-transportation.

[4] 2022 EPA Automotive Trends Report – Executive Summary, December 2022, EPA-420-S-22-001. https://www.epa.gov/system/files/documents/2022-12/420s22001.pdf.

[5] "Decarbonizing Combustion Vehicles: A Portfolio Approach to GHG Reductions," study prepared for the Transportation Energy Institute by Stillwater Associates, July 2023. https://www.transportationenergy.org/research/reports/decarbonizing-combustion-vehicles-a-portfolio-approach-to-ghg-reductions/.

[6] EPA's proposed rule covers light-duty vehicles (i.e., less than 8,500 pounds gross vehicle weight rating) and medium-duty vehicles (i.e., up to 14,000 pounds GVWR), https://afdc.energy.gov/data/10380.

ii. Zero emission vehicles also have emissions impacts.

As with ICEVs, ZEVs[7] have carbon emissions impact associated both with their production and throughout their lifetime which EPA should incorporate in its analysis. While ZEVs can be an important part of a diverse transportation future to reduce emissions, they do produce GHG emissions. For instance, BEV production, use, and the disposal of BEV batteries, are not zero-emission activities. Further, all fuels – whether conventional fuels or electricity – have associated carbon emissions regardless of their source. A study conducted by Ricardo, which is included in a report by the Transportation Energy Institute,[8] concludes that BEVs "have higher embedded GHG emissions" and therefore carbon intensity of the electricity mix also plays a vital role in defining the magnitude of carbon emissions in this phase. While meaningful reductions have historically been accomplished by focusing on tailpipe emissions from the vehicle, the growing market share of different technologies that include significant upstream emissions warrant inclusion of those emissions in the standard.

We encourage the agency to not only acknowledge and address the emissions of ZEVs, but to also continue to study the impacts. Failure to do both would be arbitrary and capricious. As noted below in these comments, and in our comments on the Heavy-Duty GHG Phase 3 proposed rule,[9] we strongly recommend that EPA include both a readiness assessment prior to program implementation as well as a program review once implementation begins. There will be CO_2 emissions associated with the production and use of BEVs,[10] and it is important to address these emissions to provide a full picture of the emissions impacts and mitigation needs.

c. Both this Proposal and the Heavy-Duty Vehicle Proposal Miss the Mark.

i. EPA is missing millions of vehicles that will contribute to emissions.

API is concerned that this proposal, as well as EPA's Heavy-Duty proposed[11] GHG rule, seriously miss the mark with respect to reducing emissions from the transportation sector. The proposals focus heavily on ZEV technologies, and specifically BEVs, for reductions in the 2027 to 2032 timeframe. Yet, EPA is leaving emissions reductions on the table for existing LMDVs, given the lifespan of these vehicles, as well as new ICE vehicles that will be sold between now and 2032. According to Oak Ridge National Lab (ORNL)[12] there were over 105 million cars and 148 million light trucks in the U.S. in 2020. In 2021, over 3.3 million new cars and over 11.2 million

---

[7] In these comments, "ZEV" refers broadly to PHEVs, FCEVs and BEV refers specifically to battery electric vehicles.

[8] Ricardo, Inc. "Life Cycle Analysis Comparison: Electric and Internal Combustion Engine Vehicles", study prepared for the Transportation Energy Institute (formerly known as the Fuels Institute). January 2022. https://www.transportationenergy.org/research/reports/life-cycle-analysis-comparison-electric-and-internlife-cycle-analysis-comparison-electric-and-intern.

[9] API Comments on "Greenhouse Gas Emissions Standards for Heavy-Duty Vehicles—Phase 3", Document ID EPA-HQ-OAR-2022-0985-1423.

[10] Kelly, J. et al., "Cradle-to-grave lifecycle analysis of U.S. light-duty vehicle-fuel pathways: a greenhouse gas emissions and economic assessment of current (2020) and future (2030-2035) technologies", June 2022, ANL-22/27. Figure B.8. https://greet.es.anl.gov/publication-c2g_lca_us_ldv.

[11] 88 Fed. Reg. 25,926 (April 27, 2023).

[12] "Transportation Energy Data Book: Edition 40", Oak Ridge National Laboratory. ORNL/TM-2022/2376. https://tedb.ornl.gov/.

new light trucks were sold. The average age of a light-duty vehicle (LDV) is over 12 years. The U.S. Department of Energy's Energy Information Administration (EIA)[13] projects the stocks of light-duty internal combustion engines will exceed 247 million vehicles in 2050. EPA's overly limited focus on ZEVs, and specifically BEV solutions, ignores options that could better accomplish the agency's objectives to achieve greater transportation sector-related emission reductions at lower cost to society.

EPA's proposal extends to "medium-duty vehicles" (MDVs), previously referred to as "heavy-duty class 2b and 3 vehicles or heavy-duty pickups and vans."[14] Vehicles in this class may include large SUVs, heavy-duty pickups, utility vans, mini-buses, step vans, delivery vans, and light dump trucks (i.e., GVWR up to 14,000 pounds) which have different and diverse usage applications [15] compared to lighter LDVs and medium-duty passenger vehicles (MDPVs), which fall into EPA's LDV classifications of light-duty passenger cars and light-duty trucks. The MDV market (i.e., class 2b and 3 vehicles) is made up of purchasers that want to get "the right tool for the job" and often include service providers such as plumbers, landscapers, and utility company fleets.[16] Although there is little published regarding makeup, usage, and environmental impact of class 2b and class 3 vehicles, there are approximately 13 million class 2b and 3 million class 3 vehicles in the U.S. fleet and these vehicles may remain in fleets up to 15 years.[17] Purchasing decisions and usage of class 2b and class 3 vehicles are driven by demands of meeting commercial, business, and personal use and these vehicles are likely used in distinctly different applications compared to lighter LDVs covered by EPA's proposal. Accordingly, these vehicles should not be included in the LMDV program. Further, as discussed in Section h below, EPA exceeded its authority in changing the definitions.

ii. EPA failed to address emission reductions in the existing LMDV fleet to help achieve near-term emission reductions.

Fuel- and vehicle-based GHG emissions reduction solutions are currently available in the marketplace and could achieve nearer-term emission reductions from the existing light- and medium-duty vehicle fleet. A singular focus on future ZEV technologies does not seem to meet the stated goals of the proposed program. The proposal would require a significant ramp-up of electric vehicle production in relation to the scale of the current market, would depend on infrastructure that may not be readily available at the scale needed to meet the proposal's requirements, and would be on an extremely challenging (at best) timeline. Meaningful emission reductions are achievable sooner, and potentially at lower cost, via the use of proven and available technology. For example, the U.S. Department of Energy (DOE) Co-Optimization of Fuels & Engines (Co-Optima) initiative examined fuels and engine/vehicle technologies

---

[13] U.S. Energy Information Administration. "Annual Energy Outlook 2023." March 2023. https://www.eia.gov/outlooks/aeo/.

[14] 88 Fed. Reg. 29196 (May 5, 2023).

[15] Oak Ridge National Laboratory. "Electrification Beyond Light Duty: Class 2b-3 Commercial Vehicles." ORNL/TM-2017/744. 2017. https://info.ornl.gov/sites/publications/Files/Pub106416.pdf.

[16] Ibid.

[17] Ibid.

simultaneously.[18] The combination of sustainable fuels uncovered by the Co-Optima research can reduce the emissions of vehicles now, while enabling a faster transition to net-zero-carbon emissions for on-road transportation in the future. The lifecycle GHG emissions of these studied fuels were found to be reduced by more than 60%.[19] Such an approach could be utilized by EPA to better achieve the stated goals of the agency. EPA must address this factor.

iii. Non-electrification solutions.

EPA's analysis is flawed in that it failed to account for non-electrification solutions.

1. Technology neutrality – all solutions should be allowed to compete.

In the preamble to the proposed rule, EPA states that "[t]he proposed standards are performance based and do not mandate any specific technology for any manufacturer or any vehicle type" and "[e]ach manufacturer is free to choose its own set of technologies with which it will demonstrate compliance…".[20] We disagree, as the stringency of the proposed standards – and even the technology mixes suggested by EPA in the proposal – essentially forces manufacturers to solely focus development efforts on BEVs.

Although EPA asserts that the proposed rule standards do not mandate any specific technology, EPA demonstrates compliance with its proposed standards by modeling new light-duty BEV sales that increase from 36% in 2027 to 67% in 2032. That means, within 5 years, the ratio of new BEV sales to total sales will increase from one third to two thirds of new car sales. For the MDV category, EPA[21] modelled compliance with average new sales reaching 46% in 2032, up from 17% in 2027. EPA modeling relies heavily on the electrification of vans, which reaches 98% by 2032. These compliance projections are much higher than sales of battery electric MDVs in 2020 of less than 1 percent.[22]

API strongly believes in an all-of-the-above strategy to reducing emissions, and we recommend that EPA adjust the standards to allow all solutions the ability to compete. Further, doing so would provide more time for other technologies to be proven with less risk to vehicle original equipment manufacturers (OEMs) and the public if electrification expansion of LMDVs does not pan out in the proposal's implementation timeframe.

---

[18] U.S. Department of Energy Office of Energy Efficiency & Renewable Energy, "The Road Ahead Toward a Net-Zero-Carbon Transportation Future Findings and Impact, FY15–FY21." https://www.energy.gov/sites/default/files/2022-06/beto-co-optima-fy15-fy21-impact.pdf.

[19] Gaspar, Daniel J., West, Brian H., Ruddy, Danial, Wilke, Trenton J., Polikarpov, Evgueni, Alleman, Teresa L., George, Anthe, Monroe, Eric, Davis, Ryan W., Vardon, Derek, Sutton, Andrew D., Moore, Cameron M., Benavides, Pahola T., Dunn, Jennifer, Biddy, Mary J., Jones, Susanne B., Kass, Michael D., Pihl, Josh A., Pihl, Josh A., Debusk, Melanie M., Sjoberg, Magnus, Szybist, Jim, Sluder, C S., Fioroni, Gina, and Pitz, William J. 2019. "Top Ten Blendstocks Derived From Biomass For Turbocharged Spark Ignition Engines: Bio-blendstocks With Potential for Highest Engine Efficiency". United States. https://doi.org/10.2172/1567705.

[20] 88 Fed. Reg. 29329 (May 5, 2023).

[21] 88 Fed. Reg. 29331 (May 5, 2023).

[22] Table 3-1. "Multi-Pollutant Emissions Standards for Model Years 2027 and Later Light-Duty and Medium-Duty Vehicles - Draft Regulatory Impact Analysis", EPA-420-D-23-003. April 2023.

To that end, various studies have highlighted the importance of allowing all technologies to be utilized to reduce emissions faster, more effectively, and at a lower cost.[23,24] By limiting the scope to tailpipe emissions, the proposal is inherently not technology neutral. Setting strict tailpipe-only standards results in a limited, prescribed solution set.

2. Current and future solutions – lower carbon fuels, hydrogen, ICE-based solutions.

As previously noted in our comments, lower-carbon options currently exist and could be used for near-term reductions. Lower carbon fuels are available in the market now, and research and development to bring costs down and improve operability is ongoing.

While still in the early stages and very small market penetration (in model year 2021 there were three hydrogen FCEV models produced, but they were only available in the state of California and Hawaii and in very small numbers[25]), hydrogen-based vehicles are a promising technology that many stakeholders are considering.[26] As acknowledged by EPA in the DRIA,[27] modeled compliance relied on the assumption that 55% of new sales of class 2b and class 3 vehicles would be BEV or FCEV. Furthermore, hydrogen fueling infrastructure is covered by the Bi-partisan Infrastructure Law (BIL) and the Inflation Reduction Act (IRA) funding. API members are engaged in hydrogen projects to support development of hydrogen focused technology. Companies[28] are partnering with OEMs to explore commercial business opportunities to build demand for vehicles powered by hydrogen.

As noted by the American Trucking Associations (ATA), in testimony before the U.S. Senate Committee on Environment and Public Works:[29]

> When battery electric vehicles are not the answer, federal support should refrain from playing favorites, and instead assist in the buildout of alternative fuel facilities. Proposals for hydrogen infrastructure for trucks need to ensure that the infrastructure is in place where that technology best fits in supply chains. Where lifecycle emissions can be

---

[23] National Academy of Sciences. "Cost, Effectiveness, and Deployment of Fuel Economy Technologies for Light-Duty Vehicles." 2015. https://nap.nationalacademies.org/download/21744.

[24] National Academy of Sciences. "Assessment of Technologies for Improving Light-Duty Vehicle Fuel Economy 2025-2035." 2021. https://nap.nationalacademies.org/download/26092.

[25] "Multi-Pollutant Emissions Standards for Model Years 2027 and Later Light-Duty and Medium-Duty Vehicles - Draft Regulatory Impact Analysis." EPA-420-D-23-003. April 2023.

[26] Morales, M. (April 25, 2023). "Automakers deeply invested in hydrogen-powered cars." *TopSpeed*. https://www.topspeed.com/automakers-invested-hydrogen-powered-cars/.

[27] Ibid.

[28] https://corporate.exxonmobil.com/what-we-do/lower-emission-transportation/emerging-vehicle-and-fuel-technology/exxonmobil-and-porsche-strategic-collaboration;https://www.chevron.com/newsroom/2021/q2/chevron-toyota-pursue-strategic-alliance-on-hydrogen; https://www.bp.com/en/global/corporate/news-and-insights/press-releases/bp-and-daimler-truck-ag-to-accelerate-the-deployment-of-hydrogen-infrastructure.html.

[29] U.S. Senate Committee on Environment and Public Works, hearing on "The Future of Low Carbon Transportation Fuels and Considerations for a National Clean Fuels Program", February 15, 2023. https://www.epw.senate.gov/public/index.cfm/2023/2/the-future-of-low-carbon-transportation-fuels-and-considerations-for-a-national-clean-fuels-program.

> reduced by deploying renewable diesel and renewable natural gas, those fuel stocks need to be available for trucking.

While this statement is in relation to heavy-duty vehicles, the issues are the same for light- and medium-duty vehicles. Infrastructure readiness and reduction of lifecycle emissions without picking one technology over others should be EPA's focus for the proposed program.

Bio and renewable fuels can and should be considered as part of an "all-of-the-above" approach to decarbonization of the transportation sector, including biocircularity. As previously noted, API members are currently investing heavily in renewable fuel production – continued investment and development will increase the available volumes of such fuels in the marketplace and allow them to serve both as a viable lower carbon solutions leading up to the start of the EPA proposed rule, throughout implementation, and beyond.

Further, EPA's LCA modeling for the proposal is based on biocircularity with atmospheric CO_2 consumed by biomass, resulting in zero tailpipe carbon emissions if the combusted biofuels were made from renewable biomass. The agency is thus not taking the source of carbon into account and is classifying all carbon tailpipe emissions as the same related to their atmospheric GHG impact.

d. EPA is Not Taking a Realistic Approach.

i. EPA's limits are not set on a realistic scientific based approach.

EPA's proposed standards are based on projected ZEV penetration rates based on OEM stated ambitions and on California ZEV mandates and states that follow California rules under Section 177 of the Clean Air Act. These ambitions are stretch goals that OEMs may not reach. Further, EPA should consider a lifecycle approach that would accurately capture all the emissions associated with the life of a vehicle and capture the efficiency differences of different technologies in different applications.

ii. Criteria pollutants proposed stringency of requirements do not factor non-BEV technologies.

EPA proposes to reduce[30] the NMOG+NOx standard by 60% from the current 30 mg/mile level to 12 mg/mile in 2032. We do not believe this reduction is justified either on a health benefit or a cost-effectiveness basis. Furthermore, the criteria pollutant proposal for NMOG+NOx is another example of setting a performance standard that can only be met by a specific vehicle technology. EPA has not demonstrated a technically feasible path for OEMs to meet NMOG+NOx standards with a mixed vehicle fleet comprised of large and small light-duty vehicles with ICE technologies. The examples given in the DRIA (Table 3-14) for vehicles that currently meet less than 15 mg/mile NMOG+NOx is limited to sedans and smaller SUVs, but do not include pick-up trucks and full-size SUVs. Trucks and SUVs represent a significant portion of OEM fleets.[31] EPA instead anticipates and sets the standard to require the use of BEVs by

---

[30] In its recent Advanced Clean Cars II regulation, the California Air Resources Board has maintained a 30 mg/mile NMOG+NOx standard.

[31] Henry, J. (January 3, 2022). "Light Trucks Now Outselling Cars 3-to-1". *Forbes.com.* Retrieved June 30, 2023. https://www.forbes.com/wheels/news/light-trucks-now-outselling-cars/.

OEMs to sell large SUVs and trucks, instead of allowing for a choice of technology paths which could include ICE vehicles in the fleet. This is arbitrary and capricious and could likely have implications for consumers choice and costs. Moreover, only 19 vehicles were certified below 15 mg/mi that rely only on ICE technologies out of the approximately 299 carline models certified by EPA in 2021.

EPA has also not demonstrated that a particulate matter (PM) 0.5 mg/mi limit is technologically feasible on the basis of measurement capabilities and test procedure. EPA has stated that the agency is not reopening the test procedures, nor does the agency believe that test procedure changes are required, to PM for the proposed PM standards. The agency fails in justifying this decision. The EPA needs to reconsider if it is possible to measure PM emissions of 0.5 mg/mile accurately with current methods. The test set utilized in the NPRM to suggest that test-to-test repeatability is sufficiently precise to support a 0.5 mg/mile standard was noted to use an aerosol generator, presumably to generate PM. In contrast an actual engine will produce PM with more composition and concentration variability, which could impact repeatability. Further, FCA reported[32] the challenges of measuring 1 mg/mile of PM. It can be assumed that these uncertainties would only increase for a PM target of 0.5 mg/mile "[a]s the PM standard is transitioning to 1 mg/mile, this study showed that the net PM mass on the filter will be approaching tunnel ambient background levels. At these net filter PM mass levels, the sources of errors in measurement are numerous. If these sources of errors are not mitigated, the uncertainty can be substantial exceeding the PM limit of 1 mg/mile." It is important to highlight that the 2023 EPA certification vehicle test data shows that there were approximately 83 carline models (out of approximately 376 carlines tested on US06) that achieved a certification level of emissions of 0 gm/mile (and a rounded emission test results level below 0.5 mg/mile) of PM on the US06 drive cycle.

Another issue with the proposed PM standards is related to the new testing requirement at -7°C in the Federal Test Procedure (FTP) cycle. In the NPRM EPA states "as was the case for light-duty vehicles, the -7°C FTP cycle is crucial because it differentiates Tier 3 levels of PM from GPF-level PM and because -7°C is an important real-world temperature that addresses uncontrolled cold PM emissions in Tier 3." The temperature selection of -7°C (19.4°F) is arbitrary and capricious because it is not a real-world temperature applicable to a large portion of the U.S. National Oceanic and Atmospheric Administration (NOAA) data of winter temperature averages for every state from 1971 to 2000[33] suggests that only Alaska, North Dakota, Minnesota, Maine, Wisconsin and Vermont have average winter temperatures below -7°C.[34] The winter average of all 50 states is 0.1 °C (32. °F), which further suggests that a temperature of -7°C is not a real-world temperature.

---

[32] Yassine, M., "Challenges in PM Measurement at 1 mg/mile and Tunnel Background Correction," SAE Technical Paper 2023-01-0370, 2023, https://doi.org/10.4271/2023-01-0370.

[33] "Winter Temperature Averages for Every State": https://www.currentresults.com/Weather/US/average-state-temperatures-in-winter.php.

[34] According to the U.S. Census Bureau, these states account for less than 5% of the population of the United States ("State Population Totals and Components of Change: 2020-2022": https://www.census.gov/data/tables/time-series/demo/popest/2020s-state-total.html).

EPA fails to properly account for all of the cost increases associated with the enforcement of gasoline particulate filter (GPF) technologies. The GPF cost model is described in DRIA Chapter 3.2 and GPF cost is included in the OMEGA model. The model anticipates the direct manufacturing cost (DMC) for a bare downstream GPF, which ranges from $51 dollars for a 1.0-liter engine using a relatively low GPF 249 volume to engine displacement ratio, up to $166 dollars for a 7.0 liter engine using a relatively high GPF volume to engine displacement ratio. In the DRIA (page 3-60) GPF cost is based on the ICCT 2011 work, which is now over 10 years old. Further, the EPA assumes that the GPFs that OEMs will utilize to meet more stringent PM and GHG targets will be those new generation of MY 2022 GPFs with "high filtration efficiencies generally over 95 percent" and low backpressure. The assumed costs for MY 2022 GPF with higher efficiency appear to be unreasonably low and caused the modeling to overestimate feasibility. Furthermore, it is not clear if the associated equipment for effective operation of the GPF such as associated sensors and controllers are included in the cost assessment performed by EPA. The agency should reevaluate its assessment based on more realistic efficiency levels to avoid arbitrary and capricious action.

iii. Review of Annual Energy Outlook (AEO) data and projections.

EPA's BEV projections differ significantly from other federal agencies and reflect that EPA is improperly mandating that a significant proportion of new LDV and MDV must be powered by electric drivetrains and setting unrealistic tailpipe emission standards. The EIA published market share projections for light-duty BEV and PHEV sales in its Annual Energy Outlook[35] 2023 (AEO 2023). The AEO 2023 Reference Case modeling includes laws, such as the IRA and the BIL, and other adopted regulations in its analysis. The AEO 2023 incorporates the IRA by adjusting EV purchase prices to account for the Clean Vehicle Credit using official estimates of vehicles that will be eligible for tax credits. In addition to the Reference Case, the AEO conducts a range of scenario modeling, that considers different assumptions and uncertainties. Across the range of modelled scenarios in AEO 2023, EIA[36] concluded that sales of BEVs and PHEVs do not exceed 29% and the share of the on-road light-duty vehicle stocks comprised of BEVs and PHEVs did not exceed 26%, over the projection period to 2050.

Analysis of BEV-only[37] sales data from the AEO 2020 (pre-COVID) and 2023 (most recent) editions indicate BEVs sales are projected to increase in comparison to the respective Reference Cases. For example, in 2032, BEV sales are projected to reach 13% in the AEO 2023 Reference Case up from 5% in the AEO 2020 Reference Case. Increased BEV sales in AEO 2023 compared to AEO 2020 likely reflect emerging trends, technological improvements, relative manufacturing costs and purchase prices, subsidies, consumer behavior, and other factors. Also, minimum projections for BEV sales in the AEO 2023 are nearly identical to the AEO 2020 Reference Case (see chart below). However, projections for maximum BEV sales in AEO 2023 reach only 23% in

---

[35] U.S. Energy Information Administration. "Annual Energy Outlook 2023." March 2023. https://www.eia.gov/outlooks/aeo/.

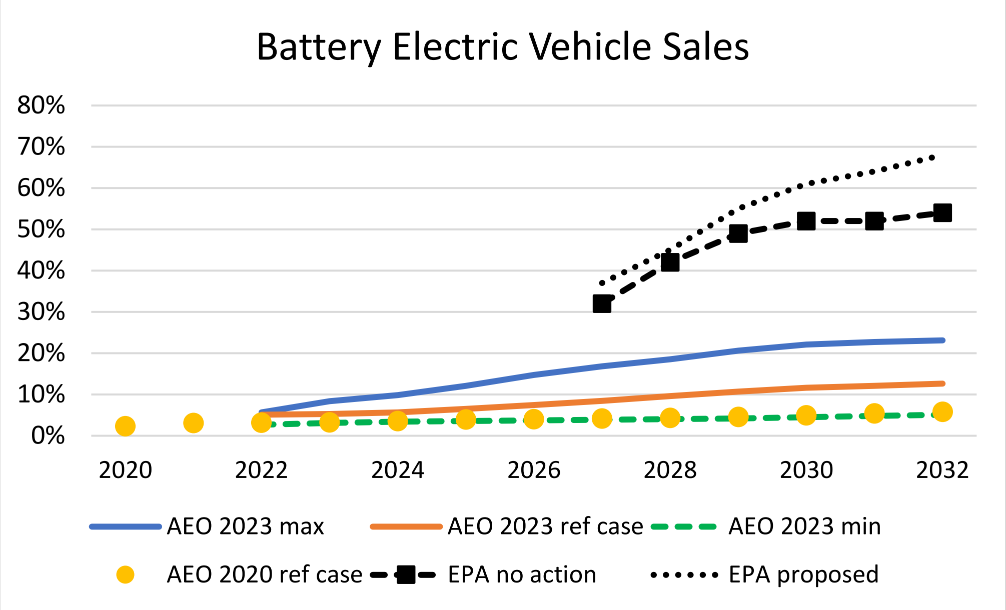
[36] U.S. Energy Information Administration. "Incentives and lower costs drive electric vehicle adoption in our Annual Energy Outlook." *Today in Energy*. Accessed May 15, 2023. https://www.eia.gov/todayinenergy/detail.php?id=56480.

[37] Transportation supplemental tables for AEO 2020 and AEO 2023 can be found here: https://www.eia.gov/outlooks/aeo/.

2032. Figure 1 below illustrates BEV sales across a wide range of scenarios as projected by EIA.

BEV sales projected by EPA,[38] under a scenario to meet the proposed standards and a "no action" scenario, are included in the chart. BEV sales required to meet EPA's proposed standards or "no action" scenario are significantly higher than any scenario projected by EIA in its AEO 2023 analysis. Differences in trajectories between EPA's proposed standards and the AEO projections illustrate EPA selecting and essentially forcing one technology over others and setting an unrealistic stringency for tailpipe emission standards. Although EIA has projected BEV sales to increase (i.e., AEO 2023 vs. AEO 2020) because of recently enacted federal subsidies and expenditures (i.e., BIL and IRA), along with technological advancements, 2032 BEV sales are projected to reach to only 13% in the AEO 2023 Reference Case compared to EPA's proposed standard at 67%. This is a significant difference in projected BEV sales and the agency has not provided adequate information to explain this major difference. EPA must explain why its projections differ so significantly from its sister agency with far more expertise in such projections than EPA.

Figure 1. Battery Electric Vehicle Sales Projected by EIA and EPA



iv. Vehicle readiness.

1. Technology readiness.

The proposed rule identified various LMD ZEVs available in the marketplace or in production, as well as select manufacturer goals and commitments to producing LMD ZEVs by a certain timeframe. However, there is significant uncertainty regarding EPA's expectation for rapid availability of ZEV powertrains on the proposed rule's timeline. OEM goals and

---

[38] Table 108, 88 Fed. Reg. 29335 (May 5, 2023).

commitments, coupled with IRA/BIL funding may help to increase the availability of LMD ZEVs; however, it will be extremely challenging to meet the proposal's implementation schedule. Based on EIA projections, it seems highly unlikely that vehicles will be available at the rates EPA is projected for the 2027-2032 timeframe.

Even with a fully stocked LMD ZEV market, key barriers to entry include customer uptake, capital costs to purchase vehicles, and infrastructure readiness.

2. ZEV penetration/customer uptake and adoption rates.

LMD ZEVs are currently not available in sufficient quantities or at affordable levels to significantly displace ICEVs. Given the lower costs, current ICEV owners may choose to continue to use and extend the life of their ICEVs to avoid these issues. EPA must address the potential impacts of this likelihood on its emissions projections.

3. Compounding concern resources will also be used for HDV, on the same timeframe.

EPA released the proposals for LMDV and HDV simultaneously – and the programs have the same proposed implementation timeline of 2027-2032. API has serious concerns about the implications of this timing. Both proposed programs are significantly flawed in that they rely on resources and infrastructure that are not yet ready. Even with EPA's projections regarding the use of BIL and IRA funding, the transportation industry will be competing for the same resources to successfully stand up both programs simultaneously. Furthermore, the availability of and process for obtaining such funding is not certain.

v. Infrastructure.

1. Leadtime and deployment.

API, and many other stakeholders, are concerned about the lack of infrastructure for the LMD ZEV market.[39] Even coupled with significant tax credits and incentives, consumers likely will not purchase new LMD ZEVs in the volumes that would be required by the proposal without a reliable charging infrastructure.

EPA notes in the proposal various partnerships and plans to build battery manufacturing plants in the U.S., taking advantage of incentives such as the IRA, one must view these as highly complex projects – in addition to siting and construction, it will take time for these new battery manufacturing facilities to be up and running to ramp up to full production. Further, there is the probability that not all announced projects will materialize.

2. The electricity grid and charging.

In the DRIA, EPA estimates that by 2050, the proposed rule would drive annual electricity demand higher by 430 terawatt hours (TWh). This number represents 10% of today's electricity demand. EPA makes the claim that it is relatively small in the context of total electricity demand in 2050 (4.4%). EPA does not include in its assessment a clear explanation on how this estimate was obtained and, accordingly, has not provided meaningful opportunity for

---

[39] Khan, Hafiz Anwar Ullah; Price, Sara; Avraam, Charalampos; Dvorkin, Yury. "Inequitable Access to EV Charging Infrastructure." New York University, Tandon School of Engineering. February 2022. https://rosap.ntl.bts.gov/view/dot/61454.

the public to comment. API requests further clarification on the assessment of electricity demand projections by EPA. The past two decades have seen an annual growth in energy generation (i.e., total electricity consumption, or load, and system losses) averaging 30 TWh.[40] Historically, the U.S. electric power system has evolved over time to accommodate new energy demand. However, the rapid pace at which BEVs will have to be in the market to comply with the proposed rule, in addition to the HD GHG Phase 3 rule proposed ZEV deployment, poses several potential challenges at the distribution level that warrant further analysis[41]:

- Distribution capacity expansion could present additional costs. Areas that should be assessed are: (a) high power charging of light-duty EVs (at 150kW and above), (b) high-power charging of medium- and heavy-duty vehicles (potentially at over 1 MW), (c) legacy infrastructure constraints in dense urban areas, and (d) low-power charging of light-duty EVs on distribution systems.
- Transmission constraints must be assessed. Transmission expansions must be deliberate as these investments in the U.S. power system are costly and time consuming.
- Ramping up capabilities of the generating fleet of the bulk power system should be considered for BEVs at scale.
- Analysis of medium- and heavy-duty EV market growth scenarios are needed to assess the impact on energy generation and generation capacity.

Additional factors such as utilities' readiness for the installation of new capacity, sufficient utility labor, capital, land use, other environmental regulations, reliability requirements, and the policy environment must be taken into consideration.[42]

BEV impact on the order of 2-4% increased electricity demand may appear "modest" in an aggregate sense, but EPA has failed to include in their assessment that grid supply-demand strain is a localized phenomenon (both spatially and temporally). Add on the increased demand from electrification ambitions and the system becomes more tenuous and requires additional consideration. While the light-duty and medium-duty NPRM[43] notes "vehicle-to-grid software and systems that allow management of vehicle charging time and rate have been found to create value for electric vehicle drivers, electric grid operators, and ratepayers;" however, we submit that vehicle to grid (V2G) technology is still a topic of active research and development activity and early pilot demonstrations and will take years[44] for effective widespread deployment to help with load-balancing. Depending on the time of day and the extent of renewable electricity in the grid mix for a given location, it should be noted that the carbon intensity of the electricity that gets consumed by these

---

[40] Energy Information Administration. "Monthly Energy Review." *Total Energy.* June 2023. https://www.eia.gov/totalenergy/data/monthly/.

[41] USDRIVE. "Summary Report on EVs at Scale and the U.S. Electric Power System." November 2019. https://www.energy.gov/eere/vehicles/articles/summary-report-evs-scale-and-us-electric-power-system-2019.

[42] Ibid.

[43] 88 Fed. Reg. 25983 (April 27, 2023).

[44] Deloitte. "2023 power and utilities industry outlook." https://www2.deloitte.com/content/dam/Deloitte/tw/Documents/energy-resources/2023-power-and-utilities-industry-outlook-en.pdf.

vehicles may also fluctuate depending upon fluctuation of renewable energy availability.[45,46]

Upgrades to the typical duration of an electricity transmission system capital project timeline would need to be accelerated from roughly 10-year timelines to have a chance to support the proposed ZEV demand, while current large-scale electric generation and storage projects are increasingly facing backlogs year-on-year due to long lead times for permitting and approvals, supply chain shortages, and shortage of skilled workers. While government programs have recently been put in place to help overcome some of these hurdles, they will take time for the benefits of those programs to be realized.[47,48,49]

EPA's proposal indicates that by 2035, the "power sector modeling results showed that non-hydroelectric renewables (primarily wind and solar) will be the largest source of electric generation (approximately 46 percent of total generation), and they would account for more than 70 percent of generation by 2050." This will primarily be driven by the incentives included in the IRA. If these projections become a reality, further analysis and consideration should be given to the intermittency of a grid primarily powered by these sources of energies. As indicated by a study[50] conducted by the National Renewable Energy Laboratory (NREL), dramatically accelerating electrification of sectors such as transportation, may make it more difficult to decarbonize the electricity system due to the higher rate of generation and transmission capacity additions needed. Wood Mackenzie's[51] forecasts for BEV sales includes the projection that charging will account for about 4% of total U.S. retail electricity sales in the early 2030s. Faster growth in BEV sales would likewise result in greater demands on the grid, and at a time when the power industry is also under pressure to cut its own greenhouse gas emissions.

---

[45] Salma Elmallah et al. December 2022. "Can Distribution Grid Infrastructure Accommodate Residential Electrification and Electric Vehicle Adoption in Northern California?" Energy Institute at Haas. WP 327R. https://haas.berkeley.edu/wp-content/uploads/WP327.pdf).

[46] Davidson, F. T., D. T., Rhodes, J., & Nagasawa, K. December 4, 2018. "Switching to electric vehicles could save the US billions, but timing is everything." *The Conversation*. Retrieved June 30, 2023, from https://theconversation.com/switching-to-electric-vehicles-could-save-the-us-billions-but-timing-is-everything-106227.

[47] McKinsey. "Upgrade the grid: Speed is of the essence in the energy." 2022. www.mckinsey.com/~/media/mckinsey/business%20functions/operations/our%20insights/gii/voices/upgrade%20the%20grid%20speed%20is%20of%20the%20essence%20in%20the%20energy%20transition/upgrade-the-grid-speed-is-of-the-essence-in-the-energy-transition.pdf.

[48] Deloitte. "2023 power and utilities industry outlook." https://www2.deloitte.com/content/dam/Deloitte/tw/Documents/energy-resources/2023-power-and-utilities-industry-outlook-en.pdf.

[49] Rocky Mountain Institute. "Increasing Equitable EV Access and Charging: A Path Forward for States." 2022. https://rmi.org/insight/increasing-equitable-ev-access-charging/.

[50] Denholm, Paul, Patrick Brown, Wesley Cole, et al. 2022. "Examining Supply-Side Options to Achieve 100% Clean Electricity by 2035." National Renewable Energy Laboratory. NREL/TP-6A40-81644. https://www.nrel.gov/docs/fy22osti/81644.pdf.

[51] Crooks, E. April 13, 2023. "The EPA plans to rev up US EV sales." Wood Mackenzie. https://www.woodmac.com/news/opinion/the-epa-plans-to-rev-up-us-ev-sales/.

Another critical aspect to be considered is that normal BEV charging behavior will put extra load pressure[52] on the grid, especially at peak hours. As a general practice, a passenger BEV user will charge the vehicle during the evening, which is also the time that electricity demand from the residential sector generally peaks. EV charging at peak hours is anticipated to be more expensive, as additional generation capacity may be required. Moreover, the current consumer trend toward acquiring larger vehicles, which typically have lower battery efficiency and further charging requirements, suggests increasing energy consumption per mile. We believe that electricity demand from BEVs should not cause additional burden to other electricity users, especially during emergencies. However, EPA has not provided an adequate 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 significant shift in the national fleet from ICEVs to BEVs. Furthermore, in its cost-benefit analysis of the proposed standards, EPA has failed to account for the full costs associated with the charging infrastructure and grid infrastructure upgrades that would be necessary. It is also important to note that 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 in certain areas of the country, which would have an impact on fire response and other emergency services.

EPA has failed to adequately address the major impacts of the proposed rule on the electricity grid and charging infrastructure. It would be arbitrary and capricious for EPA not to adjust its analysis to take into account these factors.

e. API Supports Consumer Choice for Vehicles.

API[53] supports the concept that different vehicle technologies that reduce greenhouse gas emissions should be allowed to compete equally for consumer and market acceptance and growth. However, API has concerns with regards to the EPA's approach and its effect on consumer choice.

The stringency of the proposed standard is essentially forcing electrification of the transportation sector and is not in alignment with most Americans that, according to a Pew Center survey,[54] favor "using a mix of energy sources to meet the country's needs" and a majority of survey respondents oppose phasing out gasoline powered vehicles by 2035. Concerns with charging availability[55] could be relieved with vehicle technologies (e.g., PHEVs[56])

---

[52] United Nations Industrial Development Organization. "Best Practices in Electric Mobility." Discussion Paper. 2019. https://www.unido.org/sites/default/files/files/2019-09/EMG%20Discussion%20Paper.pdf.

[53] https://www.api.org/news-policy-and-issues/blog/2021/05/18/us-consumers-need-balance-choice-in-transportation-policy.

[54] Tyson, A. et al. "Gen Z, Millennials Stand Out for Climate Change Activism, Social Media Engagement With Issue." Pew Research Center. May 2021. https://www.pewresearch.org/science/2021/05/26/gen-z-millennials-stand-out-for-climate-change-activism-social-media-engagement-with-issue/.

[55] Noblet, S. "Closing The Great EV Charging Gap." August 2021. *Forbes.* https://www.forbes.com/sites/stacynoblet/2021/08/10/closing-the-great-ev-charging-gap/?sh=6cf9107f73f4.

[56] EPA is proposing a fleet utility factor (FUF) curve that will increase CO_2 compliance values for PHEVs. 88 Fed. Reg. 292557 (May 5, 2023).

where the length of an average daily trip is approximately 30 miles.[57]

A critical part of relying on an EV for transportation is the ability to charge the battery. According to J.D. Power,[58] EV owners in markets with a high volume of EVs are experiencing problems with charging. Even with the high growth rate of EV chargers, satisfaction has flat-lined and a "shortage of public charging availability" is the main reason car buyers avoid EVs.

The AEO 2023[59] contains long term projections based on current laws and regulations in place at the time of modeling. As part of that modeling, the AEO includes projections for vehicle sales and vehicle sales projections include consumer choice modeling[60]. EIA's consumer choice modeling includes fuel choice, sales penetration among similar technologies, market share among different technology sets, and vehicle attributes (i.e., sales price, fuel economy, battery replacement costs, range, etc.). EIA reported that for the first time since 2010, critical mineral prices increased "significantly" in 2022 resulting in the first year to year increase in electric vehicle battery prices. According to AEO projections, which consider current policies and regulations, and consumer choice, BEV sales penetration remains well below EPA's estimates in the proposed rule, which are induced by its proposed stringent standards. EPA must explain why its projections differ so significantly from EIA. Furthermore, EIA[61] projects electric vehicles to be less competitive from a cost standpoint than gasoline powered vehicles in the much larger non-luxury market.

Vehicles powered by internal combustion engines (ICE) offer "outstanding "drivability and reliability" according to the Department of Energy[62] and "increasing the efficiency of internal combustion engines (ICEs) is one of the most promising and cost-effective approaches to dramatically improving the fuel economy of the on-road vehicle fleet in the near- to mid-term." Increasing sales of EVs does not necessarily mean they are more reliable. According to this survey data[63] "[e]lectric cars are less reliable" than cars powered by petroleum, where software related problems cause reliability issues for consumers. In a Consumer Reports survey,[64] data reported by EV owners indicate that EVs, as a category, have "more frequent problems" compared to conventional vehicles. EPA should take into account these factors in their analysis.

---

[57] 2019 Bureau of Transportation data indicates 49% of 2019 national trips by distance were less 25 miles.

[58] J.D. Power. "Growing Electric Vehicle Market Threatens to Short-Circuit Public Charging Experience, J.D. Power Finds." August 2022. https://www.jdpower.com/business/press-releases/2022-us-electric-vehicle-experience-evx-public-charging-study.

[59] U.S. Energy Information Administration. "Annual Energy Outlook 2023." March 2023. https://www.eia.gov/outlooks/aeo/.

[60] https://www.eia.gov/outlooks/aeo/assumptions/pdf/TDM_Assumptions.pdf

[61] U.S. Energy Information Administration. "Issues in Focus: Inflation Reduction Act Cases in the AEO2023." March 2023. Annual Energy Outlook 2023. https://www.eia.gov/outlooks/aeo/IIF_IRA/.

[62] U.S. Energy Information Administration. "Transportation Demand Module Assumptions." March 2023. https://www.energy.gov/sites/default/files/2015/11/f27/QTR2015-8C-Internal-Combustion-Engines.pdf.

[63] Hull, R. "Electric cars are LESS reliable than petrols and diesels with nearly a third reporting faults taking longer to fix - and Tesla is rated worst overall, says Which?" March 2022. *Daily Mail*. https://www.dailymail.co.uk/money/cars/article-10569557/Electric-cars-reliable-petrol-diesel-says-Which.html.

[64] Tucker, S. December 2022. "Consumer Reports: EVs Less Reliable Than Gas-Powered Cars." *Kelley Blue Book*. https://www.kbb.com/car-news/consumer-reports-evs-less-reliable-than-gas-powered-cars/.

f. Critical Minerals, Energy Security, BEV Supply Chains, Feasibility and Modeling.

i. Critical minerals.

Reliance on a limited number of technologies (e.g., ZEVs) on the timeline required by the proposed rule will likely result in a non-resilient transport sector that is vulnerable to unexpected disruptions. Both the federal government and the private sector have recognized that critical minerals are essential to the future of ZEV technology, and likewise, that unstable critical mineral supply chains could disrupt this future.

BEV battery supply chains, including critical minerals and precursors are controlled by a small number of countries, some with unsustainable environmental and human rights practices, and geopolitical concerns. The mining sector will need to grow exponentially to meet demand, and mining is an energy- and environmental-intensive activity. The accelerated BEV technology penetration rate required under EPA's proposal poses significant challenges for best practices to be widely and fully deployed in the timeframe anticipated by the proposed rule.

Regarding the availability of critical minerals, especially those essential to the manufacturing of a Li-ion battery, the supply is dominated by three lithium producing countries — Australia, Chile and China, which account for nearly 90 percent of the global market.[65] While 70% of global cobalt production comes from the Democratic Republic of Congo,[66] most of the mines are owned/operated by China and more than 60 percent of cobalt processing is located in China. China produces 67 percent of the world's graphite.[67] The U.S. imports most of its manganese from Gabon, a less geopolitically stable country, providing 65 percent of the United States' supply.[68] Electricity networks need a large amount of copper and aluminum. The need for grid expansion that would result from this rapid increase in electricity demand underpins a doubling of annual demand for copper and aluminum.[69] China possesses over half of the entire world's aluminum smelting capacity.

There are sources that indicate a shortage of critical minerals as well as volatility in critical mineral prices. U.S. energy security would also undergo a dramatic paradigm shift if vehicle technologies were shifted from ICEVs to ZEVs in the exponential rate that the proposal contemplates. Domestic production of critical minerals required for battery production is insufficient to meet the projected demands. Although Congress and the Administration have

---

[65] "The Role of Critical Minerals in Clean Energy Transitions", International Energy Agency World Energy Outlook Special Report. May 2021. https://iea.blob.core.windows.net/assets/ffd2a83b-8c30-4e9d-980a-52b6d9a86fdc/TheRoleofCriticalMineralsinCleanEnergyTransitions.pdf.

[66] Ibid.

[67] Robinson, G.R., Jr., Hammarstrom, J.M., and Olson, D.W., 2017, Graphite, chap. J of Schulz, K.J., DeYoung, J.H., Jr., Seal, R.R., II, and Bradley, D.C., eds., Critical mineral resources of the United States—Economic and environmental geology and prospects for future supply: U.S. Geological Survey Professional Paper 1802, p. J1–J24, https://doi.org/10.3133/pp1802J.

[68] https://oec.world/en/profile/bilateral-product/manganese-ore/reporter/usa

[69] "The Role of Critical Minerals in Clean Energy Transitions", International Energy Agency World Energy Outlook Special Report. May 2021. https://iea.blob.core.windows.net/assets/ffd2a83b-8c30-4e9d-980a-52b6d9a86fdc/TheRoleofCriticalMineralsinCleanEnergyTransitions.pdf.

taken significant steps to accelerate this activity by funding, facilitating, and promoting the rapid growth of U.S. supply chains for these products through the IRA, BIL, and numerous Executive Branch initiatives, more will still be needed given the proposed increase in demand. Further, EPA failed to consider all the complexities, such as federal permitting, National Environmental Protection Act reviews, and the supply chains for these critical materials in their technology feasibility assessment. API requests that EPA include a thorough evaluation of the full supply chains for each critical mineral/material in their final proposal and their implications on energy security, factoring in sensitivity cases and acknowledging potential disruptions in the supply chain. Please see Appendix A for more discussion regarding our concerns on critical minerals.

ii. Energy Security.

API has concerns with EPA's projections that the proposed standards would increase U.S. energy security because "[a] reduction of U.S. net petroleum imports reduces both financial and strategic risks caused by potential sudden disruptions in the supply of petroleum to the U.S., thus increasing U.S. energy security."[70] EPA's treatment of "energy security" is overly focused on oil imports, petroleum markets and consumption of refined products. Especially in the context of EPA's proposed rule which will require a significant increase in production of batteries. The agency should focus on the energy security implications beyond liquid fuels.

Mineral security and energy security, defined as "the uninterrupted availability of energy sources at affordable prices"[71] are essentially interchangeable concepts because the proposed rule will require affordable supplies of critical minerals, that while available within the U.S., are largely inaccessible due to permitting challenges.[72]

According to the Congressional Research Service,[73] the U.S. has a heavy dependence on imported critical minerals and for the five critical minerals used in battery production there is a "higher potential" for disruptions to the supply chain. In addition to domestic reserves of critical minerals where it may not even be economical to produce,[74] there is a lack of liquidity[75] in global markets that are highly concentrated. Markets for critical minerals are "small, thin, and opaque"[76] and inefficient which is crippling to development and advancement of critical minerals.

U.S. energy security would also undergo a dramatic paradigm shift if vehicle technologies were shifted from ICEVs to ZEVs in the exponential rate that the proposal would likely entail. The U.S. would move from being energy secure to being dependent largely upon foreign sources for the minerals needed to make ZEV technologies such as batteries.

---

[70] 88 Fed. Reg. 29,345 (May 5, 2023).

[71] 88 Fed. Reg. 29,388 (May 5, 2023).

[72] The Martec Group, "Electric vehicle growth in the U.S.: A look Into the EV Battery Supply Chain", March 2022, https://martecgroup.com/electric-vehicle-battery-supply-chain/.

[73] Tracy, B. S. (2022). "Critical Minerals in Electric Vehicle Batteries" (CRS Report No. R47227). https://crsreports.congress.gov/product/pdf/R/R47227.

[74] Ibid.

[75] Hendrix, C. December 2022. "Markets for Critical Minerals Are Too Prone to Failure." *Barron's*. https://www.barrons.com/articles/markets-critical-minerals-lithium-cobalt-copper-51671227168.

[76] Ibid.

iii. BEV Supply Chains.

Given the market and domestic resource challenges identified above, the EPA has failed to properly address effects on energy security of the U.S. The proposed rule would make the U.S. more reliant on imported critical minerals that are subject to supply disruptions and market concentrations. As EPA mentions, disruptions in petroleum supply chains and critical mineral supply chains are not perfectly comparable; however, similarities should not be ignored.

We also have concerns with the methodology EPA uses to estimate energy security benefits which were originally developed by Oak Ridge National Laboratory's (ORNL) 2008 study entitled, "The Energy Security Benefits of Reduced Oil Use, 2006-2015"(Draft RIA Section 7.3.5). Portions of this methodology are outdated and are no longer applicable given the current structure of global oil markets.

In ORNL's study, a significant portion of the estimated security premium is the potential reduction of "the transfer of U.S. wealth to foreign producers" which "can lead to macroeconomic contraction, dislocation, and GDP losses" during an oil supply disruption. In 2008, when ORNL calculated energy security premiums, net U.S. crude and product imports were over 50 percent of U.S. liquid petroleum consumption. However, since ONRL's calculations the U.S. has become, and is projected to be, a net oil and product exporter, thus an increase in global oil prices would likely lead to a net transfer of wealth to the U.S. not away from it. Without modifications that account for the transfer of wealth to the U.S. during a supply disruption, EPA's calculated energy security premium estimates are likely overstated and not meaningful.

iv. Feasibility and Modeling.

A review of EPA's modeling cost and assumptions for battery costs, critical minerals, battery raw materials, and impacts of federal incentives calls into question EPA's approach and conclusions regarding feasibility of the proposed standards.

- The cost reduction model used in the analysis seems to be based on a model used for part cost reductions driven by improved economies of scale on fixed capital equipment. Given that raw materials make up a significant portion of battery costs, EPA should also use a raw material supply cost model that considers the increasing costs for raw materials with increased supply.
- Cost and price are concepts that the agency uses interchangeably in the regulation. The true cost of the regulation is not fully calculated since the portion of the consumer-facing price is paid for by the government. The agency should fully account for the technical feasibility of any CO_2-reducing technology on a cost basis as defined in the CAA regardless of governmental taxation breaks for electric vehicle technology production and sale.
- The cost impact of "fueling" the significant number of electric vehicles assumed in the regulation (67% implied EV share by 2032) is not fully calculated or considered as part of the technical feasibility analysis and cost for the technology. The costs of adding

additional solar, wind, and hydropower plants should be considered in the regulation as they are a necessary part of bringing electric vehicles to market.

These topics are further addressed in Appendix B.

g. Program Review.

i. Assessment of both vehicle and infrastructure development/deployment progress.

The design of a program with heavy reliance on infrastructure that may not be widely available on the timeline proposed is optimistic at best. The proposal appears premature on the stated timeline, and essentially in conjunction with the HD GHG Phase 3 program, which would be competing for the same resources. If EPA is not willing to adjust the timeline and/or standards of the proposed programs, API requests that the agency consider incorporating a pre-program assessment as well as a program progress assessment. It is imperative that EPA provide a real-world evaluation, with an honest assessment provided to the public, regarding progress on infrastructure readiness and ZEV technology deployment. The opportunity for stranded investments by all stakeholders impacted by this program is just too great not to incorporate pre- and mid-program reviews.

For a mid-program assessment, EPA could consider something akin to the Midterm Evaluation that was finalized in the 2012 joint agency rulemaking establishing the MY 2017-2025 LD GHG standards.[77] Further, we recommend that EPA engage a broad stakeholder community to identify necessary elements to incorporate into such an assessment.

ii. Future program incentives and program adjustment of standards.

In the development of the program, EPA needs to consider future program incentives such as adoption of a lifecycle approach, combined with fuel carbon intensity reductions. Such an approach would provide a broad spectrum of industries that power the transportation system (e.g., OEMs, petroleum refiners, power generators, and renewable fuel manufacturers) with incentives to reduce emissions.

In addition, we also request that the agency report on the findings following review with enough time to adjust the standards if needed. Adequate lead time must be provided to the regulated community to allow for necessary adjustments to regulatory compliance strategies, and to avoid stranded investments as much as possible. A proposal based on stretch goals must incorporate an "offramp" or some opportunity to pivot if the essential elements of the program, such as charging/fueling infrastructure, do not materialize.

iii. Impacts of IRA.

The NPRM cites the Inflation Reduction Act (IRA – enacted in 2022) as key legislation that will support the domestic supply chain for battery and electric vehicle production, subsidize EV purchases, and incentivize the build-out of charging infrastructure and renewable power

---

[77] "Midterm Evaluation of Light-Duty Vehicle Greenhouse Gas Emissions Standards for Model Years 2022-2025." https://www.epa.gov/regulations-emissions-vehicles-and-engines/midterm-evaluation-light-duty-vehicle-greenhouse-gas.

production. However, as outlined below, EPA overstates the potential impacts of the IRA.

The EPA makes misleading claims regarding the ability of the IRA's Clean Vehicle Credits to "incentivize the growth and manufacturing capacity of onshore sourcing of critical minerals."[78] While critical minerals, from any origin, can be used for manufacturing battery electric vehicles, the IRA establishes restrictive domestic content requirements for tax credit eligibility. In other words, the IRA tax credits are not a subsidy or policy that directly remove "potential barriers to wider adoption of PEVs,"[79] but rather potentially only provide tax credits if domestic content requirements are met.[80]

According to the National Mining Association:[81] demand for minerals is souring and policies in the U.S. are lagging; scaling up the U.S. supply chain requires increased extraction and processing; withdrawing federal leases covering reserves of nickel, cobalt, and copper are described as "self-sabotage"; and "permitting delays have been, and continue to be, one of the most significant risks to meeting domestic mineral production goals." According to NMA testimony, automakers are "warning with ever greater frequency that the coming battery material shortfall could stop the EV revolution" and a shortage of batteries could arrive as early as 2024. The NMA reports new mining is needed to meet demand, but it takes, on average, 7 to 10 years to secure permits to open or expand a mine. Even as the NMA acknowledges domestically mined minerals are incentivized,[82] the NMA indicates the mine permitting process is "unwieldly" and discourages[83] investment in domestic mining.

The IRA places income and purchase price limits on tax credit eligibility, along with foreign content restrictions beginning in 2024. Overall, according to the Center for Strategic and International Studies (CSIS)[84], it could be "impossible" for a battery electric vehicle to obtain the full value of the tax credit (i.e., $7,500) in the near term.

h. **Legal Concerns.**

The aggressive push to electrify the LDV and MDV fleet is the defining characteristic of the Proposed Rule from a legal standpoint. EPA explains that its "feasibility assessments in past rulemaking were predominantly based on ICE-based technologies that provided incremental

---

[78] 88 Fed. Reg. 29195 (May 5, 2023).

[79] 88 Fed. Reg. 29346 (May 5, 2023).

[80] Center for Strategic and International Studies. Tax credits are also subject to other requirements – "An Electric Debate: Local Content Requirements and Trade Considerations." October 2022. https://www.csis.org/analysis/electric-debate-local-content-requirements-and-trade-considerations.

[81] "Unleashing American Energy, Lowering Energy Costs, and Strengthening Supply Chains.", United States House of Representatives Committee on Energy & Commerce, Testimony of Katie Sweeney, Executive Vice President & General Counsel National Mining Association, February 7, 2023.

[82] National Mining Association. "The Future of Mining Rests on the Actions of Today." September 2022. https://nma.org/2022/09/22/future-of-mining/.

[83] Legislative Hearing, United States House of Representatives Committee on Natural Resources, Testimony of Rich Nolan, President & CEO, National Mining Association, February 28, 2023. https://nma.org/wp-content/uploads/2023/02/National-Mining-Association-2-28-23-Nolan-Testimony.pdf.

[84] Center for Strategic and International Studies. "An Electric Debate: Local Content Requirements and Trade Considerations." October 2022. https://www.csis.org/analysis/electric-debate-local-content-requirements-and-trade-considerations.

tailpipe GHG reductions." 88 Fed. Reg. at 29238. Here, in contrast, EPA projects that the Proposed Rule at full implementation would result in the electrification of 67% of the LDV fleet – over 25% more than the 39% penetration rate that EPA projects in the no action base case. *Id*. at 29329. EPA similarly projects that 46% of the MDV fleet will be electrified, reflecting 98% electrification of all vans. *Id*. at 29331. These numbers make it clear that the Proposed Rule would establish a legal mandate effectively requiring that electric vehicles must comprise a significantly greater proportion of the LDV and MDV fleet than otherwise would be the case. While BEVs can and should be a choice available to manufacturers and vehicle purchasers, we disagree that EPA should impose a binding mandate for the production of BEVs and outline why such a mandate exceeds EPA's authority under the Clean Air Act (CAA).

i. EPA does not have authority to impose standards that are only achievable through the use of BEV technology because there is no clear statement in the Clean Air Act authorizing EPA to mandate a shift away from internal combustion engines.

The Proposed Rule marks a shift in EPA's approach to regulating emissions from LDVs and MDVs. EPA, consistent with the Clean Air Act, has traditionally established standards based on technology that can control the amount of emissions from LDVs and MDVs. EPA deviated from this approach in its 2021 GHG standards, setting standards based on a formula that the agency estimated would increase the market share for electric vehicles from 3.6% to 7% for model year 2023 and 17% for model year 2026. But even then, EPA contended that its "assessment, consistent with past EPA assessments, shows that the final standards can largely be met with increased sales of advanced gasoline vehicle technologies, and projects modest (17 percent) penetration rates of electrified vehicle technology" by 2026. 86 Fed. Reg. 74434, 74484 (Dec. 30, 2021). And EPA argued that it relied on advances in internal combustion engine ("ICE") powertrains to achieve the required GHG reductions and purported not to push for a shift from ICE powertrains to electrified vehicles.

Here, EPA goes even further and seeks to totally transform the transportation sector. It proposes standards that would effectively require that BEVs must comprise two-thirds of the LDV fleet and nearly half of the MDV fleet at full implementation, which is a substantially greater proportion of the fleet any prediction of the market demand would support. Indeed, according to EPA, "[in] MY 2032 when the proposed standards reach the lowest level, it is possible that only BEVs and PHEVs are generating positive credits, and all ICE vehicles generate varying levels of deficits." 88 Fed. Reg. at 29342. In other words, EPA predicts that manufacturers will not be able to comply with the proposed rule without producing significant numbers of electric vehicles. EPA thus seeks to require a fundamental transformation of the LDV fleet from ICE powertrain technology to electric vehicles.

Such a shift from ICE powertrains to electric powertrains would be truly transformative. BEVs require fundamentally different vehicle technologies than those used on conventionally fueled vehicles – e.g., electric motors instead of internal combustion engines, batteries to store power rather than on-board fuel tanks. Moreover, BEVs rely on a wholly different infrastructure (e.g., electric power generation and distribution, charging stations, battery manufacturing) – much of which does not yet exist or exists only in limited form. Additionally, switching to BEVs will fundamentally change the manner in which vehicles are used, for example requiring careful scheduling of vehicle operations to accommodate the long periods needed to adequately charge the vehicles. Lastly, a BEV mandate would produce widespread effects on the national economy, such as the reduced need for oil and gas production, gas processing, changes to petroleum refining, and distribution. Such changes are extraordinary and far more expansive than those caused by EPA's LDV and MDV GHG standards up to now.

EPA asserts that the BEV mandate is authorized under Clean Air Act ("CAA") Sections 202(a)(1) and (2). 88 Fed. Reg. at 29231. EPA claims that these provisions "are technology forcing when EPA considers that to be appropriate." *Id*. at 29232. EPA further asserts that "Section 202 does not specify or expect any particular type of motor vehicle propulsion system to remain prevalent." *Id*. The Agency also asserts that its extraordinary new interpretation of the statute is supported by legislative history claiming that Congress understood that powertrain technologies might evolve over time and quotes Representative Pallone as opining that the "recently enacted [Inflation Reduction Act] "reinforces the longstanding authority and responsibility of [EPA] to regulate GHGs as air pollutants under the Clean Air Act," 204 and "the IRA clearly and deliberately instructs EPA to use" this authority by "combin[ing] economic incentives to reduce climate pollution with regulatory drivers to spur greater reductions under EPA's CAA authorities."" *Id*. at 29233.

But the U.S. Supreme Court has concluded that such an "extraordinary" claim of authority exists only when there is "clear congressional authorization." *West Virginia v. EPA*, 142 S.Ct. 2587, 2609 (2022). CAA §§ 202(a)(1) and (2) contain no such clear authorization. At their core, CAA §§ 202(a)(1) and (2) authorize EPA to establish "standards applicable to the emission of any air pollutant from any class or classes of new motor vehicles or new motor vehicle engines, which in [the Administrator's] judgment cause, or contribute to, air pollution which may reasonably be anticipated to endanger public health or welfare." Because this provision includes no clear statement that EPA may mandate a fundamental shift in propulsion technology, EPA lacks authority to impose emissions limitations that effectively will require the production and sale of electric vehicles. EPA cannot rely on the views of individual Members who participated in the CAA or the IRA to claim vast new authority from long extant statutory provisions.

The lack of a clear statement is particularly notable given that Congress's most recent efforts to address GHG emissions – the Inflation Reduction Act and the Bipartisan Infrastructure Act – almost exclusively consisted of economic incentives and pointedly gave EPA no new or expanded authority to substantively regulate GHG emissions. If Congress had intended to give EPA authority to mandate a fundamental shift in powertrain technology, surely it would have done more than create consumer facing incentives. Moreover, EPA's claim of authority plainly conflicts with other relevant statutes, such as the Renewable Fuel Program, under which Congress mandated that significant and increasing volumes of renewable fuels should be blended into that national motor fuel supply. In contrast, the Proposed Rule is designed to significantly reduce the amount of motor fuel consumed by the light and medium duty fleet. The Proposed Rule thus would frustrate Congressional intent by reducing rather than expanding the volume of renewable fuel consumed by motor vehicles in the U.S.

It also is telling that EPA has abandoned any pretense of "co-regulating" with NHTSA, the national regulatory authority that actually has been authorized by Congress to establish motor vehicle fuel efficiency standards. *Id.* at 29227 n. 384. Among other things, this is a clear attempt to free EPA from unambiguous statutory obligations that otherwise would constrain a joint rulemaking (e.g., NHTSA "may not consider "the fuel economy (i.e., the availability) of dedicated alternative fueled automobiles – including battery-electric vehicles – in any model year for which standards are being set." 87 Fed. Reg. 25710, 25994 (May 2, 2022)). It is simply not plausible that the general standard-setting authority of CAA § 202(a) can be construed to confer omnibus authority for EPA to effectively rewrite directly relevant statutory directives.

ii. EPA's authority under CAA §§ 202(a)(1) and (2) to prescribe emissions standards for vehicles and engines does not extend to a mandatory shift in powertrain technology.

As explained above, the Proposed Rule would effectively require that a significant proportion of new LDV and MDV must be powered by electric drivetrains. That proportion significantly exceeds the level of new vehicle electric vehicle sales that otherwise would occur. As a result, the Proposed Rule would constitute a mandate to produce electric vehicles.

Moreover, electric vehicles are not just another form of conventional diesel or gasoline fueled ICE-driven vehicles. For example, a BEV cannot be produced by modifying a conventional ICE drivetrain (e.g., by changing combustion conditions) or by adding pollution control technology to a conventional ICE drivetrain (e.g., catalytic converter or gasoline particulate filter). Rather, BEVs employ wholly different propulsion technology as compared with conventional ICE drivetrains. BEVs use electricity and batteries rather than liquid fuels stored in fuel tanks and employ electric motors for propulsion rather than ICE engines.

EPA asserts that CAA §§ 202(a)(1) and (2) authorize the imposition of an electric vehicle mandate. But for the following four reasons, EPA does not have authority under CAA §§ 202(a)(1) and (2) or under any other CAA provision to impose such a fundamental and mandatory shift in powertrain technology.

First, EPA may regulate a class of motor vehicles under CAA § 202(a)(1) only if emissions from that class of vehicles "cause, or contribute to, air pollution which may reasonably be anticipated to endanger public health or welfare." EPA treats BEVs as if they do not have emissions for the purposes of this proposal. 88 Fed. Reg. at 29297. As a result, under EPA's rationale, BEVs do not emit the pollutants that are the object of the Proposed Rule and cannot cause or contribute to the endangerment that EPA asserts as the basis for its authority to regulate here under CAA § 202(a)(1). Thus, it is beyond EPA's authority to include electric vehicles in its regulations under § 202(a) or to impose an electrification mandate.

Second, CAA § 202(e) – entitled "New power sources or propulsion systems" – states that EPA may defer the certification for a new motor vehicle employing a new power source or propulsion system until after the Agency has "prescribed standards for any air pollutants emitted by such vehicle or engine which in [the Administrator's] judgment cause, or contribute to, air pollution which may reasonably be anticipated to endanger the public health or welfare but for which standards have not been prescribed under [CAA § 202(a)]." Thus, EPA must take two actions when assessing a new power source or propulsion system. EPA first must determine whether emissions from the new power source or propulsion system cause or contribute to air pollution that endangers public health or welfare. If the answer is yes, EPA must then establish new emissions standards for the new power source or propulsion system or, alternatively, determine that appropriate standards have already been established.

BEVs clearly constitute a new power source or propulsion system. As a result, before certifying any BEVs, CAA § 202(e) requires that EPA determine whether emissions from BEVs cause or contribute to air pollution that endangers public health or welfare. But, EPA treats BEVs as if they do not have emissions. Consequently, EPA cannot determine that emissions from BEVs cause or contribute to any endangerment caused by emissions and, therefore, the Agency has no need or authority to impose emissions standards on BEVs prior to certifying them.

Third, CAA § 202(a)(1) authorizes EPA to establish "standards applicable to the emission of any air pollutant from any ***class or classes*** of new motor vehicles or new motor vehicle engines." CAA § 202(a)(1) (emphasis added). This provision requires EPA to define appropriate classes of vehicles for purposes of making the cause/contribute finding and in subsequently establishing emission standards.

From the outset of its CAA-based motor vehicle regulatory program, EPA has properly distinguished between fundamentally different powertrain technologies – e.g., regularly developing and issuing separate standards for gasoline-powered vehicles and diesel-powered vehicles. In contrast, EPA here combines all powertrain types into the same classes for purposes of imposing emission standards. That is contrary to the statute, arbitrary, and capricious because conventionally powered vehicles have fundamentally different emissions characteristics than electric powered vehicles. See also CAA § 202(e) (requiring EPA to separately evaluate emissions from "a new power source or propulsion system.")

As demonstrated by EPA's prior LDV GHG standards, there is a wide variety of emissions control techniques that may be applied to conventionally powered LDV to reduce GHG emissions – including such things as improved engine efficiency, better aerodynamics, and lower rolling resistance. Applying such measures to BEVs does not affect their GHG emissions profile because, by EPA's definition, BEVs do not emit GHGs. This shows that conventionally powered vehicles and BEVs should not occupy the same class under these rules because wholly different regulatory approaches are needed to appropriately control GHG emissions from these two fundamentally different types of vehicles.

Fourth, EPA's regulatory approach is unlawful because it treats BEVs as if their powertrain were an emissions control technology and then mandates the use of that purported emission control technology. EPA claims throughout the proposed rule that its proposed standards do not require manufacturers to implement any specific technology and, instead, that they retain flexibility to comply with the rule in whatever manner they deem appropriate. *See, e.g.,* 88 Fed. Reg. at 29232. But the proposed rule inescapably will require a significant industry-wide shift from internal combustion to BEVs. A particular manufacturer may avoid producing a BEV though creative use of the ABT provisions, but the industry as a whole will have no choice but to produce increasing numbers of BEVs over time. This is contrary to CAA § 202(a), which authorizes EPA to set emissions standards, but does not authorize EPA to mandate the use of any particular emissions control technology in meeting those standards.

iii. EPA has no authority under CAA §§ 202(a)(1) and (2) to establish emissions standards based on credit trading among manufacturers.

The Proposed Rule is fundamentally different from prior LDV GHG rules in that EPA factors credit trading among manufacturers into its standard setting analysis. EPA explains that "[i]n light of the evidence of increased adoption of trading as a compliance strategy, EPA has included the ability of manufacturers to trade credits as part of our central case compliance modeling for this proposal, rather than as a sensitivity analysis as we did in the modeling for the 2021 rule." 88 Fed. Reg. at 29343. So, rather than allowing for credit trading as a "compliance flexibility" for purposes of implementing the standards, credit trading is included in setting the standards in the first instance.

The use of credit trading in standard setting is legally flawed for two reasons. First, it is true that EPA has long used credit trading as a compliance method under its vehicle emissions standards. But here EPA is doing more – EPA uses credit trading in setting the standards themselves. EPA provides no explanation of its legal authority for this novel approach.

Second, CAA § 202(a)(2) requires EPA to consider cost and technical feasibility in setting emissions standards. By factoring credit trading into standard setting, EPA unreasonably is diluting the cost impact of the Proposed Rule on manufacturers that opt not to engage in credit trading. As EPA notes, "trading is an optional compliance flexibility." 88 Fed. Reg. at 29343. And EPA acknowledges "that automakers may choose to use it in their compliance strategies to varying degrees." *Id*. But rather than assess the costs of compliance for manufacturers that choose not to engage in credit trading, EPA asserts without analysis or other support that "reduced use of credit trading may result in somewhat higher costs for the program, but we do not believe it would alter our conclusion that the standards are feasible." *Id*. An agency "belief" that is untethered to facts or analysis does not provide an adequate basis for EPA to conclude that the proposed emissions standards are cost effective in the absence of trading. EPA thus fails to satisfy its clear statutory obligation to factor costs into the proposed emissions standards.

iv. EPA exceeded its authority by ignoring the distinctions Congress made between heavy duty vehicles and light-duty vehicles and commingling them in the same averaging, banking, and trading (ABT) program with smaller vehicles.

EPA explains in the Proposed Rule that "[l]ight-duty trucks (LDTs) that have gross vehicle weight ratings above 6,000 pounds and all MDVs are considered ''heavy-duty vehicles'' under the CAA." 88 Fed. Reg. at 29226 n. 382. This comports with CAA § 202(b)(3)(C), which defines the term "heavy duty vehicle" to mean "a truck, bus, or other vehicle manufactured primarily for use on the public streets, roads, and highways (not including any vehicle operated exclusively on a rail or rails) which has a gross vehicle weight (as determined under regulations promulgated by the Administrator) in excess of six thousand pounds." This definition communicates Congress's clear intent that heavy-duty vehicles should be regulated as a distinct class of vehicles, separate from light-duty vehicles.

The Proposed Rule violates this obligation by regulating certain heavy-duty vehicles as light-duty vehicles and by commingling these two classes in the same averaging, banking, and trading program (which, as addressed in subsection iii, above, is unlawfully considered in formulating the proposed emissions standards).

The problem here involves "medium duty vehicles" ("MDV"), which EPA defines to mean Class 2b and 3 vehicles. 88 Fed. Reg. at 29226. EPA explains that it "has not previously used the MDV nomenclature, referring to these larger vehicles in prior rules as either heavy-duty Class 2b and 3 vehicles or heavy-duty pickups and vans." EPA further explains that it previously "addressed medium-duty vehicle emissions as part of regulatory programs for GHG emissions along with the heavy-duty sector." *Id*. at 29227. The exception was "medium duty passenger vehicles" ("MDPV") which EPA previously has defined as "vehicles between 8,501 and 10,000 pounds GVWR designed primarily for the transportation of persons." *Id*. at 29226 n. 382. According to EPA, "[w]hen [it] established its GHG standards in 2010, EPA included MDPVs in the light-duty vehicle GHG program as well," such that "[e]ssentially, MDPVs are heavy-duty vehicles that are included in light-duty vehicle programs." *Id*. at 29278.

EPA here proposes to expand the definition of MDPV in two ways: (1) "EPA is proposing to include in the MDPV definition any passenger vehicles at or below 14,000 pounds GVWR with a work factor at or below 5,000 pounds except for pickups with an open bed interior length of eight feet or larger which would continue to be excluded from the MDPV category"; and (2) EPA proposes "to include in the MDPV category any pickups with a GVWR below 9,900 pounds and an interior bed length less than eight feet regardless of whether the vehicle work factor is above 5,000 pounds. Pickups at or above 9,900 pounds up to 14,000 pounds GVWR with a work factor above 5,000 pounds would be included as MDPVs only if their interior bed length is less than six feet." *Id*. EPA proposed these changes out of concern that "potential market changes [] could move passenger vehicles out of the LD regulatory class." *Id*.

The inclusion of heavy-duty vehicles (i.e., "a truck, bus, or other vehicle manufactured primarily for use on the public streets, roads, and highways … which has a gross vehicle weight … in excess of six thousand pounds," CAA § 202(b(3)(C)) in the same class as light-duty vehicles for purposes of setting emissions standards violates EPA's obligation to regulate heavy-duty vehicles and light-duty vehicles as separate classes under CAA § 202. This fundamental error is magnified by the current proposal to expand the category of MDPVs to include both heavier vehicles and an expanded range of lighter vehicles.

v. The use of BEV technology is not an emissions standard under CAA §§ 202(a)(1) and (2).

By factoring BEVs into the proposed emission standards, EPA effectively is treating BEVs as an emissions control technology that can form the basis of an emission standard. This exceeds EPA's authority under CAA § 202(a).

CAA § 202(a)(1) authorizes EPA to prescribe "standards applicable to emissions." In other words, EPA is authorized to prescribe emission standards for motor vehicles. The term "emission standard" means a requirement "which limits the quantity, rate, or concentration of emissions of air pollutants." CAA § 302(k).

The problem with EPA's regulatory approach here is that a BEV is not an emissions control technology for a conventionally powered vehicle. A BEV does not and cannot limit the "quantity, rate, or concentration" of air pollutant emissions from a conventionally powered vehicle. Rather, a BEV represents an entirely different type of propulsion system and powertrain. The existence of BEVs has no bearing on the relative emissions from conventionally powered vehicles.

Consequently, a BEV powertrain is not an emissions reduction technology applicable to conventionally powered vehicles and cannot form the basis of emission standards applicable to conventionally powered vehicles.

vi. The Clean Air Act already expressly provides a regulatory scheme for Clean Fuel Vehicles in Part C of Title II. That regulatory scheme precludes the regulation of BEVs together with internal combustion engines.

CAA § 242(a) requires EPA to "promulgate regulations under this part containing clean-fuel vehicle standards for the clean-fuel vehicles specified in this part." A clean fuel vehicle is one that is powered by a "clean alternative fuel," which is defined to include electricity. CAA § 241(2). The state implementation plan for areas designated in severe or greater nonattainment with ozone National Ambient Air Quality Standards must include a clean-fuel vehicle program. CAA § 182(c)(4). The program must apply to centrally fueled fleets. *Id*. at § 246.

EPA cites the Clean Fuel Vehicles program as an indication that Congress generally intended to "promote further progress in emissions reductions." 88 Fed. Reg. at 29233. EPA thus points to the Clean Fuel Vehicles program as supporting its proposed interpretation that CAA §§ 202(a)(1) and (2) authorize EPA to mandate the production and sale of BEVs. But in doing so, EPA fails to address the regulatory program required under the Clean Fuel Vehicles program and fails to reconcile the particular requirements of that program with the CAA § 202(a) general rulemaking authority on which it relies as the primary authority for the Proposed Rule.

The Clean Fuel Vehicles program plainly requires EPA to establish a separate regulatory scheme for clean fuel vehicles, including electric powered vehicles. "Clean-fuel vehicles . . . subject to standards set forth in this part shall comply with all motor vehicle requirements of this subchapter. . . which are applicable to conventional gasoline-fueled vehicles of the same category and model year . . . except to the extent that any such requirement is in conflict with the provisions of this part." CAA § 242(b), 42 U.S.C. § 7582(b). This provision clearly signals that Congress intended for EPA to develop specific standards for clean fuel vehicles (including BEVs) and also ensure that those clean fuel vehicles comply with the separate emissions standards set for ICE powered vehicles. In the very least, Congress's explicit inclusion of electric powered vehicles in the Clean Fuel Vehicles program and its exclusion of any mention of electric powered vehicles in Section 202 must be given meaning. *Compare* 42 U.S.C. § 7581 *with* 42 U.S.C. § 7521(a), (e); *Bittner v. United States*, 143 S. Ct. 713, 720 (2023) ("When Congress includes particular language in one section of a statute but omits it from a neighbor, we normally understand that difference in language to convey a difference in meaning (*expressio unius est* *exclusio alterius*).") This Clean Fuel Vehicles Program would be rendered meaningless if, as in the Proposed Rule, EPA were to consider conventionally fueled vehicles together with clean fuel vehicles (including BEVs) in developing and implementing emissions standards.

Moreover, the Clean Fuel Vehicles program is narrowly targeted to the worst ozone nonattainment areas and to the pollutants that contribute to ambient ozone levels. The program also imposes important constraints on how vehicles may be regulated (for example, as explained above, it dictates separate emissions standards for clean fuel vehicles). These detailed and prescriptive requirements demonstrate that Congress intended EPA to regulate clean fuel vehicles only in particular ways. EPA's claim in the Proposed Rule of omnibus authority to regulate clean fuel vehicles along with conventionally fueled vehicles cannot be reconciled with the targeted and carefully crafted regulatory scheme set out in the Clean Fuel Vehicles program.

In sum, the CAA clearly instructs EPA as to where and how clean fuel vehicles should be regulated. Those specific requirements displace any authority EPA might otherwise have had to regulate clean fuel vehicles under the general authority of CAA §§ 202(a)(1) and (2). EPA is thus mistaken in asserting that CAA §§ 202(a)(1) and (2) authorize the proposed LDV and MDV emissions standards. In addition, by failing to explain the legal basis on which EPA purports to fulfil its obligations under CAA §§ 202 and 242, the Proposed Rule fails to provide adequate notice and opportunity to commenters on the important legal questions surrounding the scope and extent of the Clean Fuel Vehicles program and how the specific regulatory scheme established under that program can be reconciled with EPA's claim of authority under CAA §§ 202(a)(1) and (2).

vii. The proposed emissions standards are unfounded because EPA fails to explain its rationale for selecting the proposed emissions control levels.

EPA provides an expansive explanation of the Proposed Rule in the 263-page Federal Register notice. But noticeably missing is any explanation of how EPA derived the numeric emissions standards that the Proposed Rule would establish. The "footprint-based standard curve coefficients" for cars and light trucks are clearly presented in the proposal. 88 Fed. Reg. at 29236. While EPA describes these curves as "targets, rather than standards," the curves effectively represent the emissions standards because the enforceable obligation for each manufacturer is derived by summing the actual sales-weighted values derived through application of the curves. *Id*. at 29236 n. 405. Because of the ABT compliance provisions, a manufacturer can demonstrate compliance for its fleet even if each of its vehicles does not meet the emissions limit applicable to that vehicle according to the curves. But each manufacturer must meet an enforceable in-use emissions standard for each vehicle type based on the level of emissions to which the vehicle is certified.

In presenting the curves, EPA discusses a wide variety of relevant factors -- including the upper and lower cutpoints, the slope of the curve, incentives/disincentives for consumer choice of larger vehicles (and the resulting impact on overall GHG emissions reductions), the impact of BEVs, and the relationship between the car and truck curves (the latter Including consideration of load and towing capacity). In addition, the preamble includes extensive discussion of the predicted costs of the Proposed Rule and technical feasibility. But nowhere does EPA explain how the numeric values of the curves (i.e., the actual GHG emissions rate that would be applied to each vehicle upon application of the curve) were derived and how those particular values are justified.

It is bedrock administrative law that an "agency must examine the relevant data and articulate a satisfactory explanation for its action including a rational connection between the facts found and the choice made." *Motor Vehicle Mfrs. Assn. of the United States, Inc. v. State Farm Mut. Automobile Ins. Co.,* 463 U.S. 29, 43 (1983). EPA's failure to do so here renders the Proposed Rule fatally arbitrary and capricious.

Additionally, the lack of explanation violates EPA's procedural obligation to develop a statement of basis and purpose that, among other things, explains "the factual data on which the proposed rule is based" and "the methodology used in … analyzing the data." CAA § 307(d)(3). Unless that failure is corrected, API and other interested parties do not have adequate notice of and opportunity to comment on one of the most fundamental aspects of the Proposed Rule.

viii. EPA lacks authority to set limits on aromatics and other high-boiling material.

The proposed rule asks for comments on whether EPA should engage in a rulemaking to address potential limits on aromatics and high-boiling material as fuel standards under CAA § 211(c). Although EPA has not proposed to engage in a rulemaking at this time, API urges the agency to avoid a costly and burdensome rulemaking effort that would exceed its authority.

The proposed rule acknowledges that fuel standards would not assist the new vehicle fleet to comply with the new standards, but suggests the agency is thinking about them to reduce particulate matter from the existing fleet. However, EPA lacks authority to set fuel standards to address vehicle emissions from the existing vehicles, which are already able to comply with their applicable particulate matter standards.

EPA's authority to regulate vehicle emissions applies only prospectively. EPA may only set standards for classes of "new motor vehicles." CAA § 202(a)(1). In turn, EPA may only consider controlling or regulating fuel after it has determined there are no other "economically feasible means of achieving emissions standards under section [202]." Regulating fuel cannot be needed to achieve the Section 202 standards for existing vehicles because those vehicles already meet their applicable particulate matter standards without any additional fuel regulation. Any attempt to rely on the inability of existing vehicles to comply with the particulate matter standards for new vehicles because of lack of alternative controls would be contrary to the Act's focus on prospective standards.

In any event, EPA may not issue standards under CAA § 211(c) at this time because, as the proposed rule readily admits, EPA has not "considered all relevant medical and scientific evidence available to [it], including consideration of other technologically or economically feasible means of achieving" the standards under section 202. *See* § 202(c)(2)(A). Unless and until EPA completes that analysis and allows stakeholders an opportunity to comment on it, EPA may not set new standards under CAA § 211(c).

i. Additional Concerns.

EPA must address several aspects of their analysis of vulnerabilities associated with critical minerals as outlined in Appendix A and related to cost, modeling, and assumptions as outlined in Appendix B.

j. Response to EPA Request for Information on Particulate Matter Fuel Controls.

In Appendix C we respond to EPA's request to review the Agency's rationale for considering fuels controls in a future rulemaking to reduce PM emissions. API finds the Agency has not appropriately considered all data and issues raised by a potential rulemaking. Furthermore, EPA needs to reconsider their analytical conclusions, limitations of SimDis, refinery modeling specifications, and that tire wear and entrained road dust related PM emissions are significant. Please note that due to the compressed comment period for such a complex request for information, coupled with the lack of an extension, API may supplement the docket.

APPENDICES

Appendix A: Critical Minerals Assessment

Appendix B: Detailed Look at the Assumptions Used in the EPA Analysis in the NPRM and the DRIA – Assessment Prepared by Martec

Appendix C: Consideration of Potential Fuels Controls for a Future Rulemaking

Appendix A:

Critical Minerals Assessment

There are hurdles to address in order to support the scale-up adoption of BEV. These hurdles include impacts on supply chains, energy resilience and the environment. Consideration to both the hurdles and mitigation measures should be given to inform responsible and effective implementation of vehicle standards.

Reliance on a limited number of technologies (e.g., BEVs) on the timeline required by the proposed rule will likely result in a non-resilient transport sector that is vulnerable to unexpected disruptions. Both the federal government and the private sector have recognized that critical minerals are essential to the future of BEVs, and likewise, that unstable critical mineral supply chains could disrupt this future. A BEV passenger car requires six times[85] more minerals than a conventional gasoline car. A PHEV requires just one-sixth the critical minerals compared to a BEV, making it a more achievable bridge while the industry scales.[86] We understand that EPA's current analysis does not include PHEV in their technology penetration rates, and that EPA plans to incorporate these technologies in the final rule. API recommends the critical minerals section of the rule be revisited considering PHEV in the assumptions and analysis. Additionally, EPA needs to explain why more of the total electrical vehicle miles travelled (VMT) could not be satisfied by PHEV, which would allow supply chains to better accommodate the demand for critical minerals and hence lower potential global environmental risk.

I. Mineral availability and mining.

BEV battery supply chains, including critical minerals and precursors are controlled by a small number of countries, some with unsustainable environmental and human rights practices, and geopolitical concerns. The mining sector would need to grow exponentially to meet the proposed rule's demands. According to a forecast by BMI, at least 384 combined new mines for graphite, lithium, nickel, and cobalt are required to meet the global demand by 2035.[87] These numbers highlighted by the BMI report were derived prior to EPA releasing the new rule proposals, which will significantly increase the need for new mines.

Mining is an energy- and environmental-intensive activity. Critical minerals for electric batteries such as lithium and copper are particularly vulnerable to water stress given their high-

---

[85] International Energy Agency. "The Role of Critical World Energy Outlook Special Report Minerals in Clean Energy Transitions." 2022. https://iea.blob.core.windows.net/assets/ffd2a83b-8c30-4e9d-980a-52b6d9a86fdc/TheRoleofCriticalMineralsinCleanEnergyTransitions.pdf.

[86] Pratt, G. "Carbon is our enemy: Let's Use Everything We've Got To Fight It." *Toyota Times*. September 2021. https://toyotatimes.jp/en/spotlights/172.html.

[87] More than 300 new mines required to meet battery demand by 2035: https://source.benchmarkminerals.com/article/more-than-300-new-mines-required-to-meet-battery-demand-by-2035.

water requirements.[88] Over 50 percent of today's lithium and copper production is concentrated in areas with high water stress levels. Activities associated with mining produce GHG emissions, as well as particulate matter emissions, nitrogen oxide emissions, and other air pollutant emissions from mining equipment. A strong focus on environmental and ethical best practices in this sector are needed to safeguard natural lands, biodiversity, sustainable water use, indigenous peoples' rights, and labor protections.[89]

Regarding the availability of critical minerals, especially those essential to the manufacturing of a Li-ion battery, the supply is dominated by three lithium producing countries — Australia, Chile and China, which account for nearly 90 percent of the global market. While 70% of global cobalt production comes from the Democratic Republic of Congo,[90] most of the mines are owned/operated by China and more than 60 percent of cobalt processing is located in China. China produces 67 percent of the world's graphite.[91] The U.S. imports most of its manganese from Gabon, a less geopolitically stable country, providing 65 percent of the United States' supply.[92] Electricity networks need a large amount of copper and aluminum. The need for grid expansion that would result from this rapid increase in electricity demand underpins a doubling of annual demand for copper and aluminum.[93] China possesses over half of the entire world's aluminum smelting capacity.

II. Supply chain resilience.

Looking forward toward 2030, based on current and anticipated global production plans, a global supply shortfall is likely to begin toward the end of the decade. If planned mining projects do not deliver as expected, some critical minerals could face shortages as early as next year.[94] Globally, it takes on average over 16 years to move mining projects from first discovery to production.[95] The ability to quickly scale minerals production is further affected by ore quality, which in recent years has been declining and thus requires more material to be mined,

---

[88] International Energy Agency. "The Role of Critical Minerals in Clean Energy Transitions", International Energy Agency World Energy Outlook Special Report. https://iea.blob.core.windows.net/assets/ffd2a83b-8c30-4e9d-980a-52b6d9a86fdc/TheRoleofCriticalMineralsinCleanEnergyTransitions.pdf.

[89] The Global Investor Commission on Mining 2030: https://mining2030.org/.

[90] International Energy Agency. "The Role of Critical Minerals in Clean Energy Transitions", International Energy Agency World Energy Outlook Special Report. https://iea.blob.core.windows.net/assets/ffd2a83b-8c30-4e9d-980a-52b6d9a86fdc/TheRoleofCriticalMineralsinCleanEnergyTransitions.pdf.

[91] "Graphite," Professional Paper 1802-J, US Geological Survey. https://pubs.er.usgs.gov/publication/pp1802J#:~:text=China%20provides%20approximately%2067%20percent%20of%20worldwide%20output,costs%20and%20some%20mine%20production%20problems%20are%20developing.

[92] Observatory of Economic Complexity: https://oec.world/en/profile/bilateral-product/manganese-ore/reporter/usa.

[93] International Energy Agency. "The Role of Critical Minerals in Clean Energy Transitions", International Energy Agency World Energy Outlook Special Report. https://iea.blob.core.windows.net/assets/ffd2a83b-8c30-4e9d-980a-52b6d9a86fdc/TheRoleofCriticalMineralsinCleanEnergyTransitions.pdf.

[94] L. Lee, Energy Intelligence "Mining the Gap to a Net-Zero Future," May 15, 2023. https://www.energyintel.com/00000188-1e5f-d806-ad9f-5edfeb1d0000?utm_campaign=website&utm_source=sendgrid.com&utm_medium=email.

[95] "International Energy Agency. "The Role of Critical Minerals in Clean Energy Transitions", International Energy Agency World Energy Outlook Special Report. https://iea.blob.core.windows.net/assets/ffd2a83b-8c30-4e9d-980a-52b6d9a86fdc/TheRoleofCriticalMineralsinCleanEnergyTransitions.pdf.

more resources such as water in stressed areas for processing, and ultimately greater environmental impacts.

EPA also fails to consider the value chain before the battery cell production. The domestic supply chain is in its early stages and to meet the proposed goals, automakers and battery manufacturers will still need to rely on foreign sources of critical materials and precursors. For instance, BMI foresees a 77 percent deficit in domestic available cathode active material to meet 2035 demands in North America. This estimate was done prior to the proposal. This step in the value chain will require import/export until it is further built out, which will add to cost to the battery pack.[96] Although Congress and the Administration have taken significant steps to accelerate this activity by funding, facilitating, and promoting the rapid growth of U.S. supply chains for these products through the IRA, BIL, and numerous Executive Branch initiatives, more will still be needed given the increase in demand.

For any one of these minerals, this regulation, taken to its logical end, puts the U.S into a situation resembling the oil embargoes of the 1970s, where foreign actors control majorities of the critical raw material supplies used in the manufacture of fuels, battery, and motor components designed to provide transportation mobility services for the U.S. consumer. Compared with fossil fuel supply, the supply chains for clean energy technologies can be even more complex (and in many instances, less transparent).[97, 98]

EPA failed to consider all the hurdles and complexities such as federal permitting, National Environmental Policy Act reviews, and the supply chains for these critical materials in their technology feasibility assessment. API requests EPA include a thorough evaluation of the full supply chains for each critical mineral/material in their final proposal and their implications on energy security.

III. Operational inefficiency of battery production facilities.

While many OEMs and battery manufacturers have announced plans to build gigafactories in North America, taking advantage of incentives such as the IRA, one must view these as highly complex projects. It should also be noted that it will take time for these new battery manufacturing facilities to ramp up to full production. Capacity gives a reflection of what a plant could potentially produce; capacity reflects ambition. EPA notes in the DRIA that "the Department of Energy estimates that recent plant announcements for North America to date could enable an estimated 838 GWh of capacity by 2025, 896 GWh by 2027, and 998 GWh by 2030, the vast majority of which is cell manufacturing capacity." This assumes battery manufacturing capacity at initial opening or at mature stage at 100% scale. This is not accurate. In their early years, battery factories will likely operate at approximately 50 percent production

---

[96] Benchmark Minerals Intelligence, BMI (*see* Charts 2, 3 & 4): https://source.benchmarkminerals.com/article/ambition-versus-reality-why-battery-production-capacity-does-not-equal-supply.

[97] International Energy Agency. "The Role of Critical Minerals in Clean Energy Transitions", International Energy Agency World Energy Outlook Special Report. https://iea.blob.core.windows.net/assets/ffd2a83b-8c30-4e9d-980a-52b6d9a86fdc/TheRoleofCriticalMineralsinCleanEnergyTransitions.pdf.

[98] SAFE. "The Commanding Heights of Global Transportation," https://secureenergy.org/wp-content/uploads/2020/09/The-Commanding-Heights-of-Global-Transportation.pdf.

capacity. Mature battery factories today rarely operate above 80 percent utilization rates.[99] The EPA projects a ten-fold increase in North American battery manufacturing capacity in just eight years, from 90 gigawatt hours per year in 2022, to 998 GWh/year in 2030, with the great majority of that sited in the U.S. Wood Mackenzie projects U.S. capacity of less than half that level, at 422 GWh/ year in 2030.[100] Given the disparity in forecasts from different reputable sources, EPA's technology feasibility assessment should factor sensitivity cases and acknowledge potential disruptions in the supply chain.

IV. Raw materials are specialty chemicals, not commodities.

To meet the ambitions that OEMs have set forth in terms of percentage of BEV entering the market, they must secure adequate amounts of raw materials. With the projected supply and demand gap that many analysts foresee, as mentioned earlier, pricing of critical minerals could remain volatile as we have seen through the early 2020s. There are varying views by different analysts on the direction of critical mineral pricing scenarios. Morgan Stanley estimates BEV manufacturers will need to increase prices by 25 percent to account for rising battery prices.[101] Battery raw materials are not commodities, they are classified as specialty chemicals, and pricing should be analyzed as such as they will not follow traditional commodity pricing structures, especially given where these supplies are geographically concentrated in areas with geopolitical instabilities.

V. Recycling of batteries and related electrical components is in its infancy.

Another critical aspect to be considered with this proposal is that recycling of the battery and related electrical components of BEVs are in a state of infancy and poses unique materials handling and safety challenges. The environmental profiles of both BEVs and ICEVs should be considered in light of the production, operation, and disposal of the vehicle (its useful life). Electric battery disposal-related issues are likely to impact the environment and need to be addressed in EPA's proposal:

- Battery packs could contribute 250,000 metric tons of waste to landfills for every 1 million retired BEVs.[102]
- Less than five percent of lithium-ion batteries, the most common batteries used in BEVs, are currently being recycled "due in part to the complex technology of

---

[99] Xiao, Maya, "Lithium-ion battery production goes global," January 26, 2022. https://www.controleng.com/articles/lithium-ion-battery-production-goes-global/.

[100] Wood Mackenzie: https://identity.woodmac.com/sign-in?goto=https%3A%2F%2Fmy.woodmac.com%2Fdocument%2F150115630

[101] Thornhill, J. "Morgan Stanley Flags EV Demand Destruction as Lithium Soars," see Chart 7. *Bloomberg*. March 24, 2022. https://www.bloomberg.com/news/articles/2022-03-25/morgan-stanley-flags-ev-demand-destruction-as-lithium-soars#xj4y7vzkg.

[102] Kelleher Environmental. "Research Study on Reuse and Recycling of Batteries Employed in Electric Vehicles: The Technical, Environmental, Economic, Energy and Cost Implications of Reusing and Recycling EV Batteries." September 2019. https://www.api.org/oil-and-natural-gas/wells-toconsumer/fuels-and-refining/fuels/vehicle-technology-studies.

the batteries and cost of such recycling."[103]

- Economies of scale will play a major role in improving the economic viability of recycling, which currently cost is the main bottleneck. Increasing collection and sorting rates is a critical starting point.[104]

- The cathode is where much of the material value in a Lithium-ion battery is concentrated. Currently, there are numerous cathode chemistries being deployed. Each of these chemistries needs to be known, and then the appropriate method of recycling identified, which poses a challenge, as batteries pass through a global supply chain and all materials are not well tracked.

- Lithium can be recovered from existing Lithium-ion recycling practices, but it is not economical at current lithium prices. Cobalt, one of the highest supply risk materials for BEV in the short- and medium-term, is currently being profitably recovered.

- Benchmark forecasts near-term recyclers are likely to use scrap material from the increasing number of gigafactories coming online versus used electric vehicle batteries. Scrap material is anticipated to account for 78 percent of recyclable materials in 2025.[105]

- In 2022, Benchmark expected over 30 gigawatt hours of process scrap to be available for recycling, growing ten-fold across the next decade. Loss rates vary by region and tend to be higher in earlier years of a gigafactory.[106]

- EV batteries are high-cycle batteries and are made to function for approximately 10 years, shorter time for a medium-duty vehicle. Many 'spent' EV batteries still have 70-80 percent of their capacity left, which is more than enough to be repurposed into other uses such as energy storage and other lower-cycle applications.[107] This will extend the time that batteries and raw materials remain in use.

- Repurposing used EV batteries could generate significant value and help bring down the cost of residential and utility-scale energy storage to bring forth

---

[103] Harper, G., Sommerville, R., Kendrick, E. et al. Publisher Correction: "Recycling lithium-ion batteries from electric vehicles." *Nature* 578, E20 (2020). https://doi.org/10.1038/s41586-019-1862-3.

[104] International Energy Agency. "The Role of Critical Minerals in Clean Energy Transitions", International Energy Agency World Energy Outlook Special Report. https://iea.blob.core.windows.net/assets/ffd2a83b-8c30-4e9d-980a-52b6d9a86fdc/TheRoleofCriticalMineralsinCleanEnergyTransitions.pdf.

[105] BMI (see Chart 8): https://source.benchmarkminerals.com/article/battery-production-scrap-to-be-main-source-of-recyclable-material-this-decade.

[106] BMI: https://source.benchmarkminerals.com/article/battery-production-scrap-to-be-main-source-of-recyclable-material-this-decade.

[107] Engel, H., Hertzke, P., & Siccardo, G. (2019, April). Second-life EV batteries: The newest value pool in Energy Storage. McKinsey Center for Future Mobility. https://www.mckinsey.com/~/media/McKinsey/Industries/Automotive%20and%20Assembly/Our%20Insights/Second%20life%20EV%20batteries%20The%20newest%20value%20pool%20in%20energy%20storage/Second-life-EV-batteries-The-newest-value-pool-in-energy-storage.pdf.

further penetration of renewable power to electricity grids. Initial trials are underway.[108]

- Clear guidance on repackaging, certification, standardization, and warranty liability of spent EV batteries would be needed to overcome safety and regulatory challenges reuse poses at scale.[109]
- Recycling BEV batteries to recover high-value metals has not been proven at commercial scale. Many analysts are aligned that recycling will not become an integral supplier of raw materials until the 2030s, and at that point, only will provide approximately 20 percent of demand.[110]

---

[108] "The Role of Critical Minerals in Clean Energy Transitions", International Energy Agency World Energy Outlook Special Report. https://iea.blob.core.windows.net/assets/ffd2a83b-8c30-4e9d-980a-52b6d9a86fdc/TheRoleofCriticalMineralsinCleanEnergyTransitions.pdf.

[109] Ibid.

[110] BMI: https://source.benchmarkminerals.com/article/battery-production-scrap-to-be-main-source-of-recyclable-material-this-decade.

Appendix B:

Detailed Look at the Assumptions Used in the EPA Analysis in the NPRM and the DRIA – Assessment Prepared by Martec

EPA referred to the proposed rule[111] as "the most ambitious pollution standards ever for cars and trucks," while also saving the "average consumer $12,000 over the lifetime of a light-duty vehicle." EPA has also estimated that the benefits of the proposed standards would exceed costs by at least $1 trillion. In reaching its conclusions, the agency also expects the proposed regulations would require "67% of new light-duty sales" to be solely powered by batteries and new power generation facilities to "fuel" these new BEVs. These changes would require significant changes in the way vehicles are designed, built, and fueled. However, as these changes occur, the agency has promised large savings to the consumer and a net positive impact on the U.S. economy. The following is a detailed look at the assumptions used in the EPA analysis in the NPRM and the DRIA to determine if the claims made are valid.

EPA has failed to adequately explain several aspects of their analysis. In order to provide the public with meaningful ability to comment there are several aspects that need further clarification:

- The cost reduction model used in the analysis seems to be based on a model used for part cost reductions driven by improved economies of scale on fixed capital equipment. Given that raw materials make up a significant portion of battery costs, EPA should also use a raw material supply cost model that considers the increasing costs for raw materials with increased supply.
- Cost and price are concepts that the agency uses interchangeably in the regulation. The true cost of the regulation is not fully calculated since the portion of the consumer-facing price is paid for by the government. The agency should fully account for the technical feasibility of any CO_2-reducing technology on a cost basis as defined in the CAA regardless of governmental taxation breaks for electric vehicle technology production and sale.
- The cost impact of "fueling" the significant number of electric vehicles assumed in the regulation (67% implied EV share by 2032) is not fully calculated or considered as part of the technical feasibility analysis and cost for the technology. The costs of adding additional solar, wind, and hydropower plants should be considered in the regulation as they are a necessary part of bringing electric vehicles to market.

---

[111] https://www.epa.gov/regulations-emissions-vehicles-and-engines/proposed-rule-multi-pollutant-emissions-standards-model.

Battery Cost Modeling

The NPRM includes several citations[112] of battery cost analysis used by the EPA in developing the technical feasibility of the regulation based on Argonne National Laboratory's BatPaC Model Software. This software includes an analysis of several different battery chemistries and a breakdown of the individual costs for various components needed to manufacture an automotive battery at scale.[113] Argonne's assessment of the 2022 battery cost concludes that 63% of the total battery cost is from raw materials on the anode and cathode of the individual cells. This is an important fact for EPA to consider in the assessment of long-term battery cost modeling as the model for parts and raw materials are fundamentally different.

The NPRM then applies a modeling equation to these initial cost/kWh values to develop long-term costs on a year-by-year basis. This model is detailed in the DRIA in section 2.5.2.1.3.[114]

1) Calculate the cumulative GWh needed by BEVs placed into the analysis fleet through the last model year.

2) Calculate the cost reduction factor due to learning:

factor = 4.1917 × (cumulative GWh through last year) $^{-0.225}$

3) Calculate battery cost in the base year, as a function of pack kWh, according to the equation in RIA 2.5.2.1.2: $\$/kWh$ = 261.61 × (gross kWh) $^{-0.184}$

4) Multiply the result of Step 3 by the result of Step 2.

This model makes several unrealistic assumptions:

- No lower bound with increasing volume – at some point in the future, the real cost of battery cells will be $0.00 based on the model used in the NPRM due to cumulative GWh production.
- Cumulative GWh calculation based on production of batteries in the U.S. but it needs to be based on the global production of batteries to establish a baseline.
    - It is global economics that support the costs of battery production, not the economics of the U.S. alone.
    - Global battery volume is expected to rise from ~700GWh to 5,300GWh by 2035.[115]
- $75/kWh was selected for 2035; however, the modeling cited above implies a $46/kWh value based on the model parameters.

---

[112] 40 CFR Parts 85, 86, 600, 1036, 1037, and 1066 [EPA–HQ–OAR–2022–0829; FRL 8953–03– OAR] pages 29295, 29299, 29301, 29302.

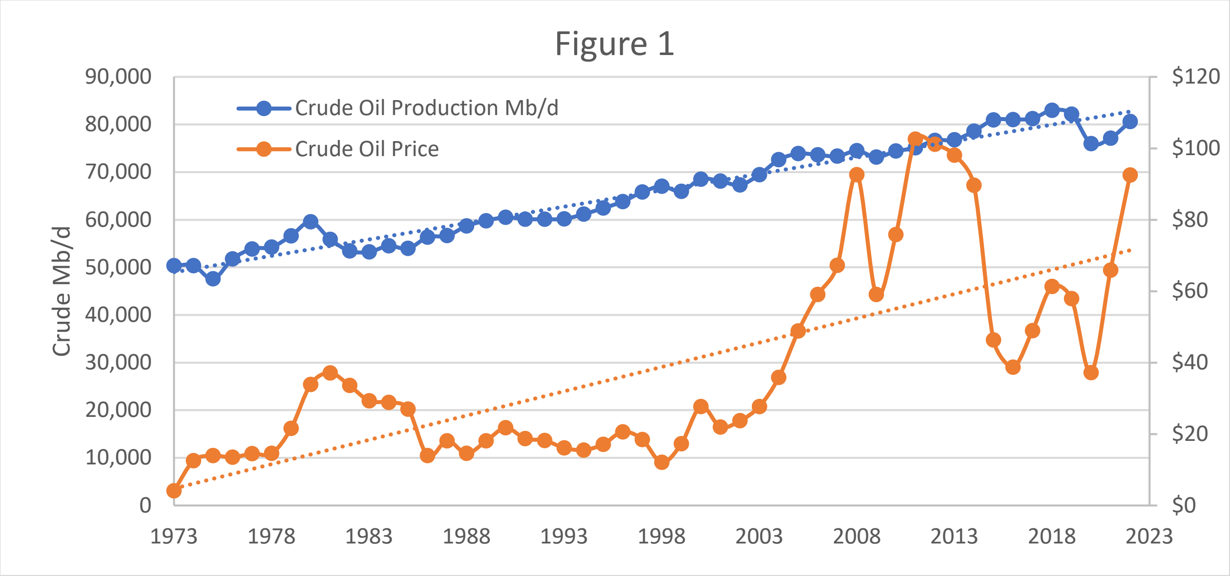
[113] https://www.anl.gov/cse/batpac-model-software.

[114] Multi-Pollutant Emissions Standards for Model Years 2027 and Later Light-Duty and Medium-Duty Vehicles - Draft Regulatory Impact Analysis (EPA-420-D-23-003, April 2023).

[115] https://emobilityplus.com/2023/04/21/global-electric-vehicle-battery-market-to-reach-616-billion-by-2035-report/.

  - The cost model cited in the NPRM appears to be voided by several assumptions for cost reduction milestones in section 2.5.2.1.3.
- Manufacturing battery cells operates on the same cost curve as manufacturing standard automotive parts - the cost of the materials in manufacturing battery cells operates on a different cost curve to standard automotive part production and this is not accounted for in the model.
  - Resource modeling is not capital-dependent but resource dependent. This curve follows an increasing cost as production levels are increased and not a reduction as cited in the regulatory framework of the NPRM.
- Biasing the model with the initial development phase will not represent the long-term trend and therefore a more appropriate model should be used to represent real-world costs and volume impacts.

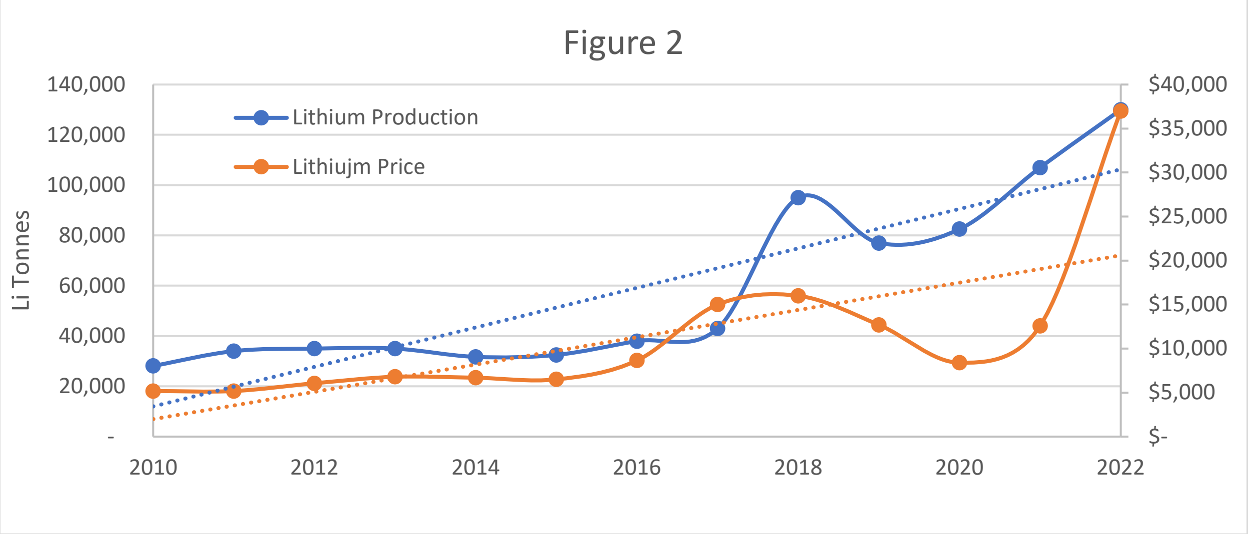
Since Argonne has established a 63% critical raw material value in their development of the BatPaC, it is important for the regulation to follow the economics of raw materials rather than capital depreciation and learning models for purposes of accuracy. Perhaps following the economics of oil production would be more representative of modeling the costs of 63% of the batteries in automotive applications.



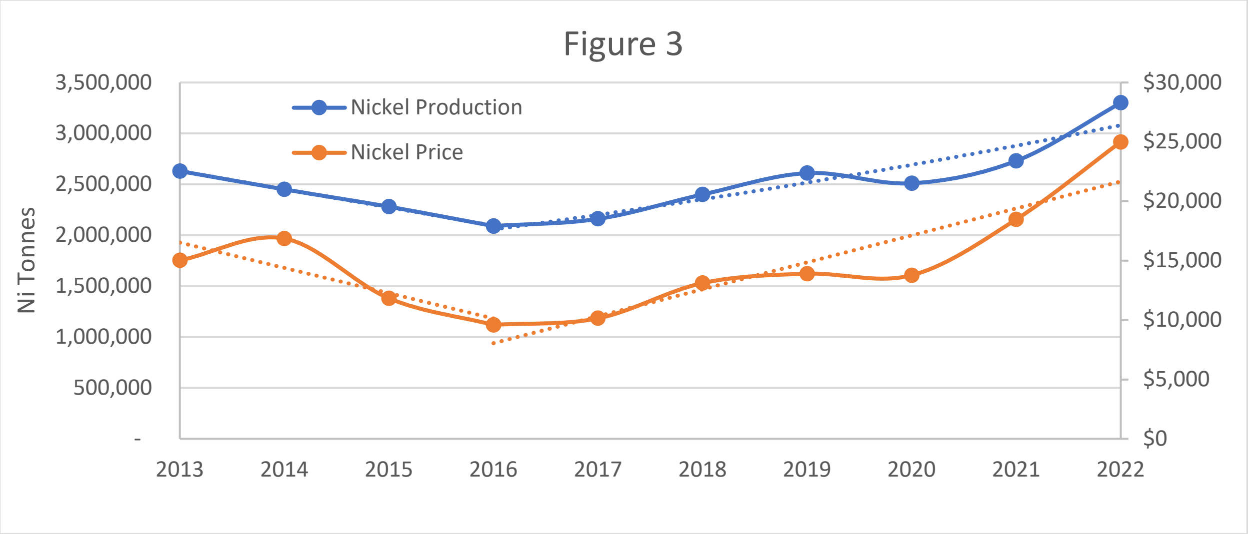
As shown in Figure 1, over the last 40 years the global supply of oil has increased by ~50%.[116] During that same period, the price increased by ~200%.

---

[116] EIA Global crude oil production and price sourced in May 2023.



As shown in Figure 2, lithium has followed a similar trend to oil – Global production[117] is up 400%, and prices are up 600%.



Nickel also follows a similar trend shown in Figure 3. Rising in price with increased demand and falling with reduced demand over the last 10 years.[118]

These examples show how real-world resource costs are impacted by demand. Unlike the automotive parts model used in the regulation, price and volume tend to move in the same direction for critical battery raw materials. This is because these raw materials are produced in the lowest-cost locations, to begin with, and then move to higher-cost locations to meet demand over time. We see this with oil resources as well. The lowest cost-to-produce sources are used first and only after those sources are at capacity are the higher cost sources then

---

[117] USGS Global lithium production and price sourced in May 2023.

[118] USGS Global nickel production and price sourced in May 2023.

consumed by the market. We fully expect to see the same trend with all critical raw materials for battery production long term, contrary to the assumptions in the NPRM.

Based on the Argonne value of 63% raw material cost in an average automotive battery, we suggest the agency develop a new costing model to properly account for the 63% resource-based costs and use the current model only for the remaining 37% to account for the capital depreciation and learning on the remaining value of the battery.

Battery Raw Materials

Global demand for critical raw materials has been increasing with the increase in demand for automotive batteries as shown in Table 1. The key raw materials of interest for batteries are lithium, nickel, cobalt, and graphite. The production of these materials has increased by 18% to 251% over the last 10 years.[119]

Table 1

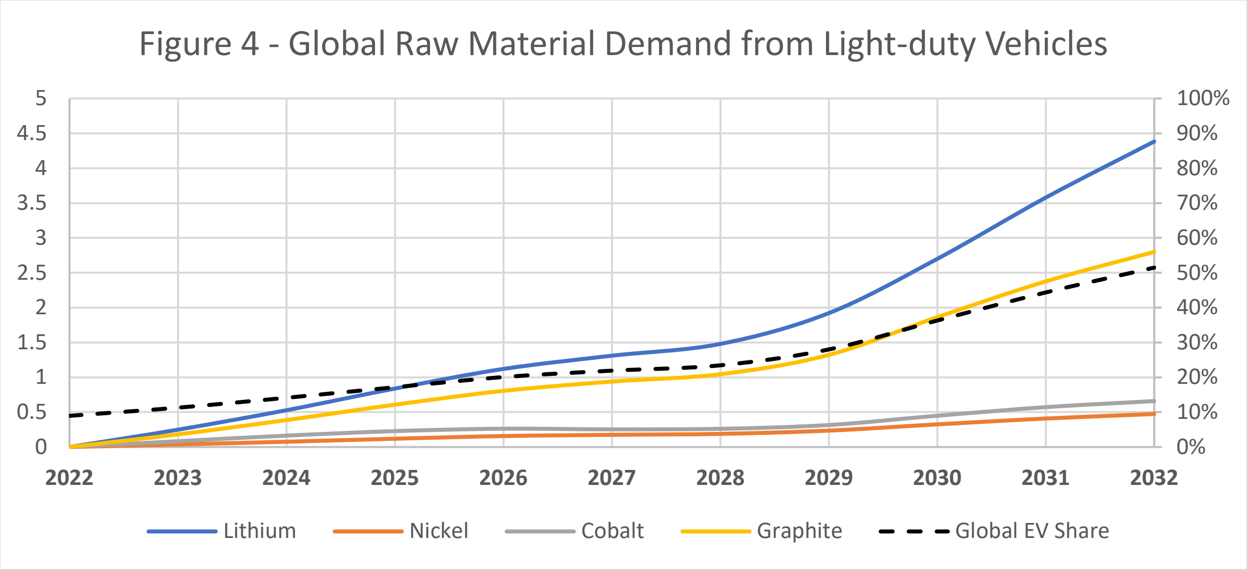
Raw Material (1000 tons)	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	% Increase
Lithium	37	35	36	32.5	35	43	96	87.1	83.2	107	130	251%
Graphite	1100	1190	1170	1190	1200	1200	930	1100	1100	1130	1300	18%
Nickel	2100	2490	2400	2530	2250	2100	2300	2610	2500	2730	3300	57%
Cobalt	110	120	112	124	123	110	140	144	140	165	190	73%

If we assume that the global production of electric light-duty vehicles grows to ~50% by 2032 and that technological improvements will be made in battery cell chemistry consistent with known publicly available technology announcements, the demand for these critical raw materials will continue to increase by 47% to 438% by 2032.[120] The output of this analysis is that there will be significant pressure on the mining industry to develop and process the raw materials to meet automotive battery demand.

---

[119] USGS Global material production sourced in May 2023.

[120] Martec Group study on raw material demand from light-duty vehicles – 2022.



In Figure 4 above, the increase in global production of raw materials for just light-duty vehicles is calculated based on the assumed global demand of 50% BEVs by 2032. The global average kWh per vehicle is assumed to be 71kWh and battery chemistry is expected to be ~30% LFP and 70% NMC battery types. This analysis then calculates the amount of raw material per kWh based on these inputs.[121]

What the outputs show is that lithium will need to increase the amount of mined material by more than 4 times in the next 10 years to keep up with just global light-duty automotive demand. Graphite is also expected to need ~3 times the amount currently produced globally. Nickel seems to be a low number at only a 50% increase from the 2022 production level however, nickel is already consumed in large quantities for other applications. This 50% increase represents ~1.6M tons of nickel while the 400% increase in lithium is only 400k tones.

The agency must consider the global demand for these raw materials in the final regulatory impact assessment and the associated increase in costs to develop supply for these raw materials that are more in line with market forces rather than assuming the cost of these raw materials will decrease with increasing production as stated in the DRIA.[122]

No-Action EV Scenario Assumption

The regulation accepts as a baseline a 40% BEV share of new vehicle sales by 2030 as part of the assumed no-action scenario.[123] This scenario appears to be driven by OEM announcements for future technology penetration for vehicles sold in the U.S.[124]

---

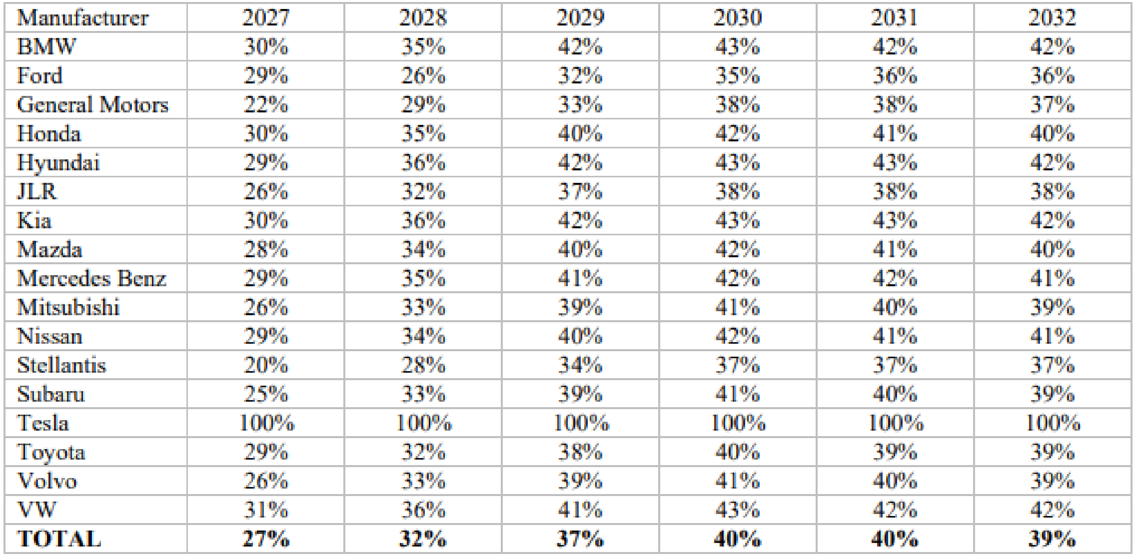
[121] https://www.nature.com/articles/s43246-020-00095-x#Sec16 Supplementary Table 23.

[122] Draft Regulatory Impact Analysis EPA-420-D-23-003 April 2023, Figure 2-24.

[123] Draft Regulatory Impact Analysis EPA-420-D-23-003 April 2023, Table 13-67.

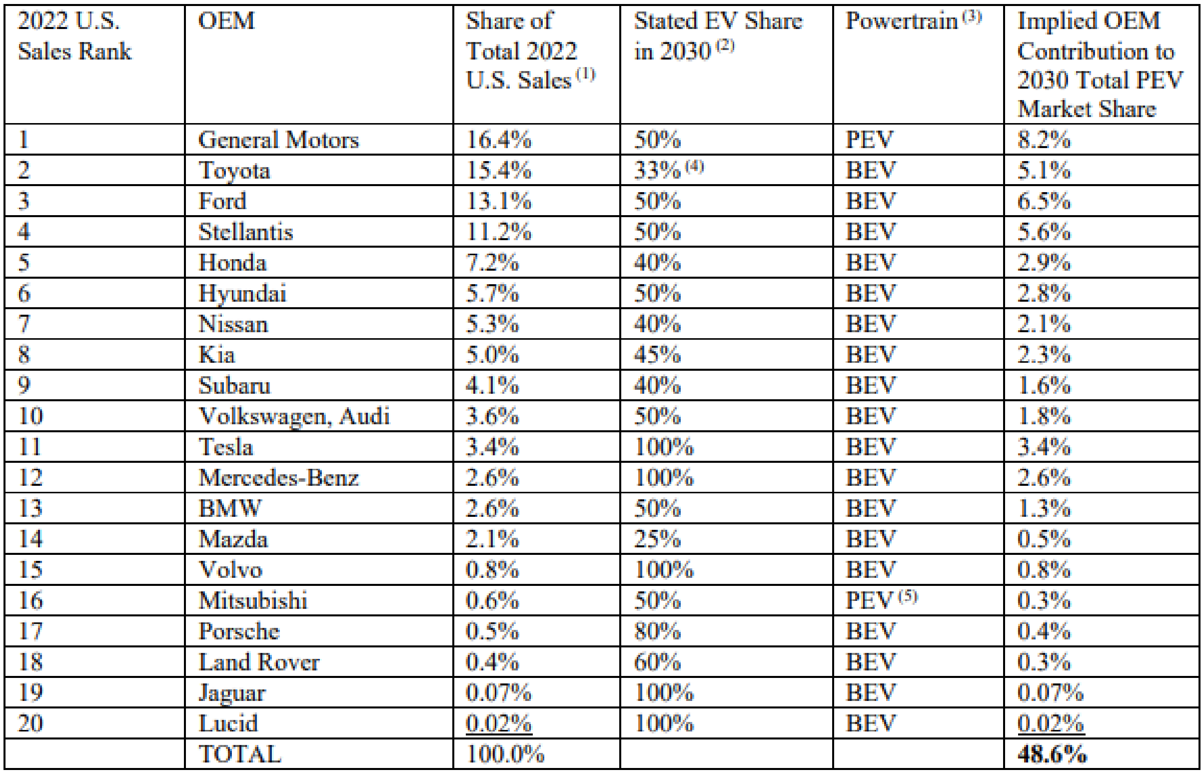
[124] 40 CFR Parts 85, 86, 600, 1036, 1037, and 1066 [EPA–HQ–OAR–2022–0829; FRL 8953–03– OAR] page 29192 Table 1.

Table 13-67: Projected BEV Penetrations, No Action - Combined



Manufacturer	2027	2028	2029	2030	2031	2032
BMW	30%	35%	42%	43%	42%	42%
Ford	29%	26%	32%	35%	36%	36%
General Motors	22%	29%	33%	38%	38%	37%
Honda	30%	35%	40%	42%	41%	40%
Hyundai	29%	36%	42%	43%	43%	42%
JLR	26%	32%	37%	38%	38%	38%
Kia	30%	36%	42%	43%	43%	42%
Mazda	28%	34%	40%	42%	41%	40%
Mercedes Benz	29%	35%	41%	42%	42%	41%
Mitsubishi	26%	33%	39%	41%	40%	39%
Nissan	29%	34%	40%	42%	41%	41%
Stellantis	20%	28%	34%	37%	37%	37%
Subaru	25%	33%	39%	41%	40%	39%
Tesla	100%	100%	100%	100%	100%	100%
Toyota	29%	32%	38%	40%	39%	39%
Volvo	26%	33%	39%	41%	40%	39%
VW	31%	36%	41%	43%	42%	42%
TOTAL	**27%**	**32%**	**37%**	**40%**	**40%**	**39%**

Table 1. Example of U.S. electrified new sales percentages implied by OEM announcements for 2030 or before



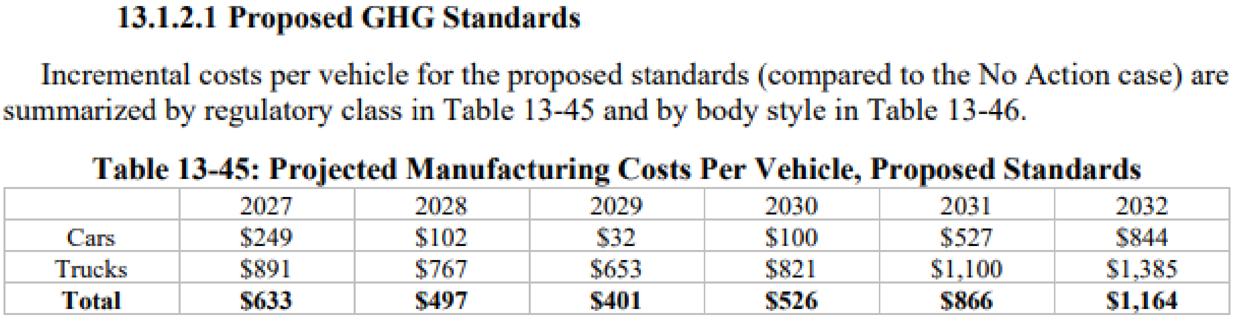
2022 U.S. Sales Rank	OEM	Share of Total 2022 U.S. Sales (1)	Stated EV Share in 2030 (2)	Powertrain (3)	Implied OEM Contribution to 2030 Total PEV Market Share
1	General Motors	16.4%	50%	PEV	8.2%
2	Toyota	15.4%	33% (4)	BEV	5.1%
3	Ford	13.1%	50%	BEV	6.5%
4	Stellantis	11.2%	50%	BEV	5.6%
5	Honda	7.2%	40%	BEV	2.9%
6	Hyundai	5.7%	50%	BEV	2.8%
7	Nissan	5.3%	40%	BEV	2.1%
8	Kia	5.0%	45%	BEV	2.3%
9	Subaru	4.1%	40%	BEV	1.6%
10	Volkswagen, Audi	3.6%	50%	BEV	1.8%
11	Tesla	3.4%	100%	BEV	3.4%
12	Mercedes-Benz	2.6%	100%	BEV	2.6%
13	BMW	2.6%	50%	BEV	1.3%
14	Mazda	2.1%	25%	BEV	0.5%
15	Volvo	0.8%	100%	BEV	0.8%
16	Mitsubishi	0.6%	50%	PEV (5)	0.3%
17	Porsche	0.5%	80%	BEV	0.4%
18	Land Rover	0.4%	60%	BEV	0.3%
19	Jaguar	0.07%	100%	BEV	0.07%
20	Lucid	0.02%	100%	BEV	0.02%
	TOTAL	100.0%			**48.6%**

OEM technology announcements have not always translated to implementation. For example:

- GM had made the claim in 2007 that they would have 1 million fuel cells on the road by 2012.[125]
    - This claim was never reached, and only limited fuel cell vehicles have ever been produced by GM.
- Ford made the claim in 2001 that their SUVs would increase their fuel economy by 25% by 2005.[126]
    - This claim was only reached after the global recession in 2008 forced buyers out of choosing the larger vehicles they were consuming prior to the recession.

Even the President of the United States isn't the best source of forecasting automotive technology. In the 2011 State of the Union speech, President Obama claimed that there would be 1 million EVs on the road by 2015.[127] The reality was only ~200,000 electric vehicles were on the roads in 2015 and it would take another 6 years (2021) for the 1 million EV goal to finally be reached.

Furthermore, we also question the agency's use of these forward-looking statements as a basis of fact when establishing the baseline cost assumption. The forward-looking statements on BEV penetration rates by the OEMs are predicated on expectations of potential regulatory standards set by the agency. This circular reasoning cannot support EPA's proposal here as the referenced forward-looking statements are largely a function of OEMs striving to create certainty and minimize risk as they attempt to comply with forthcoming regulations.



13.1.2.1 Proposed GHG Standards

Incremental costs per vehicle for the proposed standards (compared to the No Action case) are summarized by regulatory class in Table 13-45 and by body style in Table 13-46.

Table 13-45: Projected Manufacturing Costs Per Vehicle, Proposed Standards

	2027	2028	2029	2030	2031	2032
Cars	$249	$102	$32	$100	$527	$844
Trucks	$891	$767	$653	$821	$1,100	$1,385
Total	**$633**	**$497**	**$401**	**$526**	**$866**	**$1,164**

We question the rationale for requiring 67% BEV sales for compliance by 2032 but not accounting for the cost of these BEVs over the existing regulation as part of the regulatory impact analysis. Using Argonne's battery cost values from BatPaC we would expect an average cost of ~$12,000 for the battery system to be accounted for in the analysis. Additionally, the agency also assumes a cost of ~$3,500 for electric drive units, inverters, and charging systems.

---

[125] https://www.reuters.com/article/us-gm-fuelcells/gm-aims-to-be-first-to-make-1-million-hydrogen-cars-exec-idUSSHA9988820071114.

[126] https://www.autoweek.com/news/a2108121/fords-goal-boosting-suv-fuel-economy-2005-proves-elusive/.

[127] https://www1.eere.energy.gov/vehiclesandfuels/pdfs/1_million_electric_vehicles_rpt.pdf.

Removing the cost of the ICE powertrain and components from the vehicle would leave ~$7,500 to be accounted for in the regulation. With a 67% BEV market share assumption, this would be ~$5,000 compliance cost, not $1,164 as shown in the DRIA.

The agency needs to fully account for the costs of the regulation requiring 67% of BEVs to be sold by 2032 and not use incremental costs above the assumed volume of BEVs by the automakers themselves.

Fueling the BEVs

Section 5 of the DRIA discusses the electrical infrastructure impacts of the regulation forcing 67% BEV market share for new vehicles by 2032.[128]

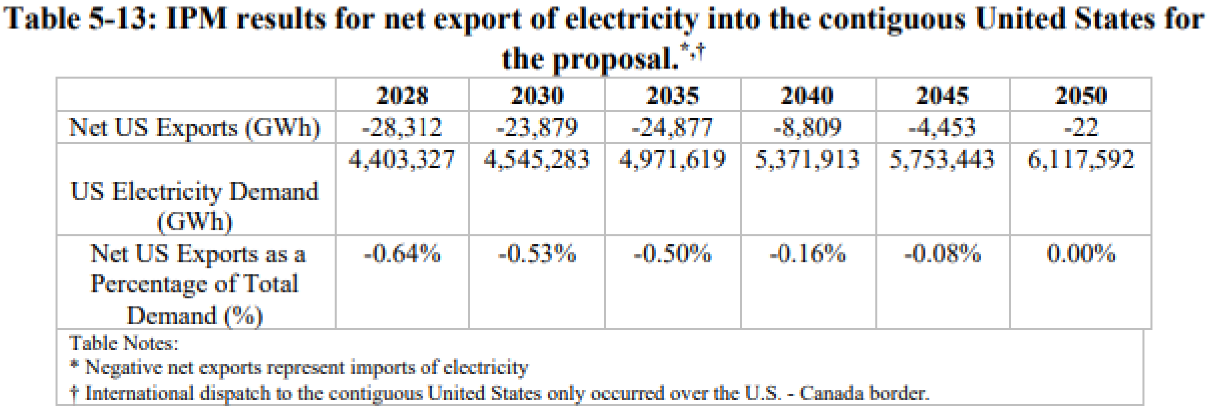


Table 5-13: IPM results for net export of electricity into the contiguous United States for the proposal.*,†

	2028	2030	2035	2040	2045	2050
Net US Exports (GWh)	-28,312	-23,879	-24,877	-8,809	-4,453	-22
US Electricity Demand (GWh)	4,403,327	4,545,283	4,971,619	5,371,913	5,753,443	6,117,592
Net US Exports as a Percentage of Total Demand (%)	-0.64%	-0.53%	-0.50%	-0.16%	-0.08%	0.00%

Table Notes:
* Negative net exports represent imports of electricity
† International dispatch to the contiguous United States only occurred over the U.S. - Canada border.

This table shows an increase in power generation capacity of 968,586 GWh per year by 2040 due to the impact of the proposed rulemaking. However, this section does not consider the additional costs to the power generation market as a result of this regulation, merely the net increase in total power generation. The agency states:

- "However, as the expected increase in electricity generation associated with the proposal relative to a no-action case is relatively small – approximately 4.4 percent increase in 2050 – we do not expect the U.S. electric power distribution system to be adversely affected by the projected additional number of charging electric vehicles."

Since the proposed rule now requires BEVs as part of the assumed technology needed to meet the proposed standards, the agency should also now account for the additional costs borne by the power generation market to meet the requirements of the standard. Ignoring the costs is not valid since the proposed rule forces market penetrations higher than would otherwise be natural.

Based on publicly available information[129] and the agency's assumed path of new power generation sources from wind and solar, the average cost of building the infrastructure required to support the assumed BEVs in operation by 2040 is ~$1,800/kWh. This means that there could

---

[128] Draft Regulatory Impact Analysis EPA-420-D-23-003 April 2023, Table 5-13.
[129] https://proest.com/construction/cost-estimates/power-plants/.

be ~$200B of infrastructure cost that is ignored by the agency as “relatively small.” The financial burden placed on the power generation industry is not small and should be accounted for accurately in the final regulatory impact analysis.

Required Updates

EPA must accurately assess the financial costs the proposed regulation would impart on the U.S. consumer. Accordingly, EPA should:

- Use a raw material supply cost model that considers the increasing costs for raw materials with increased supply. Automotive battery costs are largely driven by raw materials (63% of total cost) and sources for these raw materials are becoming increasingly more expensive.
- Include the cost of all vehicles that are needed to meet the regulation not merely the additional volume of vehicles needed to meet the regulation over the assumed electric vehicle volumes of the automakers.
- Fully account for the technical feasibility of any CO_2-reducing technology on a cost basis as defined in the CAA regardless of governmental taxation breaks for electric vehicle technology production and sale.
- Consider the costs of adding additional solar, wind, and hydropower plants in the regulation as they are a necessary part of bringing electric vehicles to market as described by EPA.

Failure to do so would be arbitrary and capricious.

Appendix C:

Consideration of Potential Fuels Controls for a Future Rulemaking

EPA notes in the NPRM that the Agency "…has not undertaken sufficient analysis to propose changes to fuel requirements…"[130] and has not provided enough support to set limits at this time. In reviewing EPA's rationale for considering fuels controls in a future rulemaking to reduce PM emissions, API finds the Agency has not appropriately considered all data and issues raised by a potential rulemaking. In the ten sections below, API provides detailed comments on EPA's analysis, finding generally that such a rulemaking on potential fuels controls is unnecessary. If EPA plans to continue to review this issue, API and its members would like the opportunity to meet with the agency to work on this topic.

1. Impacts of High-Boiling Components on Emissions

   In its analysis of the available research studies, EPA has overstated both the certainty in the findings and the leverage of high-boiling components on PM emissions. Fuels quality can enable and support vehicle emissions systems performance. Fuels quality contributions, however, are smaller than those achieved by vehicle technologies.

2. Survey of High-Boiling Materials in Market Gasoline

   EPA's survey of high-boiling components and PMI of market gasoline (which does not identify its data sources) overstates the current number of high-PMI gasolines. API member experience finds the presence of high-PMI gasolines in the market to be significantly less than EPA estimates. Moreover, PMI equations were developed on early, light duty vehicles with Tier 2 technology. PMI calculations are not necessarily correlated with modern vehicle technology.

3. Sources of High-Boiling Compounds in Gasoline Production and How Reductions might Occur – Refinery Impacts

   EPA's analysis of high-boiling components in gasoline production is over-simplified and neglects significant effects of proposed reduction technologies. Segregation of gasoline heavy-ends to distillates presents specification-compliance challenges for diesel and jet fuel, replacement of octane is more complex than claimed. Reducing the gasoline high boiling point as a surrogate for heavy aromatic content would also cut a significant amount of the gasoline pool that is not contributing to PM generation. This would translate into both economical and logistical impacts (e.g., alternate disposition, or blending into diesel pool) that would ultimately impact costs to consumers.

4. Methods of Compliance Determination

   EPA's proposed use of ASTM D7096 Simulated Distillation by gas chromatography is inappropriate as a control method on gasoline heavy-ends because (1) SimDis is not well

---

[130] 88 Fed. Reg. 29397 (May 5, 2023).

correlated with the better (yet still imperfect) PMI by detailed hydrocarbon analysis and (2) SimDis is not adequately precise to use as a control method.

5. Statutory Authority

   EPA lacks authority to set fuel standards to address vehicle emissions from the existing vehicles, which are already able to comply with their applicable particulate matter standards. We also question the Agency's legal authority to move forward with these fuel controls, which would appear to have no environmental benefit for new motor vehicles.

6. Structure and Level of the Standard

   As EPA notes in the NPRM, it is difficult to effectively comment on structure and level of a standard in the absence of a compliance method; however, any standard based on SimDis will be challenging to implement because of the method's low precision and absence from current rules and specifications. Averaging, banking, and trading would be preferrable to a price per gallon cap which could be difficult to both measure and design controls to ensure operations are below the required threshold.

7. Impact of PMI on Engine Design and Efficiency

   The low-speed-preignition (LSPI) phenomenon is complex with some mechanisms strictly related to lubricants formulation. EPA overstates the potential impact of fuel specification changes in reducing LSPI occurrences.

8. Cost and Impacts on Refining

   EPA's use of refinery LP models is inadequately described and oversimplified in the analysis presented. EPA's analysis neglects the uniqueness and complexity needed in LP models to accurately represent a specific refinery, focuses on a single refinery configuration and neglects important alternatives, lacks appropriate constraints, and appears to neglect impacts of decreased light-end utilization that would result from a heavy-ends control limit.

9. Estimated Emissions and Air Quality Impacts

   EPA overestimates the impact of reducing gasoline vehicle tailpipe PM emissions to improve air quality and health, especially as compared to other vehicle related PM emissions such as tire wear and entrained dust.

10. Analysis of EPA References to CRC Studies

    In this section API presents counterpoint interpretations of the CRC studies citied in EPA's analysis, especially concerning the impacts of heavy-boiling components on PM emissions.

The following sections cover the raised issues above more in detail.

1. Impacts of High-Boiling Components on Emissions

EPA acknowledges that fuel standards would not assist the new vehicle fleet comply with the new standards, but suggests the agency is thinking about reducing particulate matter from the existing fleet, which are already able to comply with their current particulate matter standards. While vehicle technologies have proven to be the primary means to control vehicle emissions, fuels quality can enable and support vehicle emissions systems performance. Fuels quality contributions, however, are smaller than those achieved by vehicle technologies. For instance, Tier III engine technologies such as higher fuel injection pressures, for gasoline direct injection (GDI), and future technologies with gasoline particulate filter (GPF), that can be used for both GDI and port-fuel injection (PFI), are capable to meet the very stringent 2025 LEV III 1 mg/mi mass particulate emissions standards or beyond[131]. Current vehicle technologies, without a GPF, are capable of reducing significantly PM emissions, and further constraints on the fuel will have limited impact on further reducing these emissions. The 2023 EPA certification vehicle test data shows that there were approximately 83 carline models (out of approximately 376 carlines tested on US06) that achieved a certification level of emissions of 0 gm/mile (and a rounded emission test results level below 0.5 mg/mile) of PM on the US06 drive cycle. These carlines were able to meet a 0.5 mg/mile PM emissions level using current certification gasolines, without the need for specialty lower PMI fuels. Additionally, newer vehicle technologies without GPFs have been demonstrated to have minimal sensitivity to fuel changes.[132] In regard to future vehicles, EPA's DRIA states that GPF technologies are more effective at reducing PM emissions than fuel controls (e.g., PMI limit or T99 limits). Specifically, Figure 3-19 of the DRIA describes that PM emissions can be reduced by 99%, 96% and 96% for the testing cycles -7°C FTP, 25°C FTP, and US06, respectively. In contrast when considering a fuel control approach, the NPRM points to studies where it was found that there was a 1-2 percent PM emissions increase for each percent PMI increase. When assessed together, fewer PM emission reductions are gained through fuel controls compared to vehicle hardware approaches.

Furthermore, even if fuel controls were required to significantly reduce PM emissions from existent and future vehicles, which they are not, EPA's proposed methodology is flawed. PMI equations were developed on early, light duty vehicles with Tier 2 technology. New Tier 3 vehicles used advancements in fuel pressure, injector nozzle design and combustion strategy. PMI calculations are not necessarily correlated with modern vehicle technology. PMI equations were developed on Tier 2 gasolines, current EPA gasoline would not be expected to have the same emissions profile.

PM indices also have proven biased for alcohol molecules and are not accurate for current vehicle and fuels technologies. "PMI was found to perform well if the fuels being evaluated had the same ethanol content, but it proved to be a biased indicator when applied to groups of fuels with varying ethanol content – i.e., E0 (neat), E10 (10% ethanol by volume), and

---

[131] https://doi.org/10.1016/j.scitotenv.2022.161225.

[132] Citation: Singh, R., Voice, A., Fatouraie, M., and Levy, R., "Fuel Effects on Engine-out Emissions Part 1 - Comparing Certification and Market Gasoline Fuels," SAE Int. J. Adv. & Curr. Prac. in Mobility 3(6):3121-3137, 2021, https://doi.org/10.4271/2021-01-0541.

higher ethanol-content fuels. LA92 Phase I PM emissions from fuels with ethanol were found to be consistently greater than emissions from nonoxygenated fuels of the same PMI" [CRC Project No. RW-107-2].

A study[133] presented at the 33rd CRC Real World Emissions Workshop[134], demonstrated and concluded that PMI was not predictive of engine out (or tailpipe) PM emissions. Further, it was concluded that FBP performed somewhat better predictor than PMI, but was still a weak indicator.

2. Survey of High-Boiling Materials in Market Gasoline

EPA discusses their assessment of the trends of T90 from ASTM D86 (high-boiling material) over the past two decades, followed by a summary of available PMI data.

The PMI Profile of Market Gasoline discussion in this section also points out that median PMI is 1.6 for US fuels with 10% remaining above 2.0, suggesting an opportunity to reduce PMI. However, Figure 42[135] in the NPRM shows two-time frames (2008-12) and (2021-2022) but no source for the data. When conducting industry projects (i.e., CRC) where higher PMI fuels are being solicited, it has become almost impossible to find these in real-world fuels.[136]

3. Sources of High-Boiling Compounds in Gasoline Production and How Reductions might Occur – Refinery Impacts

EPA's analysis of high-boiling components in gasoline production is over-simplified and neglects significant effect of proposed reduction technologies. It should be pointed out that high boiling point does not necessarily mean high aromatic content. Reducing the gasoline high boiling point as a surrogate for heavy aromatic content would cut a significant amount of the gasoline pool that is not contributing to PM generation. This would translate into both economical and logistical impacts (e.g., alternate disposition, or blending into diesel pool). that would ultimately impact costs to consumers. Segregation of gasoline heavy-ends to distillates may impact octane, and replacement of octane is more complex than claimed. A potential impact resulting in a reduction of octane would reduce vehicle fuel economy limiting the advantages of higher octane. Work from the Department of Energy's Co-optima concluded, for downsize boosted engine technology, RON and octane sensitivity (enabled through high aromatic fuels) have the most potential to improve efficiency among all fuel properties.[137] For naturally aspirated, port fuel-injected legacy vehicles, CRC[138] showed that decreases in energy consumption of up to 2% for a small SUV was possible through the use of a 97 RON fuel compared to 91 RON fuel on a US06

---

[133] "Can modern vehicle emissions be predicted from fuel properties?," Voice, Alexander, Chanel Sitto, Aramco Americas – Transport Technology, March 2023.

[134] The 33rd Real World Emissions Workshop, March 26-29, 2023, Long Beach, CA. (https://crcao.org/33rd-crc-real-world-emissions-workshop/)

[135] 88 Fed. Reg. 29397 (May 5, 2023).

[136] One API member recently surveyed its gasoline BOB production (i.e., gasoline prior to blending ethanol) and found 95% of BOBs with PMI below 2.0.

[137] https://doi.org/10.1016/j.pecs.2020.100876.

[138] https://crcao.org/wp-content/uploads/2020/12/CRC-Project-AVFL-20a_SAE-Paper-2020-01-5117.pdf.

drive cycle.

Shifting boiling points of naphtha produced on the fluid catalytic cracker (FCC), reformer, and coker to produce lighter distillate or kerosene may cause potential market issues, including:

- Overall gasoline production may fall if fuel producers are required to shift gasoline molecules to distillates, which may lead to higher gasoline prices for consumers.
- There may be equipment constraints that prevent shifting of the cut point without restricting overall refining capacity, which could lead to higher consumer prices if overall production falls.
- The value of alkylate and ethanol (non-aromatic high octane blend components) may increase. The alkylate production would probably fall if FCC units were constraint because of tightened specifications.
- There may also be constraints in aromatics content and cetane number for putting these aromatic molecules into jet fuel or distillate, which may further reduce capacity or cause increased shipping of diesel blend components to maintain distillate specifications.
- There are some capital projects that refiners may pursue to help mitigate the impacts, but these too could result in increased cost of supply to gasoline consumers.

4. Methods of Compliance Determination

ASTM D7096 Simulated Distillation by GC Analysis: EPA proposes to use ASTM D7096 simulated distillation by gas chromatography (SimDis) to control / reduce gasoline particulate matter index (PMI) because the actual analytical method needed to calculate PMI --- detailed hydrocarbon analysis (DHA) --- is too costly and time-consuming to use as a production control. While API members agree that DHA is inappropriate for the reasons cited by the Agency, our experience indicates SimDis is not a reasonable alternative because (1) SimDis cannot distinguish between heavy gasoline constituents that contribute to PMI from those that do not, (2) SimDis results are not well correlated to PMI by DHA, and (3) SimDis is not adequately precise to use as a control method.

ASTM D7096 SimDis identifies the carbon number of hydrocarbons and estimates boiling point ranges, but it does not differentiate molecules that contribute highly to PM emissions (and PMI) from molecules in the same boiling point range that have minimal contribution to PM emissions. If EPA were to place limits on gasoline blending by using a SimDis constraint, a significant part of the available gasoline pool would be eliminated without sound technical reasoning.

Measurements by API members shows poor correlation between PMI and/or C10+ aromatics and Simulated Distillation Endpoint, T98, T95, or T90. While the heavy aromatics which contribute to PM emissions are in the high end of the distillation, many other non-PM formers are also present. Consequently, SimDis is too crude in its selectivity to use as a control method for reducing PMI.

ASTM D7069-19 states reproducibility of the method to be 8.3°F for T95 and 18.5°F for FBP. At EPA's proposed control point of T99 by SimDis, the reproducibility would be more closely represented by that of FBP stated in the method. Subsequently, a fuel specification with a SimDis T99 cut-off of 450 °F or 425 °F would result in an indefinite and inconsistent portion of heavy gasolines removed from the gasoline pool. From a compliance standpoint, fuel qualities that can be measured with greater precision are optimal because they can be tightly correlated with unit operations.

VUV Methods: EPA's analysis of VUV as a compliance tool contains errors regarding the appropriate methods, and inappropriately dismisses VUV as being insufficiently available for use as a control method.

EPA cites ASTM D8071 as the applicable method to substitute for DHA and use in PMI calculation, but this is incorrect. The D8071 method only gives compound classifications, not detailed component analysis needed for PMI calculation. The most suited VUV method for this application is D8369.

API disagrees with EPA's finding that VUV is insufficiently mature and available for consideration as a method to quantity gasoline PMI. When using the appropriate method D8369, API members find the VUV results are equivalent to PMI calculated from DHA but at a fraction of the analysis cost and time. In addition, most API members companies and many commercial laboratories have already implemented VUV analysis.

5. Statutory Authority

The proposed rule asks for comments on whether EPA should engage in a rulemaking to address potential limits on aromatics and high-boiling material as fuel standards under CAA § 211(c). Although EPA has not proposed to engage in a rulemaking at this time, API urges the agency to avoid a costly and burdensome rulemaking effort that would exceed its authority.

The proposed rule acknowledges that fuel standards would not assist the new vehicle fleet to comply with the new standards, but suggests the agency is thinking about them to reduce particulate matter from the existing fleet. However, EPA lacks authority to set fuel standards to address vehicle emissions from the existing vehicles, which are already able to comply with their applicable particulate matter standards.

EPA's authority to regulate vehicle emissions applies only prospectively. EPA may only set standards for classes of "new motor vehicles." CAA § 202(a)(1). In turn, EPA may only consider controlling or regulating fuel after it has determined there are no other "economically feasible means of achieving emissions standards under section [202]." Regulating fuel cannot be needed to achieve the Section 202 standards for existing vehicles because those vehicles already meet their applicable particulate matter standards without any additional fuel regulation. Any attempt to rely on the inability of existing vehicles to comply with the particulate matter standards for new vehicles because of lack of alternative controls would be contrary to the Act's focus on prospective standards.

In any event, EPA may not issue standards under CAA § 211(c) at this time because, as the proposed rule readily admits, EPA has not "considered all relevant medical and scientific evidence available to [it], including consideration of other technologically or economically feasible means of achieving" the standards under section 202. *See* § 202(c)(2)(A). Unless and until EPA completes that analysis and allows stakeholders an opportunity to comment on it, EPA may not set new standards under CAA § 211(c).

Please note that due to the compressed comment period for such a complex request for information, coupled with the lack of an extension, API may supplement the docket.

6. Structure and Level of the Standard

As mentioned at the beginning of Appendix C, vehicle technologies have proven to be the primary means for controlling vehicle emissions. Fuels quality can improve vehicle emissions systems and help achieve air quality objectives, but fuels contributions are smaller than those achieved by vehicle technologies.

To the extent a structure and level of standard may be considered, an averaging, banking, and trading solution has worked well for mogas sulfur and benzene. Much like a Low Carbon Fuels Standard program, it allows the industry to meet the goals of the program at the lowest possible cost while providing flexibility to blend fuel under abnormal operations. This would be preferrable to a price per gallon cap which could be difficult to both measure and design controls to ensure operations are below required thresholds.

7. Impact of PMI on Engine Design and Efficiency

EPA mentions that another potential reason to consider a PMI limit is related to low-speed preignition (LSPI) and requests comments on the impact of PMI on engine design and efficiency. References below point to other factors that impact LSPI that need to be considered. Fuel specification changes may not be sufficient to reduce LSPI occurrences.

CRC Project CM-137-17-1[139] (Review of Low-Speed Pre-Ignition Literature) makes clear that one single LSPI initiation mechanism cannot be derived from the published literature. However, the report did allow for the general statement that "improved oil formulation and oil ignitability as well as a design that leads to reduced oil intrusion from, for example, the crankcase ventilation system or past the piston rings is of benefit. Further the report went on to indicate that low calcium and High ZNDTP or MODTC oil formulations are linked to low LSPI counts.

ILSAC GF-6A and GF-6B[140] specifications represent the latest performance requirements for gasoline engine oils set by the International Lubricant Specification Advisory Committee (ILSAC). GF-6A and GF-6B were introduced in May 2020 and are designed to provide protection against low-speed pre-ignition (LSPI) in engines operating on ethanol-containing fuels up to E85.

---

[139] "REVIEW OF LOW-SPEED PRE-IGNITION LITERATURE," CRC Report No. CM-137-17-1, June 2019, (https://crcao.org/wp-content/uploads/2019/07/CM-137-17-1_FinalReport-June-2019.pdf).

[140] ILSAC Standard For Passenger Car Engine Oils. (https://www.api.org/products-and-services/engine-oil/eolcs-categories-and-classifications/oil-categories#tab-ilsac).

For automotive gasoline engines, the latest engine oil service category includes the performance properties of each earlier category. Therefore, the latest engine oil specifications will provide full protection for automotive engines where an earlier oil category is recommended by the engine manufacturer.

SAE paper 2017-24-0061[141] shows that high aromatic and high sensitivity fuels help to mitigate knock under high load for boosted SI engines. Similarly, in SAE paper 2011-01-0342[142] low-aromatics fuel blends showed an increase tendency to auto-ignition and knock (traditional engine knock, not LSPI) characterized by the presence of a low-temperature heat release regime prior to the main combustion phase. It should be noted that LSPI, autoignition, and knock are different phenomenon and not related.

The LSPI phenomenon is complex with some mechanisms strictly related to lubricants formulation. Fuel specification changes may not reduce LSPI occurrences. Proposed PMI limits could reduce the aromatic content of the gasoline pool and potentially result in an unintentional increase of knock or autoignition events for the current on-road carpark.

8. Cost and Impacts on Refining

EPA's qualitative description of refining impacts from restriction of gasoline heavy-boiling components is over-simplified and incomplete. EPA asserts an easy shift of gasoline heavy-ends to distillates; in the experience of API members, it is often challenging to make such shifts while keeping distillate fuel properties on specification, especially flashpoint. In addition, EPA's analysis focuses on octane loss as the only detriment to segregating heavy-ends from the gasoline pool, neglecting the value of these components' low volatility as a volatility "sink" which allows blending of butanes and other light components. Eliminating heavy-ends would result in a significant loss of light components to the gasoline pool as well to meet maximum RVP requirements. Finally, EPA considers only one refinery configuration where fluid catalytic cracking (FCC) dominates gasoline production, augmented by alkylation to upgrade FCC light olefins. Among API member refineries are plants which have neither FCC or alkylation units; impacts on these refineries are neglected in EPA's analysis.

EPA correctly identifies LP optimization as a useful tool for estimating refinery cost impacts of process changes, and provides results from a Haverly optimization program. Unfortunately, the Agency does not describe how it modeled the single refinery configuration considered. Although challenging to review without knowing key assumptions, correlations, and constraints used in the Haverly model, the results presented raise several concerns to API members. Among these concerns are the apparent lack of proper constraints, allowing the LP to make up lost gasoline heavy-ends with increased isomerization and alkylation; in practice, these units are likely fully utilized without headroom for increased production. Also, the results fail to discuss the light-ends utilization impact from eliminating the heavy-ends as RVP soak.

---

[141] Szybist, J., Wagnon, S., Splitter, D., Pitz, W. et al., "The Reduced Effectiveness of EGR to Mitigate Knock at High Loads in Boosted SI Engines," SAE Int. J. Engines 10(5):2305-2318, 2017, https://doi.org/10.4271/2017-24-0061.

[142] Amann, M., Mehta, D., and Alger, T., "Engine Operating Condition and Gasoline Fuel Composition Effects on Low-Speed Pre-Ignition in High-Performance Spark Ignited Gasoline Engines," SAE Int. J. Engines 4(1):274-285, 2011, https://doi.org/10.4271/2011-01-0342.

Finally, the results are again limited to a single, simple refinery configuration. API members routinely use LP models for refinery planning and preliminary optimization, but the models required to accurately represent a real refinery are highly complex and unique to a specific plant; a one-size-fits-all Haverly model is highly insufficient to quantify refining impacts of EPA's proposed restriction of gasoline heavy-ends blending. EPA should provide access to the model files with the assumed correlations to allow the public to fully analyze the results.

While the preliminary results suggest some directional relationship, API has concerns with:

(1) The accuracy of the correlation between PMI and the 99% SimDis by D7096; and

(2) Whether the minimum distillate flash and minimum gasoline T50 limits were modeled sufficiently.

Adding a restrictive max 99% point specification to gasoline, which already has a limiting minimum T50 specification, puts gasoline blending in a tight box which has the potential to increase costs to society. Similarly, our ability to shift transitional molecules from gasoline to distillate is limited by the flash specification.

EPA states, "The estimated costs for the 5°F, 10°F, and 15°F reductions in T90 were 0.5, 2.2, and 3.0 cents per gallon, respectively." These relative costs are questionable, as the cost per degree should be monotonically increasing as the reduction becomes more severe. An economic model should be graduated, beginning with the lower-cost steps first. The EPA model seems to contradict this economic fundamental when its 5°F to 10°F reduction costs 1.7 cpg (=2.2-0.5), while the 10°F to 15°F reduction costs only 0.8 cpg (=3.0-2.2).

The proposed 99% SimDis specification would significantly reduce the molecules that can swing between gasoline and diesel, which is the primary model the industry uses to adapt to changing demands and inventory imbalances. With reduced blending flexibility, refiners will have much less ability to increase gasoline yields. Restricting gasoline end points could lead to gasoline price spikes in periods of market volatility.

9. Estimated Emissions and Air Quality Impacts

EPA has failed to assess particulate matter impacts from tire wear or entrained road dust. Tire wear and entrained road dust emissions account for a majority of the total $PM_{2.5}$ emissions associated with traffic.[143] There is a high correlation between both tire wear, and entrained road dust emissions, and vehicle weight. Studies have also found electric vehicles to be heavier than the equivalent class/size of ICEVs due to the inclusion of the battery. Therefore, converting ICEVs to ZEVs, as a result of the proposed regulation on "Multi-Pollutant Emissions Standards for Model Years 2027 and Later Light- Duty and Medium-Duty Vehicles" would significantly increase the average vehicle weight on roadways, which in turn would increase tire,

---

[143] https://www.epa.gov/air-emissions-inventories.

brake, and entrained road dust emissions. Including these emissions[144, 145, 146,147] in the analysis could potentially change EPA's conclusions and significance findings in the DRIA. Hence, EPA must evaluate these emissions and their impacts.

There are several sources in the literature that raise questions as to the absolute and relative magnitude of the potential reductions to PM concentrations, and subsequent health benefits, that reducing PMI could have that are not included in the proposed rule: that EPA needs to evaluate:

- The 2019 OECD report lays out the relative contribution of primary PM emissions from road transport, showing approximately 1/3 $PM_{2.5}$ from non-exhaust (tires, brakes, road wear) in 2014[148] (Figure 2.1).
- The 2019 OECD report also includes data from EPA (2019 NEI) that shows that less than half of primary PM2.5 from road transportation is from vehicles, and this represents 3% of total primary PM2.5. See Table 2.3
- Total PM 2.5 is a combination of primary PM 2.5 emissions plus secondary species (inorganic and organic). Secondary aerosols often dominate. Primary PM can range from 10% to 70%, and is often less than 50%.[149,150]
- Mobile sources of secondary organic aerosols are a small fraction of the total in both absolute and population weighted terms.[151] On-road sources already a generally small fraction without limiting to just light duty/passenger (Figure 7).[152]

10. Analysis of the references to CRC studies

Comments on references used in Section IX[153]: Consideration of Potential Fuels Controls for a Future Rulemaking.

Proposed Rule Statement:

Statement: "*Numerous emissions studies have associated high-boiling compounds in gasoline with increased tailpipe PM emissions.*"[154]

Statement references[155]:

868 Coordinating Research Council, "Evaluation and Investigation of Fuel Effects on

---

[144] https://ww3.arb.ca.gov/ei/areasrc/fullpdf/2021_paved_roads_7_9.pdf.
[145] https://doi.org/10.1016/j.scitotenv.2022.156961.
[146] http://dx.doi.org/10.1016/j.atmosenv.2016.03.017.
[147] https://doi.org/10.1016/j.scitotenv.2022.161225.
[148] OECD (2020), Non-exhaust Particulate Emissions from Road Transport: An Ignored Environmental Policy. Challenge, OECD Publishing, Paris, https://doi.org/10.1787/4a4dc6ca-en.
[149] https://www.science.org/doi/10.1126/science.1180353.
[150] https://www3.epa.gov/ttnchie1/conference/ei13/mobile/hodan.pdf.
[151] https://acp.copernicus.org/articles/21/17115/2021/acp-21-17115-2021.pdf.
[152] https://www.science.org/doi/10.1126/science.1180353.
[153] **The focus of section IX is PM emissions reduction, and therefore will serve as the focus of comments.
[154] 88 Fed. Reg. 29398 (May 5, 2023).
[155] Statement reference numbers refer to footnote numbering in the proposed rule.

Gaseous and Particulate Emissions on SIDI In-Use Vehicles," Report No. E–94–2, March 2016.

869 USEPA "Assessing the Effect of Five Gasoline Properties on Exhaust Emissions from Light-Duty Vehicles Certified to Tier 2 Standards: Analysis of Data from EPAct Phase 3 (EPAct/V2/E–89)," April 2013. Document EPA–420–R–13–002.

Background: references 868 (CRC report E-94-2) and 869 (EPA EPAct study) refer to large fuel effects-emissions studies seeking to determine what gasoline properties drive vehicle emissions (mainly PM). E-94-2 looked at emissions across a mix of Tier 2, GDI vehicles (12) running match-blended gasoline fuels that approximated market gasoline fuels (PMI, AKI, and ethanol levels were varied). In the EPAct work, ethanol, T50, T90, aromatics, and RVP were varied. For the study, 27 fuels were developed (i.e., match-blended) and tested in 15 light-duty vehicles (Tier 2, MY2008, **all PFI**).

API Comment: Although PMI was strongly correlated with increasing PM emissions in E-94-2, PM increased with increasing C10+ aromatics in EPAct, both studies contain faults. E-94-2, for example, used match-blended fuels, which received criticism when the final report was released for not being representative of market fuels. In addition, EPAct results are no longer relevant due to the MY2008 test fleet. In short, the references are dated, and more-recent attempts by CRC to study emissions impacts of newer, Tier 3 vehicles with injection pressures approaching 350 bar are inconclusive, warranting further study. Generally, higher injection pressures lower PM emissions; and the positive correlation between PMI and PM is less clear (CRC E-135).

Statement: *"…analysis of a large number of market fuel samples has shown that the high-boiling tail of gasoline contains a high proportion of aromatics, and that the heaviest few percent of this material has very high leverage on PM emissions."*[156]

Statement references:

870 Chapman E., Winston-Galant M., Geng P., Latigo R., Boehman A., "Alternative Fuel Property Correlations to the Honda Particulate Matter Index (PMI)," SAE Technical Paper 2016–01–2550, 2016.

871 Ben Amara A., Tahtouh T., Ubrich E., Starck L., Moriya H., Iida J., Koji N., "Critical Analysis of PM Index and Other Fuel Indices: Impact of Gasoline Fuel Volatility and Chemical Composition," SAE Technical Paper 2018–01–1741, 2018.

872 Sobotowski R.A., Butler A.D., Guerra Z., "A Pilot Study of Fuel Impacts on PM Emissions from Light-duty Gasoline Vehicles," SAE Int. J. Fuels Lubr. 8(1):2015.

873 Aikawa, K., Sakurai K., Jetter J.J., "Development of a Predictive Model for Gasoline Vehicle Particulate Matter Emissions," SAE Technical Paper 2010–01–2115, 2010.

Background: Honda published the SAE paper introducing the PMI concept in 2010 (873), and while it took a few years to gain notoriety, its dependency on DHA has motivated others to find alternative, easier pathways towards a predictive PM emissions metric (GM in 870; Toyota

---

[156] 88 Fed. Reg. 29398 (May 5, 2023).

in 871). Regardless of metric, heavier fuel components tend to lead to higher PM emissions.

API Comment: So much of the supporting work is based on assessments using Tier 2 technology. We know Tier 3 vehicles are transitioning to higher injection pressures (which lowers PM, generally), but many fuel effects studies are ongoing or in development. Lastly, it would be unfortunate if some type of fuel distillation cut limited potential use of low-carbon feedstocks for future fuels.

Statement: *PMI has been used in several emission studies and modeling analyses correlating fuel parameters to PM, and our assessment of potential impacts of fuel formulation changes on PM emission inventories, presented in Section IX.7, rely heavily on PMI."*[157]

Statement references:

> 879 Butler A.D., Sobotowski R.A., Hoffman G.J., and Machiele, P., "Influence of Fuel PM Index and Ethanol Content on Particulate Emissions from Light-Duty Gasoline Vehicles," SAE Technical Paper 2015–01–1072, 2015.
>
> 880 Coordinating Research Council, "Alternative Oxygenate Effects on Emissions," Report No. E–129–2, October 2022.

Background: Reference 879 refers to an SAE paper authored by EPA staff members involved in the EPAct study (2015-01-1072). The authors work to integrate PMI into the EPAct data, while also observing ethanol-PM interactions. 10 of 15 vehicles used in the EPAct study showed a correlation between PM and PMI; in addition, the authors postulated that ethanol addition appears to exacerbate the inability of heavier components to volatilize, resulting in increased PM (it should be noted that the remaining 5 vehicles did not exhibit any PM sensitivity to PMI or ethanol). Reference 880 is a CRC report covering results from E-129-2, a program run out of NREL on a single cylinder research engine running a couple of base gasolines (low- and high-PMI) blended with various alcohols. The primary objective of this program was to develop data to better understand competing effects between heat of vaporization (as mentioned above in reference to the EPAct study) and dilution (i.e., diluted gasoline results in lower emissions). While PM emissions generally increased with increasing PMI, correlation strength was highly variable across multiple test conditions.

API Comment: While PMI has become the most 'robust' parameter for indicating a fuel's propensity for PM formation, it has limitations. For example, in E-129-2, ethanol blended into the 'low' PMI (1.21) fuel appeared to show HOV effects dominated. In the 'high' PMI blend (2.75), HOV effects dominated at the high-speed condition, but dilution seemed to dominate at the low-speed condition (i.e., PM decreased with increasing ethanol content). The choice to include this reference is interesting as the results are far from absolute, and beg more questions for future study. For the SAE EPA paper (reference 879), I have concerns with the age of the vehicle fleet used in the study (MY2008), technology (PFI), as well as 1/3 of the fleet exhibiting no sensitivity to PMI and/or ethanol with respect to PM emissions.

---

[157] 88 Fed. Reg. 29398 (May 5, 2023).

Attachment 2:

API comments to EPA (dated June 16, 2023) on Greenhouse Gas Emissions Standards for Heavy-Duty Vehicles – Phase 3

American
Petroleum
Institute

Will Hupman
Vice President - Downstream
202-682-8463
HupmanWR@api.org

June 16, 2023

The Honorable Michael Regan
Administrator
U.S. Environmental Protection Agency
1200 Pennsylvania Avenue, NW
Washington, DC 20460

Filed electronically: https://www.regulations.gov

Re: Greenhouse Gas Emissions Standards for Heavy-Duty Vehicles—Phase 3 (Docket ID No. EPA-HQ-OAR-2022-0985)

Dear Administrator Regan:

The American Petroleum Institute appreciates the opportunity to submit the following comments on the proposed rule entitled "Greenhouse Gas Emissions Standards for Heavy-Duty Vehicles—Phase 3." API is a national trade association representing all aspects of America's oil and natural gas industry. Our industry supports nearly 11 million U.S. jobs and accounts for approximately 8 percent of U.S. GDP. API has nearly 600 members, from fully integrated oil and natural gas companies to independent companies, comprising all segments of the industry, including producers, refiners, suppliers, retail marketing, pipeline operators, and marine transporters, as well as service and supply companies that support all segments of industry. As producers, suppliers and retailers of transportation fuels that power the more than 99% of all vehicles covered by the proposed rule, API members have a significant interest in, and will be heavily impacted by, the vehicle emissions standards that would be imposed by the standards.

API's *Climate Action Framework* reflects our policies and goals, which are incorporated in our comments below. The challenge of meeting the world's growing need for energy while simultaneously ushering in a lower-carbon future is massive, intertwined, and fundamental. It is the opportunity of our time – governments, industries, and consumers must act to solve it together. Our industry is at the center of this challenge. We share the goal of reduced emissions across the broader economy and, specifically, those from energy production, transportation and use by society.

API supports technology-neutral policies at the federal level that drive GHG emissions reductions in the transportation sector, taking a holistic "all-of-the-above" approach to fuels, vehicles, and infrastructure systems. Such policies include: 1) federal fuel standards, 2) a full lifecycle approach to vehicle standards, 3) optimization of fuel/vehicle systems to improve efficiency, and 4) supportive infrastructure measures. We have significant concerns that the proposed rule does not include many of these elements. A few of these concerns are summarized below and our detailed comments are attached.

a. *API supports decarbonization of the transportation sector.*

API is aligned with EPA's goal to address greenhouse gas emissions in the transportation sector, and API members have similarly been working to advance the development, transmission, and use of cleaner fuels and technologies to provide lower-carbon choices for consumers.

b. *API supports the concepts of a lifecycle approach to GHG emissions reductions.*

EPA should employ a technology-neutral approach that holistically encompasses the lifecycle GHG emissions of both the fuel and the vehicle, rather than narrowly focusing on tailpipe emissions only.

c. *Both this proposal and the light- and medium-duty proposal miss the mark.*

EPA's focus on zero-emission vehicle (ZEV) solutions, and specifically battery electric vehicles (BEVs), ignores fuel- and vehicle-based options that could better accomplish the agency's objectives to expeditiously achieve greater transportation sector-related emission reductions from the entire vehicle fleet (both new and in-use) at lower cost.

d. *Technical Feasibility*

API is concerned that there is significant uncertainty with regard to technology and infrastructure readiness for the proposed 2027-2032 timeframe; further, the transportation industry will be competing for the same resources to successfully implement both the heavy-duty and light- and medium-duty proposed programs on the same timeframe.

e. *Energy Security*

API is concerned that the proposed rule could negatively impact U.S. energy security if vehicle technologies are shifted to ZEVs in the exponential rate that the proposal would likely entail, as it would increase the country's dependence upon foreign sources for needed minerals forgoing the use of existing U.S. resources.

f. *Program Review*

API recommends that EPA consider incorporating pre- and mid-program assessments into its final program, with sufficient lead time following review to adjust the standards if needed.

g. *Legal Concerns*

API is concerned that EPA is exceeding its statutory authority under the Clean Air Act by, among other things, mandating the production of ZEVs.

Please note that due to the compressed comment period for such a complex rule, coupled with the lack of an extension, the record is still being developed and API will also be submitting supplemental documentation that is important to this rulemaking.

Thank you for the opportunity to provide our comments on this important rulemaking. If you have any questions, please do not hesitate to contact me.

Sincerely,

Will Hupman

c: Mr. Brian Nelson, Office of Transportation and Air Quality, Assessment and Standards Division

Detailed Comments of API on "Greenhouse Gas Emissions Standards for Heavy-Duty Vehicles—Phase 3" (Docket ID No. EPA-HQ-OAR-2022-0985)

a. API supports decarbonization of the transportation sector.

API appreciates EPA's efforts to address transportation sector greenhouse gas (GHG) emissions. As detailed in the API Climate Action Framework, we support technology-neutral federal policies that drive GHG emissions reductions in the transportation sector and our members have committed to delivering solutions that reduce the risks of climate change while meeting society's growing energy needs. API members work to advance the development, transmission, and use of cleaner fuels and technologies to provide lower-carbon choices for consumers. Specifically, API members have made, and continue to make, significant investments in new technologies that reduce carbon emissions in transportation, including:

- Stand-alone production and coprocessing of bio-feedstocks to make renewable fuels.
- Manufacturing of low-carbon ethanol.
- Manufacturing of renewable natural gas from wastewater, landfill gas, and biodigesters at farms as fuel for compressed natural gas (CNG) vehicles.
- Production of blue and green hydrogen for transportation and stationary applications including building infrastructure.
- Direct air carbon capture.
- Carbon capture and sequestration of CO_2.
- Development of advanced plastics to meet auto industry standards and consumer expectations while mitigating environmental impact through emissions reduction and improved vehicle efficiency by light-weighting.
- Installation of electric vehicle charging stations.
- Installation of hydrogen fueling stations.

API shares the goal of reduced emissions across the broader economy and, specifically, those from energy production, transportation and use by society. To achieve meaningful emissions reductions that meet the climate challenge, it will take a combination of policies, innovation, industry initiatives and a partnership of government and economic sectors. The objective is large enough that no single approach can achieve it.

b. API supports the concepts of a lifecycle approach to GHG emissions reductions.

i. EPA should use a lifecycle assessment (LCA) approach vs. tailpipe only

To effectively achieve emissions reductions in the transportation sector, we believe that technology-neutral solutions are needed, utilizing an approach that addresses fuels, vehicles, and infrastructure systems. This is best accomplished through holistic policies that encompass the lifecycle emissions of both the fuel and the vehicle. This combination makes for the most effective reduction of transportation GHG emissions, as emissions occur at multiple stages of the lifecycle of internal combustion engine vehicles (ICEVs) and battery electric vehicles (BEVs) and the fuels used in them. Further, utilizing a lifecycle approach would enable quantification of the emissions associated with heavy-duty (HD) vehicles, and allow technologies to be identified that provide more expeditious and robust GHG emissions reductions.

Use of a lifecycle approach would better achieve the goals of the proposed rule, as it would allow the agency and stakeholders alike to fully identify and reduce transportation sector carbon emissions and to identify and develop meaningful solutions. The reductions achieved by EPA's existing programs – including the Phase 1 and Phase 2 HD GHG rules, and criteria pollutant programs – are due in large part to addressing emissions holistically, and utilizing all available and emerging technology to do so.[1] The myopic focus on tailpipe emissions in the proposed rule essentially means that the rule would only address certain transportation carbon emissions, while ignoring other sources of emissions and potential emissions reduction solutions. A lifecycle approach would allow EPA to quantify all of the emissions associated with HD vehicles, and to mitigate those emissions more effectively.

ii. Zero emission vehicles also have emissions impacts

As with ICEVs, ZEVs have carbon emissions impact associated both with their production and throughout their lifetime which EPA should incorporate in its analysis. While ZEVs can be an important part of a diverse transportation future to reduce GHG emissions, they do produce GHG emissions. Battery electric vehicle (BEV) and fuel cell electric vehicle (FCEV) production, use, and the disposal of BEV batteries, are not zero-emission activities. Further, all fuels – whether conventional fuels or electricity – have associated carbon emissions regardless of their source. As noted in the results of a report by the American Transportation Research Institute (ATRI), BEVs and FCEVs generate significant CO_2 emissions and will continue to have CO_2 emissions impacts in the future. Further, for certain HD truck classes, especially in the near term, BEVs may be more CO_2 emissions-intensive relative to comparable ICEVs in performing the same work (*see Table 17, Figure 11*).[2] While meaningful reductions have historically been accomplished by focusing on tailpipe emissions from the vehicle, the growing market share of different technologies that include significant upstream emissions warrant inclusion of those emissions in the standard.

The HD ZEV market is nascent, which has resulted in limited data on their emissions impacts and the proposal does not present or consider the actual GHG emissions associated with their production and use. We encourage the agency to not only acknowledge and address the CO_2 emissions of HD ZEVs, but to also continue to study the impacts. (As noted below in

---

[1] By EPA's own account, transportation pollution has been reduced significantly since the passage of the Clean Air Act – fuel sulfur levels are 90 percent lower and new heavy-duty vehicles are nearly 99 percent cleaner than 1970 models (https://www.epa.gov/transportation-air-pollution-and-climate-change/history-reducing-air-pollution-transportation), and new heavy-duty diesel engines being manufactured today achieve near-zero criteria pollutant emissions with increasing fuel efficiency and lower CO_2 emissions.

[2] "Understanding the CO_2 Impacts of Zero-Emission Trucks", American Transportation Research Institute, May 2022.

these comments, we strongly recommend that EPA include both a readiness assessment prior to program implementation as well as a program review once implementation begins.) The nascent HD ZEV market makes it hard to adequately assess the emissions impact due to the lack of available technology to actually evaluate. Yet, there will be CO_2 emissions associated with the production and use of ZEVs, and it is important to address these emissions to provide a full picture of the emissions impacts and mitigation needs.

c. Both this proposal and the light- and medium-duty proposal miss the mark.

i. EPA is missing millions of vehicles that will contribute to emissions

API is concerned that this proposal, as well as EPA's light- and medium-duty proposed GHG rule, seriously misses the mark with respect to reducing carbon emissions from the transportation sector. The proposals focus heavily on ZEV technologies, and specifically BEVs, for reductions in the 2027 to 2032 timeframe. Yet, EPA is leaving emissions reductions on the table for existing HD vehicles, given HD vehicles' lifespan, as well as new ICEVs that will be sold between now and 2032. EPA's overly limited focus on ZEV solutions, and specifically BEVs, ignores options that could better accomplish the agency's objectives to achieve greater transportation sector-related emission reductions at lower cost to society.

According to data from the American Trucking Associations (ATA), over 38 million trucks were registered and used for business purposes (excluding government and farm) in 2020[3], with an additional 400,000-500,000 HD trucks expected to be sold annually, based on data over the past decade[4]. The proposed rule's focus on new zero-emission vehicles ignores the secondary benefit that a technology-neutral approach could accomplish through reductions from millions of in-fleet vehicles that will contribute to carbon emissions over the life of the program.

ii. EPA failed to address carbon reductions in the existing HDV fleet to help achieve near-term emission reductions

Fuel- and vehicle-based carbon reduction solutions are currently available in the marketplace, and could achieve nearer-term emission reductions from the existing HD fleet. A singular focus on future ZEV technologies (some of which may not come to fruition as anticipated) does not seem to meet the stated goals of the proposed program. The proposal would require the use of potential technologies that are unproven at the scale of the current market, would depend on infrastructure that is not yet available, and would be on an extremely challenging (at best) timeline. Meaningful carbon emission reductions are achievable sooner, and potentially at lower cost, via the use of proven and available technology. For example, the U.S. Department of Energy (DOE) Co-Optimization of Fuels & Engines (Co-Optima) initiative

---

[3] American Trucking Associations "Economics and Industry Data": https://www.trucking.org/economics-and-industry-data.

[4] "ATD Data 2022", North American Dealers Association – American Truck Dealers division (https://www.nada.org/media/5008/download?inline).

examined fuels and engine/vehicle technologies simultaneously.[5] The combination of sustainable fuels uncovered by Co-Optima research can reduce the emissions of vehicles now, while enabling a faster transition to net-zero-carbon emissions for on-road transportation in the future. Such an approach could be utilized by EPA to better achieve the stated goals of the proposed Phase 3 program.

iii. Non-electrification decarbonization solutions

1. Technology neutrality – all solutions should be allowed to compete

In the preamble to the proposed rule, EPA states that "[t]he proposed standards do not mandate the use of a specific technology, and EPA anticipates that a compliant fleet under the proposed standards would include a diverse range of technologies, including ZEV and ICE vehicle technologies." (*81 FR 25952*) EPA further notes that the proposal does not *mandate* ZEV sales like California's programs. However, we disagree, as the stringency of the proposed standards – and even the technology mixes suggested by EPA in the proposal – essentially forces manufacturers to solely focus development efforts on BEVs. API strongly believes in an all-of-the-above strategy to reducing carbon emissions, and we recommend that EPA adjust the standards to allow all solutions the ability to compete. Further, doing so would provide more time for nascent technologies to be proven with less risk to vehicle original equipment manufacturers (OEMs) and the public if these technologies do not pan out in the proposal's implementation timeframe.

To that end, various studies have highlighted the importance of allowing all technologies to be utilized to reduce emissions faster, more effectively, and at a lower cost.[6] [7] By limiting the scope to tailpipe emissions, the proposal is inherently not technology neutral. Setting strict tailpipe-only standards results in a limited, prescribed solution set.

2. Current and future solutions – lower carbon fuels, hydrogen, ICE-based solutions

As previously noted in our comments, lower carbon options currently exist and could be used for near-term reductions as well as the early years of the HD GHG Phase 3 program. Lower carbon fuels are available in the market now, and research and development to bring costs down and improve operability is ongoing. Vehicle-based solutions also currently exist and

---

[5] U.S. Department of Energy Office of Energy Efficiency & Renewable Energy, "The Road Ahead Toward a Net-Zero-Carbon Transportation Future Findings and Impact, FY15–FY21" (https://www.energy.gov/sites/default/files/2022-06/beto-co-optima-fy15-fy21-impact.pdf).

[6] "Environmental Benefits of Medium- and Heavy-Duty Zero Emission Vehicles Compared with Clean Bio- & Renewable-Fueled Vehicles 2022-2032," prepared for Diesel Technology Forum by Stillwater Associates LLC, July 19, 2022.

[7] "Multi-Technology Pathways to Achieve California's Air Quality and Greenhouse Gas Goals: Heavy-Heavy-Duty Truck Case Study," prepared for Western States Petroleum Association by Ramboll US Consulting, Inc., February 1, 2021.

are being developed, including the development of engines and vehicles to meet EPA's recently finalized HD Low NOx program.

While still in the early stages of development and prove out, hydrogen-based vehicles (FCEVs and H2-ICE) are a promising technology that many stakeholders are considering. API members are engaged in hydrogen projects to support development of hydrogen focused technology. Companies are partnering with HD OEMs to explore commercial business opportunities to build demand for commercial vehicles and industrial applications powered by hydrogen. Demonstration projects target hard-to-abate applications like rail and marine, with a goal to develop viable large-scale businesses and advance a thriving hydrogen economy.

As noted by the American Trucking Associations (ATA), in testimony before the U.S. Senate Committee on Environment and Public Works[8]:

> When battery electric vehicles are not the answer, federal support should refrain from playing favorites, and instead assist in the buildout of alternative fuel facilities. Proposals for hydrogen infrastructure for trucks need to ensure that the infrastructure is in place where that technology best fits in supply chains. Where lifecycle emissions can be reduced by deploying renewable diesel and renewable natural gas, those fuel stocks need to be available for trucking.

Bio and renewable fuels, such as renewable diesel, renewable natural gas, and biodiesel can and should be considered as part of an "all-of-the-above" approach to decarbonization of the transportation sector, including biocircularity. Especially for HD vehicles (and other hard-to-abate sectors) which may not be EV-ready or have infrastructure available, renewable fuels can serve as a lower emission and cost option that is readily available. As previously noted, API members are currently investing heavily in renewable fuel production – continued investment and development will increase the available volumes of such fuels in the marketplace and allow them to serve both as a viable lower carbon solutions leading up to the start of the Phase 3 program, throughout implementation, and beyond. Further, key findings of a study prepared for the Diesel Technology Forum showed results (for the scenarios considered in the study) of cumulative GHG reductions that were up to three times greater than BEVs for ICEVs fueled with 100 percent renewable diesel, and reductions from vehicles fueled with biodiesel blends were on par with BEV reductions.[9]

Further, EPA's LCA modeling for the proposal is based on biocircularity with atmospheric CO_2 consumed by biomass, resulting in zero tailpipe carbon emissions if the combusted biofuels

---

[8] U.S. Senate Committee on Environment and Public Works, hearing on "The Future of Low Carbon Transportation Fuels and Considerations for a National Clean Fuels Program", February 15, 2023 (https://www.epw.senate.gov/public/index.cfm/2023/2/the-future-of-low-carbon-transportation-fuels-and-considerations-for-a-national-clean-fuels-program).

[9] "Environmental Benefits of Medium- and Heavy-Duty Zero Emission Vehicles Compared with Clean Bio- & Renewable-Fueled Vehicles 2022-2032," prepared for Diesel Technology Forum by Stillwater Associates LLC, July 19, 2022.

were made from renewable biomass. The agency is thus not taking the source of carbon into account, and is classifying all carbon tailpipe emissions as the same related to their atmospheric GHG impact. For example, the agency should have considered in its analysis that a Class 7/8 ICEV run on 100% Renewable Diesel made from used cooking oil would have a greater than 70 percent tailpipe carbon reduction. EPA's approach is not consistent with other existing EPA policies (e.g., the Renewable Fuel Standard).

iv. Stakeholders missing from the discussion – utilities

EPA requested comment on stakeholders that may be missing from the discussion. As noted during the public hearing testimony, of the various stakeholders who testified, representation from the utilities was lacking. We implore the agency to fully engage the utilities in discussion prior to finalizing the Phase 3 rule. Because infrastructure is such an important piece of the program, the main stakeholder group needs to be included in the design of the program to provide EPA guidance. For example, a set of truck chargers of sufficient size to charge a fleet of fully electric trucks requires power enough for a small town.[10] If there are National Electric Vehicle Infrastructure (NEVI) charging facilities (i.e., four direct current fast chargers (DCFCs) with the capability to deliver 150 kW simultaneously) located on the same grid, there could be significant challenges to delivering the power without impacting other residential, commercial, and industrial customers. Further, a guidance report by the North American Council for Freight Efficiency (NACFE) and RMI highlights that "[c]harging infrastructure includes not only the chargers themselves, but the interrelated system of vehicles, duty cycles, chargers, and electric utilities."[11]

v. EPA's limits are not set on a realistic scientific based approach

EPA's proposed standards are based on projected ZEV penetration rates based on OEM stated ambitions and on California ZEV targets such as the Advanced Clean Trucks rule. These ambitions are stretch goals that OEMs likely will not be able to comply with. For instance, one study found that multi-year queues for service, uncertainty, and growing costs are delaying grid upgrade and increasing power production costs, which will translate into inability to meet the targets set by the California rules.[12] EPA's targets are also based on using the 2027 model year as a baseline, which has not materialized yet. This approach misses the mark as it is not grounded on application fit, total cost of ownership (TCO), or necessary infrastructure considerations. EPA should revisit its methodology for setting the standards by holistically evaluating technology adoption rates based on feasibility of all technologies per specific application requirements, and consider a more realistic baseline. Further, EPA should consider

---

[10] "Charging Infrastructure Challenges for the U.S. Electric Vehicle Fleet," American Trucking Research Institute, December 2022.

[11] "Charging Forward with Electric Trucks," North American Council for Freight Efficiency (NACFE) and RMI, June 2023.

[12] Gladstein, Neandross & Associates (GNA), "State of Sustainable Fleets 2023 Market Brief", May 2023, Santa Monica, CA. Available at: https://www.stateofsustainablefleets.com/.

a lifecycle approach that would accurately capture all the emissions associated with the life of a vehicle and capture the efficiency differences of different technologies in different applications.

d. Technical Feasibility

i. Vehicle readiness

1. Technology readiness

The proposed rule identified various HD ZEVs available in the marketplace or in production, as well as select manufacturer goals and commitments to producing HD ZEVs by a certain timeframe. However, given the nascent technology, there is significant uncertainty regarding EPA's expectation for rapid availability of ZEV powertrains. Further, it should be noted that these vehicles are small in number, some are not able to perform the work that a comparable ICEV would perform (due to charging, range, and duty-cycle constraints), and all are for localized operations; long-haul ZEVs are in the pilot stage and have significant challenges. OEM goals and commitments, coupled with IRA/BIL funding may help to increase the availability of HD ZEVs; however, it will be extremely challenging to meet the proposal's implementation schedule. We have concerns that vehicles may not be available at the rates that EPA is projecting for the 2027-2032 timeframe.

Even with a fully stocked HD ZEV market, key barriers to entry include customer uptake, capital costs to purchase vehicles, and infrastructure readiness.

2. ZEV penetration/customer uptake and adoption rates

HD ZEVs are currently not available in sufficient quantities or at affordable levels to significantly displace ICEVs. Further, the cost to purchase a ZEV is currently prohibitive – not only is the purchase price currently higher than that of an ICEV, some fleet owners and operators are finding that HD ZEVs result in more work or trips needed to accomplish the same task as with an ICEV. This is largely due to battery range and charging, but can also be affected by temperature, road grade, and other factors. A study by ATA noted vehicle and fleet owner concerns with regard to total cost of ownership, despite IRA and BIL funding.[13] [14]

Owners may choose to continue to use and extend the life of ICEVs, along with lower carbon fuels and/or other low carbon technologies, to avoid these issues. And at lower costs than those of ZEVs.

3. Capital cost to purchase vehicles

The average cost of a HD tractor is about $180,000, while the electric version of the same vehicle can be nearly $400,000. Expending this additional capital for a vehicle that may

---

[13] Advanced Clean Transportation (ACT) Expo 2023 Mainstage - Monday - 2023 State of Sustainable Fleets: https://vimeo.com/824774094.

[14] Advanced Clean Transportation (ACT) Expo 2023 Keynote Address: https://vimeo.com/824772504.

not meet the duty-cycle, is significantly heavier (and thus reduces the payload of the vehicle), and may require additional vehicles to achieve the same job, creates massive challenges that may not be able to be overcome.

4. Compounding concern – resource focus will be on LD, on the same timeframe

EPA released the proposals for HD and for LD/MD simultaneously – and the programs will be implemented on the same 2027-2032 timeframe as well. API has serious concerns about the implications of this timing. Both proposed programs are significantly flawed in that they rely on resources and infrastructure that are not yet ready. However, this would provide even greater difficulty for the HD program, as HD ZEVs are not at the same level of readiness as LD vehicles and the deployment of charging infrastructure is at an even greater disadvantage. Even with EPA's projections regarding the use of BIL and IRA funding, the transportation industry will be competing for the same resources to successfully stand up both programs. Furthermore, the availability of and process for obtaining such funding is not certain.

ii. Infrastructure

1. Leadtime and deployment

API, and many other stakeholders, are concerned about the lack of infrastructure for the HD ZEV market. Even coupled with significant tax credits and incentives, fleet operators and vehicle owners will not purchase new HD ZEVs without a reliable charging infrastructure. For the small number of HD ZEVs that are currently available[15], it appears most are utilizing depot charging and the vehicles are largely being used for shorter trips.

EPA notes in the proposal various partnerships and plans to build battery manufacturing plants in the U.S., taking advantage of incentives such as the IRA, one must view these as highly complex projects – in addition to siting and construction, it will take time for these new battery manufacturing facilities to ramp up to full production. Further, there is the probability that not all announced projects will materialize.

2. Grid and charging

A robust analysis of the potential for the development and application of ZEV technologies in the HD sector must be conducted by EPA. We have concerns that EPA is overly optimistic about the technology readiness of ZEVs across the HD vehicle classes. Even with the low numbers of vehicles available on which to provide data, numerous studies and reports have been issued noting important concerns regarding ZEV readiness of the HD fleet. For example, a 2022 report by ATRI identified three overarching challenges in the deployment of HD ZEVs: electricity needs, battery materials and technology sourcing, and truck charging and parking

---

[15] https://ww2.arb.ca.gov/news/california-approves-groundbreaking-regulation-accelerates-deployment-heavy-duty-zevs-protect#:~:text=There%20are%20already%20about%20150%20existing%20medium-%20and,that%20are%20commercially%20available%20in%20the%20U.S.%20today

infrastructure.[16] The report cites the need for up to a 40 percent increase (based on HD vehicle class) in the nation's present electricity generation to fully electrify the U.S. vehicle fleet, and individual states would need 28 to 63 percent to meet vehicle travel needs. ATRI quantified that the truck charging needs at a single rural rest area would be equal to the amount of daily electricity required to power more than 5,000 U.S. households.

EPA requested comment on whether certain HD sectors may need alternate standards or timing due to the energy content required for charging. The ATRI study, as well as a study prepared for the Diesel Technology Forum, indicate significant electricity demand and costs associated with HD ZEV charging for larger vehicles as well as for fleets with multiple vehicles. HD vehicle charging may require megawatt-levels of charging, which will require significant buildout of electricity distribution that does not exist today.[17]

iii. Critical minerals

Reliance on a limited number of technologies (e.g., ZEVs) on the timeline required by the proposed rule will likely result in a non-resilient transport sector that is vulnerable to unexpected disruptions. Both the federal government and the private sector have recognized that critical minerals are essential to the future of ZEV technology, and likewise, that unstable critical mineral supply chains could disrupt this future.

BEV battery supply chains, including critical minerals and precursors are controlled by a small number of countries, some with unsustainable environmental and human rights practices, and geopolitical concerns. The mining sector will need to grow exponentially to meet demand, and mining is an energy- and environmental-intensive activity. The accelerated ZEV technology penetration rate required under EPA's proposal poses significant challenges for best practices to be widely and fully deployed in the timeframe anticipated by the proposed rule.

Regarding the availability of critical minerals, especially those essential to the manufacturing of a Li-ion battery, the supply is dominated by three lithium producing countries — Australia, Chile and China, which account for nearly 90 percent of the global market. While 70% of global cobalt production comes from the Democratic Republic of Congo[18], most of the mines are owned/operated by China and more than 60 percent of cobalt processing is located in China. China produces 67 percent of the world's graphite.[19] The U.S. imports most of its

---

[16] "Charging Infrastructure Challenges for the U.S. Electric Vehicle Fleet", American Transportation Research Institute, December 2022.

[17] "Environmental Benefits of Medium- and Heavy-Duty Zero Emission Vehicles Compared with Clean Bio- & Renewable-Fueled Vehicles 2022-2032," prepared for Diesel Technology Forum by Stillwater Associates LLC, July 19, 2022.

[18] "The Role of Critical Minerals in Clean Energy Transitions", International Energy Agency World Energy Outlook Special Report: https://iea.blob.core.windows.net/assets/ffd2a83b-8c30-4e9d-980a-52b6d9a86fdc/TheRoleofCriticalMineralsinCleanEnergyTransitions.pdf.

[19] "Graphite," Professional Paper 1802-J, US Geological Survey: https://pubs.er.usgs.gov/publication/pp1802J#:~:text=China%20provides%20approximately%2067%20percent%20of%20worldwide%20output,costs%20and%20some%20mine%20production%20problems%20are%20developing.

manganese from Gabon, a less geopolitically stable country, providing 65 percent of the United States' supply.[20] Electricity networks need a large amount of copper and aluminum. The need for grid expansion that would result from this rapid increase in electricity demand underpins a doubling of annual demand for copper and aluminum.[21] China possesses over half of the entire world's aluminum smelting capacity.

There are sources that indicate a shortage of critical minerals as well as volatility in critical mineral prices. U.S. energy security would also undergo a dramatic paradigm shift if vehicle technologies were shifted from ICEVs to ZEVs in the exponential rate that the proposal contemplates. Domestic production of critical minerals required for battery production is insufficient to meet the projected demands. Although Congress and the Administration have taken significant steps to accelerate this activity by funding, facilitating, and promoting the rapid growth of U.S. supply chains for these products through the IRA, BIL, and numerous Executive Branch initiatives, more will still be needed given the proposed increase in demand. Further, EPA failed to consider all the complexities, such as federal permitting, National Environmental Protection Act reviews, and the supply chains for these critical materials in their technology feasibility assessment. API requests that EPA include a thorough evaluation of the full supply chains for each critical mineral/material in their final proposal and their implications on energy security, factoring in sensitivity cases and acknowledging potential disruptions in the supply chain. Please see Appendix A for more discussion regarding our concerns on critical minerals.

e. Energy Security

i. Support energy security through production of U.S. energy

U.S. energy security would also undergo a dramatic paradigm shift if vehicle technologies were shifted from ICEVs to ZEVs in the exponential rate that the proposal would likely entail. The U.S. would move from being energy secure to being dependent largely upon foreign sources for the minerals needed to make ZEV technologies such as batteries.

ii. Address EPA's projections—

1. Decrease in non-GHG refinery emissions

We question the agency's projections of refinery emissions decreases due to reduced fuel demand (Draft RIA, Table 4/18). The analysis assumes that there will be less domestic fuel demand due to a marked uptick in the use of HD ZEVs. However, as we have noted throughout these comments, there is significant concern that the market may not reach the levels of HD ZEV penetration suggested by the proposal. If fleets continue to use ICEVs in significant numbers, which could reasonably be expected based on various factors (e.g., the life of HD

---

[20] https://oec.world/en/profile/bilateral-product/manganese-ore/reporter/usa

[21] "The Role of Critical Minerals in Clean Energy Transitions", International Energy Agency World Energy Outlook Special Report: https://iea.blob.core.windows.net/assets/ffd2a83b-8c30-4e9d-980a-52b6d9a86fdc/TheRoleofCriticalMineralsinCleanEnergyTransitions.pdf.

vehicles, costs of purchasing new vehicles, etc.), even with an increased use in biofuels, there will continue to be a demand for conventional fuels. There could also be increased demand for refined products in other countries that the U.S. could supply.

Furthermore, EPA's analysis assumes that lower domestic fuel demand, due to increased usage of HD ZEVs, will result in reduced refinery throughput. However, this assumption may not hold true as the U.S. has emerged as a major player in the global market for refined products, actively exporting significant quantities. While the EPA assumes that a gallon of reduced domestic demand would reduce net crude and product imports by 0.864 (Draft RIA Section 6.5), their assumption fails to consider the possibility that refinery throughput could remain steady while the U.S. simultaneously increases its exportation of refined products.

EPA justifies its assumption that imports will fall 86.4 percent by comparing the AEO 2022 Reference case with the AEO 2022 Low Economic Growth case. This comparison is not suitable for drawing these conclusions because in the Low Economic Growth case, U.S. refined product exports are lower compared to the Reference Case, suggesting a decline in global demand for refined products. Regardless of the assumption's merits, the EPA doesn't explicitly state, in its regulatory impact analysis, that the reduced global demand for refined products is, in part, an assumption based on the forecasts EPA uses for its analysis and not attributable to its regulation.

2. Cost benefits due to "reductions in energy security externalities caused by U.S. petroleum consumption and imports"

Similarly, we have concerns with EPA's projections that the Phase 3 rule would increase U.S. energy security because "[a] reduction of U.S. petroleum imports reduces both financial and strategic risks caused by potential sudden disruptions in the supply of imported petroleum to the U.S." EPA's treatment of "energy security" is overly focused on oil imports, petroleum markets and consumption of refined products. Especially in the context of EPA's proposed rule, which will require a significant increase in production of batteries, the agency should focus on the energy security implications beyond liquid fuels.

Mineral security and energy security, defined as "the uninterrupted availability of energy sources at affordable prices"[22] are essentially interchangeable concepts because EPA's proposed rule will require affordable supplies of critical minerals, that while available within the U.S., are largely inaccessible due to permitting challenges.[23]

---

[22] 88 Fed. Reg. 25,929 (April 27, 2023).

[23] The Martec Group, "Electric vehicle growth in the U.S.: A look Into the EV Battery Supply Chain", March 2022, https://martecgroup.com/electric-vehicle-battery-supply-chain/.

According to the Congressional Research Service[24], the U.S. has a heavy dependence on imported critical minerals and for the five critical minerals used in battery production there is a "higher potential" for disruptions to the supply chain. In addition to domestic reserves of critical minerals where it may not even be economical to produce[25], there is a lack of liquidity[26] in global markets that are highly concentrated. Markets for critical minerals are "small, thin, and opaque,"[27] as well as inefficient, which can be crippling to development of critical minerals.

Given the market and domestic resource challenges identified above, the EPA has failed to properly address effects on energy security of the U.S. The proposed rule would make the U.S. more reliant on imported critical minerals that are subject to supply disruptions and market concentrations. As EPA mentions, disruptions in petroleum supply chains and critical mineral supply chains are not perfectly comparable; however, similarities should not be ignored.

We also have concerns with the methodology EPA uses to estimate energy security benefits which were originally developed by Oak Ridge National Laboratory's (ORNL) 2008 study entitled, "The Energy Security Benefits of Reduced Oil Use, 2006-2015"(Draft RIA Section 7.3.5). We believe that portions of this methodology are outdated and are no longer applicable given the current structure of global oil markets.

In ORNL's study, a significant portion of the estimated security premium is the potential reduction of "the transfer of U.S. wealth to foreign producers" which "can lead to macroeconomic contraction, dislocation, and GDP losses" during an oil supply disruption. In 2008, when ORNL calculated energy security premiums, net U.S. crude and product imports were over 50 percent of U.S. liquid petroleum consumption. However, since ONRL's calculations the U.S. has become, and is projected to be, a net oil and product exporter, thus an increase in global oil prices would likely lead to a net transfer of wealth to the U.S. not away from it. Without modifications that account for the transfer of wealth to the U.S. during a supply disruption, EPA's calculated energy security premium estimates are likely overstated and not meaningful.

f. Program Review

i. Assessment of both vehicle and infrastructure development/deployment progress

The design of a program with such significant unknowns and heavy reliance on technology and infrastructure that will "hopefully" or is "anticipated/expected to" be available is optimistic at best. The proposal appears premature on the stated timeline, and essentially in conjunction with the LD/MD program, which would be competing for the same resources. If

---

[24] Tracy, B. S. (222). *Critical Minerals in Electric Vehicle Batteries* (CRS Report No. R47227). Retrieved from Congressional Research Service website: https://crsreports.congress.gov/product/pdf/R/R47227.

[25] Ibid.

[26] https://www.barrons.com/articles/markets-critical-minerals-lithium-cobalt-copper-51671227168

[27] https://www.barrons.com/articles/markets-critical-minerals-lithium-cobalt-copper-51671227168

EPA is not willing to adjust the timeline and/or standards of the Phase 3 program, API requests that the agency consider incorporating a pre-program assessment as well as a program progress assessment. It is imperative that EPA provide a real-world evaluation, with an honest assessment provided to the public, regarding progress on infrastructure readiness and ZEV technology deployment. The opportunity for stranded investments by all stakeholders impacted by this program is just too great not to incorporate pre- and mid-program reviews.

For a mid-program assessment, EPA could consider something akin to the Midterm Evaluation that was finalized in its 2012 rulemaking establishing the MY 2017-2025 LD GHG standards.[28] Further, we recommend that EPA engage a broad stakeholder community to identify necessary elements to incorporate into such an assessment.

ii. Future program incentives and program adjustment of standards

In the development of the Phase 3 program, EPA needs to consider future program incentives such as adoption of a lifecycle approach, combined with fuel carbon intensity reductions. Such an approach would provide a broad spectrum of industries that power the transportation system (e.g., OEMs, petroleum refiners, power generators, and renewable fuel manufacturers) with incentives to reduce GHGs.

In addition, we also request that the agency report out on the findings following review with enough time to adjust the standards if needed. Adequate leadtime must be provided to the regulated community to allow for necessary adjustments to regulatory compliance strategies, and to avoid stranded investments as much as possible. A proposal based on stretch goals must incorporate an "offramp" or some opportunity to pivot if the essential elements of the program, such as charging/fueling infrastructure, do not materialize.

g. **Legal Concerns.**

The Phase 3 proposal is fundamentally different than the Phase 1 and Phase 2 HD GHG rules that preceded it. Rather than continuing to rely exclusively on improved technology for gasoline- and diesel-powered vehicles, the rule instead would establish standards that require a significant portion of new vehicle production and sales to consist of ZEVs (again, most of which EPA projects would be BEVs). While we believe that ZEVs can and should be a choice available to manufacturers and vehicle purchasers, we disagree that EPA should impose a binding mandate for the production of ZEVs and believe that such a mandate exceeds EPA's authority under the Clean Air Act (CAA).

---

[28] https://www.epa.gov/regulations-emissions-vehicles-and-engines/midterm-evaluation-light-duty-vehicle-greenhouse-gas

i. EPA does not have authority to impose standards that are only achievable through the use of ZEV technology because there is no clear statement in the Clean Air Act authorizing EPA to mandate a shift away from internal combustion engines.

The Proposed Rule marks a pronounced shift in EPA's approach to regulating greenhouse gas ("GHG") emissions from heavy-duty vehicles. EPA explains in the Proposed Rule, it "did not premise the HD GHG Phase 2 CO_2 tractor emission standards on application of hybrid powertrains or ZEV technologies." 88 Fed. Reg. at 25957. But in the current proposal, the Agency "developed technology packages that include both ICE vehicle and ZEV technologies." *Id*. at 25958. Moreover, the Proposed Rule would do more than just lock in the ZEV sales projected to occur in the absence of this rule. Instead, it would mandate that more ZEVs be sold than otherwise would be the case. Today, ZEVs make up just a tiny fraction of the heavy-duty vehicle fleet and current new heavy-duty vehicle sales. Under the Proposed Rule, EPA projects that, by 2032, ZEVs would comprise 50% of new vocational vehicle sales and 25-30% of new tractor sales. *Id*. at 26000.

Such a shift from internal combustion engines ("ICE") to ZEVs would be truly transformative. BEVs, which EPA predicts will be the technology that is mostly used to satisfy the proposed ZEV mandate, require fundamentally different vehicle technologies than those used on conventionally fueled vehicles – e.g., electric motors instead of internal combustion engines, batteries to store power rather than on-board fuel tanks. Moreover, BEVs rely on a wholly different infrastructure (e.g., electric power generation and distribution, charging stations, battery manufacturing) – much of which does not yet exist or exists only in limited form. Additionally, switching to BEVs will fundamentally change the manner in which vehicles are used, for example requiring careful scheduling of vehicle operations to accommodate the long periods needed to adequately charge the vehicles. Lastly, a ZEV mandate would produce widespread effects on the national economy, such as the reduced need for oil and gas production, gas processing, changes to petroleum refining, and distribution. Such changes are fundamentally different and far more expansive than those caused by EPA's heavy-duty motor vehicle emissions standards up to now, which worked by requiring changes to ICE drivetrains and vehicles and in the fuels used by these vehicles instead of (as here) forcing a shift to a wholly different powertrain technology.

EPA asserts that the ZEV mandate is authorized under Clean Air Act ("CAA") Sections 202(a)(1) and (2). 88 Fed. Reg. at 25927. EPA explains that these provisions "are technology forcing when EPA considers that to be appropriate." *Id*. at 25949. EPA further explains that "Section 202 does not specify or expect any particular type of motor vehicle propulsion system to remain prevalent." *Id*. The Agency points to legislative history to support the notion that Congress understood that powertrain technologies might evolve over time and quotes Representative Pallone as opining that the "recently enacted [Inflation Reduction Act] "reinforces the longstanding authority and responsibility of [EPA] to regulate GHGs as air pollutants under the Clean Air Act," 204 and "the IRA clearly and deliberately instructs EPA to use" this authority by "combin[ing] economic incentives to reduce climate pollution with regulatory drivers to spur greater reductions under EPA's CAA authorities."" *Id*. at 25050.

But such an expansive claim of authority cannot depend on a generally stated statute, such as CAA §§ 202(a)(1) and (2), or on the views of Members who participated in the development of the CAA or the IRA. The U.S. Supreme Court has concluded that such an "extraordinary" claim of authority exists only when there is "clear congressional authorization." *West Virginia v. EPA*, 142 S.Ct. 2587, 2609 (2022). At their core, CAA §§ 202(a)(1) and (2) authorize EPA to establish "standards applicable to the emission of any air pollutant from any class or classes of new motor vehicles or new motor vehicle engines, which in [the Administrator's] judgment cause, or contribute to, air pollution which may reasonably be anticipated to endanger public health or welfare." Because this provision includes no clear statement that EPA may mandate a fundamental shift in propulsion technology, EPA lacks authority to impose emissions limitations that effectively will require the production and sale of ZEV vehicles.

The lack of a clear statement is particularly notable given that Congress's most recent efforts to address GHG emissions – the Inflation Reduction Act and the Bipartisan Infrastructure Act – almost exclusively consisted of economic incentives and pointedly gave EPA no new or expanded authority to substantively regulate GHG emissions. If Congress had intended EPA to have authority to mandate a fundamental shift in powertrain technology, surely it would have done more than spend money on the issue. Moreover, EPA's claim of authority plainly conflicts with other relevant statutes, such as the Renewable Fuel Program, under which Congress mandated that significant and increasing volumes of renewable fuels should be blended into that national motor fuel supply. In contrast, the Proposed Rule is designed to significantly reduce the amount of motor fuel consumed by the heavy-duty fleet. The Proposed Rule thus would frustrate Congressional intent by reducing rather than expanding the volume of renewable fuel consumed by motor vehicles in the U.S.

It also is telling that EPA has abandoned any pretense of "co-regulating" with NHTSA, the national regulatory authority that actually has been authorized by Congress to establish motor vehicle fuel efficiency standards. Among other things, this is a clear attempt to free EPA from unambiguous statutory obligations that otherwise would constrain a joint rulemaking, such as the requirements that NHTSA must provide a full four years of model year lead time and NHTSA may not regulate more than five years in advance. It is simply not plausible that the general standard-setting authority of CAA § 202(a) can be construed to confer omnibus authority for EPA to effectively rewrite directly relevant statutory directives.

ii. EPA's authority under CAA §§ 202(a)(1) and (2) to prescribe emissions standards for vehicles and engines does not extend to a mandatory shift in powertrain technology.

As explained above, the Proposed Rule would require that a significant proportion of new heavy-duty vehicles must be powered by ZEV drivetrains. That proportion exceeds the level of new vehicle ZEV sales that otherwise would occur. As a result, the Proposed Rule would constitute a mandate to produce ZEV vehicles.

Moreover, ZEVs are not just another form of conventional diesel or gasoline fueled ICE-driven vehicles. For example, a ZEV cannot be produced by modifying a conventional ICE drivetrain (e.g., by changing combustion conditions) or by adding pollution control technology to a conventional ICE drivetrain (e.g., catalytic converter or diesel particulate filter). Rather, ZEVs employ wholly different propulsion technology as compared with conventional ICE drivetrains. The BEVs that EPA predicts will make up the vast majority of the ZEVs that would have to be produced under the Proposed Rule use electricity and batteries rather than liquid fuels stored in fuel tanks and employ electric motors for propulsion rather than ICE engines. In short, ZEVs are a fundamentally different type of drivetrain than conventional ICE drivetrains.

EPA asserts that CAA §§ 202(a)(1) and (2) authorize the imposition of a ZEV mandate. But for the following four reasons, EPA does not have authority under CAA §§ 202(a)(1) and (2) or under any other CAA provision to impose such a fundamental and mandatory shift in powertrain technology.

First, EPA may regulate a class of motor vehicles under CAA § 202(a)(1) only if emissions from that class of vehicles "cause, or contribute to, air pollution which may reasonably be anticipated to endanger public health or welfare." EPA treats ZEVs as if they do not emit GHGs for the purposes of this proposal. As a result, under EPA's rationale, ZEVs do not emit the pollutant that is the object of the Proposed Rule and cannot cause or contribute to the endangerment that EPA asserts as the basis for its authority to regulate here under CAA § 202(a)(1). Thus, it is beyond EPA's authority to impose a ZEV mandate.

Second, CAA § 202(e) – entitled "New power sources or propulsion systems" – states that EPA may defer the certification for a new motor vehicle employing a new power source or propulsion system until after the Agency has "prescribed standards for any air pollutants emitted by such vehicle or engine which in [the Administrator's] judgment cause, or contribute to, air pollution which may reasonably be anticipated to endanger the public health or welfare but for which standards have not been prescribed under [CAA § 202(a)]." Thus, EPA must take two actions when assessing a new power source or propulsion system. EPA first must determine whether emissions from the new power source or propulsion system cause or contribute to air pollution that endangers public health or welfare. If the answer is yes, EPA second must establish new emissions standards for the new power source or propulsion system or, alternatively, determine that appropriate standards have already been established.

ZEVs clearly constitute a new power source or propulsion system. As a result, before certifying any ZEVs, CAA § 202(e) requires EPA determine whether emissions from ZEVs cause or contribute to air pollution that endangers public health or welfare. But, under EPA's rationale, ZEVs do not emit GHGs, which is the pollutant that would be regulated under the Proposed Rule. Consequently, EPA cannot determine that emissions from ZEVs cause or contribute to any endangerment caused by GHG emissions and, therefore, the Agency has no need or authority to impose GHG emissions standards on ZEVs prior to certifying them.

Third, CAA § 202(a)(1) in relevant part authorizes EPA to establish "standards applicable to the emission of any air pollutant from any ***class or classes*** of new motor vehicles or new motor vehicle engines." CAA § 202(a)(1) (emphasis added). This provision requires EPA to define appropriate classes of vehicles for purposes of making the cause/contribute finding and in subsequently establishing emission standards.

From the outset of its CAA-based motor vehicle regulatory program, EPA has properly distinguished between fundamentally different powertrain technologies – e.g., regularly developing and issuing separate standards for gasoline-powered vehicles and diesel-powered vehicles. In contrast, EPA here combines all powertrain types into the same classes for purposes of imposing GHG emission standards. That is unreasonable and arbitrary because conventionally powered vehicles have fundamentally different emissions characteristics than electric powered vehicles. See also CAA § 202(e) (requiring EPA to separately evaluate emissions from "a new power source or propulsion system.")

As demonstrated by EPA's Phase 1 and Phase 2 GHG standards for heavy-duty vehicles, there is a wide variety of emissions control techniques that may be applied to conventionally powered heavy-duty vehicles to reduce GHG emissions – including such things as improved engine efficiency, better aerodynamics, and lower rolling resistance. Applying such measures to ZEVs does not affect their GHG emissions profile because, by EPA's definition, ZEVs do not emit GHGs. This shows that conventionally power vehicles and ZEVs should not occupy the same class under these rules because wholly different regulatory approaches are needed to appropriately control GHG emissions from these two fundamentally different types of vehicles. Further to our argument, the Clean Fuel Vehicles program can only be prescribed to areas that have the worst ozone nonattainment and to the pollutants that contribute to ambient ozone levels.

Fourth, EPA's regulatory approach is unlawful because it treats ZEVs as if their powertrain were an emissions control technology and then mandates the use of that purported emission control technology. EPA claims throughout the proposed rule that its proposed standards do not require manufacturers to implement any specific technology and, instead, that they retain flexibility to comply with the rule in whatever manner they deem appropriate. But the proposed rule inescapably will require a significant industry-wide shift from internal combustion to ZEVs. A particular manufacturer may avoid producing a ZEV though creative use of the ABT provisions, but the industry as a whole will have no choice but to produce increasing numbers of ZEVs over time. This is contrary to CAA § 202(a), which authorizes EPA to set emissions standards, but does not authorize EPA to mandate the use of any particular emissions control technology in meeting those standards.

iii. EPA has no authority under CAA §§ 202(a)(1) and (2) to establish emissions standards based on the average performance of two emissions control technologies.

The Proposed Rule is fundamentally different from the Phase 1 and Phase 2 GHG standards for heavy-duty vehicles in the manner in which the emission standards are established. EPA explains that the prior Phase 2 GHG standards for HD vehicles were not premised on the application of hybrid powertrains or ZEV technology. 88 Fed. Reg. at 25957. In contrast, the HD 3 proposal "include[s] both ICE vehicle and ZEV technologies." *Id.* at 25958.

In particular, averaging is incorporated into EPA's standard setting analysis in the Proposed Rule. EPA for each model year and for each vehicle type conducts an analysis of what standards could be met by traditional ICE vehicles and whether ZEVs are available for that model year for that vehicle type and, if so, at what volume. EPA then proposes an emissions standard for each model year and vehicle type that is a blended rate of the ICE value and the ZEV value (which is presumed to be zero) that is based on EPA's projection of how much of the market could be met with ZEVs. *Id.* at 25991-2.

EPA asserts that it "has long included averaging provisions for complying with emission standards in the HD program and in upholding the first HD final rule that included such a provision the D.C. Circuit rejected petitioner's challenge in the absence of any clear evidence that Congress meant to prohibit averaging." 88 Fed. Reg. at 25950. That is the only legal justification EPA asserts for using averaging in standard setting.

The use of averaging in standard setting is legally flawed for two reasons. First, EPA's asserted legal justification is inadequate. It is true that EPA has long used emissions averaging as a compliance method under its vehicle emissions standards. But here EPA is doing more – EPA uses averaging in setting the standards themselves. EPA provides no explanation of its legal authority for this novel approach.

Second, and in any event, EPA does not have legal authority to consider emissions averaging in standard setting. CAA § 202(a)(1) authorizes EPA to establish emission standards for "classes" of motor vehicles. In this case, EPA has used emissions data from two distinctly different classes of vehicles (ICE-powered vehicles and BEVs) in setting a single standard. That exceeds EPA's authority under CAA § 202(a)(1). Moreover, using averaging is unreasonable because there is no identifiable vehicle configuration that corresponds to EPA's proposed standards. That means the industry as a whole would have to certify at least two fundamentally different types of vehicles to satisfy the proposed standards. As a result, EPA is effectively setting two different standards for the same pollutant for the same class of vehicles under the guise of establishing a unitary standard for a single class of vehicles.

Furthermore, CAA § 202(a)(3)(A)(i) requires that HD standards reflect the "greatest degree of emissions reduction achievable through the application of technology which the EPA determines will be available." 42 U.S.C. § 7521(a)(3)(A)(i). Congress specifically directed EPA to set emissions for vehicles, not fleets of vehicles. Congress further required EPA to test these "motor vehicles or motor vehicle engines" to ensure they "conform to the standards." 42 U.S.C. § 7525(a)(2); see also id. § 7525(a)(1) (requiring certificates of conformity for specific vehicles). And Congress authorized EPA to grant waivers from certain nitrogen-oxide emissions standards "of no more than 5 percent of [a] manufacturer's production or more than fifty thousand vehicles or engines, whichever is greater." The testing of specific vehicles or engines and the presence of the waiver provisions cannot be implemented as intended under an averaging structure in which a significant portion of the fleet can be above the emissions standard so long as other vehicles perform sufficiently well to create average compliance.

iv. The use of ZEV technology is not an emissions standard under CAA §§ 202(a)(1) and (2).

By factoring ZEVs into the proposed emission standards, EPA effectively is treating ZEVs as an emissions control technology that can form the basis of an emission standard. This exceeds EPA's authority under CAA § 202(a).

EPA is authorized under CAA § 202(a)(1) to prescribe "standards applicable to emissions." In other words, EPA is authorized to prescribe emission standards for motor vehicles. The term "emission standard" means a requirement "which limits the quantity, rate, or concentration of emissions of air pollutants." CAA § 302(k).

The problem with EPA's regulatory approach here is that a ZEV is not an emissions control technology for a conventionally powered vehicle. A ZEV does not limit the "quantity, rate, or concentration" of air pollutant emissions from a conventionally powered vehicle. Rather, a ZEV represents an entirely different type of propulsion system and powertrain. The existence of ZEVs has no bearing on the relative emissions from conventionally powered vehicles.

Consequently, a ZEV powertrain is not an emissions reduction technology applicable to conventionally powered vehicles and cannot form the basis of emission standards applicable to conventionally powered vehicles.

v. The Clean Air Act already expressly provides a regulatory scheme for Clean Fuel Vehicles in Part C of Title II. That regulatory scheme precludes the regulation of ZEVs together with internal combustion engines.

CAA § 242(a) requires EPA to "promulgate regulations under this part containing clean-fuel vehicle standards for the clean-fuel vehicles specified in this part." A clean fuel vehicle is one that is powered by a "clean alternative fuel," which is defined to include electricity. CAA § 241(2). CAA § 245 limits EPA's authority to regulate heavy-duty clean fuel vehicles – specifying that EPA may establish standards for NOx and NMHC, and further specifying that no standards may be promulgated for heavy-duty vehicles of more than 26,000 lbs. gross vehicle weight. The state implementation plan for areas designated in severe or greater nonattainment with ozone National Ambient Air Quality Standards must include a clean-fuel vehicle program. CAA § 182(c)(4). The program must apply to centrally fueled fleets. *Id*. at § 246.

EPA cites the Clean Fuel Vehicles program as an indication that Congress generally intended to "promote further progress in emissions reductions." 88 Fed. Reg. at 25950. EPA thus points to the Clean Fuel Vehicles program as supporting its proposed interpretation that CAA §§ 202(a)(1) and (2) authorize EPA to mandate the production and sale of ZEVs. But in doing so, EPA fails to address the regulatory program required under the Clean Fuel Vehicles program and fails to reconcile the particular requirements of that program with the CAA § 202(a) general rulemaking authority on which it relies as the primary authority for the Proposed Rule.

The Clean Fuel Vehicles program plainly requires EPA to establish an alternative regulatory scheme for clean fuel vehicles, including electric powered vehicles. For heavy duty vehicles, CAA § 242(b) specifies that such vehicles "shall comply with all requirements of this title which are applicable in the case of conventional gasoline-fueled or diesel-fueled vehicles of the same category and model year." This provision clearly signals that Congress intended EPA to develop emissions standards for ICE-powered vehicles and to apply those standards to clean fuel vehicles (including BEVs). In the very least, Congress's explicit inclusion of electric powered vehicles in the Clean Fuel Vehicles program and its exclusion of any mention of electric powered vehicles in Section 202 must be given meaning. *Compare* 42 U.S.C. § 7581 *with* 42 U.S.C. § 7521(a), (e); *Bittner v. United States*, 143 S. Ct. 713, 720 (2023) ("When Congress includes particular language in one section of a statute but omits it from a neighbor, we normally understand that difference in language to convey a difference in meaning (*expressio unius est exclusio alterius*).") This Clean Fuel Vehicles Program would be rendered meaningless if, as in the Proposed Rule, EPA were to consider conventionally fueled vehicles together with clean fuel vehicles (including BEVs) in developing and implementing emissions standards.

Moreover, the Clean Fuel Vehicles program is narrowly targeted to the worst ozone nonattainment areas and to the pollutants that contribute to ambient ozone levels. The program also imposes important constraints on how vehicles may be regulated (for example, as explained above, it dictates separate emissions standards for clean fuel vehicles and limits the applicability of those standards to only certain heavy-duty vehicles). These detailed and prescriptive requirements demonstrate that Congress intended EPA to regulate clean fuel vehicles only in particular ways. EPA's claim in the Proposed Rule of omnibus authority to regulate clean fuel vehicles along with conventionally fueled vehicles cannot be reconciled with the targeted and carefully crafted regulatory scheme set out in the Clean Fuel Vehicles program.

Lastly, the Proposed Rule also is flawed because EPA fails to acknowledge the regulatory requirements imposed under the Clean Fuel Vehicles program and fails to explain how it still finds authority to regulate under CAA § 202(a) in the face of the more specific obligations imposed under the Clean Fuel Vehicles program. That violates EPA's procedural obligation to set forth in the Proposed Rule "the major legal interpretations … underlying the proposed rule." CAA § 307(d)(3)(C).

In sum, the CAA clearly instructs EPA as to where and how heavy-duty clean fuel vehicles should be regulated. Those specific requirements displace any authority EPA might otherwise have had to regulate clean fuel vehicles under the general authority of CAA §§ 202(a)(1) and (2). EPA is thus mistaken in asserting that CAA §§ 202(a)(1) and (2) authorize the proposed Phase 3 emissions standards for heavy-duty vehicles. In addition, the Proposed Rule fails to provide adequate notice and opportunity to commenters on the important legal questions surrounding the scope and extent of the Clean Fuel Vehicles program and how the specific regulatory scheme established under that program can be reconciled with EPA's claim of authority under CAA §§ 202(a)(1) and (2).

Appendix A

Critical Minerals Assessment

There are hurdles to address in order to support the scale-up of HD ZEV technology adoption. These hurdles include impacts on supply chains, energy resilience and the environment. Consideration to both the hurdles and mitigation measures should be given to inform responsible and effective implementation of vehicle standards.

Reliance on a limited number of technologies (e.g., ZEVs) on the timeline required by the proposed rule will likely result in a non-resilient transport sector that is vulnerable to unexpected disruptions. Both the federal government and the private sector have recognized that critical minerals are essential to the future of BEVs, and likewise, that unstable critical mineral supply chains could disrupt this future.

I. Mineral availability and mining

BEV battery supply chains, including critical minerals and precursors are controlled by a small number of countries, some with unsustainable environmental and human rights practices, and geopolitical concerns. The mining sector would need to grow exponentially to meet the proposed rule's demands. According to a forecast by BMI, at least 384 combined new mines for graphite, lithium, nickel, and cobalt are required to meet the global demand by 2035.[29] This analysis was heavily centric on the requirements for the light-duty vehicle sector. Impacts from heavy-duty vehicle sector requirements would be additive.

Mining is an energy- and environmental-intensive activity. Critical minerals for electric batteries such as lithium and copper are particularly vulnerable to water stress given their high water requirements[30]. Over 50 percent of today's lithium and copper production is concentrated in areas with high water stress levels. Activities associated with mining produce GHG emissions, as well as particulate matter emissions, nitrogen oxide emissions, and other air pollutant emissions from mining equipment. A strong focus on environmental and ethical best practices in this sector are needed to safeguard natural lands, biodiversity, sustainable water use, indigenous peoples' rights, and labor protections.[31]

Regarding the availability of critical minerals, especially those essential to the manufacturing of a Li-ion battery, the supply is dominated by three lithium producing countries — Australia, Chile and China, which account for nearly 90 percent of the global market. While

---

[29] More than 300 new mines required to meet battery demand by 2035: https://source.benchmarkminerals.com/article/more-than-300-new-mines-required-to-meet-battery-demand-by-2035.

[30] "The Role of Critical Minerals in Clean Energy Transitions", International Energy Agency World Energy Outlook Special Report: https://iea.blob.core.windows.net/assets/ffd2a83b-8c30-4e9d-980a-52b6d9a86fdc/TheRoleofCriticalMineralsinCleanEnergyTransitions.pdf

[31] https://mining2030.org/

70% of global cobalt production comes from the Democratic Republic of Congo[32], most of the mines are owned/operated by China and more than 60 percent of cobalt processing is located in China. China produces 67 percent of the world's graphite.[33] The U.S. imports most of its manganese from Gabon, a less geopolitically stable country, providing 65 percent of the United States' supply.[34] Electricity networks need a large amount of copper and aluminum. The need for grid expansion that would result from this rapid increase in electricity demand underpins a doubling of annual demand for copper and aluminum.[35] China possesses over half of the entire world's aluminum smelting capacity.

II. Supply chain resilience.

In the Draft Regulatory Impact Analysis (DRIA), EPA states "according to analyses by the U.S. Department of Energy's Li-Bridge, no shortage of cathode active material or lithium chemical supply [also known as critical materials] is seen globally through 2035 under current projections of global demand." There are many sources that contradict this point. Looking forward toward 2030, based on current and anticipated global production plans, a global supply shortfall is likely to begin toward end of the decade, if planned mining projects do not deliver as expected, some critical minerals could face shortages as early as next year.[36] Globally, it takes on average over 16 years to move mining projects from first discovery to production.[37] According to a review of multiple sources, there is a six-fold demand growth expectation by 2030, and approximately 15 times by 2040, the supply-demand gap only widens. The ability to quickly scale minerals production is further affected by ore quality, which in recent years has been declining and thus requires more material to be mined, more resources such as water in stressed areas for processing, and ultimately greater environmental impacts.

The EPA acknowledges in the DRIA that "much of the supply chain supporting the manufacture of ZEVs is located outside of the U.S." However, the agency claims that "more than half of battery cells and 84 percent of assembled packs in ZEVs sold in the U.S. from 2010 to 2021 were produced in the U.S." Although this is true, it does not take into account the

---

[32] "The Role of Critical Minerals in Clean Energy Transitions", International Energy Agency World Energy Outlook Special Report: https://iea.blob.core.windows.net/assets/ffd2a83b-8c30-4e9d-980a-52b6d9a86fdc/TheRoleofCriticalMineralsinCleanEnergyTransitions.pdf.

[33] "Graphite," Professional Paper 1802-J, US Geological Survey: https://pubs.er.usgs.gov/publication/pp1802J#:~:text=China%20provides%20approximately%2067%20percent%20of%20worldwide%20output,costs%20and%20some%20mine%20production%20problems%20are%20developing.

[34] https://oec.world/en/profile/bilateral-product/manganese-ore/reporter/usa

[35] "The Role of Critical Minerals in Clean Energy Transitions", International Energy Agency World Energy Outlook Special Report: https://iea.blob.core.windows.net/assets/ffd2a83b-8c30-4e9d-980a-52b6d9a86fdc/TheRoleofCriticalMineralsinCleanEnergyTransitions.pdf.

[36] L. Lee, Energy Intelligence "Mining the Gap to a Net-Zero Future," May 15, 2023: https://www.energyintel.com/00000188-1e5f-d806-ad9f-5edfeb1d0000?utm_campaign=website&utm_source=sendgrid.com&utm_medium=email.

[37] "The Role of Critical Minerals in Clean Energy Transitions", International Energy Agency World Energy Outlook Special Report: https://iea.blob.core.windows.net/assets/ffd2a83b-8c30-4e9d-980a-52b6d9a86fdc/TheRoleofCriticalMineralsinCleanEnergyTransitions.pdf.

value chain before the battery cells production. The domestic supply chain is in its early stages and to meet the proposed goals, automakers and battery manufacturers will still need to rely on foreign sources of critical materials and precursors. For instance, BMI foresees a 77 percent deficit in domestic available cathode active material to meet 2035 demands in North America. This estimate was done prior to the proposal. This step in the value chain will require import/export until it is further built out, which will add to cost to the battery pack.[38] Although Congress and the Administration have taken significant steps to accelerate this activity by funding, facilitating, and promoting the rapid growth of U.S. supply chains for these products through the IRA, BIL, and numerous Executive Branch initiatives, more will still be needed given the increase in demand.

For any one of these minerals, this regulation, taken to their logical end, puts the U.S into a situation resembling the oil embargoes of the 1970s, where foreign actors control majorities of the critical raw material supplies used in the manufacture of fuels, battery, and motor components designed to provide transportation mobility services for the U.S. consumer. Compared with fossil fuel supply, the supply chains for clean energy technologies can be even more complex (and in many instances, less transparent).[39] [40]

EPA failed to consider all the hurdles and complexities such as federal permitting, National Environmental Policy Act reviews, and the supply chains for these critical materials in their technology feasibility assessment. API requests EPA include a thorough evaluation of the full supply chains for each critical mineral/material in their final proposal and their implications on energy security.

III. Operational inefficiency of battery production facilities.

While many OEMs, mostly light-duty vehicle manufacturers, and battery manufacturers have announced plans to build gigafactories in North America, taking advantage of incentives such as the IRA, one must view these as highly complex projects. It should also be noted that it will take time for these new battery manufacturing facilities to ramp up to full production. Capacity gives a reflection of what a plant could potentially produce; capacity reflects ambition. EPA notes in the DRIA that "the Department of Energy estimates that recent plant announcements for North America to date could enable an estimated 838 GWh of capacity by 2025, 896 GWh by 2027, and 998 GWh by 2030, the vast majority of which is cell manufacturing capacity." This assumes battery manufacturing capacity at initial opening or at mature stage at 100% scale. This is not accurate. In their early years, battery factories will likely operate at approximately 50 percent production capacity. Mature battery factories today rarely operate

---

[38] Benchmark Minerals Intelligence, BMI (*see* Charts 2, 3 & 4): https://source.benchmarkminerals.com/article/ambition-versus-reality-why-battery-production-capacity-does-not-equal-supply.

[39] "The Role of Critical Minerals in Clean Energy Transitions", International Energy Agency World Energy Outlook Special Report: https://iea.blob.core.windows.net/assets/ffd2a83b-8c30-4e9d-980a-52b6d9a86fdc/TheRoleofCriticalMineralsinCleanEnergyTransitions.pdf.

[40] https://secureenergy.org/wp-content/uploads/2020/09/The-Commanding-Heights-of-Global-Transportation.pdf

above 80 percent utilization rates.[41] The EPA projects a ten-fold increase in North American battery manufacturing capacity in just eight years, from 90 gigawatt hours per year in 2022, to 998 GWh/year in 2030, with the great majority of that sited in the U.S. Wood Mackenzie projects U.S. capacity of less than half that level, at 422 GWh/ year in 2030.[42] Given the disparity in forecasts from different reputable sources, EPA's technology feasibility assessment should factor sensitivity cases and acknowledge potential disruptions in the supply chain.

IV. Raw materials are specialty chemicals, not commodities.

In the DRIA, EPA states "despite recent short-term fluctuations in price, the price of lithium is expected to stabilize at or near its historical levels by the mid- to late- 2020s, further suggesting that a critical long-term shortage is not expected to develop." This analysis misses the mark. Some projects may not materialize if pricing goes too low translating into low margins, or due to high costs of supply in needed operations. To meet the ambitions that OEMs have set forth in terms of percentage of BEV entering the market, they must secure adequate amounts of raw materials. With the projected supply and demand gap that many analysts foresee, as mentioned earlier, pricing of critical minerals could remain volatile as we have seen through the early 2020s. There are varying views by different analysts on the direction of critical mineral pricing scenarios. Morgan Stanley estimates BEV manufacturers will need to increase prices by 25 percent to account for rising battery prices.[43] Battery raw materials are not commodities, they are classified as specialty chemicals, and pricing should be analyzed as such as they will not follow traditional commodity pricing structures, especially given where these supplies are geographically concentrated in areas with geopolitical instabilities.

V. Recycling of batteries and related electrical components is in its infancy.

Another critical aspect to be considered with this proposal is that recycling of the battery and related electrical components of BEVs are in a state of infancy and poses unique materials handling and safety challenges. The environmental profiles of both BEVs and ICEVs should be considered in light of the production, operation, and disposal of the vehicle (its useful life). Electric battery disposal-related issues are likely to impact the environment and need to be addressed in EPA's proposal:

- Battery packs could contribute 250,000 metric tons of waste to landfills for every 1 million retired BEVs.[44]

---

[41] Xiao, Maya, "Lithium-ion battery production goes global," January 26, 2022: https://www.controleng.com/articles/lithium-ion-battery-production-goes-global/.

[42] Wood Mackenzie: https://identity.woodmac.com/sign-in?goto=https%3A%2F%2Fmy.woodmac.com%2Fdocument%2F150115630

[43] https://www.bloomberg.com/news/articles/2022-03-25/morgan-stanley-flags-ev-demand-destruction-as-lithium-soars#xj4y7vzkg, see Chart 7.

[44] Kelleher Environmental, "Research Study on Reuse and Recycling of Batteries Employed in Electric Vehicles: The Technical, Environmental, Economic, Energy and Cost Implications of Reusing and Recycling EV Batteries," September 2019 (Kelleher Environmental Study). See https://www.api.org/oil-and-natural-gas/wells-toconsumer/fuels-and-refining/fuels/vehicle-technology-studies.

- Less than five percent of lithium-ion batteries, the most common batteries used in BEVs, are currently being recycled "due in part to the complex technology of the batteries and cost of such recycling."[45]
- Economies of scale will play a major role in improving the economic viability of recycling, which currently cost is the main bottleneck. Increasing collection and sorting rates is a critical starting point.[46]
- The cathode is where the majority of the material value in a Lithium-ion battery is concentrated. Currently, there are numerous cathode chemistries being deployed. Each of these chemistries needs to be known, and then the appropriate method of recycling identified, which poses a challenge, as batteries pass through a global supply chain and all materials are not well tracked.
- Lithium can be recovered from existing Lithium-ion recycling practices, but it is not economical at current lithium prices. Cobalt, one of the highest supply risk materials for BEV in the short- and medium-term, is currently being profitably recovered.
- Benchmark forecasts near-term recyclers are likely to use scrap material from the increasing number of gigafactories coming online versus used electric vehicle batteries. Scrap material is anticipated to account for 78 percent of recyclable materials in 2025.[47]
- In 2022, Benchmark expected over 30 gigawatt hours of process scrap to be available for recycling, growing ten-fold across the next decade. Loss rates vary by region, and tend to be higher in earlier years of a gigafactory.[48]
- EV batteries are high-cycle batteries and are made to function for approximately 10 years, shorter time for a mid-duty vehicle.
- Many 'spent' EV batteries still have 70-80 percent of their capacity left, which is more than enough to be repurposed into other uses such as energy storage and other lower-cycle applications.[49] This will extend the time that batteries and raw materials remain in use.
- Repurposing used EV batteries could generate significant value and help bring down the cost of residential and utility-scale energy storage to bring forth

---

[45] Harper, G., Sommerville, R., Kendrick, E. et al. Publisher Correction: "Recycling lithium-ion batteries from electric vehicles." *Nature* 578, E20 (2020). https://doi.org/10.1038/s41586-019-1862-3.

[46] "The Role of Critical Minerals in Clean Energy Transitions", International Energy Agency World Energy Outlook Special Report: https://iea.blob.core.windows.net/assets/ffd2a83b-8c30-4e9d-980a-52b6d9a86fdc/TheRoleofCriticalMineralsinCleanEnergyTransitions.pdf.

[47] BMI: https://source.benchmarkminerals.com/article/battery-production-scrap-to-be-main-source-of-recyclable-material-this-decade, (See Chart 8).

[48] BMI: https://source.benchmarkminerals.com/article/battery-production-scrap-to-be-main-source-of-recyclable-material-this-decade.

[49] Engel, H., Hertzke, P., & Siccardo, G. (2019, April). Second-life EV batteries: The newest value pool in Energy Storage. McKinsey Center for Future Mobility. https://www.mckinsey.com/~/media/McKinsey/Industries/Automotive%20and%20Assembly/Our%20Insights/Second%20life%20EV%20batteries%20The%20newest%20value%20pool%20in%20energy%20storage/Second-life-EV-batteries-The-newest-value-pool-in-energy-storage.pdf.

further penetration of renewable power to electricity grids. Initial trials are underway.[50]

- Clear guidance on repackaging, certification, standardization, and warranty liability of spent EV batteries would be needed to overcome safety and regulatory challenges reuse poses at scale.[51]
- Recycling BEV batteries to recover high-value metals has not been proven at commercial scale. The majority of analysts are aligned that recycling will not become an integral supplier of raw materials until the 2030s, and at that point, only will provide approximately 20 percent of demand.[52]

---

[50] “The Role of Critical Minerals in Clean Energy Transitions”, International Energy Agency World Energy Outlook Special Report: https://iea.blob.core.windows.net/assets/ffd2a83b-8c30-4e9d-980a-52b6d9a86fdc/TheRoleofCriticalMineralsinCleanEnergyTransitions.pdf.

[51] Ibid.

[52] BMI: https://source.benchmarkminerals.com/article/battery-production-scrap-to-be-main-source-of-recyclable-material-this-decade.

Attachment 3:

WSPA comments to CARB (dated October 17, 2022) in response to ISOR draft which references the Ramboll study

Tanya DeRivi
Vice President, Climate Policy
Western States Petroleum Association

October 17, 2022

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

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

Re: Comments on Advanced Clean Fleets Regulation ISOR Draft EA

The Western States Petroleum Association (WSPA) appreciates the opportunity to comment on the Initial Statement of Reasons (ISOR) and included Draft Environmental Analysis (EA) for the proposed Advanced Clean Fleets (ACF) Regulation, posted by the California Air Resources Board (CARB) on August 30, 2022 ahead of the Public Hearing on October 27, 2022.[1] WSPA is a non-profit trade association that represents companies that import and export, produce, refine, transport and market petroleum, petroleum products, natural gas and other energy supplies in California and four other western states, and has been an active participant in air quality planning issues for over 30 years.

WSPA members are both fuel providers and fleet operators under the proposed ACF regulations. As an organization, we are not in support of the current proposed regulation for the reasons summarized below and detailed in Attachment A. The current ACF proposal excludes and precludes criteria pollutant and greenhouse gas emission reductions that a multi-technology/multi-fuel strategy using commercially available, CARB-certified trucks fueled by low carbon-intensity fuels can provide. An affordable and reliable multi-fuel strategy does not rely upon an unprecedented expansion of electric generation, transmission and distribution infrastructure and can reduce emissions while electric infrastructure is developed. The current ACF proposal needs to be revised to capture the emission reduction benefits of a multi-technology/multi-fuel strategy. We encourage CARB to hold a workshop to address these and other key stakeholder suggestions and then revise the proposal, ISOR and Draft EA before presenting the ACF for adoption. As our members are fuel providers and fleet owners that would be regulated under the ACF, we also ask that CARB include Low Carbon Fuels Standard (LCFS) staff as part of the ACF rulemaking process to assess and harmonize the direct and indirect effects of the ACF rule on the LCFS program, and vice versa.

Fuel suppliers in California, across the United States (U.S.), and worldwide are investing billions of dollars to produce low-carbon renewable fuels such as renewable diesel (RD), biodiesel (BD)

---

[1] CARB. Notice of Public Hearing to Consider Proposed Advanced Clean Fleets Regulation on October 27, 2022. Available at: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/acf22/notice2.pdf. Accessed: October 2022.

and renewable natural gas (RNG) for medium-duty vehicles and heavy-duty vehicles (MDV/HDV). These investments are encouraged and often required by regulations such as LCFS and Cap-and-Trade regulations on the U.S. West Coast and Canada, and by the federal Renewable Fuels Standard (RFS). Industry continues to make progress in reducing the carbon intensity of these fuels by optimizing feedstock sources and feedstocks, manufacturing processes and transportation.

These trends are most evident in California, where WSPA-member companies and others have invested heavily to produce renewable fuels for MDV/HDV. Per CARB LCFS data, nearly 3.4 million gallons per day of BD and RD are currently supplied to California consumers,[2] which is 34% of current total California diesel demand.[3] CARB's LCFS regulation effectively requires these products and the investments necessary to deliver them. CARB has publicly supported many of the announced renewable fuels projects.[4]

CARB's proposed zero-emission vehicle (ZEV) mandate risks stranding billions of dollars of private investment that has already been made in direct response to CARB's own LCFS regulation. We encourage CARB to provide a compliance option for renewable fuels in the proposed ACF.

Additionally, there are numerous deficiencies and/or omissions in the ISOR and Draft EA analyses, including but not limited to those below that must be addressed before CARB takes action on the proposed ACF.

- Inadequate Environmental Assessment: CARB has failed to fully assess the impacts of the proposed ACF regulation on particulate matter (PM) and greenhouse gas (GHG) emissions, critical mineral resources, and California's water supply. Additionally, CARB has failed to evaluate an alternative that would allow for low-carbon intensity (low-CI), low-NO_X technologies to compete with ZEVs in their alternative analyses presented in the draft Environmental Assessment for the proposed ACF. Refer to Comments A.2 through A.7 in Attachment A for further details.
- Inadequate Electric Grid Assessment: CARB must perform a more in-depth assessment of the impacts to the electric grid as a result of the ACF proposal to fully assess the impact on California's infrastructure and 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 private electric vehicle (EV) chargers. Additionally, CARB has not addressed the feasibility

---

[2] CARB. 2022. Low Carbon Fuel Standard Quarterly Data Spreadsheet. July 31. Available here: https://ww2.arb.ca.gov/sites/default/files/2022-08/quarterlysummary_073122_0.xlsx. Accessed: October 2022.

[3] CARB. 2022. EMFAC Emissions Inventory. Available here: https://arb.ca.gov/emfac/emissions-inventory/d1a08e88bd07b3f76564d6d3b1fa544ec97e6400. Accessed: October 2022.

[4] CARB. Cleaner fuels have now replaced more than 3 billion gallons of diesel fuel under the Low Carbon Fuel Standard. Available at: https://ww2.arb.ca.gov/news/cleaner-fuels-have-now-replaced-more-3-billion-gallons-diesel-fuel-under-low-carbon-fuel. Accessed: October 2022.

of the current grid to expand to meet the additional demand that the draft regulation would present. Refer to Comments A.8 through A.11 in Attachment A for further details.

- Inadequate Exemption Language: CARB has failed to adequately consider the lead time needed for permitting electric charging infrastructure, and the process for appealing a rejected exemption request. Refer to Comments A.12 through A.14 in Attachment A for further details.

Conclusion

WSPA strongly encourages CARB to address the above deficiencies to ensure that CARB complies with its legal obligations under the California Health and Safety Code (HSC), Administrative Procedure Act (APA), and California Environmental Quality Act (CEQA). Specifically, CARB has a legal duty to address the following:

- *Leakage:* HSC § 38562(b)(8) requires CARB to minimize the "leakage" potential of any regulatory activities. In its ACF Proposal, CARB fails to consider the leakage potential of its ZEV mandate, based on an accurate lifecycle analysis of the 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 2040 and beyond.
- *Feasible Regulatory Alternatives:* Under Government Code § 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. The ACF proposal includes a 100% ZEV sales mandate for new medium- and heavy-duty vehicles beginning in the 2040 model year and beyond. This is not a performance standard; it is a technology mandate.[5] Further, CEQA requires CARB to 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." Cal. Code Regs. title 14, § 15126.6(c). CARB has failed to evaluate and/or analyze a technology neutral performance-based standard that would allow low-carbon fuel and engine technologies to compete with ZEVs in their alternative analyses presented in the Draft EA and the Standardized Regulatory Impact Assessment (SRIA) for the proposed ACF, as discussed in Comment 9.
- *Additional Environmental Impacts*: CARB's Draft EA does not consider potentially significant environmental impacts, in contravention of CARB's CEQA obligations. CEQA requires that the Draft 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." Cal. Code Regs. title17, § 60004.2(a). As detailed in Comments 5-8, CARB's Draft EA is deficient in several respects—CARB fails to account for energy impacts associated with increased electricity production, impacts on hydrology and water quality from increased hydrogen production, impacts from mining of lithium and other rare earth metals, and cumulative impacts for the State's electrical generation, transmission, and distribution infrastructure.
- *Cost-Effectiveness and Economic Impacts:* As described in Comments 3, 4, and 9, CARB's analysis does not adequately consider significant economic impacts stemming from the ACF

---

[5] CARB asserts that "[t]he proposed ACF regulation does not prescribe any specific technology or any equipment – rather, it allows regulated entities to acquire affected categories of any medium- and heavy-duty vehicles that have demonstrated that they emit zero emissions of criteria or GHG emissions," ISOR, at 269-70.

Proposal. HSC §§ 38562 and 43018 and APA § 11346.3 require CARB to broadly consider a wide range of impacts to the state's economy, including competitive impacts to California business enterprises.[6] As detailed below, this assessment must consider economic impacts to utilities stemming from the electrification of the transportation sector experienced, as well as lifecycle GHG impacts from ZEV technologies. Further, CARB must consider any less costly but equally effective alternatives pursuant to HSC § 57005. The ISOR and associated rulemaking document do not satisfy this obligation because nowhere does CARB compare the lifecycle 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.

- *Technological Feasibility:* Various provisions of the HSC require CARB to consider technological feasibility for proposed motor vehicle standards, including HSC §§ 38560, 38562, 39602.5, 43013, and 43018.[7] This consideration must assess 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 fuel (electricity, hydrogen) and the infrastructure to deliver the fuel. CARB must perform a complete and sufficient assessment of the technological feasibility of the ACF ZEV mandates including but not limited to the assessment of mineral resource availability, impacts to the California electric grid, and application of ZEVs to long-distance use cases, as detailed in Comments 5 and 10, below.

Finally, we note that the ACF ISOR does not reference the need to obtain a Clean Air Act waiver from the U.S. Environmental Protection Agency (unlike for both the Advanced Clean Trucks and Advanced Clean Cars II regulations, which did). While the Clean Air Act grants California certain leeway to address localized pollution, the Energy and Policy Conservation Act's broad preemption provision prevents CARB from adopting such regulations when they are "related to" fuel economy, regardless of any accompanying localized pollution benefits.

Thank you for consideration of our comments. We would welcome the opportunity to discuss these concerns in more detail. If you have any immediate questions, please feel free to contact me at tderivi@wspa.org. We look forward to working with you on these important issues.

Sincerely,

Tanya DeRivi

Tanya DeRivi
Vice President, Climate Policy
WSPA

Attachment A: Detailed Comments

---

[6] Notably, in its ISOR, CARB cites these provisions as authorizing the ACF Proposal. *See* ISOR, at 236, 269.
[7] CARB cites these provisions as providing authority for the ACF Proposal in the ISOR. *See* ISOR, at 236-37.

ATTACHMENT A

Detailed Comments

As noted in the cover letter, detailed comments are provided below:

A.1 The California Air Resources Board (CARB) must address previous comments made by WSPA which include but are not limited to the following.

- The rule should include a compliance pathway for low-NO_X trucks operating on lower-carbon-intensity fuels (including renewable diesel and renewable natural gas), consistent with the expeditious path to criteria air pollutant and greenhouse gas (GHG) reduction goals;
- As noted in recent studies, more than one battery electric (BE) truck would be required to perform the work of a single internal combustion engines (ICE) vehicle.[8,9] CARB does not account for the additional BE trucks that would be needed to replace ICE trucks in the emissions inventory modeling and cost analysis; and
- The proposed rule should include explicit regulatory offramps that link the targets to battery electric vehicle (BEV), fuel cell electric vehicles (FCEV) and related electrical generation/transmission/distribution/charging infrastructure availability in each end-use and duty-cycle.
- WSPA incorporates by reference the previous comments submitted by WSPA throughout the ACF rulemaking process.[10]

Comments on Draft EA/ISOR

A.2 The ISOR and Draft EA fail to assess all of the impacts of the proposed ACF regulation on the statewide particulate matter emission inventory.

As noted on Page 15 of the Draft EA one of the primary objectives of the proposed ACF regulation is to "accelerate the deployment of Zero-Emission Vehicles (ZEVs) that achieve the maximum emissions reduction possible from medium- and heavy-duty vehicles to assist in the attainment of NAAQS for criteria air pollutants."[11] Several regions of the State are in non-attainment of the Federal PM_{10} and $PM_{2.5}$ standards.[12] Hence CARB should analyze the impacts of the proposed ACF regulation on total statewide and region specific PM_{10} and $PM_{2.5}$ emissions inventories and not limit its analysis to just the

---

[8] As noted in the 2020 NCST study on short haul good movement, even with improved battery technology in 2030, 1.2 BE trucks would be required to replace a single diesel truck. This number would be even higher in the early compliance years.

[9] Genevieve Giuliano, Maged Dessouky, Sue Dexter, Jiawen Fang, Shichun Hu, Seiji Steimetz, Thomas O'Brien, Marshall Miller, Lewis Fulton. 2020. Developing Markets for Zero Emission Vehicles in Short Haul Goods Movement: A Research Report from the National Center for Sustainable Transportation. Available at: https://escholarship.org/uc/item/0nw4q530. Accessed: October 2022.

[10] WSPA. 2021. Comments on Advanced Clean Fleets March Workshop. May 10. Available here: https://www.arb.ca.gov/lists/com-attach/36-acf-comments-ws-UCdTJlUkAzFVDFMy.pdf. Accessed: October 2022. WSPA. 2021. Comments on ACF Regulation September Workshop. October 29. Available here: https://www.arb.ca.gov/lists/com-attach/109-acf-comments-ws-VCNSJ1EgADIKU1c2.pdf. Accessed: October 2022.

[11] CARB. 2022. Advanced Clean Fleets Draft Environmental Analysis. August 30. Available here: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/acf22/appd.pdf. Accessed: October 2022

[12] Ambient Air Quality Standards Designation Tool. Available here: https://ww2.arb.ca.gov/aaqs-designation-tool. Accessed: October 2022.

portions of the particulate matter inventories where it projects reductions with the adoption of this regulation.[13]

While the ISOR provides estimates for the changes in exhaust particulate matter and break wear**, <u>it does not assess particulate matter impacts from tire wear or entrained road dust</u>**. The ZEV vehicles that would replace the existing ICE vehicles under the proposed ACF are generally heavier and would cause greater tire wear and entrained road dust emissions. If heavier zero emission (ZE) trucks are allowed under the regulation, then the impacts of these on increased entrained road dust must be quantitatively evaluated. If overall truck weight restrictions remain enforced, additional ZE trucks would be needed to move the same tonnage of cargo. If truck weight restrictions are increased for ZE trucks, increased emissions of tire wear and entrained road dust must be accounted for. The tire wear and entrained road dust emissions account for >80% of the total PM emissions associated with medium and heavy-duty vehicles. Including these emissions in the analysis could potentially change the conclusions of CARB's analysis and the significance finding of the Draft EA, hence CARB must evaluate these emissions.

As shown in CARB's methodology for Entrained Road Travel and Paved Road Dust,[14] the AP-42 emission factor equation used to estimate paved road dust emissions per vehicle mile travelled is proportional to vehicle weight. ZEVs add significant weight as compared to comparable ICE vehicle models. A study by the American Transportation Research Institute (ATRI)[15] found that the weight of a BEV Class 8 Sleeper Cab tractor is nearly double that of a comparable internal combustion engine vehicle (ICEV), weighing 32,016 pounds (lbs) versus 18,216 lbs. So, converting ICEV to ZEVs under the proposed ACF regulation would significantly increase the average vehicle weight on the California roadways, which in turn would increase the entrained road dust emission factors and emissions.

CARB also assumes that tire wear emissions for ZEV are the same as ICE vehicles and takes no consideration of how the significant increase in ZEV vehicle weight as compared to ICE vehicles will increase tire wear emissions. The 2016 study titled "Non-Exhaust PM Emissions from Electric Vehicles"[16] concluded that increased vehicle weight would increase both tire wear and entrained road dust emissions. The assumption that a ZEV, which would have a higher average weight, would have the same tire wear emissions as an ICE is made without citation and should be reassessed and evaluated in the ACF ISOR.

The cost benefit analysis in the Standardized Regulatory Impact Assessment (SRIA) for the proposed ACF estimated monetized health benefits associated with the reductions in exhaust and brake wear particulate matter emissions. These benefits were used to calculate the benefit-cost ratio of the proposed regulation. As noted in the above

---

[13] California Health & Safety Code ("HSC") § 39602.5 requires CARB to consider ambient air quality standards and attainment in its ACF Proposal.

[14] CARB. Miscellaneous Process Methodology 7.9: Entrained Road Travel, Paved Road Dust. 2021. Available here: https://ww3.arb.ca.gov/ei/areasrc/fullpdf/2021_paved_roads_7_9.pdf. Accessed: October 2022.

[15] ATRI. Understanding the CO_2 Impacts of Zero-Emission Trucks. 2022. Available here: https://truckingresearch.org/wp-content/uploads/2022/05/ATRI-Environmental-Impacts-of-Zero-Emission-Trucks-Exec-Summary-5-2022.pdf. Accessed: October 2022.

[16] Timmers, Victor and Peter Achten. "Non-exhaust PM emissions from electric vehicles". March 2016. Available here: http://www.soliftec.com/NonExhaust%20PMs.pdf. Accessed: October 2022.

paragraphs there are other portions of the total particulate matter emissions (e.g., tire wear and entrained road dust) that would increase as a result of the proposed ACF and have not been considered. CARB should complete their benefit-cost analysis to consider all changes in total particulate matter emissions and associated health impacts.

A.3 CARB did not conduct a full life-cycle greenhouse gas emissions assessment for the vehicle/fuel system to assess GHG emission impacts of their proposal and alternatives. This results in a misrepresentation of the impacts of the proposed regulation.

To understand the potential GHG impacts of the proposed ACF regulation, CARB **must quantitatively assess the proposal.** This should include cost-effectiveness and cost-benefit analysis.[17] CARB's proposal fails to consider the following:

- Upstream fuel cycle GHG emissions are not considered, and
- GHG emissions associated with vehicle production and end of life-cycle (e.g., recycling) changes required by the proposed regulation are not considered.

Taken together, these could be significant, particularly for battery production impacts associated with battery electric vehicles and fuel cell electric vehicles as compared to ICEVs.

Assessing the upstream fuel cycle GHG emissions is necessary when considering zero emission vehicles due to the nature of GHG emissions as global pollutants. GHG emissions are global pollutants that enter the atmospheric carbon stock and cause global consequences, no matter the point of origin. While GHG emissions may not be present at the tailpipe for a (so-called) ZEV technology, these emissions still are emitted elsewhere and therefore must be accounted for in the benefit-cost and emissions reductions analyses. Not including the upstream emissions is misleading and overstates the potential emission reductions.

Additionally, CARB is inconsistent in citing the emissions they have considered. In both Appendix C: Standardized Regulatory Impact Assessment and the ISOR it is specifically noted the assessment "is focused on tank-to-wheel (TTW) emissions, and does not include upstream emissions."[18, 19] But the Draft EA claims that "upstream emissions associated with the generation of electricity used for ZEVs… are considered in the reduction benefits of the Proposed Project."[20] CARB must update their analyses to include the upstream emissions for all fuels including electricity in the SRIA, ISOR, and the Draft EA.

Additionally, the GHG emissions associated with vehicle production should be accounted for in the analysis. This is especially important for ZEV technologies, which have components (i.e., batteries) that generate significant additional emissions during vehicle

---

[17] HSC §§ 38560, 39602.5, and 43013 require CARB to assess the cost-effectiveness of a regulation.

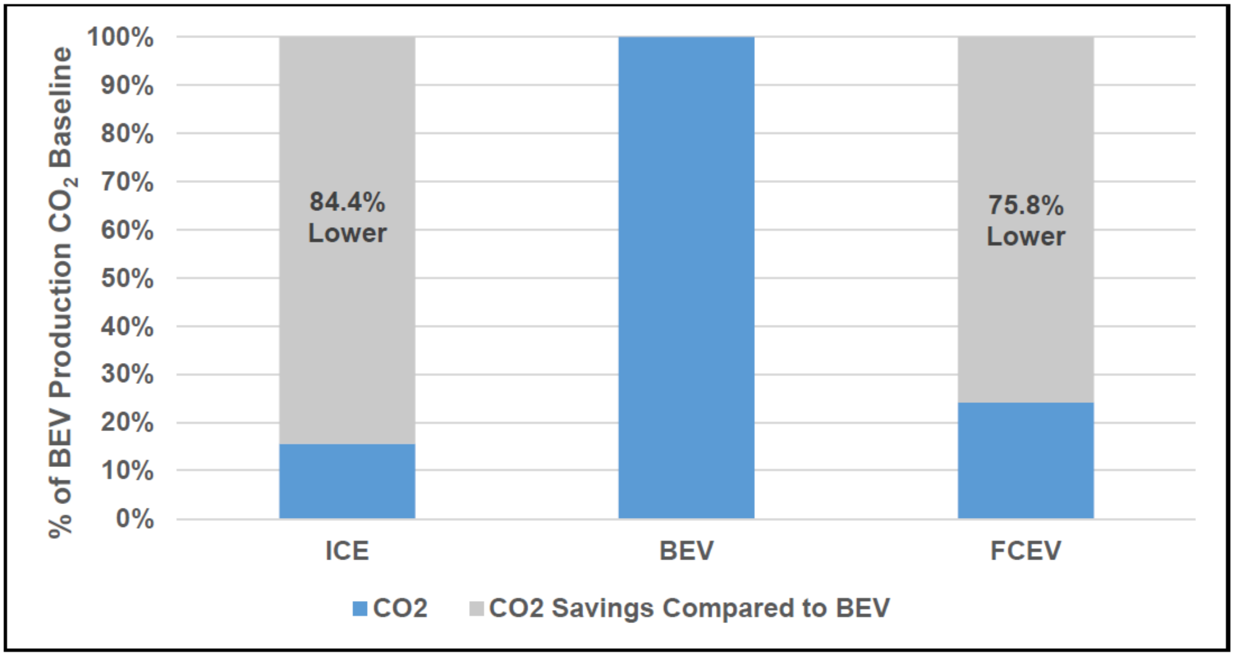
[18] CARB. 2022. Appendix C: Original Standard Regulatory Impact Assessment Submitted to Department of Finance. August 30. Available here: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/acf22/appc.pdf. Accessed: October 2022.

[19] CARB. 2022. Staff Report: Initial Statement of Reasons. August 30. Available here: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/acf22/isor2.pdf. Accessed: October 2022.

[20] CARB. 2022. Appendix D: Draft Environmental Analysis for the Advanced Clean Fleets Rule. August 30. Available here: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/acf22/appd.pdf. Accessed: October 2022.

production. A recently published study by ATRI analyzed the life-cycle emissions of a Class 8 Sleeper Cab vehicle and found that the vehicle production emissions for BEVs to be ~6 times higher than the corresponding ICEV counterpart (**Figure 1**).[21] CARB has claimed in the Advanced Clean Cars II (ACC II) Response to Comments (RTC) that "the emission benefits from the use of these materials (e.g. battery and vehicle materials) in BEVs would ultimately offset the emissions from combustion of gasoline, diesel, and other fossil fuels from the development and use of these battery materials resources."[22] However this argument is unfounded. Accounting for the vehicle cycle emissions could potentially change the conclusions of CARB's analysis and therefore must be assessed in order to understand the full environmental impacts of each technology.

Figure 1. Vehicle Cycle Emissions from Class 8 Sleeper Cabs[23]



While the ISOR estimated the reductions in tailpipe GHG emissions from the proposed ACF regulation, it fails to fully quantify the changes in upstream (well-to-tank) GHG emissions or the potential increases in vehicle cycle emissions that would occur with the implementation of this proposal. CARB must fully assess the GHG emissions impact that this regulation could have on the global carbon stock. Any assessment that does not recognize the full life-cycle GHG 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. Inclusion of the life-cycle emissions would allow for a better pathway to achieve the emission reduction objectives.

---

[21] ATRI. 2022. Understanding the CO2 Impacts of Zero-Emission Trucks. May 3. Available here: https://truckingresearch.org/2022/05/03/understanding-the-co2-impacts-of-zero-emission-trucks/. Accessed: October 2022.

[22] CARB. 2022. Response to Comments on the Draft Environmental Analysis for the Advanced Clean Cars II Program. August 24. Available here: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/accii/acciirtc1.pdf.

[23] Ibid. ATRI. 2022. Understanding the CO2 Impacts of Zero-Emission Trucks. May 3. Available here: https://truckingresearch.org/2022/05/03/understanding-the-co2-impacts-of-zero-emission-trucks/. Accessed: October 2022.

A.4 CARB should include low-CI, low-NO_X combustion technologies in its evaluation of alternatives since that pathway can meet the objectives of the regulation, as listed below.

The purpose of the California Environmental Quality Act (CEQA) is to identify project alternatives that can achieve the proposed project's objectives in the least environmentally impactful way. Low-NO_X trucks and renewable, low-CI fuels are commercially available in large scale today. As discussed in previous comment letters and Ramboll's "Multi-Technology Scenarios: Heavy-Heavy Duty Truck Sector," deploying low-NO_X vehicles coupled with low-CI fuels could deliver earlier and more cost-effective NO_X and GHG emission reduction benefits than the ZEV-centric approach the draft ACF regulation has taken.[24] The study compared the well-to-wheel emissions of different vehicle types, taking into consideration the emissions associated with fuel production and tailpipe emissions, and found that the environmental goals of the program could be met sooner and with greater certainty given that these technologies are commercially available. The growing potential for renewable fuels with negative carbon intensities provide further opportunities to achieve greater GHG emission reductions.

Further, many of these renewable fuels do not require the extensive infrastructure build-out that would be required to implement the ZEV-centric approach in the ACF proposal, allowing for an immediate delivery of emissions benefits and minimizing the costs of and risk for delays in the proposed regulation. Hence, CARB must consider and evaluate these technology/fuel pathways as alternatives to the proposed ACF regulation rather than dismissing them as "not meeting the objectives."[25]

The objectives of the ACF as listed in the ISOR,[26] do not preclude the consideration of these technology/fuel pathways as described below:

- Objective 1 is to "accelerate the deployment of ZEVs that achieve the maximum emission reductions possible."[27] This does not preclude the deployment of other technology options, such as low-CI, low-NOx combustion engines. For example, the Ramboll HHDT Case Study, [28] which CARB has had access to for over a year, showed that a ZEVs-only strategy does not achieve the maximum emission reductions possible. A fleet mix that deployed a wider range of technologies, including ZEVs, FCEVs, and low-CI, low-NOx combustion engines, out-performed the ZEV-only deployment strategy in the near-term and achieved equitable emission reductions in the long-term.
- Objectives 2 and 3 are to "reduce the State's dependence on petroleum as an energy resource and support the use of diversified fuels in the state's transportation fleet" and "decrease GHG emissions in support of statewide GHG reduction goals."[29] There are

---

[24] Ramboll "Multi-Technology Scenarios: Heavy-Heavy Duty Truck Sector". 2021. Available here: https://www.arb.ca.gov/lists/com-attach/78-sp22-kickoff-ws-B2oFdgBtUnUAbwAt.pdf. Accessed: October 2022.

[25] HSC § 57005 requires CARB to consider any less costly but equally effective regulatory alternatives.

[26] CARB. 2022. Staff Report: Initial Statement of Reasons. August 30. Available here: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/acf22/isor2.pdf. Accessed: October 2022.

[27] Ibid.

[28] Ramboll "Multi-Technology Scenarios: Heavy-Heavy Duty Truck Sector". 2021. Available here: https://www.arb.ca.gov/lists/com-attach/78-sp22-kickoff-ws-B2oFdgBtUnUAbwAt.pdf. Accessed: October 2022.

[29] CARB. 2022. Staff Report: Initial Statement of Reasons. August 30. Available here: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/acf22/isor2.pdf. Accessed: October 2022.

many renewable liquid and gaseous options that already serve as alternatives to petroleum fuels. Recent data from CARB's LCFS website shows that 800,000 gallons per day of biodiesel, 2.5 million gallons per day of renewable diesel and over 170 million diesel gallon equivalents of renewable natural gas were supplied to the California fuels market in 2021.[30] The renewable diesel and biodiesel together supplied 34% of total California diesel demand.[31] In a multi-technology/multi-fuel alternative, renewable fuels can already serve today and can continue to serve in the future as low-CI fuel options to reduce statewide GHG emissions.

- Objective 6 is to "lead the transition of California's medium- and heavy-duty transportation sector from internal combustion to all electric powertrains."[32] However, CARB's mission under the Clean Air Act is to "promote and protect public health, welfare, and ecological resources through effective reduction of air pollutants while recognizing and considering effects on the economy,"[33] not to mandate a specific vehicle technology and this listed objective may not legally be included in the regulatory framework.

While the Draft EA included alternatives that considered low-NO_X trucks and renewable, low-CI fuels, these alternatives were crafted in a way that they could be easily rejected and in some cases the reasoning for rejecting the alternatives was flawed. See additional discussion on Alternatives 3 and 8 below:

- Alternative 3: the Best Available Control Technology (BACT) concept would allow for the purchase of a ZEV, if available, then near zero emission vehicle (NZEV), and then the cleanest certified engine for compliance. CARB rejected this alternative because the emissions benefits of additional cleaner engines in the fleet would already be accounted for in the Heavy-Duty Omnibus regulation, California's Low Carbon Fuel Standard program, and the federal Renewable Fuel Standard (RFS). This reasoning is flawed for the following reasons: (a) the ACF regulation is a fleet rule; Alternative 3 would require faster turnover of the vehicles to the cleanest certified engine, thereby providing additional near-term NO_X emissions while ZEV fueling infrastructure develops, and (b) the fuels used to power ZEVs (hydrogen and electricity) are also covered under the LCFS program.
- Alternative 8 would allow fleets to use natural gas trucks as well as ZEVs to meet the ZEV requirements of the proposed ACF until 2040, when the 100% ZEV sales requirements begin. CARB rejected this alternative by stating that the shift of combustion engine purchases from diesel and gasoline to natural gas would not achieve emission reductions when compared to the baseline because the Heavy-Duty Omnibus regulation allows engine manufacturers to average their engine emissions to meet the standard. There is no rational basis for excluding natural gas trucks that meet the optional low-NOx standards as the alternative to ZEVs given that CARB's

---

[30] CARB. 2022. Low Carbon Fuel Standard Quarterly Data Spreadsheet. July 31. Available here: https://ww2.arb.ca.gov/sites/default/files/2022-08/quarterlysummary_073122_0.xlsx. Accessed: October 2022.

[31] CARB. 2022. EMFAC Emissions Inventory. Available here: https://arb.ca.gov/emfac/emissions-inventory/d1a08e88bd07b3f76564d6d3b1fa544ec97e6400. Accessed: October 2022.

[32] CARB. 2022. Staff Report: Initial Statement of Reasons. August 30. Available here: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/acf22/isor2.pdf. Accessed: October 2022.

[33] CARB. Available here: https://ww2.arb.ca.gov/about. Accessed: October 2022.

2016 Mobile Source State Implementation Plan (SIP)[34] demonstrated NO_X reductions could be achieved by low-NO_X trucks and CARB has certified numerous low-NOx truck engines.[35] Another reason that CARB offers for rejecting this natural gas truck alternative is that "ICEV purchases … would not reduce GHG emissions."[36] Instead CARB could have imposed an additional requirement that the natural gas vehicles that qualify as alternatives to ZEVs use renewable low-CI natural gas. Such an approach would help achieve GHG reductions that could be similar to or even greater than those provided by the ZEVs.

A.5 The cumulative impacts analysis for the proposed ACF regulation is inadequate.

The Draft EA references the environmental analyses of the 2030 Target Scoping Plan Update of 2017 and the Community Air Protection Blueprint of 2018. But neither plan evaluates the impacts of the increased electrical generation, transmission, and distribution infrastructure that would result from a regulation such as the proposed ACF. Furthermore, both of these documents are in the process of being updated, as required under statute, with significant changes that are reasonably foreseen and must be acknowledged and included along with ACF in this cumulative impact analysis.

As discussed later in Comment A.9 through Comment A.12, an assessment of the impacts of the proposed ACF on the State's electric grid has to be analyzed in the Draft EA. Besides this, the cumulative impacts of the proposed ACF and the recently adopted Advanced Clean Cars II regulation on the State's electrical generation, transmission, and distribution infrastructure should be evaluated and disclosed in the Draft EA.

A.6 The Draft EA analysis of the impacts of the proposed ACF regulation on mineral resources is inadequate as it fails to quantify the amount of metals that would have to be mined for battery production.

While the Draft EA lists the estimated reserves of lithium, platinum, and other elements in Tables 5 through 10, it fails to estimate the quantity of these elements that would have to be mined to produce the ZEVs required by the proposed ACF regulation.[37] CARB must quantitatively assess the impact the regulation will have on the state/worldwide demand of lithium and other rare earth metals, and the emissions that will be produced as a result of mining and shipping these materials.

The Draft EA should consider environmental impacts from mining of semi-precious metals and potential mitigations. The document does not address the potential hazards, construction, noise, or other impacts and potential mitigations for these impacts. There is mining of lithium that is likely to occur within the state (e.g., Lithium Valley) and CARB must, at the very least, assess the additional mining of rare earth metals that would be driven by the additional ZEVs required by this regulation and analyze the potential impacts associated with additional lithium mining in the State. Additionally, as noted

---

[34] Available: https://ww2.arb.ca.gov/resources/documents/2016-state-strategy-state-implementation-plan-federal-ozone-and-pm25-standards and https://ww3.arb.ca.gov/planning/sip/2016sip/rev2016statesip.pdf. Accessed: October 2022.

[35] Available: https://ww2.arb.ca.gov/new-vehicle-and-engine-certification-executive-orders and https://www.epa.gov/sites/default/files/2021-01/documents/420f21002.pdf. Accessed: October 2022.

[36] CARB. 2022. Appendix D: Draft Environmental Analysis for the Advanced Clean Fleets Rule. August 30. Available here: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/acf22/appd.pdf. Accessed: October 2022.

[37] Ibid.

above in Comment A.3, CARB must assess the GHG impacts of lithium mining and processing to analyze the full lifecycle GHG impacts of this regulation.

A.7 The Draft EA fails to evaluate the impacts of the large quantities of water that would be needed for renewable hydrogen production on the State's water supply.

CARB has not analyzed the impacts on hydrology and water quality that increased hydrogen production would necessarily require. CARB must quantify and assess the impact that increasing hydrogen production will have on the State's water supply. This is important because the State is already facing moderate to extreme drought conditions[38] and increasing water demand would put additional strain on an already extended supply system. The Hydrogen Decarbonization Pathways Report by the Hydrogen Council projects that gross water demand for hydrogen in 2030 could range from 9.9 kilogram (kg) water per kg of H_2 (lower heating value [LHV]) to 7,427.6 kg water per kg of H_2 (LHV) depending on the feedstock used.[39]

__Comments on Electric Grid__

A.8 The Draft Environmental Assessment fails to evaluate the operational impacts of the proposed ACF regulation on the State's energy demand and necessary transmission/distribution infrastructure.

While the Draft EA states that the proposed program "may also impact peak and based load period demand for electricity and other forms of energy," it fails to quantify the changes in energy demand.[40] In CARB's ACC II Response to Comments document, CARB asserted that "studies have shown no major technical challenges or risks have been identified that would prevent a growing electric vehicle fleet at the generation or transmission level, especially in the near-term."[41] One of the studies[42] cited for this claim that researched the grid's future capacity based on historical generation clearly stated that:

> "…this historical comparison overlooks factors that have changed energy generation over the years, such as market decoupling of energy supply from vertically integrated utilities. These periods of high growth in generation correspond to times in which the installation of large baseload generation (fossil and nuclear) were common. This may not be the case in the future, and other factors such as how ready utilities are to install new capacity, sufficient utility

---

[38] State of California: California Drought Action. Current Drought Conditions. Available here: https://drought.ca.gov/current-drought-conditions/. Accessed: October 2022.

[39] Hydrogen Council. 2021 Hydrogen Decarbonization Pathways. January. Available here: https://hydrogencouncil.com/wp-content/uploads/2021/01/Hydrogen-Council-Report_Decarbonization-Pathways_Part-1-Lifecycle-Assessment.pdf. Accessed: October 2022.

[40] CARB. 2022. Appendix D: Draft Environmental Analysis for the Advanced Clean Fleets Rule. August 30. Available here: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/acf22/appd.pdf. Accessed: October 2022.

[41] CARB. 2022. Response to Comments on the Draft Environmental Analysis for the Advanced Clean Cars II Program. August 24. Available here: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/accii/acciirtc1.pdf. Accessed: October 2022.

[42] US Drive. 2019. Summary Report on EVs at Scale and the U.S. Electric Power System. November. Available here: https://www.energy.gov/sites/prod/files/2019/12/f69/GITT%20ISATT%20EVs%20at%20Scale%20Grid%20Summary%20Report%20FINAL%20Nov2019.pdf. Accessed: October 2022.

> labor, capital, land use, environmental regulations, reliability requirements, and the policy environment should all be considered."

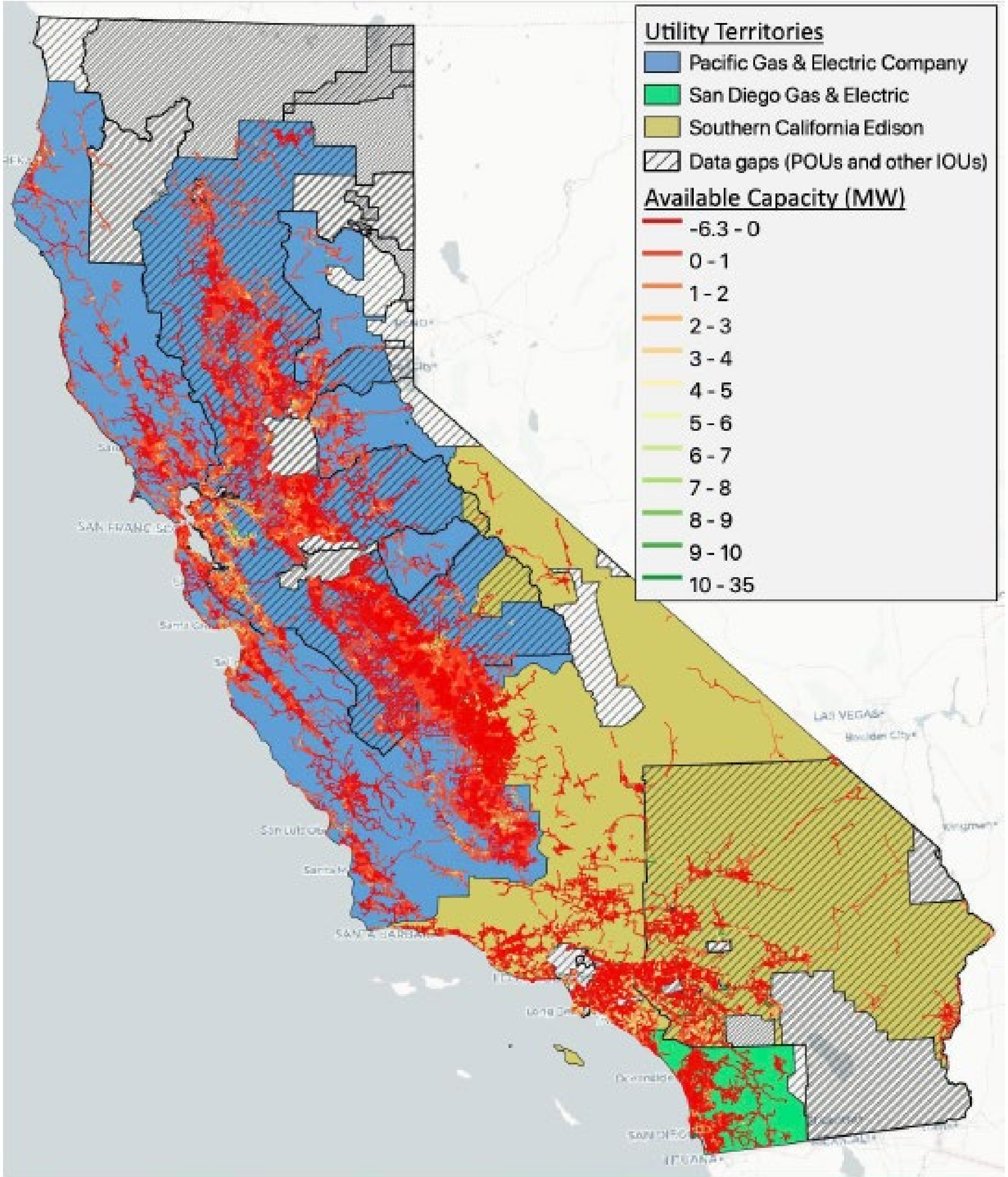
As noted in the quote above, the readiness of utilities to install new capacity must be assessed before asserting that the grid is able to handle the capacity EVs (especially heavy-duty EVs) will require.[43] The Capacity Analysis from California Energy Commission's (CEC) EDGE Model (**Figure 2** below, obtained from Page 49 in the Final ACC II EA[44]) shows the grid has no additional capacity to add electrical load for charging EVs in most circuits. You can see this in numerical terms in **Figure 3** (obtained from Virtual Medium and Heavy-duty Infrastructure Workgroup Meeting - Electricity and the Grid on January 12, 2022), 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.

---

[43] HSC §§ 38560, 38562, 39602.5, 43013, and 43018 require CARB to assess technological feasibility for its ACF Proposal.

[44] CARB. 2022. Final Environmental Analysis for the Advanced Clean Cars II Program. August 24. Available here: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/accii/acciifinalea.docx. Accessed: October 2022.

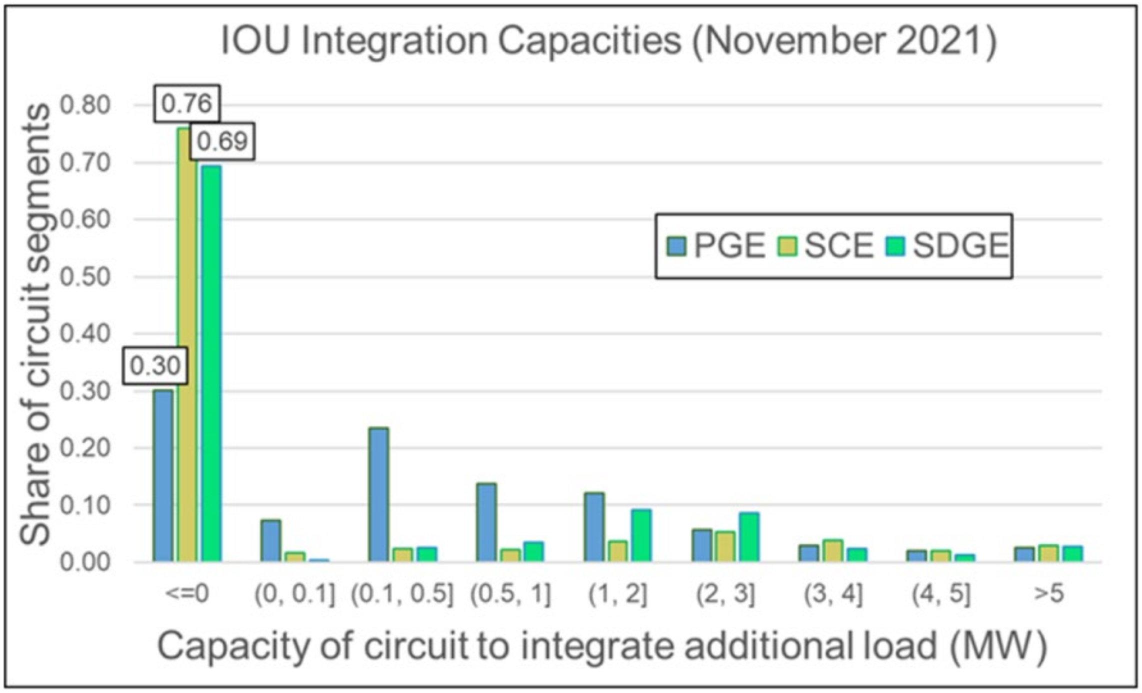
Figure 2. Capacity Analysis from CEC's EDGE Model[45] (dark red indicates no available additional capacity)



---

[45] CARB. 2022. Final Environmental Analysis for the Advanced Clean Cars II Program. August 24. Available here: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/accii/acciifinalea.docx. Accessed: October 2022.

Figure 3. Capacity of circuits to integrate additional loads[46]



The replacement of ICEVs with ZEVs under this program would result in a significant shift in the type of energy used to fuel the transportation sector that would generate significant decreases in liquid fuel use and significant increases in electricity and hydrogen use. The Draft EA cannot reasonably claim to assess the impact on the State's energy demand without quantifying these changes in energy use for various fuel types.

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.

CARB has cited growth in the electric utilities sector and noted that new infrastructure will be needed to support this transition, however, CARB has failed to account for the costs of the infrastructure needed for this regulation in the SRIA, and have instead ascribed benefits to the electric utilities sector for job growth. CARB's analysis is incomplete and misleading. CARB must evaluate the full economic impact to electric utilities because of this regulation rather than just claim the benefits while ignoring the associated costs.

---

[46] Presented during the January 12, 2022 CARB Virtual Medium and Heavy-Duty Infrastructure Workgroup Meeting - Electricity and the Grid (Part 1). Workgroup meeting recording available here: https://ww2.arb.ca.gov/our-work/programs/advanced-clean-fleets/advanced-clean-fleets-meetings-events. Accessed: October 2022.

A.9 The Draft EA must analyze the operational peak and base electricity demand associated with the proposed project and evaluate the feasibility and costs of upgrading the grid to meet the demand within the timeframe of the proposed project.

CARB must quantitatively assess the energy resource inadequacy to meet proposed ACF regulatory requirement issues raised by stakeholders. In addition, for the CEQA analysis in the Final EA, CARB would have to either provide substantive information that the effect of inadequate energy/infrastructure resources are less than significant and/or assess mitigations for the likely significant impacts.[47] The cumulative impact assessment must also look at the cumulative effect of the ACF and the approved ACC II regulation.[48]

In the Final ACC II EA, CARB recognized that "electrification of California's transportation sector, particularly when combined with increased electrification of the state's building stock, will pose a significant new challenge to grid planning and require investments in transmission and local distribution systems".[49] Using the EVI-Pro 2 model, CARB projected the electricity demand for light-duty vehicle (LDV) charging in 2030 over a 24-hour period, reaching around 5,400 megawatts at peak charging times, increasing electricity demand by up to 25% (**Figure 4**). It is equally if not more important for CARB to conduct a similar analysis on the impacts to the electricity grid due to the ACF regulation because of the significantly greater power required for heavy-duty vehicle (HDV) chargers, 150 kilowatts (kW) or greater for Class 7-8 tractors versus 19 kW or less required for LDV Level 2 chargers. The heavy localization of future HDV charging infrastructure will compound this issue, straining local electricity infrastructure, given that CARB expects most electric vehicle supply equipment (EVSE) to be installed in central depots or yards where trucks are parked overnight.[50]

CARB must assess the level of infrastructure upgrades that would be required to support the peak load under these scenarios and whether it is feasible to upgrade the grid infrastructure to meet the demand within the timeframe of the proposed project. A representative from an energy utility commented during the March 10, 2022 public workshop that their 10-year planning window may need to be expanded to 15 years. Long lead items such as high-scale transmission can take upwards of 7-10 years to build, while distribution infrastructure for individual HDV projects require a minimum of 4 months of utility construction and can take 18-24 months to complete overall.[51] Given that 1.5 million Class 2b-8 ZEVs would need to be deployed statewide by 2048 and the phased-in fleet

---

[47] 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." Cal. Code Regs. tit.17, § 60004.2(a).

[48] *See id.*

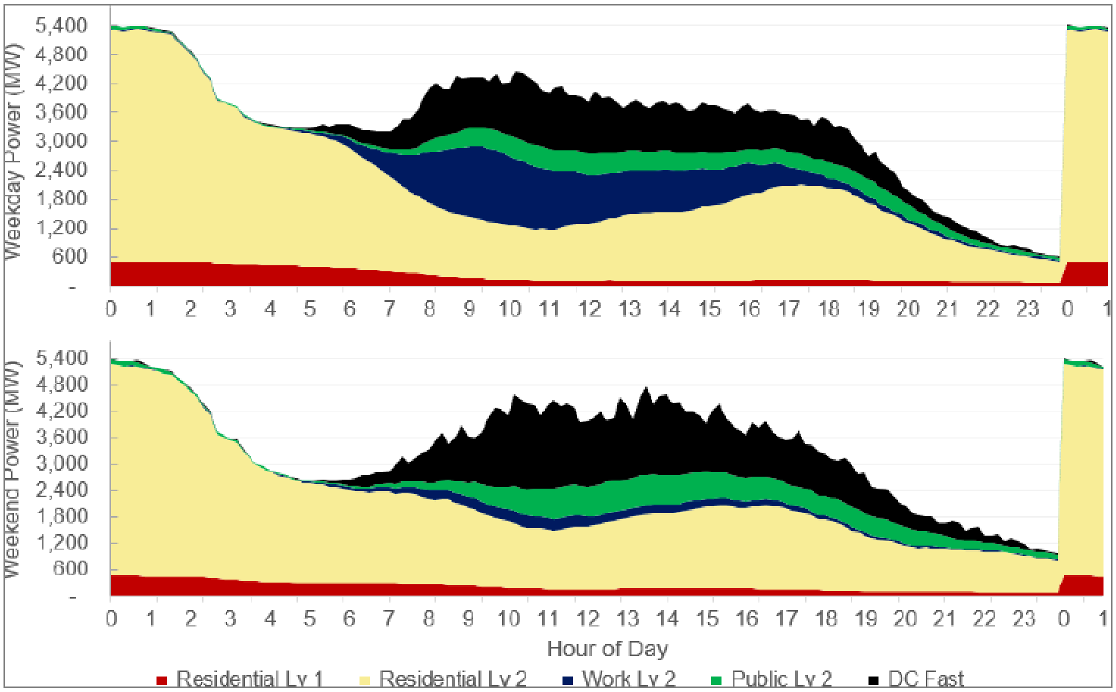
[49] CARB. 2022. Final Environmental Analysis for the Advanced Clean Cars II Program. August 24. Available here: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/accii/acciifinalea.docx. Accessed: October 2022.

[50] CARB. 2022. Appendix C: Original Standard Regulatory Impact Assessment Submitted to Department of Finance. August 30. Available here: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/acf22/appc.pdf. Accessed: October 2022.

[51] CARB Workshop Recording of ACF Virtual Medium and Heavy-Duty Infrastructure Workgroup Meetings - Electricity and the Grid (Part 2). March 2022. CARB Workshop web page (https://ww2.arb.ca.gov/our-work/programs/advanced-clean-fleets/advanced-clean-fleets-meetings-events) includes link to recording at: https://youtu.be/uLYrDh-pKQI. Accessed: October 2022.

transition begins in 2024, there seems to be too little time to complete these necessary upgrades.[52]

Figure 4. ACC II EA Projected 2030 Statewide Plug-in EV Charging Load for Intraregional Travel of 8 Million LD ZEVs in EVI-Pro2[53]



CARB claims in the ACF Draft EA that "increased deployment of ZEVs could result in a relatively small increase [in] production of electricity and hydrogen fuel"[54] and would have a less than significant cumulative impact to the energy sector <u>without</u> citing any data, modeling, or sources for this claim. Given the accelerated Senate Bill 100 (2018) and Senate Bill 1020 (2022) renewable energy targets for California's energy generation and the cumulative energy impacts of electrification under ACC II, ACF, and measures for building electrification, the state will become ever more reliant on its electric infrastructure in the coming decades. Although CARB states that the long-term operational-related utilities and service systems impacts are "beyond the authority of CARB and not within its purview," CARB has a responsibility as the CEQA lead agency to ensure that the energy impacts of regulations it puts forward are assessed and consistent with the proposed regulatory requirements and are technologically feasible within the timeframes it proposed.

---

[52] CARB. 2022. Staff Report: Initial Statement of Reasons. August 30. Available here: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/acf22/isor2.pdf. Accessed: October 2022.

[53] CARB. 2022. Final Environmental Analysis for the Advanced Clean Cars II Program. August 24. Available here: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/accii/acciifinalea.docx. Accessed: October 2022.

[54] CARB. 2022. Appendix D: Draft Environmental Analysis for the Advanced Clean Fleets Rule. August 30. Available here: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/acf22/appd.pdf. Accessed: October 2022.

A.10 CARB did not consider costs for updates to the electric grid infrastructure or costs for recycling and disposal of EV batteries in their calculation of the benefit-cost ratio for the deployment of ZEV technologies.

CARB estimated a benefit-cost ratio of 1.5 for the proposed ACF regulation in the SRIA.[55] This value was calculated as a ratio of the benefits associated with the rulemaking to the total costs for vehicle ownership. The list of costs considered are summarized in Table 38 of the SRIA and provided here for easy reference: vehicle cost (vehicle cost, sales tax, federal excise tax, residual values), fuel cost (gasoline, diesel, electricity, hydrogen fuel cost, fuel taxes), LCFS revenue, infrastructure costs (depot/retail charger costs, infrastructure upgrades, charger maintenance), maintenance costs (vehicle maintenance costs, maintenance bay upgrades), midlife overhaul costs, and other costs (diesel exhaust fluid [DEF] consumption, registration fees, depreciation, insurance, transitional costs, reporting costs). Additionally, the 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 are incorporated into the calculation.

Similar to CARB's analysis for the ACC II regulation, while the costs considered in the calculation include the costs on the customer side of the meter, CARB has failed to account for:

- costs to upgrade the electric grid infrastructure for additional generation, distribution, and transmission necessary to support BEVs[56] (i.e., CARB staff claims, without foundation, these costs would be embedded in fuel costs on page 75 of the ISOR), and
- costs for recycling and disposal of the electric vehicle batteries and the potential environmental hazards that may result from recycling and disposal.

Within the ISOR, CARB staff states that "costs are not incorporated on the utility's side of the meter as those are the responsibility of the utility as specified in Assembly Bill 841 and are implemented by each IOU [investor owned utility]" despite the fact that these costs would be a direct impact of this regulation. This regulation would cause increases to the State's energy demand that will directly require upgrades to the state's energy infrastructure.[57]

As noted in the California Energy Commission's "Deep Decarbonization in a High Renewables Future",[58] these costs would be substantial. That study estimated a cumulative cost of $0.52 trillion from 2020-2030, $0.77 trillion from 2020-2035, and $1.82 trillion from 2020-2050 for upgrading and maintaining the electric grid under a High Electrification Scenario to meet the State's GHG targets of 40% reduction from 1990 levels by 2030 and 80% reduction by 2050. Additionally, the Senate Bill 1020 legislation[59]

---

[55] CARB. 2022. Appendix C: Original Standard Regulatory Impact Assessment Submitted to Department of Finance. August 30. Available here: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/acf22/appc.pdf. Accessed: October 2022

[56] CARB. 2022. Staff Report: Initial Statement of Reasons. August 30. Available here: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/acf22/isor2.pdf. Accessed: October 2022.

[57] Ibid.

[58] E3 2018 Deep Decarbonization PATHWAYS Report. Available here: https://www.energy.ca.gov/sites/default/files/2021-06/CEC-500-2018-012.pdf. Accessed: October 2022.

[59] SB1020, Chapter 361, Statutes of 2022. Available at: https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=202120220SB1020. Accessed October, 2022.

sets new interim targets for renewable energy requirements in California and requires 90% zero-carbon energy by 2035 and 95% by 2040. Senate Bill 1020 also requires that the policy "shall not increase carbon emissions elsewhere in the western grid." This acceleration could require additional investments to be needed earlier and thus could create additional challenges especially with the additional demand that would be generated by the penetration of zero-emission trucks. It is noteworthy that the High Electrification Scenario assumes only an 18% penetration of ZEV in the in-state MDV/HDV vehicle fleet by 2050, which is significantly lower than that proposed under the ACF. Hence, costs for grid infrastructure upgrades and maintenance could be much higher and CARB should evaluate and disclose these costs.

CARB similarly fails to discuss costs for recycling and disposal of the electric vehicle batteries and the potential environmental hazards that may result from recycling and disposal, despite recognizing that such impacts exist in the Draft EA. A report by Kelleher Environmental entitled "Research Study on Reuse and Recycling of Batteries Employed in Electric Vehicles" highlights some key concerns that may result in substantial costs associated with the regulation.[60] Both the reuse and recycling of EV batteries are hindered by a lack of collection infrastructure necessary to bring large numbers of batteries to a central location to exploit economies of scale. Transportation is expensive and highly regulated as used EV batteries are classified as hazardous waste. Further, the technologies that promise to achieve high recovery rates for the metals contained in EV battery cathodes have not yet been proven at commercial scale and there is uncertainty regarding aftermarket values for the materials recovered, particularly as battery chemistries continue to evolve.

As stated in the Draft EA, California is the largest market for EVs in the U.S. and by 2027, an estimated 45,000 EV batteries could be retired within the state.[61] CARB acknowledges that the proposed project could result in a significant cumulative impact on mineral sources.[62] Such an impact should be included in the benefit-cost ratio of the Proposed ACF regulation.

A.11 CARB's sensitivity analysis does not consider the potential impacts of ACF and other regulations, such as ACC II, to California's electricity grid and electric fuel costs and only evaluates a fixed 10% increase in costs.

CARB's projected electricity costs for the ACF Total Cost of Ownership[63] are modeled using CEC's "Revised Transportation Energy Demand Forecast, 2018-2030"[64] and U.S. Energy Information Administration (EIA) 2018 Annual Energy Outlook.[65] However, neither

---

[60] Kelleher Environmental. 2020. Research Study on Reuse and Recycling of Batteries Employed in Electric Vehicles Prepared for Energy API. November. Available here: https://www.api.org/-/media/Files/Oil-and-Natural-Gas/Fuels/EV%20Battery%20Reuse%20Recyc%20API%20Summary%20Report%2024Nov2020.pdf. Accessed: October 2022.

[61] CARB. 2022. Appendix D: Draft Environmental Analysis for the Advanced Clean Fleets Rule. August 30. Available here: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/acf22/appd.pdf. Accessed: October 2022.

[62] Ibid.

[63] CARB. 2022. Total Cost of Ownership Discussion Document. Available here: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/acf22/appg.pdf Accessed: October 2022.

[64] CEC. 2018. "Revised Transportation Energy Demand Forecast, 2018-2030". April. Available here: https://efiling.energy.ca.gov/getdocument.aspx?tn=223241. Accessed: October 2022.

[65] EIA. 2018. Annual Energy Outlook 2018. February. Available here: https://www.eia.gov/outlooks/archive/aeo18/. Accessed: October 2022.

of these projections consider the potential impacts of ACC II and ACF on the electricity grid infrastructure, generation requirements, and future electricity costs, leading to potentially significant underestimations and uncertainties in future electric fueling costs.[66]

Figure 12 in the Total Cost of Ownership document shows little change in the costs of charging from 2027 through 2040 for all vehicle classes, from $0.15 to $0.25/kW hour (kWh) for Class 2b-3 Cargo Vans through Class 8 Day Cabs and $0.40 to $0.45/kWh for Class 8 Sleeper Day Cabs.[67] The sensitivity analysis applies a fixed factor of 10% to the costs provided as a seeming upper bound for the ZEV fuel costs without accounting for potential spikes to electricity costs as a result of increased electricity demand from the wide array of programs within the 2022 State SIP Strategy, including ACF and ACC II.

CARB provides no foundation for its assumption that electricity costs will remain constant in the future.

Comments on Draft ACF Language

WSPA member companies operate truck fleets in their operating facilities and for transporting crude oil, finished products to retail locations, and other materials. The proposed ACF would impact these truck fleets by 1) requiring new ZEV truck purchases and 2) potentially increasing operating costs.

The ACF could change ownership of truck fleets. Current large fleets that would be subject to the rule could experience higher truck purchase costs and higher operating costs than smaller fleets not subject to the rule. This could change truck ownership, discouraging large fleets.

Trucks delivering fuel from terminals to retail locations also optimally operate with cargo loads near the maximum total vehicle operating weight limit. Future BEV and/or FCEV trucks could be heavier than current ICE trucks, which would reduce the volume of cargo that they could haul while still meeting the weight limits. If this were to prove to be true, then fuel haulers could only respond by making more trips with the same number of trucks to deliver the same volume of fuel, and/or by purchasing and using more trucks. Both situations could increase operating costs for fuel haulers which could translate to higher costs to the consumer. We encourage CARB to consider these business realities in its consideration of the ACF, and to consider the following issues with the currently drafted ACF language.

A.12 The proposed ACF regulation requires fleet owners to use specific kilowatt-hour per mile values to estimate the ZEV ranges for the daily usage exemption; however, there are no requirements for manufacturers to meet these kilowatt-hours per mile values in the Advanced Clean Trucks (ACT) regulation.

Within the Daily Usage Exemption in the High Priority and Federal Fleets and State and Local Governments regulations, CARB requires fleet owners to convert the rated energy capacity of the commercially available ZEV into “range of the vehicle” in miles using a factor based on vehicle class established by the regulation. CARB has provided no documentation to explain why these values were selected.

---

[66] CEC. 2018. “Revised Transportation Energy Demand Forecast, 2018-2030”. April. https://efiling.energy.ca.gov/getdocument.aspx?tn=223241. Accessed: October 2022.

[67] CARB. 2022. Total Cost of Ownership Discussion Document. Available here: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/acf22/appg.pdf Accessed: October 2022.

Given that there is no complementary energy efficiency standard for ZEVs in the Advanced Clean Trucks rule or any other manufacturer requirement for heavy-duty ZEVs other than a minimum all-electric range of 75 miles for NZEVs,[68] there is no guarantee that the vehicles available for fleets to purchase will have energy efficiencies remotely resembling the values presented in the regulation. CARB should instead base this exemption on the real-world mileage and duty cycles achieved by the ZEVs or establish manufacturing criteria that supports the needs of fleet owners.

A.13 The provided exemptions do not adequately consider the lead time needed for permitting electric charging infrastructure upgrades and reliability of charging systems unique to heavy duty applications.

While the provided exemptions provide an extension for fleet owners to add a ZEV to their fleet based on delivery delays and delays in construction outside of the fleet owners' control, there is no such extension to account for delays in the permitting process, which has been a regular focus of concern among stakeholders at nearly every workgroup meeting held for the proposed ACF regulation.

In the ACF workshop on March 10, 2022, a representative from the Governor's Office of Business and Economic Development (GO-Biz) stated that permit streamlining was a focus for the Governor's Office and would like a better understanding of installation and permitting timelines.[69] However, there has been no reflection of these concerns within the regulation. The exemptions, as written, only take into consideration facility-side delays in construction, which does not account for the actual timeline of installing infrastructure. Facilities must first work with utilities to have sufficient power delivered to the site, which as previously discussed can take over a year, then acquire the permits necessary to begin construction.

Stakeholders are already experiencing permitting delays of over a year, and with the influx of infrastructure upgrades and permitting requests that will be submitted to utilities and state agencies as a result of this proposed regulation, these delays will likely stretch even longer.[70] In order to qualify for the infrastructure delay exemption, a facility would need to begin development of their site at least two and a half years in advance of the regulatory deadlines (e.g., four months, if not more, for utility power distribution upgrades; and one year, if not more, to acquire the necessary permitting in order to begin construction one year in advance of the regulatory deadline and qualify for the construction delay exemption).[71] Given that requirements for the State and Local

---

[68] CARB. 2019. Advanced Clean Trucks Final Regulation Order. December. Available here: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2019/act2019/fro2.pdf. Accessed: October 2022.

[69] CARB Workshop Recording of Virtual Medium and Heavy-Duty Infrastructure Workgroup Meetings - Electricity and the Grid (Part 2). March 2022. CARB Workshop web page (https://ww2.arb.ca.gov/our-work/programs/advanced-clean-fleets/advanced-clean-fleets-meetings-events) includes link to recording at: https://youtu.be/uLYrDh-pKQI. Accessed: October 2022.

[70] CARB Workshop Recording of Public Workshop on Draft ACF Regulation Provisions. July 2022. CARB Workshop web page (https://ww2.arb.ca.gov/our-work/programs/advanced-clean-fleets/advanced-clean-fleets-meetings-events) includes link to recording at: https://youtu.be/N0cDTVp-m8Q. Accessed: October 2022.

[71] CARB Workshop Recording of ACF Virtual Medium and Heavy-Duty Infrastructure Workgroup Meetings - Electricity and the Grid (Part 2). March 2022. CARB Workshop web page (https://ww2.arb.ca.gov/our-work/programs/advanced-clean-fleets/advanced-clean-fleets-meetings-events) includes link to recording at: https://youtu.be/uLYrDh-pKQI. Accessed: October 2022. And CARB Workshop Recording of Public Workshop on Draft ACF Regulation Provisions. July 2022. CARB Workshop web page (https://ww2.arb.ca.gov/our-

Government Fleets regulation and the High Priority Fleets regulation begin on January 1, 2024, it may already be too late for these fleets to qualify for this exemption. CARB must take into consideration stakeholders' comments regarding the lack of certainty for permitting timelines and other delays that can occur before construction begins and expand on the list of exemptions and extensions allowed under the regulation.

A.14 CARB must update the proposed ACF rule language to clarify what fleets should do if their request for adding a vehicle configuration to the ZEV unavailability list or for an exemption is rejected.

The proposed ACF rule language does not describe the process that would occur following the rejection of an application for adding a vehicle configuration to CARB's ZEV unavailability list. We request that CARB update the rule language to state that CARB staff will respond to such a request within two weeks. We also request that the rule language be updated to state that in the event CARB staff reject the request to add a vehicle configuration to the ZEV unavailability request, they should provide an explanation for the reason for rejection as well as list of commercially available make/models of ZEV(s)/NZEV(s) for said vehicle configuration to the applicant. This would allow for fleets to understand why their request was rejected, while also providing them necessary information on commercially available vehicles that they could purchase.

The proposed rule language does not explicitly provide any pathway for appeal if CARB rejects a fleet's application for the ZEV delivery delay and/or infrastructure construction delay exemptions. CARB must update the rule language to include a clearly defined appeal process for fleet owners whose applications for such exemptions are denied.

---

work/programs/advanced-clean-fleets/advanced-clean-fleets-meetings-events) includes link to recording at: https://youtu.be/N0cDTVp-m8Q. Accessed: October 2022.

Attachment 4:

Ramboll study (dated Feb. 1, 2021) "Multi-Technology Pathways to Achieve California's Air Quality and Greenhouse Gas Goals: Heavy-Heavy-Duty Truck Case Study"

Prepared for
Western States Petroleum Association

Prepared by
Ramboll US Consulting, Inc.
Los Angeles, California

Project Number
1690017786-001

Date
February 1, 2021

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

HEAVY-HEAVY-DUTY TRUCK CASE STUDY

Ramboll US Consulting, Inc.
350 S. Grand Avenue
Suite 2800
Los Angeles, California 90071

CONTENTS

Page

EXECUTIVE SUMMARY **1**

1. INTRODUCTION **1**
1.1 CARB 2020 MSS Summary 1
1.2 Purpose of this Study 1

2. MULTI-TECHNOLOGY SCENARIOS: HEAVY-HEAVY-DUTY TRUCK SECTOR EXAMPLE **2**

3. SCENARIO ANALYSIS METHODOLOGY **6**
3.1 Renewable Fuel Sub-Scenarios 6
3.2 Tailpipe (Tank-to-Wheel) Emissions 6
3.3 Upstream (Well-to-Tank) Emissions 7

4. COST ANALYSIS METHODOLOGY **9**

5. SCENARIO ANALYSIS EMISSIONS RESULTS **10**
5.1 Tailpipe NO_X Emissions 10
5.2 GHG Emissions 12
5.3 Summary of Scenario Analysis Results 14

6. COST ANALYSIS RESULTS **15**
6.1 Total Cost of Ownership Results 15
6.2 Cost Effectiveness Results 18
6.3 Data Gaps and Key Concerns 20
6.3.1 Battery Costs and Availability 20
6.3.2 Government Electricity Price Projections 22
6.3.3 Lack of Publicly Available Information to Make Renewable Fuel Availability and Price Projections 22
6.3.4 Other Unaccounted-for Costs 23

7. CONCLUSIONS **25**
7.1 Summary of Analysis Conclusions 25
7.2 Next Steps- Technical 25
7.3 Next Steps- Regulatory 26

TABLES

Table 3-1: Renewable Fuels Sub-Scenarios 6
Table 3-2: Tailpipe Emission Assumptions 7
Table 6-1: BEV Purchase Cost (without tax) by Battery Cost Source 21

FIGURES

Figure ES-1: Statewide NO_X HHDT Tailpipe Emissions 2
Figure 2-1: Heavy-Duty Vehicle Fleet Mix for 2020 MSS 6
Figure 2-2: Diesel Heavy-Heavy-Duty Truck Fleet Mixes for Ramboll Scenario Analysis 8
Figure 5-1: Statewide HHDT NO_x Tailpipe Exhaust Emissions by Scenario 15
Figure 5-2: Statewide HHDT NO_x Emissions Comparison by Scenario 15
Figure 5-3: 2045 Well-to-Wheels GHG Emissions 17
Figure 6-1: Total Cost of Ownership Results for a 10-year Useful Life 19

Figure 6-2: Total Cost of Ownership Results for a 15-year Useful Life 20
Figure 6-3: Comparison between Ramboll and CARB ACT TCO Analyses 21
Figure 6-4: Tailpipe NO_x Cost-Effectiveness for a 10-year Truck Life 23
Figure 6-5: Tailpipe NO_x Cost-Effectiveness for a 15-year Truck Life 24
Figure 6-6: Battery Cost Projections from the CARB ACT ISOR 25
Figure 6-7: Electricity Cost Projections 26
Figure 6-8: Zero Emissions Bus (ZEB) Deport Charging Infrastructure Costs 28

APPENDICES

Appendix A: Scenario Analysis Assumptions and Detailed Methodology
Appendix B: Cost Analysis Assumptions and Detailed Methodology

ACRONYMS AND ABBREVIATIONS

ACT:	Advanced Clean Truck
AC Transit:	Alameda Contra Costa Transit District
AEO:	Annual Energy Outlook
AG:	agriculture
AW:	dairy digester/animal waste
AQMP:	Air Quality Management Plan
BD:	biodiesel
BEB:	battery electric bus
BEV:	battery electric vehicle
CAA:	Clean Air Act
CA-GREET:	California Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation Model
CARB:	California Air Resources Board
CEC:	California Energy Commission
CI:	carbon intensity
DSL:	diesel
EER:	energy economy ratio
EMA:	Energy Marketers of America
EMFAC2017:	Emission Factor Model
EV:	electric vehicle
GHG:	greenhouse gases
g/bhp-hr:	grams per brake horsepower hour
HDV:	heavy-duty vehicle
HHDT:	heavy-heavy-duty truck
ICCT:	International Council on Clean Transportation
ICT:	Innovative Clean Transit
ISOR:	Initial Statement of Reasons
kWh:	kilowatt hour
LCFS:	Low Carbon Fuel Standard
LFG:	landfill gas
MHDV:	medium- and heavy- duty vehicle
META Tool:	Mobile Emissions Toolkit for Analysis

MSS:	Mobile Source Strategy
MY:	model year
NG:	natural gas
NO_X:	oxides of nitrogen
PM:	particulate matter
$PM_{2.5}$:	particulate matter less than 2.5 microns in diameter
RNG:	renewable natural gas
RNWD/RD:	renewable diesel
SB 44:	Senate Bill 44
SCAB:	South Coast Air Basin
SCAQMD:	South Coast Air Quality Management District
SIP:	State Implementation Plan
SJV:	San Joaquin Valley
SJVAPCD:	San Joaquin Valley Air Pollution Control District
SWCV:	solid waste collection vehicles
TCO:	total cost of ownership
T&D:	transmission and distribution
US EIA:	United States Energy Information Administration
USEPA:	United States Environmental Protection Agency
WWTP:	wastewater treatment plants
ZEB:	zero emission bus
ZEV:	zero emission vehicle

EXECUTIVE SUMMARY

California Senate Bill 44[1] (SB 44) requires the California Air Resources Board (CARB) to "update the 2016 mobile source strategy to include a comprehensive strategy for the deployment of medium-duty and heavy-duty vehicles in the state for the purpose of bringing the state into compliance with federal ambient air quality standards and reducing motor vehicle greenhouse gas emissions from the medium-duty and heavy-duty vehicle sector." In response, CARB developed the 2020 Draft Mobile Source Strategy (MSS)[2], which delivered a single electrification-centric approach that has failed to meet the 2023 and 2031 air quality goals, abandoned its 2016 MSS commitments, did not analyze for any alternatives, and failed to look at cost and feasibility as SB 44 required. Further, CARB does not deliver pre-2032 near-term (or short-term) reductions required for non-attainment areas to meet 2023 and 2031 federal health standard deadlines, which were promised to these impacted communities. It also ignored the potential role of renewable liquid and gaseous fuels in meeting longer-term (post-2032) greenhouse gas reduction goals.

As on-road truck emissions are a primary control measure category in non-attainment areas, Ramboll conducted an analysis of one specific sector within the MSS, California's heavy-heavy- duty truck (HHDT) fleet, to identify multiple vehicle technology and fuel pathways that could achieve these near-term air quality goals while being consistent with the meeting of the state's long-term climate goals. The multi-technology analysis of the HHDT sector in this report began in June 2020 after the original CARB 2020 MSS presentation in March 2020.[3] The main conclusions of our analysis are summarized below:

CARB's 2020 Mobile Source Strategy **did not deliver** pre-2032 near-term (or short-term) reductions required for non-attainment areas to meet 2023 and 2031 federal health standard deadlines. Ramboll's analysis of **multi-technology pathways**, which include a combination of low-emission (75% to 100% lower) vehicle technologies and fuel mixes (including lower carbon intensity liquid and gaseous fuels), demonstrates that there are faster paths to meeting near-term federal health requirements, making progress on state climate goals and achieving greater reductions per dollar spent.

- Expanded implementation of zero-emission and Low-NO_X vehicles, coupled with increased introduction of renewable liquid and gaseous fuels, can deliver earlier (as shown in **Figure ES-1**) and more cost-effective benefits than a zero-emission vehicle (ZEV)-only approach.
- As advanced low-emitting trucks are commercially available[4] to deliver benefits to communities sooner, multi-technology pathways can help achieve emission reductions without reliance on infrastructure and technology upgrades that will take years to resolve.
- There is a growing potential for renewable fuels, including those with negative carbon intensity, to meet achieve GHG reductions, which CARB has not acknowledged fully in the MSS nor assessed

---

[1] California Senate Bill 44. Available at: https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201920200SB44. Accessed January 2021.

[2] CARB Mobile Source Strategy. Available at: https://ww2.arb.ca.gov/resources/documents/2020-mobile-source-strategy. Accessed January 2021.

[3] CARB Mobile Source Strategy March 2020 Presentation. Available at: https://ww3.arb.ca.gov/planning/sip/2020mss/pres_marwbnr.pdf. Accessed January 2021.

[4] Optional Low NO_X Certified Heavy-Duty Engines. Available at: https://ww2.arb.ca.gov/sites/default/files/classic/msprog/onroad/optionnox/optional_low_nox_certified_hd_engines.pdf. Accessed: January 2021.

the potential for early and cost-effective GHG reductions through these multi-technology vehicle pathways.

- Low-emission heavy-heavy-duty trucks are cost-competitive with (or cheaper than) battery electric vehicles (BEVs). This is true even though battery technology promises (such as greater energy density/lower cost) have not been adequately demonstrated and related transmission/distribution infrastructure cost have not been included in the state's analyses.

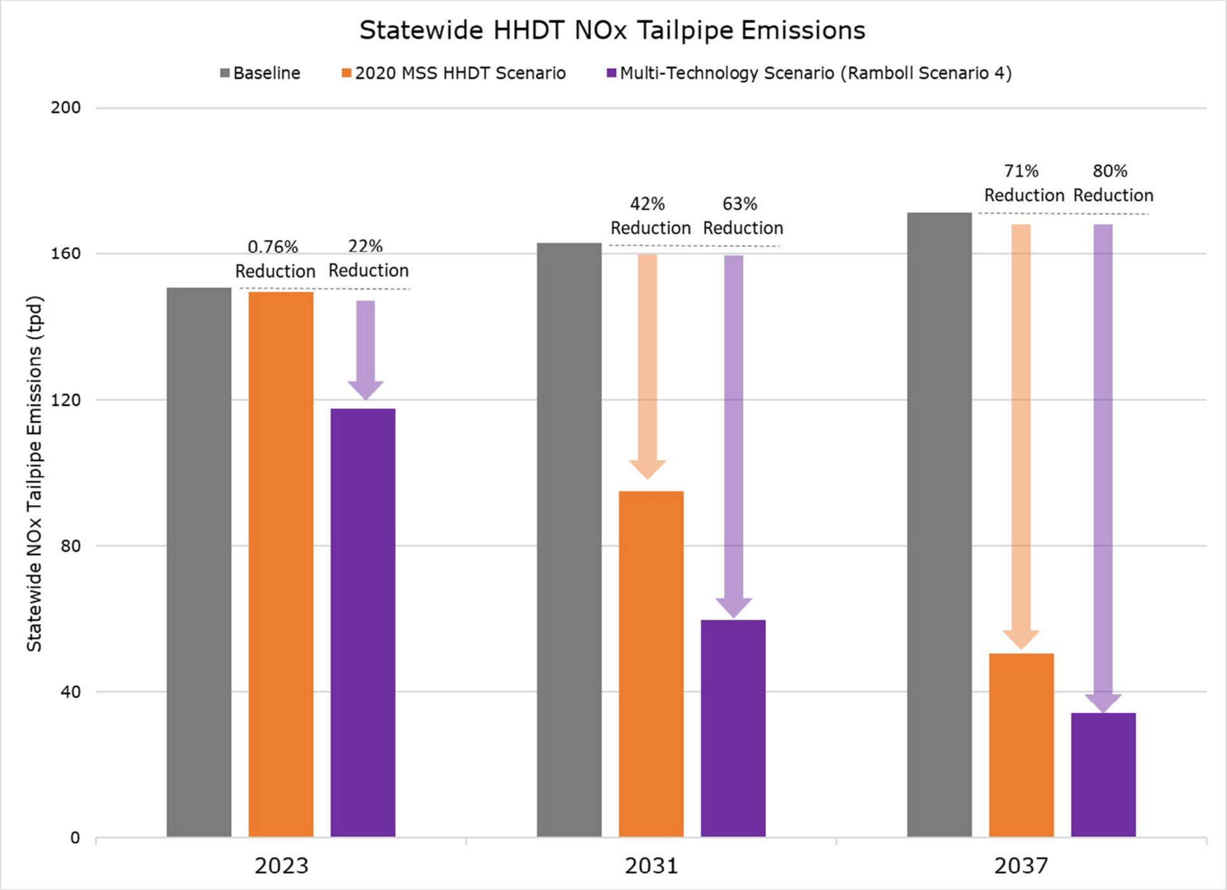


Figure ES-1. Statewide NO$_X$ HHDT Tailpipe Emissions

These conclusions emphasize the need for CARB to conduct a similar analyses across all mobile source sectors, not just the heavy-heavy-duty truck sector, in order to identify existing opportunities to meet state emission reduction commitments consistent with the federal Clean Air Act, fulfill SB 44 requirements, and comprehensively assess the costs and timelines for potential GHG reduction strategies. The analysis also identified information gaps, unsupported technical and cost assumptions, and areas of future research. The lack of citations and/or justifications for the analysis assumptions and inputs used in CARB's Mobile Emissions Toolkit for Analysis (META Tool) needs to be remedied as CARB revises the 2020 MSS and develops future rulemaking on Advanced Clean Cars 2, Advanced Clean Fleets and other rules.

Taking the Next Steps

Several commenters[5] have agreed that the 2020 MSS (and its development process, technical analyses, public process) were inadequate when compared with SB 44 requirements and the previous 2016 MSS. The South Coast Air Quality Management District (SCAQMD) comments[6] noted that "[T]he lack of discussion of the 2023 8-hour ozone attainment date in the South Coast Air Basin in the draft Mobile Source Strategy is very disturbing and likely unlawful[.]" and "given the need for both short-term and long-term reductions, ***considerations must be given for both technologies that are commercially available today (e.g., near-zero technologies) as well as technologies that are being developed and demonstrated (e.g., zero-emission technologies)***." The San Joaquin Valley Air Pollution Control District (SJVAPCD) comments[7] noted that "given the need for both short-term and long-term reductions, considerations must be given for both technologies that are commercially available today (e.g., near-zero technologies) as well as technologies that are being developed and demonstrated (e.g., zero-emission technologies)[.]" and "the District recommends that CARB more clearly articulate the existing commitments included in the 2018 Supplement and 2018 PM2.5 Plan that calls for ***the deployment of a combination of zero and near-zero technology as the most effective and achievable strategy for securing the needed near-term emissions reductions in the San Joaquin Valley and South Coast***."

Based on the results of this study and concerns raised by the local air quality districts, this paper offers the following recommendations:

- CARB should revise the 2020 MSS to include scenarios that assess the increased use of renewable liquid and gaseous fuels and low-NO_X technologies, as well as the expanded use of market-based emission reduction strategies, to achieve emission reductions consistent with SB44 requirements.
- Each scenario must be evaluated for technical feasibility, and as such would require an analysis of future fueling infrastructure availability.
- CARB should assess the associated cost of each MSS scenario in order to identify cost-effective pathways to achieving the state's emission goals, including citations and justifications for assumptions of projected costs and range of potential costs (when uncertainty is high).
- A robust economic analysis is needed of the economic impacts on affected stakeholders (and the public, who ultimately pays). The public, stakeholders, and the legislature need this information to make informed decisions about the path to achieving California's emission goals.

CARB must be transparent and unbiased in the rulemaking process. CARB should conduct technical working groups to foster stakeholder participation in scenario development and assessment, address cost data gaps identified in this study, and ensure that reasonable and achievable strategies are developed that meet SB 44 requirements. Multi-technology pathways can help the state achieve faster and more certain emission reductions to fulfil its commitment to non-attainment communities while expanding ways to reduce greenhouse gas emissions.

---

[5] Public Comments on the Workshop Discussion Draft 2020 Mobile Source Strategy. Available at: https://ww2.arb.ca.gov/resources/documents/workshop-discussion-draft-2020-mobile-source-strategy-comments-received. Accessed: January 2021.

[6] South Coast Air Quality Management District Comments on the Draft 2020 Mobile Source Strategy dated October 20, 2020. Available at: https://ww2.arb.ca.gov/sites/default/files/2020-11/SouthCoastAQMD_Comment-WorkshopDiscussionDraft2020MSS.pdf. Accessed: January 2021.

[7] San Joaquin Valley Air Pollution Control District Comments on the Draft 2020 Mobile Source Strategy dated October 21, 2020. Available at: https://ww2.arb.ca.gov/sites/default/files/2020-11/SJVAPCD_Comment-WorkshopDiscussionDraft2020MSS.pdf. Accessed: January 2021.

1. INTRODUCTION

1.1 CARB 2020 MSS Summary

The California Air Resources Board (CARB) first released the Mobile Source Strategy (MSS) in 2016,[8] which introduced a set of measures to reduce emissions from mobile sources to meet the State's air quality and climate goals over the subsequent fifteen years. A list of proposed policy measures coupled with CARB action dates and estimated emission reductions was provided in the 2016 MSS. In 2019, California Senate Bill 44 (SB 44) directed CARB to update the 2016 MSS by January 1, 2021 to bring the state in compliance with federal air quality standards and reduce greenhouse gas (GHG) emissions from the medium- and heavy-duty vehicle sector. CARB released a Workshop Discussion Draft of the 2020 MSS[9] on September 30th, 2020 followed by a Draft 2020 MSS[10] on November 24th, 2020 to inform and provide direction on future CARB rulemaking to meet the State's air quality and climate goals and to meet SB 44 requirements.

1.2 Purpose of this Study

The 2020 MSS draft is focused on meeting the State's long-term climate goals through the exploration of electrification concepts and scenarios across the mobile source sectors. There is, however, an immediate need to assess multiple vehicle/fuel technology pathways for significantly reducing oxides of nitrogen (NO_X) emissions from mobile sources, particularly heavy-heavy-duty trucks (HHDTs),[11] in order to meet the upcoming federal Clean Air Act (CAA) ozone attainment deadlines in 2023 and 2031 for South Coast Air Basin (SCAB) and San Joaquin Valley (SJV). While the 2016 MSS identified near-zero technologies such as Low NO_X natural gas (NG) engines and plug in hybrid vehicle (PHEV) technologies as potential pathways to help achieve these near-term NO_X reductions, the 2020 MSS does not address these much needed near-term NO_X reductions; instead it focuses on a vehicle electrification pathways to achieve the State's long-term climate goals.

Since the 2020 MSS does not address the NO_X reductions needed to the State's near-term air quality goals, Ramboll conducted an analysis of California's HHDT fleet to identify multiple vehicle technology and fuel pathways that could help achieve these near-term air quality goals while still meeting the long-term climate goals. This white paper provides a summary of the methodology, results, and conclusions of Ramboll's analysis. The results of these analyses can be used as a basis for further discussion with CARB, air districts, and stakeholders to amend the deficiencies in the current 2020 MSS and its related feasibility, cost, and socioeconomic analyses.

---

[8] CARB. 2016. Mobile Source Strategy. May. Available at: https://ww3.arb.ca.gov/planning/sip/2016sip/2016mobsrc.pdf. Accessed: January 2021.

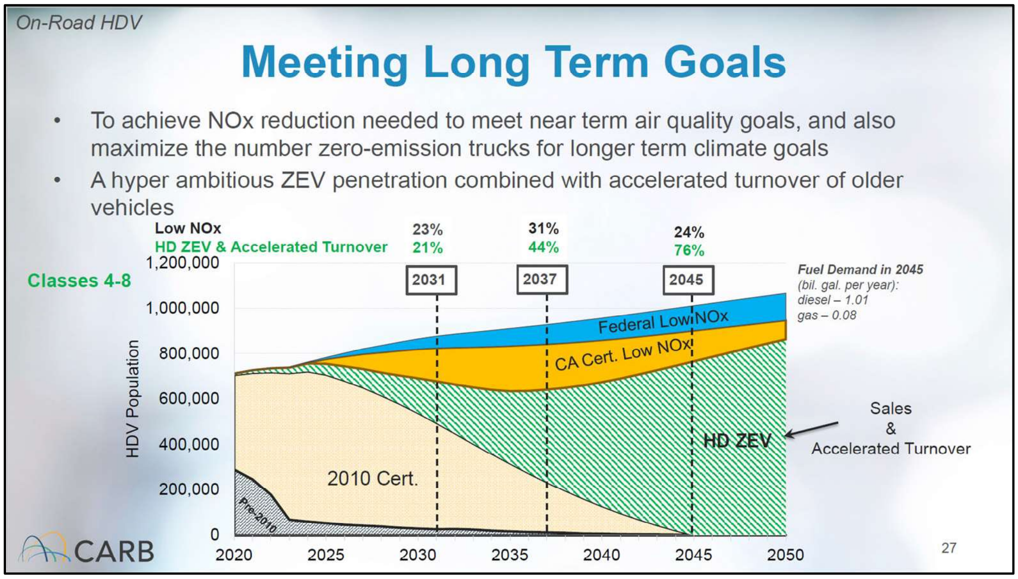
[9] CARB. 2020. Workshop Discussion Draft 2020 Mobile Source Strategy. September 30. Available at: https://ww2.arb.ca.gov/sites/default/files/2020-09/Workshop_Discussion_Draft_2020_Mobile_Source_Strategy.pdf. Accessed: January 2021.

[10] CARB. 2020. Draft 2020 Mobile Source Strategy. November 24. Available at: https://ww2.arb.ca.gov/sites/default/files/2020-11/Draft_2020_Mobile_Source_Strategy.pdf. Accessed: January 2021.

[11] HHDTs make up the largest portion of mobile source NO_X emissions in the SCAB and SJV as shown in the 2020 NO_X mobile source emission inventories for these areas. Available at: https://www.arb.ca.gov/app/emsinv/fcemssumcat/fcemssumcat2016.php. Accessed: January 2021.

2. MULTI-TECHNOLOGY SCENARIOS: HEAVY-HEAVY-DUTY TRUCK SECTOR EXAMPLE

The 2020 MSS assumes an aggressive penetration rate for zero emission vehicles (ZEVs) in the heavy-duty vehicle (HDV) sector which includes an ambitious phase-in for newer vehicles and an accelerated turnover of older and higher emitting vehicles in order to meet California's long-term climate goals. **Figure 2-1** below presents the vehicle technology fleet mix of the statewide HDV population proposed in the 2020 MSS ("CARB's 2020 MSS Scenario") at CARB's March 2020 Presentation. As shown in the figure, this scenario assumes that the fraction of ZEV in the HDV fleet will increase from ~0% in 2020 to 21% in 2031, 44% in 2037, 76% in 2045, and 80% in 2050.[12] While the 2020 MSS Workshop Discussion Draft briefly evaluates an alternative Low-NO_X "concept" that assumes an accelerated turnover to Low-NO_X vehicles, CARB does not consider or access other scenarios that use a mix of alternative vehicle and fuel technologies to achieve the California's long-term climate goals.



On-Road HDV

Meeting Long Term Goals

- To achieve NOx reduction needed to meet near term air quality goals, and also maximize the number zero-emission trucks for longer term climate goals
- A hyper ambitious ZEV penetration combined with accelerated turnover of older vehicles

Figure 2-1. Heavy-Duty Vehicle Fleet Mix for 2020 MSS[13]

Ramboll's analysis presented in this report evaluates the emission benefits of a series of multi-technology scenarios for a sub-set of the statewide HDV fleet consisting of diesel heavy-heavy-duty trucks (HHDTs) excluding solid waste collection vehicles (SWCV). The purpose of this analysis is to evaluate if there are other vehicle/fuel technology pathways besides CARB's 2020 MSS Scenario that could achieve the State's long-term climate goals while also meeting the near-term air quality goals. CARB does not provide a breakdown between the types of heavy-duty ZEVs modeled in its

---

[12] On November 24, 2020, CARB released the Draft 2020 MSS with fleet mix assumptions that differ slightly from those seen in Figure 3-1. The heavy-duty ZEV fleet mix Draft 2020 MSS are as follows: 24% in 2031, 48% in 2037, and 77% in 2045 (obtained from Draft META tool that accompanies the Draft 2020 MSS. Available at: https://ww3.arb.ca.gov/planning/sip/2020mss/draft_META.zip. Accessed: January 2021.). As Ramboll's analysis was conducted before the Draft 2020 MSS was released, it uses fleet mix percentages from the March 2020 presentation.

[13] CARB, 2020. Long-term strategy for 2020 MSS. CARB 2020 Mobile Source Strategy Public Webinar, March 25, 2020. Available at: https://ww3.arb.ca.gov/planning/sip/2020mss/pres_marwbnr.pdf. Accessed: January 2021.

long-term scenarios. As CARB assumes that the heavy-duty ZEV population will be predominately battery electric vehicles[14] (BEVs), Ramboll's scenario analysis models ZEVs as BEVs only.

A brief description of the analyzed scenarios is presented below. **Figure 2-2** presents vehicle technology fleet mixes for these scenarios. A detailed matrix of all scenarios can be found in **Appendix A.**

- **S1 - CARB Long-Term Scenario**: As shown in **Figure 2-2**, the fleet mix for this scenario assumes an aggressive penetration rate for BEV with an accelerated turnover of pre-2024 vehicles to achieve the following fractions of BEV in future calendar years that are similar to the CARB 2020 MSS Scenario: 44% in 2037, 76% in 2045, and 80% in 2050. The fraction of California Low NO_X diesel (CA Low NO_X DSL) vehicles and Federal Low NO_X diesel (Federal Low NO_X DSL) vehicles in future years is also maintained at values similar to the CARB 2020 MSS Scenario.
- **S2 – Low NO_X NG with ACT**: In this scenario, Ramboll assumed that the sales fractions of BEV in HHDTs for model year 2024 and beyond are equal to the purchase mandate stated in CARB's Advanced Clean Truck (ACT) Regulation[15] and that the fraction of Federal Low NO_X DSL HHDTs in the statewide fleet is maintained at values similar to the CARB 2020 MSS Scenario. All other new (model year [MY] 2024 and beyond) vehicles are assumed to be Low NO_X natural gas (Low NO_X NG) vehicles that are commercially available in the market today. Note, an accelerated turnover of pre-2024 vehicles, at a rate similar to the CARB 2020 MSS Scenario, is also assumed with these vehicles turning over to newer alternative technology vehicles (e.g., Federal Low NO_X DSL, Low NO_X NG, and BEV).
- **S3 – Low NO_X NG without ACT**: This scenario is identical to scenario S2 with the following exception: all BEV in S2 are replaced with Low NO_X NG vehicles.
- **S4 – Low NO_X NG with SCAQMD 2016 AQMP & ACT**: This scenario is similar to scenario S2, but assumes early adoption of Low NO_X NG HHDTs to meet or exceed South Coast Air Quality Management District's (SCAQMD's) 2016 Air Quality Management Plan (AQMP) projections for NG truck population in calendar years 2023 and 2031.[16] The conventional DSL fleet is adjusted to accommodate the early adoption of Low NO_X NG HHDTs while the sales fraction of BEVs for model year 2024 and beyond remains equal to the purchase mandate stated in CARB's ACT Regulation. Accelerated turnover of older vehicles is included as described in S2.
- **S5 – CA Low NO_X DSL with ACT**: This scenario is identical to scenario S2 with the following exception: CA Low NO_X DSL HHDTs are used to replace the Low NO_X NG HHDTs in S2.
- **S6 – CA Low NO_X DSL without ACT**: This scenario is identical to scenario S3 with the following exception: CA Low NO_X DSL vehicles are used to replace the Low NO_X NG in S3.

---

[14] CARB 2020 MSS Discussion Draft assumes that roughly 90% of the light-duty ZEV population in 2030 are BEVs and 75% in 2045.

[15] Available at: https://ww3.arb.ca.gov/regact/2019/act2019/30dayatta.pdf. Accessed: January 2021.

[16] SCAQMD 2016 AQMP Final Socioeconomic Report Appendix 2-A. Available at: https://www.aqmd.gov/docs/default-source/clean-air-plans/socioeconomic-analysis/final/appfinal_030817.pdf?sfvrsn=2. Accessed: January 2021.

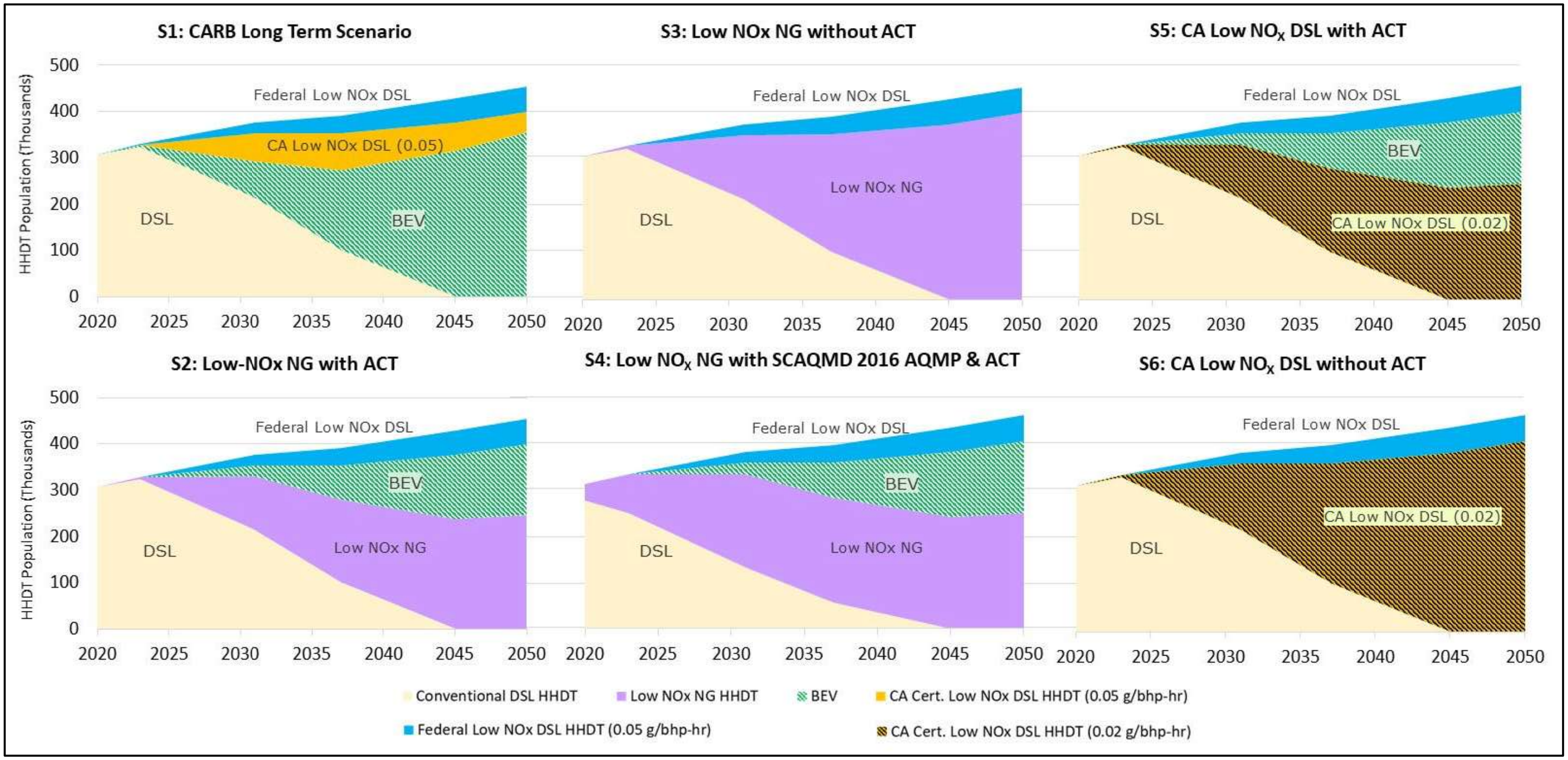


Figure 2-2. Diesel Heavy-Heavy-Duty Truck Fleet Mixes for Ramboll Scenario Analysis

- Ramboll also analyzed a baseline scenario **S0 – Baseline EMFAC2017** which represents the default fleet mix for HHDTs in the EMFAC2017 model,[17] which assumes that all new trucks will meet the 2010 United States Environmental Agency (USEPA) standard.[18] This scenario is used as a baseline to evaluate incremental emission benefits in this analysis.

Besides evaluating the above mentioned scenarios for NO_X and GHG emissions benefits, Ramboll also performed an comparative analysis of the projected total cost of ownership (TCO) and vehicle lifetime emissions of five heavy-heavy-duty truck (HHDT) technologies: Conventional diesel HHDT, Federal Low NO_X diesel HHDT, CA Low NO_X HHDT, Low NO_X NG HHDT, and Battery Electric HHDT. Details on the methodologies used for the scenario and TCO analysis are presented in **Section 4** and **Section 5**.

---

[17] CARB EMFAC 2017 v1.02. Available at: https://arb.ca.gov/emfac/2017/. Accessed December 2020.

[18] Available at: http://www.meca.org/regulation/us-epa-20072010-heavyduty-engine-and-vehicle-standards-and-highway-diesel-fuel-sulfur-control-requirements. Accessed: December 2020.

3. SCENARIO ANALYSIS METHODOLOGY

This Section describes the methodology used for Ramboll's scenario analysis. Detailed modeling inputs, outputs, and methodology are provided in **Appendix A.**

3.1 Renewable Fuel Sub-Scenarios

Ramboll analyzed four versions of scenarios S1 through S6 to explore the use of renewable fuels to achieve greenhouse gas emission reductions. These sub-scenarios are summarized in **Table 3-1** below.

Table 3-1. Renewable Fuels Sub-Scenarios

Sub-Scenarios	Sub-Scenario Descriptions
"A1" Sub-Scenarios	"A1" Scenarios assume that conventional diesel and conventional NG from fossil fuels are used to fuel 100% of the diesel and Low-NO_X NG vehicle populations, respectively, in future calendar years.
"B1" Sub-Scenarios	"B1" Scenarios assume that renewable diesel (RD) from tallow and renewable NG from landfill gas (RNG-LFG) are used to fuel 100% of the diesel and Low-NO_X NG vehicle populations, respectively, in future calendar years.
"C1" Sub-Scenarios	"C1" Scenarios are hypothetical scenarios that assume a composite mix of renewable fuels are used to fuel 100% of the diesel and Low-NO_X NG vehicle populations. For these scenarios, Ramboll assumed that the carbon intensity (CI) of renewable diesel would be an average across all renewable diesel and biodiesel CIs reported in the Low Carbon Fuel Standard (LCFS) Fuel Pathway Table.[19] Ramboll also assumed that source mix for RNG would be 50% LFG, 25% wastewater treatment plants (WWTP), and 25% agriculture (AG). "C1" scenarios are only calculated for calendar year 2045.
"C2" Sub-Scenarios	"C2" Scenarios are hypothetical scenarios that assume conventional diesel and conventional NG are used to fuel 50% of the diesel and Low-NO_X NG vehicle populations, respectively. The remaining 50% of each vehicle population is assumed to be fueled with a composite mix of renewable fuels as described in scenario C1. "C2" scenarios are only calculated for calendar year 2045.

3.2 Tailpipe (Tank-to-Wheel) Emissions

CARB's EMFAC2017 model[20] was used to estimate tailpipe emissions for NO_X and GHGs for all HHDT vehicle types included in this analysis. Specifically, EMFAC2017 was queried at the statewide level for scenario analysis years 2020, 2023, 2031, 2037, 2045 and 2050 to obtain total exhaust emissions, population, and fuel consumption data for HHDTs by model year. Tailpipe emissions for alternative technology HHDTs were calculated based on EMFAC2017 data and the assumptions in **Table 3-2**. Further details regarding tailpipe emission estimation methodology, including EMFAC2017 inputs and outputs, can be found in **Appendix A**.

---

[19] CARB LCFS Fuel Pathway Table. Available at: https://ww3.arb.ca.gov/fuels/lcfs/fuelpathways/current-pathways_all.xlsx. Accessed: January 2021.

[20] Available at: https://arb.ca.gov/emfac/2017/. Accessed: January 2021

Table 3-2. Tailpipe Emission Assumptions

Vehicle Type	Tailpipe NO_X	Tailpipe GHG
Conventional Diesel HHDT	Default EMFAC Output	Default EMFAC Output
Federal Low-NO_X Diesel HHDT	**75% NO_X** reduction from conventional diesel HHDT based on 0.05 grams per brake horsepower hour (g/bhp-hr) NOx certification	Default EMFAC Output
California Certified Low-NO_X Diesel HHDT	Scenario S1: **75% NO_X** reduction from conventional diesel HHDT based on 0.05 g/bhp-hr NOx certification Scenario S5 and Scenario S6: **90% NO_X** reduction from conventional diesel HHDT based on 0.02 g/bhp-hr NO_X certification	Default EMFAC Output
Low-NO_X Natural Gas HHDT	**90% NO_X** reduction from conventional diesel HHDT based on 0.02 g/bhp-hr NO_X certification	Default EMFAC Output
Battery Electric HHDT	Zero NO_x tailpipe emissions	Zero GHG tailpipe emissions

3.3 Upstream (Well-to-Tank) Emissions

Ramboll estimated well-to-tank (i.e., "upstream") NO_X and GHG emissions associated with fuel production and distribution for each analyzed fuel type (electricity, diesel, natural gas, renewable diesel from tallow, and renewable natural gas from landfill gas) using emission factors obtained from the CA-GREET 3.0 model.[21] Developed from Argonne National Laboratory's GREET 2016 model,[22] the CA-GREET 3.0 model is used by CARB to calculate well-to-wheel (i.e., "lifecycle") emissions from transportation fuels under the California LCFS Program. Hence, use of this model to estimate upstream emissions is consist 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) current grid mix data[23] and projections for each of the modeled calendar years 2020, 2023, 2031, 2037, 2045 and 2050.[24] Ramboll also updated the

---

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

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

[23] California Energy Commission 2018 Grid Mix Data. Available at: https://www.energy.ca.gov/data-reports/energy-almanac/california-electricity-data/2018-total-system-electric-generation. Accessed: January 2021.

[24] 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.

default assumptions for renewable fuels transportation distances within CA-GREET 3.0 to more accurately represent distribution within California. Further details regarding CA-GREET 3.0 model inputs and outputs can be found in **Appendix A**.

Emission factors from CA-GREET 3.0 are obtained per unit of energy consumed for each fuel type. In order to calculate total upstream emissions for each scenario, the total amount of energy consumed of each fuel type is calculated using Energy Economy Ratios (EERs). 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.[25] The conventional diesel fuel energy derived from EMFAC2017 for the proportion of vehicles assumed to be turned over to electric of natural gas vehicles was adjusted by the appropriate EERs for heavy-duty vehicles to obtain natural gas or electricity energy consumption. A summary of EER values used in this analysis are provided in **Appendix A**.

---

[25] CARB 2020. Low Carbon Fuel Standard Regulation. Available online at: https://ww2.arb.ca.gov/sites/default/files/2020-07/2020_lcfs_fro_oal-approved_unofficial_06302020.pdf Accessed: January 2021.

4. COST ANALYSIS METHODOLOGY

As discussed in Section 2, Ramboll conducted a total cost of ownership (TCO) analysis and cost-effectiveness analysis for five HHDT technologies: Conventional diesel HHDT, Federal Low NO_X diesel HHDT, CA Low NO_X HHDT, Low NO_X NG HHDT, and Battery Electric HHDT.

The TCO analysis includes an assessment of capital and operational costs with cost values presented in 2018 dollars. The analysis assumes the purchase of a model year (MY) 2024 truck and conducts a TCO calculation for both a 10-year (435,000 miles) and 15-year (909,900 miles) useful truck life. Where possible, cost assumptions are derived from CARB sources including the CARB ACT Regulation.[26]

Capital costs are calculated as a sum of the vehicle purchase cost and charger/charging infrastructure cost, where applicable (i.e., for battery electric trucks). Vehicle purchase costs used in this analysis do not include financing costs or incentives available from various federal, state, and local funding programs. Low-NO_X diesel truck capital costs were estimated by adding the incremental low-NO_X engine and aftertreatment to the cost of a conventional diesel truck. Vehicle purchase costs for BEVs are highly dependent on the future cost projections for batteries. Given the variability in these cost projections,[27] HHDT BEV total cost of ownership was analyzed for a MY2018 and a MY2024 vehicle. Further details regarding battery cost assumptions are provided in **Section 6.3.1** and **Appendix B.** Costs associated with the new and/or enhanced electric generation and transmission infrastructure required for deployment of BEVs are not included in this analysis.

Operational costs are calculated as a sum of fuel costs and operation & maintenance (O&M) costs. Fuel cost projections are derived from United States Energy Information Administration (EIA) Annual Energy Outlook (AEO) 2019.[28] Potential revenue from CARB LCFS credits[29] are not included in this cost analysis. CARB ACT ISOR[27] assumes that a diesel engine rebuild is not needed for an operational life of 600,000 miles. As such, Ramboll Cost analysis does not assume any midlife overhaul costs for a diesel HHDT. As consistent with CARB ACT ISOR[27], a midlife overhaul is required for HHDT BEVs, which consists of a battery replacement in year 8 of operation.

Ramboll calculated cost-effectiveness for each HHDT technology as a ratio of the incremental total cost of ownership (compared to conventional diesel HHDT) divided by incremental tailpipe NO_X emission reductions over the vehicle lifetime (compared to a conventional diesel HHDT). Ramboll estimated tailpipe NO_X emissions for each HHDT technology using EMFAC2017 outputs for a conventional diesel HHDT and the assumptions listed in **Table 3-2**.

Refer to **Appendix B** for additional information on the methodology and assumptions used for the TCO and cost-effectiveness analysis**.**

---

[26] Refer to **Appendix B** for a complete list of sources.

[27] CARB ACT ISOR[25] Appendix H. Available at: https://ww3.arb.ca.gov/regact/2019/act2019/apph.pdf. Accessed: January 2021.

[28] EIA AEO 2019. Table 3 Fuel Prices for the Pacific Region. Available at: https://www.eia.gov/outlooks/aeo/data/browser/#/?id=3-AEO2019&region=1-9&cases=ref2019&start=2017&end=2050&f=A&linechart=ref2019-d111618a.3-3-AEO2019.1-9&map=ref2019-d111618a.4-3-AEO2019.1-9&sourcekey=0. Accessed: January 2021.

[29] LCFS Credit Generation Opportunities. Available at: https://ww2.arb.ca.gov/our-work/programs/low-carbon-fuel-standard/lcfs-credit-generation-opportunities. Accessed: December 2020.

5. SCENARIO ANALYSIS EMISSIONS RESULTS

5.1 Tailpipe NO_X Emissions

Figure 5-1 below presents the estimated total NO_X tailpipe (vehicle exhaust) emissions from the statewide HHDTs excluding SWCVs for calendar year 2020 to 2050 for each modeled scenario: S0 - Baseline EMFAC2017 (represented by black line), S1 – CARB Long-Term Scenario (represented by the orange line), S2 - Low NO_X NG with ACT (represented by blue line), S3 – Low NO_X NG without ACT (represented by green line), S4 – Low NO_X NG with SCAQMD 2016 AQMP & ACT (represented by purple line), S5 – CA Low NO_X DSL with ACT (represented by yellow line), and S5 – CA Low NO_X DSL with ACT (represented by grey line). Renewable fuels are not expected to change NO_X tailpipe emissions relative to the corresponding conventional fuels they displace; therefore "A1" and "B1" sub-scenarios show the same tailpipe NO_X emission estimates for each modeled scenario.

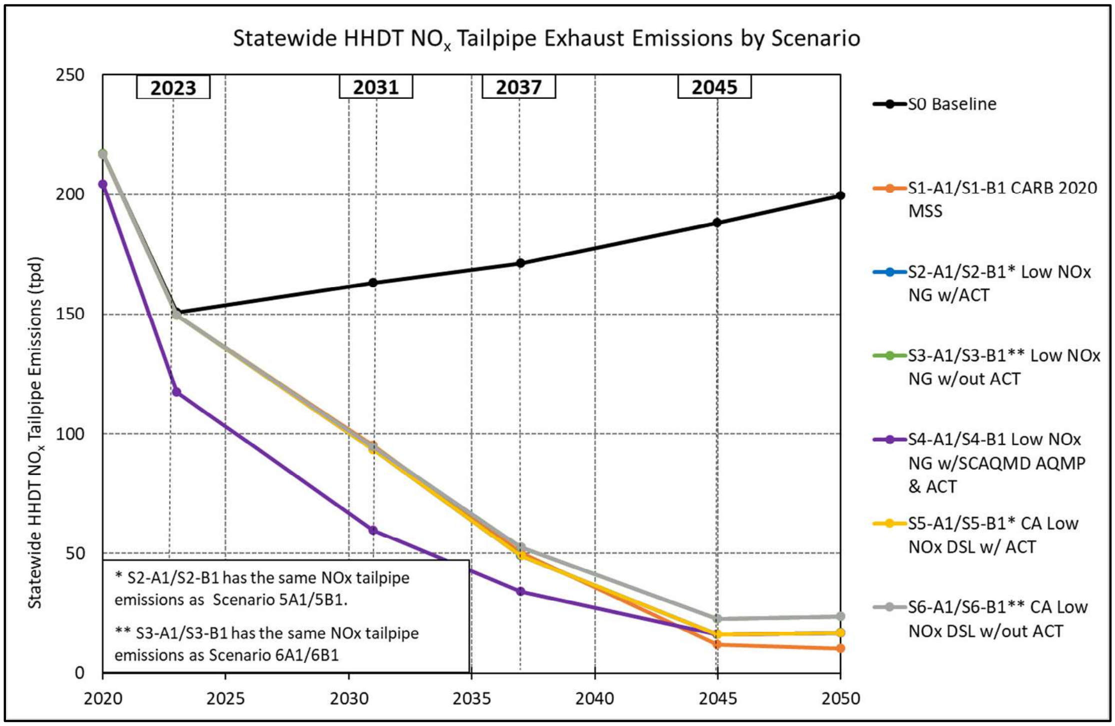
The results of the scenario analysis demonstrate that all modeled scenarios with Low NO_X engines (S2 through S6) can achieve similar NO_X reductions (compared to the baseline Scenario S0) as the CARB Long-Term Scenario (S1) presented in the 2020 MSS. In fact, as seen in **Figure 5-1** and **Figure 5-2** Scenario S4, which assumes the early adoption of Low-NO_X NG HHDTs to meet or exceed fleet mix requirements from the SCAQMD's 2016 AQMP, achieves greater NO_X reductions (compared to the baseline Scenario S0) sooner than CARB's Long-Term Scenario (S1). The CARB scenario (S1) achieves only 3% of the tailpipe NO_X emission reductions (compared to Baseline Scenario 0) that a multi-technology deployment of near-zero emission HHDTs consistent with the 2016 MSS SIP (S4) would have achieved in 2023; even by 2031, the CARB scenario only achieves 66% of the tailpipe NO_X reductions Scenario 4 would have achieved in 2031. Strategies that fail to deploy early adoption of near-zero emission trucks as CARB committed to in the 2016 MSS SIP (a key component of the SCAQMD's 2016 AQMP[30] and SJVAPCD's 2016 San Joaquin Valley SIP[31] and 2018 supplements[32]) forgo necessary near-term NO_X emission reductions needed to meet 2023 and 2031 ozone attainment deadlines in South Coast Air Basin and San Joaquin Valley.

---

[30] SCAQMD. Final 2016 AQMP-CARB/EPA/SIP Submittal. Available at: https://www.aqmd.gov/home/air-quality/clean-air-plans/air-quality-mgt-plan/final-2016-aqmp. Accessed: January 2021.

[31] SJVAPCD. 2016 Plan for the 2008 8-Hour Ozone Standard. Available at: https://www.valleyair.org/Air_Quality_Plans/Ozone-Plan-2016.htm. Accessed: January 2021.

[32] SJVAPCD. 2018 PM 2.5 Plan for the San Joaquin Valley. Available at: https://www.valleyair.org/pmplans/. Accessed: January 2021.



* S2-A1/S2-B1 has the same NOx tailpipe emissions as Scenario 5A1/5B1.

** S3-A1/S3-B1 has the same NOx tailpipe emissions as Scenario 6A1/6B1

Figure 5-1. Statewide HHDT NO$_X$ Tailpipe Exhaust Emissions by Scenario

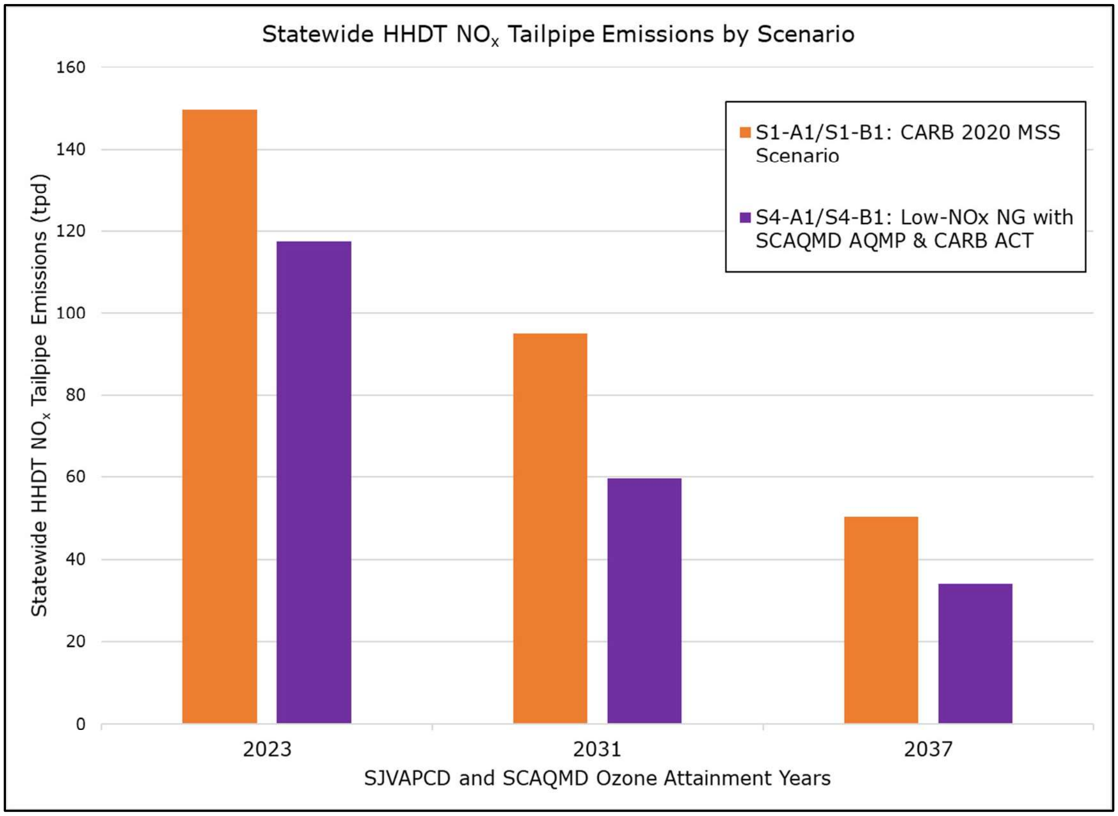
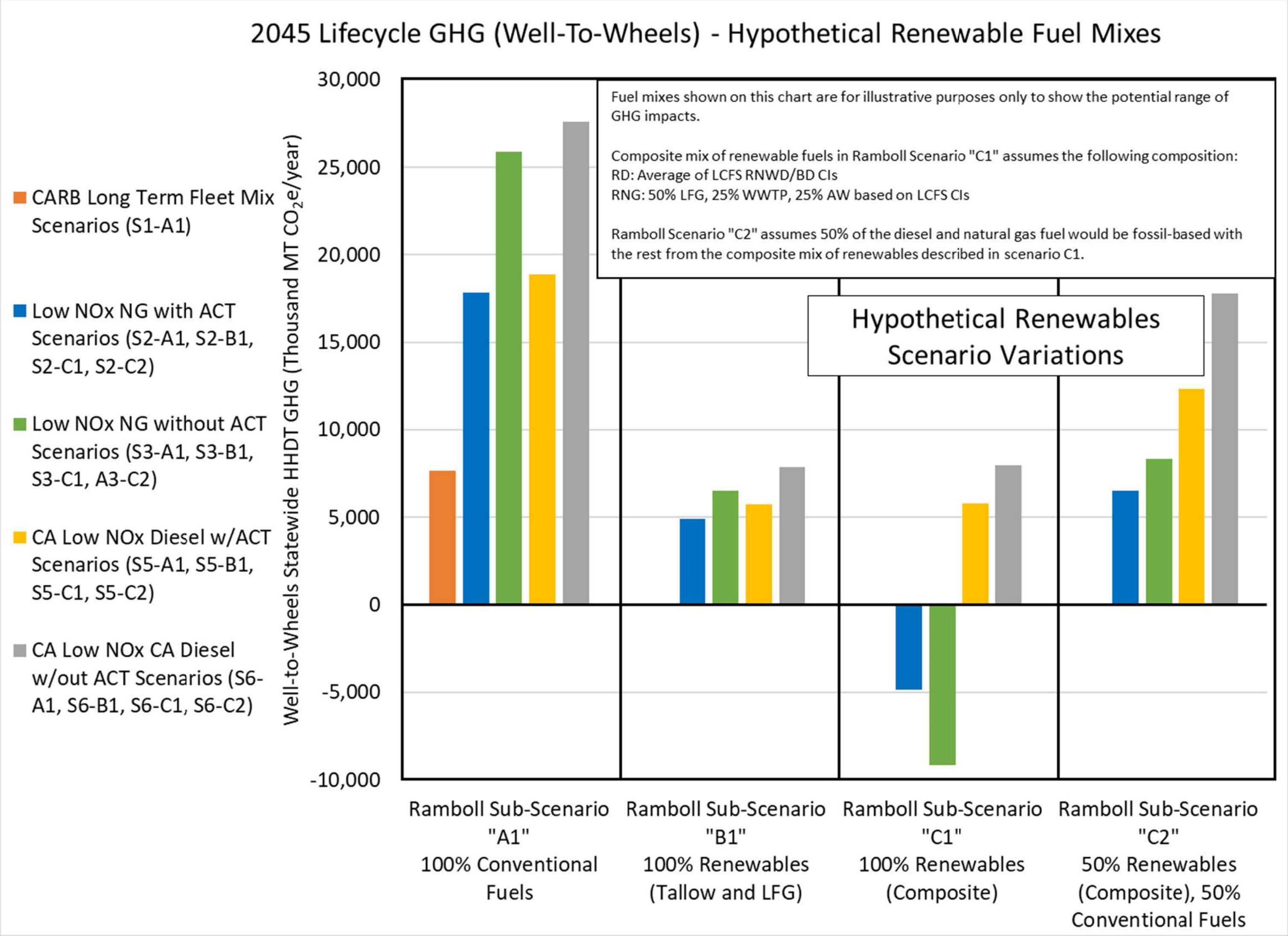


Figure 5-2. Statewide HHDT NO$_X$ Emissions Comparison by Scenario

5.2 GHG Emissions

Figure 5-3 provides a comparison of well-to-wheel (“lifecycle”) GHG emissions associated with the statewide HHDT fleet excluding the SWCVs in calendar year 2045 for the following modeled scenarios: S1 – CARB Long-Term Scenario (represented by the orange bar), S2 - Low NO_X NG with ACT (represented by blue bar), S3 – Low NO_X NG without ACT (represented by green bar), S5 – CA Low NO_X DSL with ACT (represented by yellow bar), and S5 – CA Low NO_X DSL with ACT (represented by grey bar) . As summarized previously in **Table 3-1**, sub-scenarios B1, C1, and C2 explore the use of renewable fuels to generate GHG emission reductions needed to meet the State’s long-term climate goals. The results presented in **Figure 5-3** show that the use of renewable fuels (sub-scenarios B1, C1, and C2) along with near-zero vehicle technologies (Scenarios S2, S3, S5, and S6) such as Low NO_X NG and Low NO_X DSL engines can generate GHG reductions similar to CARB Long-Term Scenario (S1). Further, Scenarios S2-C1 and S3-C1, which model an accelerated turnover of the statewide HHDT fleet (excluding SWVCs) to Low-NO_X NG vehicles fueled by a composite mix of renewable NG, could result negative lifecycle GHG emissions.



Fuel mixes shown on this chart are for illustrative purposes only to show the potential range of GHG impacts.

Composite mix of renewable fuels in Ramboll Scenario "C1" assumes the following composition:
RD: Average of LCFS RNWD/BD CIs
RNG: 50% LFG, 25% WWTP, 25% AW based on LCFS CIs

Ramboll Scenario "C2" assumes 50% of the diesel and natural gas fuel would be fossil-based with the rest from the composite mix of renewables described in scenario C1.

Figure 5-3. 2045 Well-to-Wheels GHG Emissions

5.3 Summary of Scenario Analysis Results

The tailpipe NO_X and lifecycle GHG emissions results of Ramboll's scenario analysis presented in Sections 5.1 and 5.2 clearly indicate that CARB can develop a multi vehicle/fuel technology pathway for mobile sources that not only achieves the much needed near-term NO_X reductions in SCAB and SJV by early adoption of Low NO_X vehicle technologies, but also achieves sufficient GHG reductions to meet the State's long-term climate goals through the increased use of liquid and gaseous renewable fuels.

6. COST ANALYSIS RESULTS

6.1 Total Cost of Ownership Results

The results of Ramboll's cost analysis demonstrate that Low-NOx HHDTs can deliver equivalent operational cost savings as BEVs, with a lower purchase cost and without additional infrastructure investments. **Figures 6-1 and 6-2** show the projected total cost of ownership for a 10- and 15-year useful life analysis for each truck technology: Conventional Diesel HHDT (light yellow), Federal Low-NOx Diesel HHDT (blue), CA Low-NOx Diesel HHDT (Orange), Low-NOx NG HHDT (purple), MY2018 BEV (green) and MY2024 BEV (green). Costs associated with charger and installation are show in hatched dark green. With the exception of BEV-2018 costs, all vehicles analyzed are MY2024 vehicles. As stated previously, Ramboll assessed the cost of both a MY2018 and MY2024 BEV given the variability in HD battery cost projections. These concerns are further elaborated in **Section 6.3.1** of this report. While the inclusion of LCFS credits for electric charging may result in up to $88,000 of revenue for a 10-year truck lifetime (up to $181,000 of revenue for a 15-year truck lifetime), the earnings from this potential revenue have not been included in the Ramboll cost analysis given uncertainties in future market conditions and availability of credit deficits in the LCFS program in future years. From these results, under both a 10-year and 15-year useful life analysis, the total projected cost of ownership for low-NOx trucks is below that of BEVs, even without accounting for vehicle replacement ratio differences.

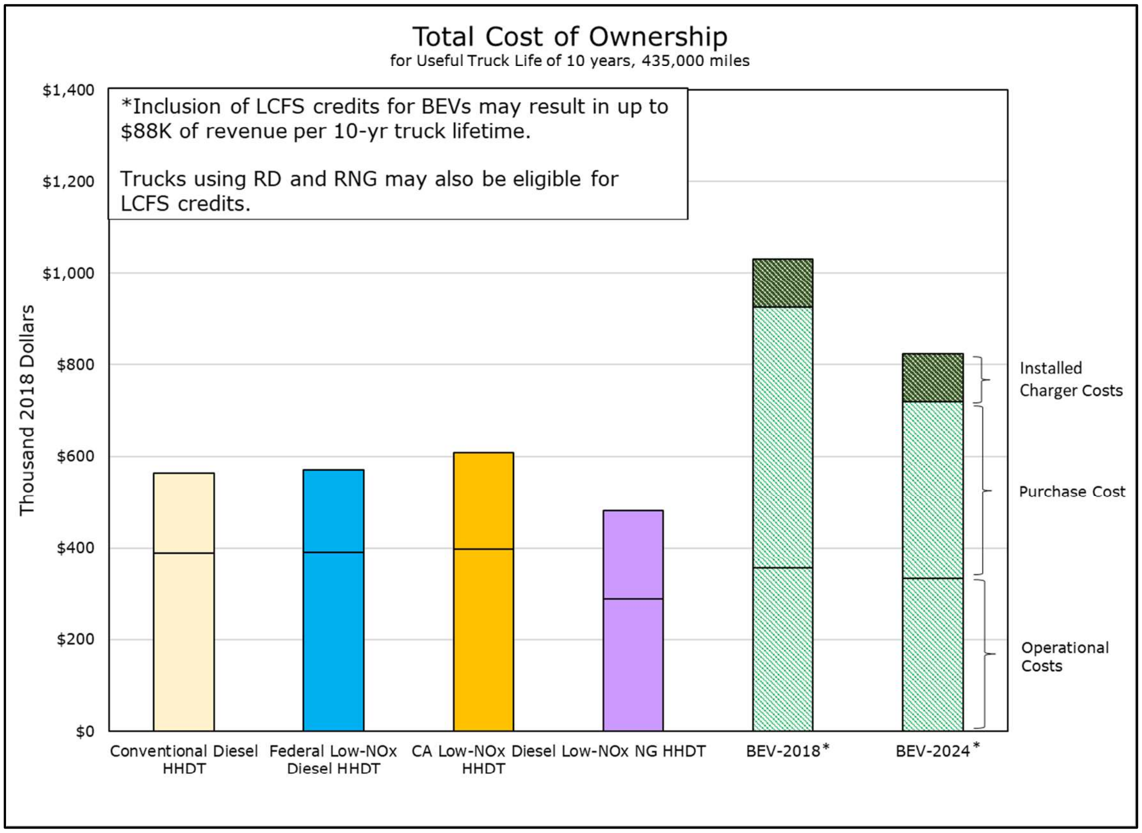


Figure 6-1. Total Cost of Ownership Results for a 10-year Useful Life

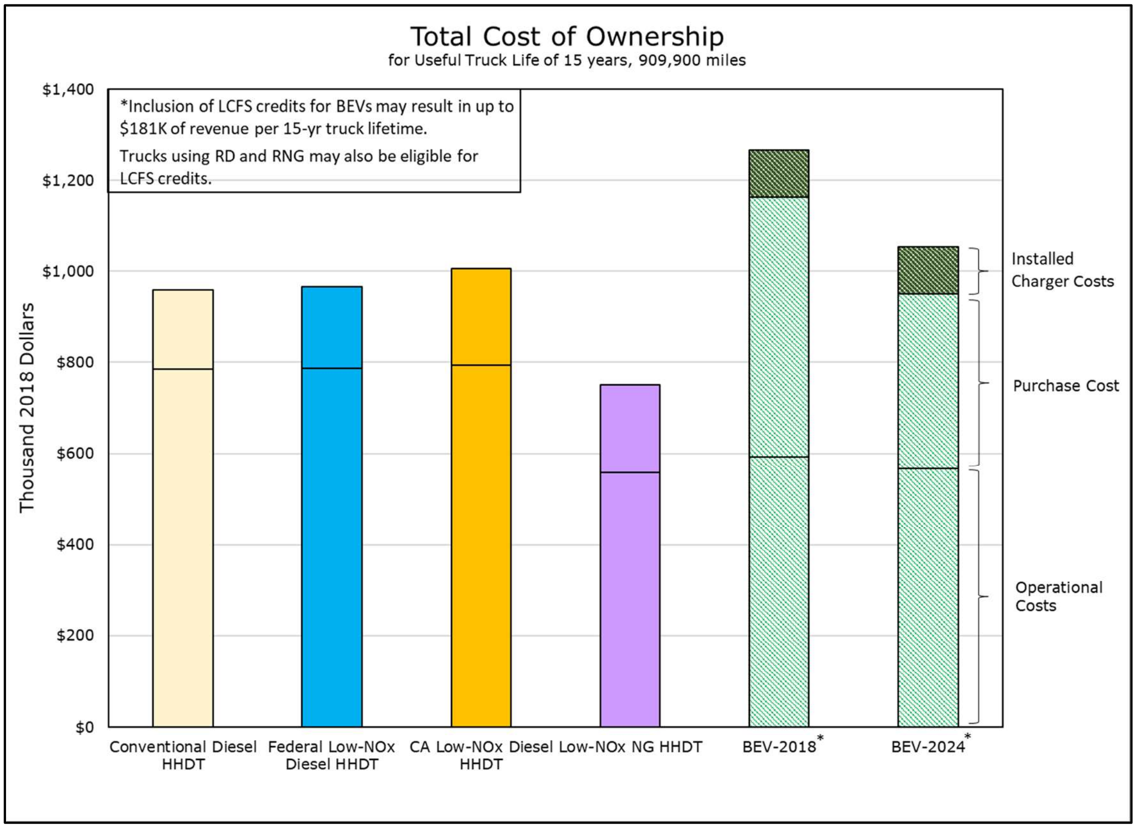


Figure 6-2. Total Cost of Ownership Results for a 15-year Useful Life

Figure 6-3 provides a comparison between the TCO analysis for conventional diesel HHDT, BEV-2018 and BEV-2024 from CARB Advanced Clean Truck (ACT) Regulation[33] and the Ramboll Analysis. Total cost of ownership is broken down by vehicle purchase cost (gray), financing costs (light blue), charger and infrastructure costs (green), and total operational costs (dark blue). Where possible, Ramboll analysis used cost assumptions from the CARB ACT regulation, nonetheless, due to the following key differences between both analyses, CARB's TCO results for BEVs (labelled as ACT ISOR 12-yr TCO in graph) are much lower than the Ramboll BEV TCO results:

- CARB's analysis reduces BEV operational costs by $130,000 to $170,000 to account for revenues generated from LCFS credits. As described earlier, Ramboll's analysis does not account for these credits.
- CARB's costs are discounted to net present value, while Ramboll's analysis reports costs in 2018 dollars.
- CARB's analysis includes financing costs for the purchase of the vehicle and charger while the Ramboll's analysis does not include this cost.
- CARB's analysis does not include infrastructure upgrade and maintenance costs in its final TCO calculation even though these assumptions are provided in the CARB ACT ISOR. Ramboll uses the cost assumptions in CARB ACT ISOR to estimate infrastructure upgrade costs.

---

[33] CARB ACT ISOR Appendix H. Available at: https://ww3.arb.ca.gov/regact/2019/act2019/apph.pdf. Accessed: January 2021.

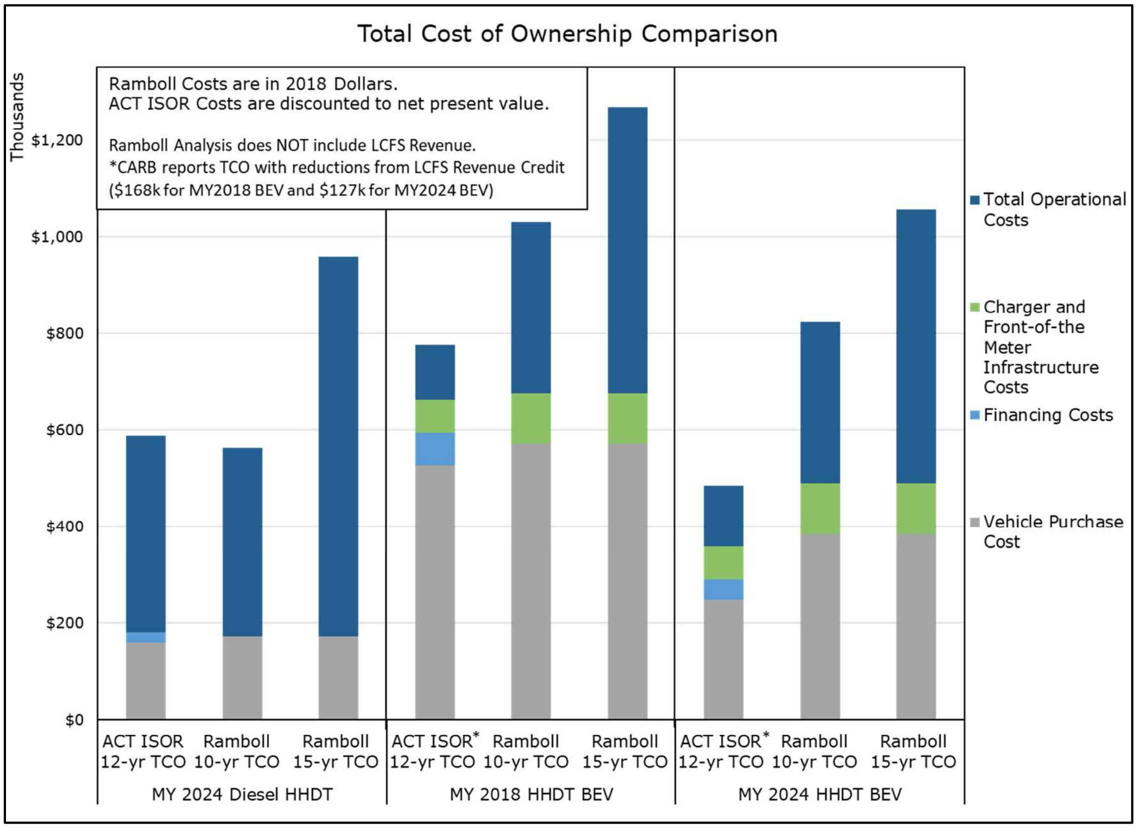


Figure 6-3. Comparison between Ramboll and CARB ACT TCO Analyses

Among the above-mentioned differences in CARB's and Ramboll's analysis approach, the primary driver for the significantly lower TCO for BEV's in CARB's analysis is the revenue generated from LCFS credits. CARB has potentially under-represented BEV operational costs by assuming significant LCFS credit offsets and projecting electricity prices up to 10% lower than those presented in the US Department of Energy's (US DOE) Annual Energy Outlook (AEO) 2018.[34] CARB estimates that LCFS credit revenues of roughly $130,000 to $170,000 per truck can be used to offset already low electricity fuel costs. This assumption fails to consider that LCFS credit revenue depends on future market conditions and availability of credit deficits from the production of higher carbon intensity fuels. Availability of LCFS credits out to the 10-15-year lifetime of a truck has not been demonstrated. Further, with the large-scale electrification of trucks that CARB is considering in the 2020 MSS, BEV truck operators who do not have the real estate to install chargers at their facility will likely charge their vehicles at private/public charging stations. There operators would; therefore, be unable to reap the benefits of LCFS credits which would go the charging station owners.

CARB's economic analysis assumes a 1:1 BEV to diesel vehicle replacement ratio, an assumption that ignores the operational implications of BEV usage in the HDT sector and provides a favorable TCO for HD BEVs compared to the diesel HDT that they replace. Previous studies on HD BEVs, specifically bus fleet operations, have shown that due to increased vehicle weight, limited battery range, long

---

[34] EIA AEO 2018. Table 3 Fuel Prices for the Pacific Region. Available at: https://www.eia.gov/outlooks/aeo/data/browser/#/?id=3-AEO2018&region=1-9&cases=ref2018&start=2016&end=2050&f=A&linechart=ref2018-d121317a.3-3-AEO2018.1-9&map=ref2018-d121317a.4-3-AEO2018.1-9&sourcekey=0. Accessed: January 2021.

charging times and unfavorable charging windows, more than one battery electric bus (BEB) will be needed to replace a conventional diesel bus. For example, some transit agencies have found that BEBs are unable to be used on many of their "route blocks" (a route block is a vehicle schedule, the daily assignment for an individual bus). The Victor Valley Transit Agency found that BEBs can only be used on 15 of their 56 route blocks, with the optimistic assumption that BEBs are able to achieve ranges of 250 miles.[35]

Lastly, CARB's economic analysis uses highly optimistic vehicle price projections for BEVs in 2024 and beyond. As described in more detail in **Section 5.3**, these price projections rely on optimistic battery price assumptions from Bloomberg Energy's light duty vehicle battery costs,[36] and as such may overestimate the cost savings from the purchase of BEVs.

6.2 Cost Effectiveness Results

Cost-effectiveness is the measure of the cost (in dollars) of a projected vehicle technology for each ton of emissions reduced. In Ramboll's TCO analysis, NO_X tailpipe cost effectiveness is calculated by dividing the incremental TCO of a vehicle (compared to a conventional diesel HHDT) by the total lifetime tailpipe NO_X emissions reductions (compared to that of a conventional diesel HHDT). A negative cost effectiveness indicates that an HHDT technology has a lower cost compared to that of a conventional diesel HHDT and, as such, is highly cost effective in achieving emission reductions.

Figure 6-4 and Figure 6-5 show the NO_X tailpipe cost effectiveness for analyzed HHDT technology types for a 10-year and 15-year truck life, respectively. The red line illustrates the typical maximum regulatory cost effectiveness of roughly $50,000/ton of NO_x reductions.[37] The cost-effectiveness values for Low NO_X Diesel and Low NO_X NG HHDT are well below this value when considering a 10-year or 15-year truck life and are always more cost-effective than the BEVs. The BEV-2018 is 2 to almost 8 times less cost-effective than the typical maximum regulatory threshold of $50,000/ton of NO_X reductions (15-year and 10-year truck life, respectively). If battery costs drop as assumed by CARB 2016 HD battery paper, operational cost savings materialize (given the concerns raised above about realizing the LCFS credits), and additional behind-the-meter electrical infrastructure costs are not accounted for, the BEV-2024 cost-effectiveness is below $50,000/ton of NO_X reductions for a 15-year truck life because of the increased operational cost benefits and NO_X reductions achieved over

---

[35] Presentation by the Victor Valley Transit Agency at the 2019 California Desert Air Working Group. Available at: https://www.mdaqmd.ca.gov/home/showdocument?id=6973. Accessed December 2020.

[36] Bloomberg 2019 Better Batteries Report. Available at: https://www.bloomberg.com/quicktake/batteries. Accessed: December 2020.

[37] This value was estimated based on a review of the following documents:

- Cost effectiveness values for CARB's on-road heavy-duty mobile source measures reported in the SCAQMD's 2016 AQMP range from a negative value to $296,000. Available at: http://www.aqmd.gov/docs/default-source/clean-air-plans/socioeconomic-analysis/final/sociofinal_030817.pdf?sfvrsn=2. Accessed: January 2021.
- CARB's Carl Moyer Program uses a maximum cost effectiveness limit of $30,000 per weighted ton of emission reductions to evaluate funding eligibility. Available at: https://ww3.arb.ca.gov/msprog/moyer/guidelines/2017gl/2017_cmp_gl_volume_1.pdf. Accessed: January 2021.
- SCAQMD's guidance for evaluating Best Available Control Technology (BACT) uses a maximum cost effectiveness value of ~$29,000 per ton of NO_x reductions. Available at: http://www.aqmd.gov/docs/default-source/bact/cost-effectiveness-values/bact-cost-effectiveness-4th-qtr-2019.pdf. Accessed: January 2021.

the additional 5-year truck life, but is still less cost-effective than the other low-emission trucks by a factor of 2 or greater.

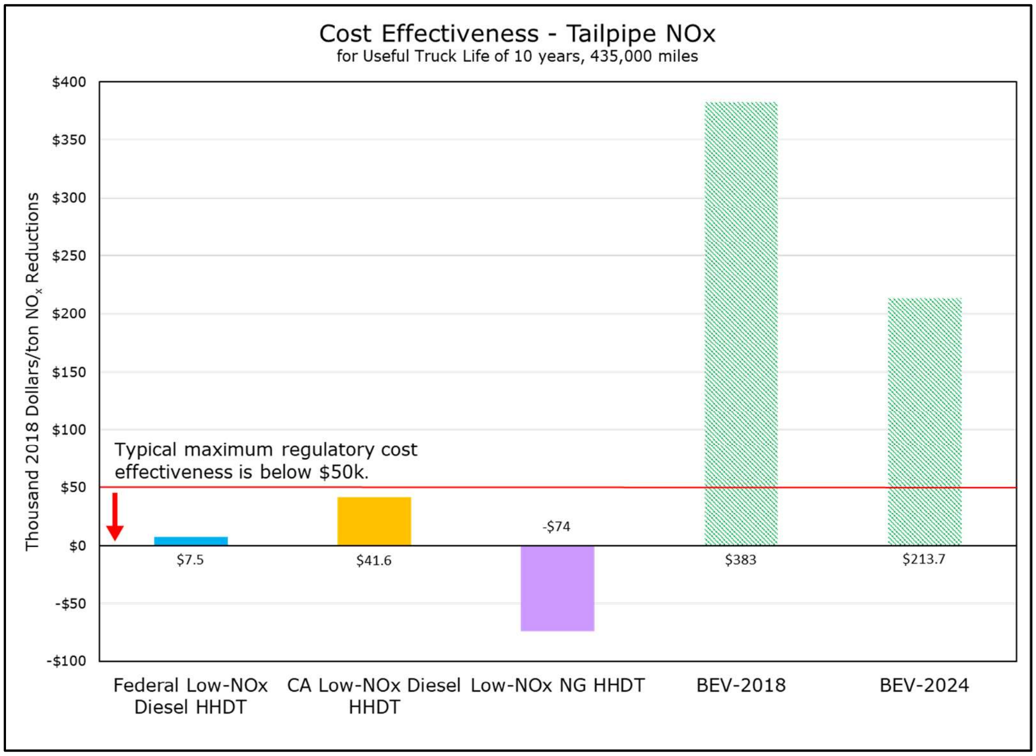


Figure 6-4. Tailpipe NO_X Cost-Effectiveness for a 10-year Truck Life

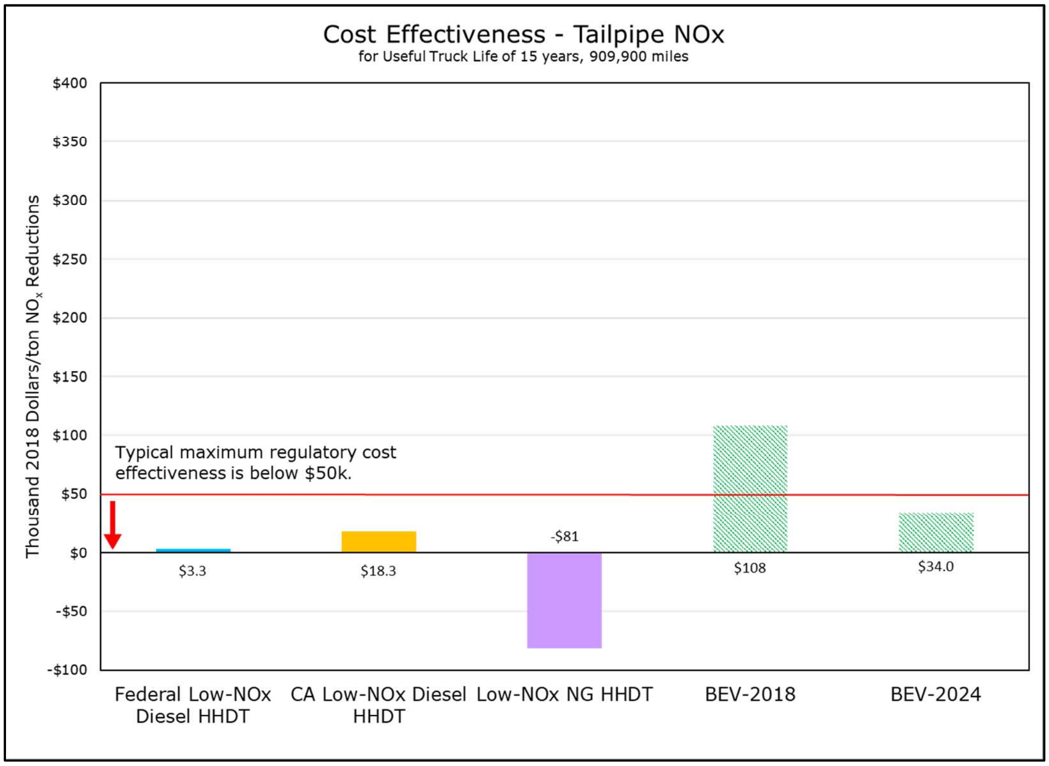


Figure 6-5. Tailpipe NO_X Cost Effectiveness for a 15-year Truck Life

6.3 Data Gaps and Key Concerns

There are a number of data gaps and concerns surrounding the assumptions used in the TCO analysis. These are discussed briefly in the following sub-sections.

6.3.1 Battery Costs and Availability

As shown in **Table 6-1** below, the CARB ACT regulation provided four data sources to future cost projections of batteries used in HHDTs. For the economic analysis that CARB performed for the ACT regulation, they used the data point that was most favorable to BEVs, Bloomberg Energy's light-duty (LD) battery cost assumptions[38] with a five-year delay, that projects a 52% decline in HHDT BEV purchase costs by 2024 as compared to 2018. As shown in **Figure 6-6**, by using the Bloomberg "5-year LD delay" projections, heavy-duty battery costs would be comparable to light-duty battery costs by 2024. This assumption that HD battery costs will see similar price declines as LD batteries has not been substantiated by existing HD battery reports. According to US DOE's 2019 Report[39] on medium- and heavy-duty vehicle (MHDV) electrification, while LDV battery costs have reduced substantially, these reductions have not been realized in the MHDV sector due to low volume purchases and customized pack specifications. The report states that MHDV-specific requirements such as high lifetime mileage, deeper discharges per cycle, overall ruggedness, and resistance to temperature extremes, along with low sales volumes are likely result in incremental vehicle costs as high as 50%-100% of the price of a conventional truck. Given these considerations, Ramboll TCO

---

[38] Bloomberg 2019 Better Batteries Report. Available at: https://www.bloomberg.com/quicktake/batteries. Accessed: December 2020.

[39] US DOE Medium- and Heavy-Duty Vehicle Electrification Report. Available at: https://info.ornl.gov/sites/publications/Files/Pub136575.pdf. Accessed: January 2021.

analysis conservatively uses battery cost assumptions from CARB's HD Battery Report,[40] rather than the Bloomberg "5-year LD delay" projections, to calculate the purchase cost of a MY2024 BEV. Note, for MY2018 BEV, Ramboll Analysis used purchase cost assumptions from the Bloomberg "5-year LD delay" to be consistent with CARB assumptions. BEV purchase costs used in the Ramboll TCO analysis are bolded in **Table 6-1** below.

Table 6-1. BEV Purchase Cost (without tax) by Battery Cost Source

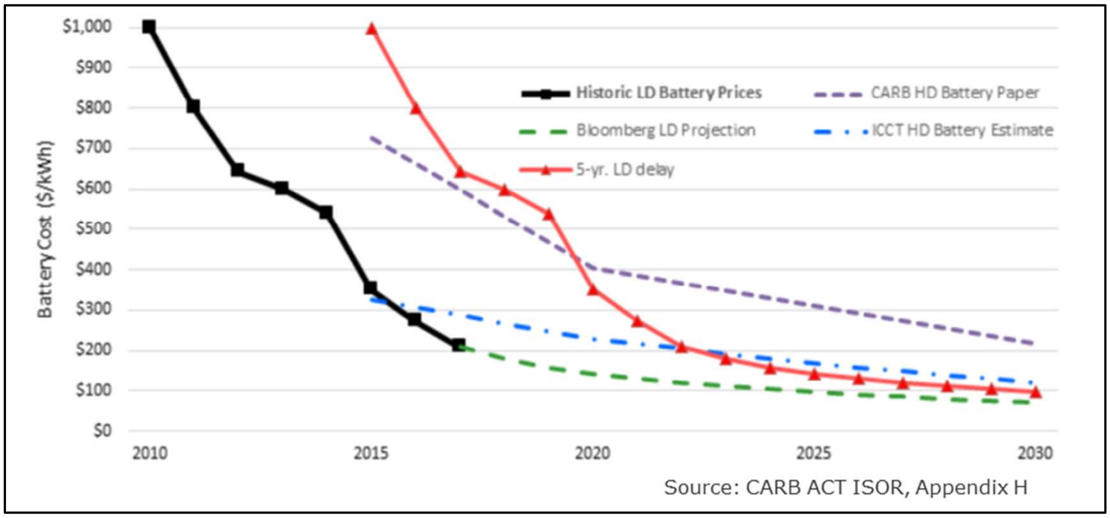
	CARB HD Battery Paper[1]	CARB ACT ISOR[2] (Bloomberg 5-yr LD Delay)	ICCT HD Battery Estimate[1]	Bloomberg LD Projection[1]
2018 HHDT BEV Purchase Cost[3]	$437,706	**$474,930**	$288,368	$238,944
2024 HHDT BEV Purchase Cost[3]	**$320,374**	$232,155	$236,111	$193,251

Notes:

[1] These purchase costs are pulled from the CARB ACT Draft Cost Calculator, which is an attachment to the ACT ISOR rulemaking documents. Available at: https://ww2.arb.ca.gov/sites/default/files/2019-05/190508tcocalc_2.xlsx. Accessed: December 2020.

[2] These purchase costs are pulled from Table 5 of the CARB ACT ISOR Appendix H (Available at: https://ww3.arb.ca.gov/regact/2019/act2019/apph.pdf. Accessed: November 2020.). Note, these values are slightly different from outputs in the CARB ACT Draft Cost Calculator.

[3] These costs assume the purchase of a 510 kWh BEV and do not include tax.



Source: CARB ACT ISOR, Appendix H

Figure 6-6. Battery Cost Projections from the CARB ACT ISOR[41]

---

[40] CARB 2016 Battery Cost for Heavy-Duty Electric Vehicles. Available at: https://www.arb.ca.gov/msprog/bus/battery_cost.pdf. Accessed: December 2020.

[41] CARB ACT ISOR Appendix H. Available at: Available at: https://ww3.arb.ca.gov/regact/2019/act2019/apph.pdf. Accessed: November 2020.

6.3.2 Government Electricity Price Projections

The CARB ACT ISOR[25] projects electricity prices at rates lower than those reported by the US Energy Information Administration (EIA) Annual Energy Outlooks (AEO) for 2018[34] and 2019[42] for the Pacific Region. As shown in **Figure 6-7** below, CARB ACT ISOR[25] sources its electricity prices from EIA AEO 2018 report and adjusts prices to be roughly $0.02/kWh lower than those reported in the 2018 report. Since CARB ACT ISOR[25] has not substantiated these lower electricity cost projections, the Ramboll Cost Analysis uses electricity prices from the most recent AEO released in 2019. **Appendix B** provides more information regarding fuel prices used in the Ramboll Cost Analysis.

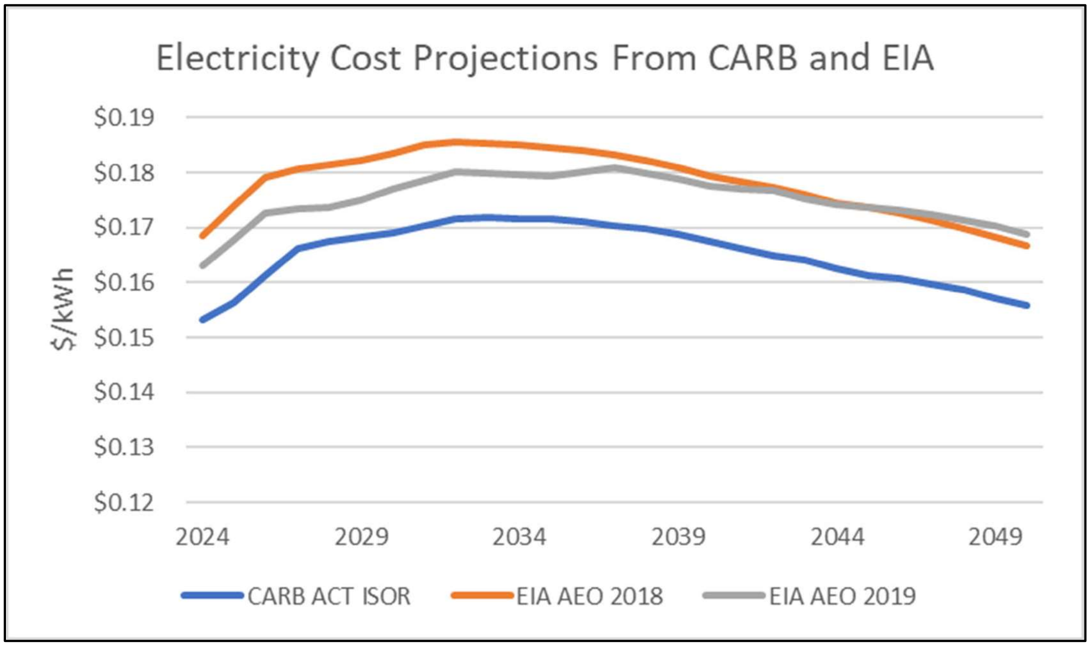


Figure 6-7. Electricity Cost Projections

6.3.3 Lack of Publicly Available Information to Make Renewable Fuel Availability and Price Projections

Due to limited literature surrounding projections of renewable fuel production and prices, Ramboll was unable to analyze the availability of renewable fuels needed to meet the fuel volumes of the renewable fuel scenarios (Scenarios “B1”, “C1” and “C2”). Existing literature reports recent growth in California renewable fuel usage, with biodiesel usage tripling between 2015 and 2019 and RNG increasing by 475% in the same time frame.[43] In 2019, roughly 80% of California transportation NG usage was comprised of RNG. US RNG production is expected to grow by a factor of ten between 2025 and

---

[42] EIA AEO 2019. Table 3 Fuel Prices for the Pacific Region. Available at: https://www.eia.gov/outlooks/aeo/data/browser/#/?id=3-AEO2019&region=1-9&cases=ref2019&start=2017&end=2050&f=A&linechart=ref2019-d111618a.3-3-AEO2019.1-9&map=ref2019-d111618a.4-3-AEO2019.1-9&sourcekey=0. Accessed: December 2020.

[43] GNA, 2020. The State of Sustainable Fleets 2020. Available at: https://www.stateofsustainablefleets.com/. Accessed: January 2021.

2040.[44] While research reports promise the growth of renewable fuels, more detailed data on fuel production and price projections are needed to access the feasibility and cost effectiveness of the renewable scenarios presented in the Ramboll Scenario and Cost analysis. Current retail prices for renewable diesel are available from the US DOE,[45] nonetheless, these reports do not provide price projections.

6.3.4 Other Unaccounted-for Costs

Additional data gaps include the need to estimate costs of increased grid generating capacity, expanded transmission and distribution (T&D), and grid impacts due to increased renewables demand in order to meet increasing electricity usage that would result from electrification of the mobile sector.

While infrastructure needed for gaseous fuel production is not expected to expand significantly, electrification strategies would require additional infrastructure upgrades. This would include, for example, the addition of in-route charging facilities for point-to-point delivery. Analyzing these additional charging infrastructure costs, among other grid related improvements, would require close collaboration with other government agencies in order to estimate and prepare for such a transition.

In 2020, Energy Marketers of America (EMA) conducted a national utility infrastructure study which concluded that EV transmission and distribution (T&D) infrastructure costs would be roughly $5,100 per EV for an average 10-year vehicle life.[46] This study reviewed three nation-wide 2030 electrification scenarios of light-duty EVs and on-road freight EVs. Depending on the EV penetration scenario, total T&D investments can range from $35–$146 billion by 2030. If these costs were borne solely by EV owners, each owner would have to pay more than $500 a year per EV or $9 every time they completely charge their 75-kWh battery vehicle. Given the results of this study, further research is needed to estimate the cost of new EV infrastructure in California.

Lastly, recent regulatory reporting by California transit agencies strongly cautions against uncritically accepting CARB's estimates of electric vehicle and related infrastructure costs. Recent reports from transit agencies[47,48,49,50] have shown that CARB projections[51] in the Innovative Clean Transit (ICT) regulation are significantly different from real world experiences. As seen in the graph below, these reports have demonstrated that Transit operators face BEV charging infrastructure costs significantly higher than CARB ICT estimates. some transit agencies have found that zero emission buses (ZEBs)

---

[44] American Gas Foundation, 2019. Renewable Sources of Natural Gas: Supply and Emissions Reduction Assessment, Figure 6. Available at: https://gasfoundation.org/2019/12/18/renewable-sources-of-natural-gas/. Accessed: January 2021.

[45] US Department of Energy Alternative Fuels Data Center, Alternative Fuel Price Report. Available online at: https://afdc.energy.gov/fuels/prices.html. Accessed: January 2021.

[46] EMA Utility Investments and Consumer Costs of Electric Vehicle Charging Infrastructure. Available at: https://www.energymarketersofamerica.org/ema_today/attachments/Energy_Marketers_of_America_Study-Utility_Infrastructure_for_EVs.pdf. Accessed: January 2021.

[47] AC Transit Rollout Plan. Available at: http://www.actransit.org/wp-content/uploads/AC-Transit-ZEB-Rollout-Plan_06102020.pdf. Accessed: January 2021.

[48] Foothill Transit Rollout Plan. Available at: http://foothilltransit.org/wp-content/uploads/2014/05/Burns-McDonnell-In-Depot-Charging-and-Planning-Study.pdf. Accessed: January 2021.

[49] Long Beach Transit ZEB Rollout Plan. Available at: https://cafcp.org/sites/default/files/Long-Beach-Transit-Zero-Emission-Rollout-Plan.pdf. Accessed: January 2021.

[50] Omnitrans ZEB Rollout Plan. Available at: https://www.gosbcta.com/wp-content/uploads/2020/05/Final-Omnitrans-Rollout-Plan.pdf. Accessed: January 2021.

[51] CARB ICT Cost Calculator. Available at: https://ww2.arb.ca.gov/resources/documents/battery-electric-truck-and-bus-charging-cost-calculator. Accessed: January 2021.

are unable to be used on many of their "route blocks" (a route block is a vehicle schedule, the daily assignment for an individual bus). Further, the Victor Valley Transit Agency found that ZEBs can only be used on 15 of their 56 route blocks, with the optimistic assumption that ZEBs are able to achieve ranges of 250 miles.[52] These concerns may also affect medium- and heavy-duty fleets. For example, this may result in:

- the need for fleets to purchase more ZEVs to meet the same operating capacity as the vehicles they are replacing;
- fleet operators finding that portions of their fleet cannot run their full routes; and
- infrastructure costs significantly higher than cost estimates.

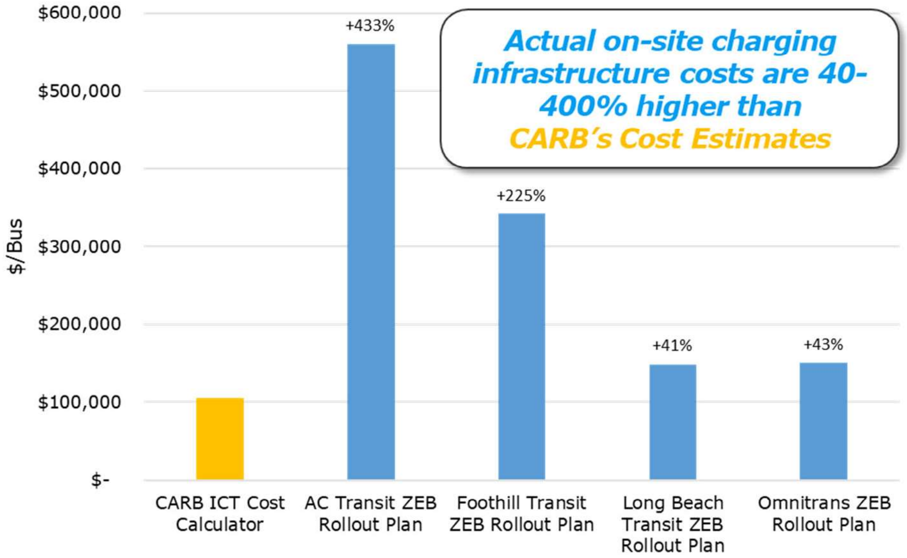


Figure 6-8. Zero Emission Bus (ZEB) Depot Charging Infrastructure Costs

---

[52] Presentation by the Victor Valley Transit Agency at the 2019 California Desert Air Working Group. Available at: https://www.mdaqmd.ca.gov/home/showdocument?id=6973. Accessed October 2020.

7. CONCLUSIONS

7.1 Summary of Analysis Conclusions

Ramboll's analysis suggests that expanded implementation of zero-emission and low-NO_X vehicles, coupled with increased introduction of renewable liquid and gaseous fuels, can deliver earlier and more cost-effective benefits than a ZEV only approach. As advanced low-emitting trucks are commercially available to deliver benefits to communities sooner, with greater certainty, multi-technology pathways can help achieve emission reductions without reliance on infrastructure and technology upgrades that will take years to resolve. The main conclusions of our analysis are summarized below:

Meeting Emission Goals

- Near-term NO_X reductions and long-term GHG goals can be achieved with a mix of advanced low-emitting trucks and renewable fuels;
- A ZEV-only strategy will not deliver required near-term NO_X reductions needed in at-risk environmental justice communities;
- BEV technology has potential for longer-term emission benefits, but relies upon technology and infrastructure developments outside CARB's control or ability to incentivize; and
- There is a growing potential for renewable fuels, including those with negative carbon intensity, to meet long-term GHG reductions.

Achieving Cost effectiveness

- Low-emission heavy-heavy-duty trucks are cost-competitive with (or cheaper than) BEVs;
- Battery technology promises (greater energy density/lower cost) have been assumed but have not been demonstrated; and
- Low-emission heavy-heavy-duty trucks are currently certified and commercially available at scale today.[53]

These conclusions emphasize the need for CARB to conduct a similar analysis across all mobile source sectors, not just the heavy-heavy-duty truck sector, in order to identify existing opportunities to meet state emission goals earlier and more cost effectively.

7.2 Next Steps- Technical

By focusing on a strategy that relies on only on ZEVs, CARB's Mobile Source Strategy falls short of its Clean Air Act commitments to deliver ready, dependable near-term benefits. As such robust scenario analysis coupled with a fleet wide cost-benefit analysis should instead be conducted to develop a reasonable and achievable strategy for California's mobile source sector to meet state emission goals. Such an analysis should build out and evaluate multiple scenarios beyond the singular pathway proposed in the current MSS draft. This includes scenarios that assess the increased use of renewable liquid and gaseous fuels and low-NO_X technologies, as well as the use of market-based emission reduction strategies like Cap-and-Trade, to achieve emission reductions. Further, each scenario must be evaluated for technical feasibility, and as such would require an analysis of future fueling

---

[53] Optional Low NO_X Certified Heavy-Duty Engines. Available at: https://ww2.arb.ca.gov/sites/default/files/classic/msprog/onroad/optionnox/optional_low_nox_certified_hd_engines.pdf. Accessed: January 2021.

availability. This would include an assessment of electric grid reliability and availability of infrastructure that would be needed to support a potential transition to a larger ZEV fleet.

In addition to the exploration of multiple scenarios, CARB should assess all associated cost of each MSS scenario in order to identify cost-effective pathways to achieving the state's emission goals. This would include providing citations and justifications for assumptions of projected costs and, as necessary, include a range of potential costs when uncertainty is determined to be high. Further, a robust economic analysis is needed to identity the economic impacts on affected stakeholders.

Performing a robust feasibility and cost analysis as laid out in this section will help to provide the public, stakeholders, and the legislature with sufficient information to make informed decisions about the path to achieving California's emission goals.

7.3 Next Steps- Regulatory

In conducting technical analysis that will inform policy decisions, CARB should remain transparent and unbiased in the rulemaking process. As part of this process, CARB should conduct technical working groups to foster stakeholder participation in scenario development and assessment. Such coordination will help to address cost data gaps identified in **Section 5.3.** and ensure that reasonable and achievable strategies are developed in accordance with SB 44 requirements.

Our analysis confirms that a ZEV-centric approach that only focuses on long-term reductions will not provide the necessary near-term reductions needed to attain federal health standards in the most affected communities in California. With the urgency to achieve near-term criteria pollutant emission reductions, CARB must explore a variety of multi-technology pathways that can help the state achieve faster and surer emission reductions to fulfil its commitment to AB 617 communities and non-attainment areas. For longer-term greenhouse gas reduction goals, CARB should consider a variety of multi-technology pathways to broaden the use of lower carbon-intensity fuels and carbon capture technologies to complement electrification (with attendant statewide infrastructure improvement costs and delays) to reduce greenhouse gas emissions.

APPENDIX A
SCENARIO ANALYSIS ASSUMPTIONS AND DETAILED METHODOLOGY

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

Tailpipe Emissions

CARB's EMFAC2017 model[1] was used to estimate tailpipe emissions for oxides of nitrogen (NO_X) and greenhouse gases (GHGs) for all heavy-heavy duty trucks (HHDT) types included in this analysis. Because Ramboll's analysis considers a sub-set of the statewide heavy duty vehicle (HDV) fleet consisting of diesel HHDTs excluding solid waste collection vehicles (SWCV), EMFAC2017 was queried separately for all HHDTs and for SWCVs. First, EMFAC2017 was queried at the statewide level for scenario analysis years 2020, 2023, 2031, 2037, 2045 and 2050 to obtain total exhaust emissions, population, and fuel consumption data for all diesel HHDTs by model year. Specific inputs used in this query are as follows:

- Run Mode: Emissions
- Region Type: Statewide
- Region: California
- Calendar Year: 2020, 2023, 2031, 2037, 2045 and 2050
- Season: Annual
- Vehicle Category: EMFAC2007 Categories - HHDT
- Model Year: All Model Years
- Speed: Aggregated
- Fuel: DSL

Subsequently, EMFAC2017 was queried for all calendar years listed above using the same configuration but for T7 SWCVs using EMFAC2011 vehicle categories. All EMFAC outputs are included in **Table A-2 through Table A-43.**

To obtain data for the adjusted statewide HHDT fleet considered in this analysis, EMFAC outputs for diesel T7 SWCVs were subtracted from corresponding EMFAC outputs for all diesel HHDTs (which included diesel T7 SWCV) for each calendar year. The resulting data, representative of total exhaust emissions, population, and fuel consumption for the statewide diesel HHDT fleet excluding T7 SWCVs, was used to determine emissions and fuel consumption in the baseline scenario S0.

For the other scenarios considered in this analysis, tailpipe emissions for alternative technology HHDTs were calculated based on the adjusted EMFAC2017 data, fleet mix percentages, and the tailpipe emissions assumptions in **Table 3-2** of the main document. Specifically, total NO_X emissions for each calendar year in each scenario were determined using the percentage of the fleet comprised of each HHDT type in each model year and the percentage reduction in NO_X emissions relative to conventional diesel HHDT for each

---

[1] EMFAC2017 Database v1.0.2. Note this analysis was conducted before the release of EMFAC2017 v.1.0.3. Available at: https://arb.ca.gov/emfac/2017/. Accessed January 2021.

alternative HHDT technology type. Thus, tailpipe emissions were determined first on a per model year basis to account for the population of each HHDT type in each model year and the reduction in tailpipe NO_X emissions achieved by each HHDT type, and total emissions in each calendar year were calculated as the sum of tailpipe emissions across all HHDT types and all model years in that calendar year.

The fleet mix composition for each model year in each calendar year was determined based on the specific technology penetration assumptions for each scenario, as described in **Section 2** of the main document and shown in **Table A-1**. Similar to the 2020 MSS, accelerated turnover of older model year HHDTs to newer vehicles is assumed in all scenarios for calendar years 2031, 2037, 2045, and 2050, and calendar year 2023 for Scenario S4. Specifically, Ramboll's analysis assumes that a fraction of pre-2024 model year (i.e., all model years up to and including 2023) diesel HHDTs are retired and replaced with newer model year alternative HHDT technologies (i.e., low-NOx diesel, low-NOx NG, BEVs) in order to achieve 2020 MSS targets for conventional diesel HHDTs (i.e., Pre-2010 and 2010 Cert.) and the required penetration of newer, alternative HHDT technologies specific to each scenario in the target calendar years. The following describes the procedure used to implement accelerated turnover:

- First, the percentage of the EMFAC-derived HHDT population comprised of pre-2024 vehicles is determined for each target calendar year and compared to the percentage given in CARB's 2020 MSS Long Term Fleet Mix.
- The ratio of these to percentages provides the scaling factor that is used to determine the number of HHDTs in each pre-2024 model year that should be retired, and the population of HHDTs in all model years up to and including 2023 is adjusted accordingly.
- Next, the scaling factor for newer model year HHDTs is determined to ensure that the same number of trucks retried are allocated to the newer model years. This scaling factor is then applied to the EMFAC-derived population of all post-2023 model year HHDTs to obtain the adjusted population data.
- The resulting adjusted HHDT population data for each model year is then used as the basis to determine the fleet mix composition, which are based on the specific technology penetration assumptions for each scenario.

Accelerated turnover calculations are carried out separately for each calendar year but consistently across all scenarios, such that the scaling factors and number of trucks turned over varies between calendar years but is the same across all scenarios in a given calendar year. The resulting fleet mix population data for each scenario, aggregated by model year, is presented in **Figure 3-2** of the main document. Detailed population breakdown by HHDT technology type and model year for each calendar year are presented in **Table A-2 through Table A-43.**

Tailpipe emissions for GHGs are calculated using the same general methodology as tailpipe NO_X emissions. Note however that only BEVs provide a reduction in tailpipe GHG emissions and all other HHDT types are assumed to have the same tailpipe GHG emissions as conventional diesel HHDTs, as described in **Table 3-2** of the main document. Specifically, BEVs are assumed to have zero tailpipe emissions of CO_2, CH_4, and N_2O. GHG emissions are reported in units of carbon dioxide equivalent (CO_2e). CO_2e is calculated based on CO_2, CH_4, and N_2O emissions, using global warming potentials (GWPs) from the International Panel on

Climate Change (IPCC) Fourth Assessment Report (AR4).[2] The GWPs used for CO_2, CH_4, and N_2O are 1, 25, and 298, respectively.

GREET Model Inputs and Assumptions

Ramboll estimated well-to-tank (i.e., "upstream") NO_X and GHG emissions associated with fuel production and distribution for each analyzed fuel type (electricity, diesel, natural gas, renewable diesel from tallow, and renewable natural gas from landfill gas) using emission factors obtained from the CA-GREET 3.0 model. A summary of these emission factors is provided in **Table A-44**.

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) current grid mix data[3] and projections for each of the modeled calendar years 2020, 2023, 2031, 2037, 2045 and 2050.[4] **Table A-45** summarizes electricity grid mix inputs into the GREET model.

Ramboll also updated the default assumptions for renewable fuels transportation distances within CA-GREET 3.0 to more accurately represent fuel production and distribution within California. RNG pipeline distance is taken from CARB CA-GREET NG distribution assumptions.[5] Tallow and renewable diesel transportation distances are updated based on biodiesel rendering and retail facilities in California, as reported by Argonne National Laboratory[6] (ANL) and the Environmental Defense Fund.[7] Details regarding the adjusted metrics are provided in **Table A-46**.

As the conventional fuels are not expected to be sourced by in-state feedstock only, this analysis assumes that feedstock electricity mix for conventional fuels comes from a U.S. average grid mix. Electricity grid mix for production and processing of all fuels was assumed to come from a California grid-average electricity mix (CAMx).

Emission factors from CA-GREET 3.0 are obtained per unit of energy consumed for each fuel type. In order to calculate total upstream emissions for each scenario, the total amount of energy consumed of each fuel type is calculated using Energy Economy Ratios (EERs). 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. A summary of EER values used in this analysis are provided in **Table A-47**. EER values for Low-NOx Diesel and NG trucks were

---

[2] 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

[3] California Energy Commission 2018 Grid Mix Data. Available at: https://www.energy.ca.gov/data-reports/energy-almanac/california-electricity-data/2018-total-system-electric-generation. Accessed December 2020.

[4] 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: December 2020.

[5] 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: August 2020.

[6] ANL Tallow-Based Diesel Pathway in GREET. Available at: https://greet.es.anl.gov/publication-tallow-13. Accessed: August 2020.

[7] EDF Biodiesel in California. Available at: https://www.edf.org/sites/default/files/sites/default/files/content/Biodiesel%20Value%20Chain%20-%20August%202013.pdf. Accessed: August 2020.

sourced from CARB Low Carbon Fuel Standard.[8] EER values for battery electric trucks were adjusted to be consistent with HHDT BEV fuel economies reported in the CARB ACT regulation.[9]

---

[8] LCFS Regulation, 2019. Table 5. Available at: https://ww2.arb.ca.gov/sites/default/files/2020-07/2020_lcfs_fro_oal-approved_unofficial_06302020.pdf. Accessed November 2020.

[9] CARB ACT Cost Calculator. Available at: https://ww2.arb.ca.gov/sites/default/files/2019-05/190508tcocalc_2.xlsx. Accessed November 2020.

APPENDIX A TABLES
SCENARIO ANALYSIS ASSUMPTIONS AND DETAILED METHODOLOGY

APPENDIX A TABLES

A-1 Scenario Matrix
A-2 NOx and GHG Tailpipe Emissions for Scenario 0 in Calendar Year 2020
A-3 NOx and GHG Tailpipe Emissions for Scenario 0 in Calendar Year 2023
A-4 NOx and GHG Tailpipe Emissions for Scenario 0 in Calendar Year 2031
A-5 NOx and GHG Tailpipe Emissions for Scenario 0 in Calendar Year 2037
A-6 NOx and GHG Tailpipe Emissions for Scenario 0 in Calendar Year 2045
A-7 NOx and GHG Tailpipe Emissions for Scenario 0 in Calendar Year 2050
A-8 NOx and GHG Tailpipe Emissions for Scenario 1 in Calendar Year 2020
A-9 NOx and GHG Tailpipe Emissions for Scenario 1 in Calendar Year 2023
A-10 NOx and GHG Tailpipe Emissions for Scenario 1 in Calendar Year 2031
A-11 NOx and GHG Tailpipe Emissions for Scenario 1 in Calendar Year 2037
A-12 NOx and GHG Tailpipe Emissions for Scenario 1 in Calendar Year 2045
A-13 NOx and GHG Tailpipe Emissions for Scenario 1 in Calendar Year 2050
A-14 NOx and GHG Tailpipe Emissions for Scenario 2 in Calendar Year 2020
A-15 NOx and GHG Tailpipe Emissions for Scenario 2 in Calendar Year 2023
A-16 NOx and GHG Tailpipe Emissions for Scenario 2 in Calendar Year 2031
A-17 NOx and GHG Tailpipe Emissions for Scenario 2 in Calendar Year 2037
A-18 NOx and GHG Tailpipe Emissions for Scenario 2 in Calendar Year 2045
A-19 NOx and GHG Tailpipe Emissions for Scenario 2 in Calendar Year 2050
A-20 NOx and GHG Tailpipe Emissions for Scenario 3 in Calendar Year 2020
A-21 NOx and GHG Tailpipe Emissions for Scenario 3 in Calendar Year 2023
A-22 NOx and GHG Tailpipe Emissions for Scenario 3 in Calendar Year 2031
A-23 NOx and GHG Tailpipe Emissions for Scenario 3 in Calendar Year 2037
A-24 NOx and GHG Tailpipe Emissions for Scenario 3 in Calendar Year 2045
A-25 NOx and GHG Tailpipe Emissions for Scenario 3 in Calendar Year 2050
A-26 NOx and GHG Tailpipe Emissions for Scenario 4 in Calendar Year 2020
A-27 NOx and GHG Tailpipe Emissions for Scenario 4 in Calendar Year 2023
A-28 NOx and GHG Tailpipe Emissions for Scenario 4 in Calendar Year 2031
A-29 NOx and GHG Tailpipe Emissions for Scenario 4 in Calendar Year 2037
A-30 NOx and GHG Tailpipe Emissions for Scenario 4 in Calendar Year 2045
A-31 NOx and GHG Tailpipe Emissions for Scenario 4 in Calendar Year 2050
A-32 NOx and GHG Tailpipe Emissions for Scenario 5 in Calendar Year 2020
A-33 NOx and GHG Tailpipe Emissions for Scenario 5 in Calendar Year 2023

A-34 NOx and GHG Tailpipe Emissions for Scenario 5 in Calendar Year 2031
A-35 NOx and GHG Tailpipe Emissions for Scenario 5 in Calendar Year 2037
A-36 NOx and GHG Tailpipe Emissions for Scenario 5 in Calendar Year 2045
A-37 NOx and GHG Tailpipe Emissions for Scenario 5 in Calendar Year 2050
A-38 NOx and GHG Tailpipe Emissions for Scenario 6 in Calendar Year 2020
A-39 NOx and GHG Tailpipe Emissions for Scenario 6 in Calendar Year 2023
A-40 NOx and GHG Tailpipe Emissions for Scenario 6 in Calendar Year 2031
A-41 NOx and GHG Tailpipe Emissions for Scenario 6 in Calendar Year 2037
A-42 NOx and GHG Tailpipe Emissions for Scenario 6 in Calendar Year 2045
A-43 NOx and GHG Tailpipe Emissions for Scenario 6 in Calendar Year 2050
A-44 Upstream Emission Factors
A-45 Electricity Grid Mix Assumptions
A-46 Renewable Fuel GREET 3.0 Transportation Assumptions
A-47 Energy Economy Ratios and Fuel Economy

Table A-1. Scenario Matrix
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Ramboll HHDT Scenarios									
Scenario #	**Scenario Name**	**Assumptions**	**Conventional DSL**	**Federal Low NO_x DSL**	**CA Cert. Low NO_x DSL**	**Low NO_x NG**	**BEV**	**Fuel Pathway For Diesel and NG**	**Scenario Description**
0	Baseline EMFAC2017	**Fleet Mix**	EMFAC2017					100% Fossil	Fleet mixes and emissions will match EMFAC2017 Baseline projections.
		Tailpipe Emission Standard							
S1-A1	CARB Long Term Fleet Mix (includes Accelerated ZEV Turnover) - Fossil Fuel	**Fleet Mix**	CARB Long-Term Fleet Mix (0% starting 2045)[1]	CARB Long-Term Fleet Mix (12% by 2050)	CARB Long-Term Fleet Mix (8% by 2050)	CARB Long-Term Fleet Mix (Assume 0% of Fleet for all years)	CARB Long-Term Fleet Mix (81% by 2050)	100% Fossil	Fleet Mixes will match CARB Long-Term Scenario.[2] Low-NO_x Diesel tailpipe emissions standards are based on CARB 2019 Proposed Standards.[3]
		Tailpipe Emission Standard	EMFAC2017	0.05 g/bhp-hr	0.05 g/bhp-hr		No Tailpipe Emissions		
S1-B1	CARB Long Term Fleet Mix (includes Accelerated ZEV Turnover) - Renewable Fuel	**Fleet Mix**	Same as 1A					100% Renewable[4] (DSL-Tallow; CNG-LFG)	
		Tailpipe Emission Standard							
S2-A1	Low NO_x CNG with ACT - Fossil Fuel	**Fleet Mix**	CARB Long-Term Fleet Mix (0% starting 2045)[1]	CARB Long-Term Fleet Mix (12% by 2050)	Assume 0% of Fleet for all Calendar Years	Remaining Fleet Mix	ACT Mandate for CA Trucks (40% by 2050)	100% Fossil	BEV fleet mixes will meet ACT ZEV Mandates[5]. Low-NO_x Diesel tailpipe emissions standards based on CARB 2019 Proposed Standards.[3] Low NOx NG standards based on CARB 2016 MSS.[6]
		Tailpipe Emission Standard	EMFAC2017	0.05 g/bhp-hr		0.02 g/bhp-hr	No Tailpipe Emissions		
S2-B1	Low NO_x CNG with ACT - Renewable Fuel	**Fleet Mix**	Same as 2A					100% Renewable[4] (DSL-Tallow; CNG-LFG)	
		Tailpipe Emission Standard							
S3-A1	Low NO_x CNG - Fossil Fuel	**Fleet Mix**	CARB Long-Term Fleet Mix (0% starting 2045)[1]	CARB Long-Term Fleet Mix (12% by 2050)	Assume 0% of Fleet for all Calendar Years	Remaining Fleet Mix	Assume 0% of Fleet for all Calendar Years	100% Fossil	No penetration of BEVs for all calendar years. Low-NO_x Diesel tailpipe emissions standards based on CARB 2019 Proposed Standards.[3] Low NO_x NG standards based on 2016 MSS.[6]
		Tailpipe Emission Standard	EMFAC2017	0.05 g/bhp-hr		0.02 g/bhp-hr			
S3-B1	Low NO_x CNG - Renewable Fuels	**Fleet Mix**	Same as 3A					100% Renewable[4] (DSL-Tallow; CNG-LFG)	
		Tailpipe Emission Standard							
S4-A1	Scenario 2 with 2016 SCAQMD AQMP - Fossil Fuel	**Fleet Mix**	CARB Long-Term Fleet Mix (0% starting 2045)[1]	CARB Long-Term Fleet Mix (12% by 2050)	Assume 0% of Fleet for all Calendar Years	2016 AQMP Fleet Mix (82,300 CNG Trucks by 2023)	ACT Mandate for CA Trucks (40% by 2050)	100% Fossil	Same as Scenario 2, but assumes early adoption of Low NOx NG vehicles to meet or exceed SCAQMD 2016 AQMP projections for 2023 and 2031.[7] Conventional DSL fleet is adjusted to accommodate early adoption of NG vehicles. BEV penetration will meet ACT ZEV Mandates.[5]
		Tailpipe Emission Standard	EMFAC2017	0.05 g/bhp-hr		0.02 g/bhp-hr	No Tailpipe Emissions		
S4-B1	Scenario 2 with 2016 SCAQMD AQMP - Renewable Fuel	**Fleet Mix**	Same as 4A					100% Renewable[4] (DSL-Tallow; CNG-LFG)	
		Tailpipe Emission Standard							
S5-A1	Low NO_x CA Diesel with ACT - Fossil Fuel	**Fleet Mix**	CARB Long-Term Fleet Mix (0% starting 2045)[1]	CARB Long-Term Fleet Mix (12% by 2050)	Remaining Fleet Mix	Assume 0% of Fleet for all Calendar Years	ACT Mandate for CA Trucks (40% by 2050)	100% Fossil	BEV fleet mixes will meet ACT ZEV Mandates[5]. No penetration of Low-NO_x NG for all calendar years. CA Low-NO_x Diesel tailpipe emissions assume 0.02 g/bhp-hr standards are achieved.
		Tailpipe Emission Standard	EMFAC2017	0.05 g/bhp-hr	0.02 g/bhp-hr		No Tailpipe Emissions		
S5-B1	Low NOx CA Diesel with ACT- Renewable Fuel	**Fleet Mix**	Same as 2A					100% Renewable[4] (DSL-Tallow; CNG-LFG)	
		Tailpipe Emission Standard							
S6-A1	Low NOx CA Diesel without ACT - Fossil Fuel	**Fleet Mix**	CARB Long-Term Fleet Mix (0% starting 2045)[1]	CARB Long-Term Fleet Mix (12% by 2050)	Remaining Fleet Mix	Assume 0% of Fleet for all Calendar Years	Assume 0% of Fleet for all Calendar Years	100% Fossil	No penetration of BEVs or Low-NO_x NG for all calendar years. CA Low-NOx Diesel tailpipe emissions assume 0.02 g/bhp-hr standards are achieved.
		Tailpipe Emission Standard	EMFAC2017	0.05 g/bhp-hr	0.02 g/bhp-hr				
S6-B1	Low NOx CA Diesel without ACT - Renewable Fuels	**Fleet Mix**	Same as 3A					100% Renewable[4] (DSL-Tallow; CNG-LFG)	
		Tailpipe Emission Standard							

Notes:

[1] All scenarios except Scenario 0 include an accelerated fleet turnover assumption similar to CARB Long Term Fleet Mix that results in 0% conventional DSL starting in 2045 and 12% Federal Low NOx DSL in 2050

[2] CARB 2020 Mobile Source Strategy March 25, 2020 Webinar Presentation. Available at: https://ww3.arb.ca.gov/planning/sip/2020mss/pres_marwbnr.pdf. Accessed: July 2020.

[3] CARB Heavy-Duty Low NOx Program September 2019 Workshop. Available at: https://ww2.arb.ca.gov/sites/default/files/classic//msprog/hdlownox/files/workgroup_20190926/staff/01_hde_standards.pdf?_ga=2.98823766.992508391.1594658953-836277372.1571089290. Accessed: July 2020.

[4] Renewable diesel and natural gas are assumed to have zero tailpipe CO_2 emissions.

[5] CARB Advanced Clean Truck Rule. Available at: https://ww3.arb.ca.gov/regact/2019/act2019/30dayattb.pdf. Accessed: July 2020.

[6] CARB 2016 Mobile Source Strategy. Available at: https://ww2.arb.ca.gov/resources/documents/2016-mobile-source-strategy. Accessed: July 2020.

[7] SCAQMD 2016 AQMP Final Socioeconomic Report Appendix 2-A. Available at: https://www.aqmd.gov/docs/default-source/clean-air-plans/socioeconomic-analysis/final/appfinal_030817.pdf?sfvrsn=2. Accessed: July 2020.

Abbreviations:

ACT - Advanced Clean Truck Rule
AQMP - Air Quality Management Plan
BEV - battery electric vehicle
bhp-hr - break horsepower hour
CA Cert. - California certified
CARB - California Air Resources Board
CNG - compressed natural gas
CO_2 - carbon dioxide
DSL - diesel
g - gram
HHDT - heavy-heavy-duty truck
LFG - landfill gas
MSS - Mobile Source Strategy
NG - natural gas
NOx - oxides of nitrogen
SCAQMD - South Coast Air Quality Management District
ZEV - zero emission vehicle

Table A-2. NOx and GHG Tailpipe Emissions for Scenario 0 in Calendar Year 2020

	EMFAC2017 Output[1]						Conventional DSL		
Model Year	Population	NOx_TOTEX (tons/day)	CO2_TOTEX (tons/day)	CH4_TOTEX (tons/day)	N2O_TOTEX (tons/day)	Fuel Consumption (1000 gal/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)
1976	29	0.02	1.7	0.000	0.000	0.15	100%	29	19,871
1977	34	0.02	2.3	0.000	0.000	0.20	100%	34	27,331
1978	66	0.04	3.9	0.000	0.001	0.35	100%	66	47,207
1979	94	0.05	5.0	0.000	0.001	0.44	100%	94	59,761
1980	87	0.05	5.1	0.000	0.001	0.45	100%	87	61,143
1981	258	0.15	15	0.000	0.002	1.3	100%	258	180,361
1982	236	0.13	13	0.000	0.002	1.2	100%	236	156,209
1983	219	0.13	13	0.000	0.002	1.1	100%	219	151,257
1984	274	0.18	18	0.000	0.003	1.6	100%	274	214,575
1985	404	0.25	25	0.000	0.004	2.2	100%	404	301,188
1986	396	0.25	25	0.000	0.004	2.2	100%	396	301,092
1987	426	0.29	27	0.000	0.004	2.4	100%	426	324,223
1988	484	0.34	32	0.000	0.005	2.9	100%	484	387,591
1989	567	0.40	38	0.000	0.006	3.4	100%	567	454,438
1990	539	0.39	37	0.000	0.006	3.3	100%	539	446,862
1991	475	0.34	28	0.000	0.004	2.5	100%	475	335,098
1992	399	0.31	25	0.000	0.004	2.2	100%	399	301,877
1993	363	0.29	25	0.000	0.004	2.2	100%	363	295,585
1994	379	0.31	28	0.000	0.004	2.5	100%	379	330,512
1995	507	0.41	37	0.000	0.006	3.3	100%	507	443,837
1996	1,142	1.8	150	0.006	0.02	13	100%	1,142	1,800,897
1997	1,167	1.8	149	0.006	0.02	13	100%	1,167	1,790,241
1998	1,370	2.2	192	0.008	0.03	17	100%	1,370	2,305,455
1999	1,972	4.1	291	0.01	0.05	26	100%	1,972	3,484,066
2000	4,067	9.0	641	0.02	0.10	57	100%	4,067	7,683,603
2001	3,153	6.6	476	0.02	0.07	42	100%	3,153	5,706,180
2002	2,427	4.6	338	0.01	0.05	30	100%	2,427	4,046,083
2003	2,907	3.5	425	0.01	0.07	38	100%	2,907	5,088,912
2004	2,913	3.0	421	0.01	0.07	38	100%	2,913	5,047,803
2005	4,812	5.1	719	0.02	0.11	64	100%	4,812	8,613,212
2006	5,968	6.9	972	0.03	0.15	87	100%	5,968	11,650,876
2007	8,303	9.5	1,454	0.03	0.23	130	100%	8,303	17,419,576
2008	12,274	13	2,417	0.02	0.38	215	100%	12,274	28,960,284
2009	14,354	16	3,080	0.03	0.48	275	100%	14,354	36,913,677
2010	11,383	13	2,653	0.02	0.42	236	100%	11,383	31,795,323
2011	13,627	10	3,166	0.01	0.50	282	100%	13,627	37,940,166
2012	39,297	19	6,724	0.01	1.1	599	100%	39,297	80,581,115
2013	21,084	14	5,397	0.010	0.85	481	100%	21,084	64,680,893
2014	23,061	12	5,525	0.01	0.87	492	100%	23,061	66,207,976
2015	28,916	14	7,779	0.02	1.2	693	100%	28,916	93,222,050
2016	41,998	22	12,488	0.02	2.0	1,113	100%	41,998	149,658,452
2017	16,101	6.6	3,944	0.008	0.62	351	100%	16,101	47,265,405
2018	12,688	5.9	3,720	0.007	0.58	332	100%	12,688	44,579,225
2019	12,851	5.6	3,844	0.007	0.60	343	100%	12,851	46,069,473
2020	8,537	3.3	2,461	0.004	0.39	219	100%	8,537	29,496,897
2021	4,246	1.1	575	0.002	0.09	51	100%	4,246	6,891,960

Table A-2. NOx and GHG Tailpipe Emissions for Scenario 0 in Calendar Year 2020
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Model Year	Federal Low NOx DSL			CA Cert. Low NOx DSL			Low NOx NG		
	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)
1976	0%	0	0	0%	0	0	0%	0	0
1977	0%	0	0	0%	0	0	0%	0	0
1978	0%	0	0	0%	0	0	0%	0	0
1979	0%	0	0	0%	0	0	0%	0	0
1980	0%	0	0	0%	0	0	0%	0	0
1981	0%	0	0	0%	0	0	0%	0	0
1982	0%	0	0	0%	0	0	0%	0	0
1983	0%	0	0	0%	0	0	0%	0	0
1984	0%	0	0	0%	0	0	0%	0	0
1985	0%	0	0	0%	0	0	0%	0	0
1986	0%	0	0	0%	0	0	0%	0	0
1987	0%	0	0	0%	0	0	0%	0	0
1988	0%	0	0	0%	0	0	0%	0	0
1989	0%	0	0	0%	0	0	0%	0	0
1990	0%	0	0	0%	0	0	0%	0	0
1991	0%	0	0	0%	0	0	0%	0	0
1992	0%	0	0	0%	0	0	0%	0	0
1993	0%	0	0	0%	0	0	0%	0	0
1994	0%	0	0	0%	0	0	0%	0	0
1995	0%	0	0	0%	0	0	0%	0	0
1996	0%	0	0	0%	0	0	0%	0	0
1997	0%	0	0	0%	0	0	0%	0	0
1998	0%	0	0	0%	0	0	0%	0	0
1999	0%	0	0	0%	0	0	0%	0	0
2000	0%	0	0	0%	0	0	0%	0	0
2001	0%	0	0	0%	0	0	0%	0	0
2002	0%	0	0	0%	0	0	0%	0	0
2003	0%	0	0	0%	0	0	0%	0	0
2004	0%	0	0	0%	0	0	0%	0	0
2005	0%	0	0	0%	0	0	0%	0	0
2006	0%	0	0	0%	0	0	0%	0	0
2007	0%	0	0	0%	0	0	0%	0	0
2008	0%	0	0	0%	0	0	0%	0	0
2009	0%	0	0	0%	0	0	0%	0	0
2010	0%	0	0	0%	0	0	0%	0	0
2011	0%	0	0	0%	0	0	0%	0	0
2012	0%	0	0	0%	0	0	0%	0	0
2013	0%	0	0	0%	0	0	0%	0	0
2014	0%	0	0	0%	0	0	0%	0	0
2015	0%	0	0	0%	0	0	0%	0	0
2016	0%	0	0	0%	0	0	0%	0	0
2017	0%	0	0	0%	0	0	0%	0	0
2018	0%	0	0	0%	0	0	0%	0	0
2019	0%	0	0	0%	0	0	0%	0	0
2020	0%	0	0	0%	0	0	0%	0	0
2021	0%	0	0	0%	0	0	0%	0	0

	BEV			Tailpipe Emission Estimates[5] (tons/day)			
Model Year	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	NO_x	CO_2	CH_4	N_2O
1976	0%	0	0	0.02	1.7	0.000	0.000
1977	0%	0	0	0.02	2.3	0.000	0.000
1978	0%	0	0	0.04	3.9	0.000	0.001
1979	0%	0	0	0.05	5.0	0.000	0.001
1980	0%	0	0	0.05	5.1	0.000	0.001
1981	0%	0	0	0.15	15	0.000	0.002
1982	0%	0	0	0.13	13	0.000	0.002
1983	0%	0	0	0.13	13	0.000	0.002
1984	0%	0	0	0.18	18	0.000	0.003
1985	0%	0	0	0.25	25	0.000	0.004
1986	0%	0	0	0.25	25	0.000	0.004
1987	0%	0	0	0.29	27	0.000	0.004
1988	0%	0	0	0.34	32	0.000	0.005
1989	0%	0	0	0.40	38	0.000	0.006
1990	0%	0	0	0.39	37	0.000	0.006
1991	0%	0	0	0.34	28	0.000	0.004
1992	0%	0	0	0.31	25	0.000	0.004
1993	0%	0	0	0.29	25	0.000	0.004
1994	0%	0	0	0.31	28	0.000	0.004
1995	0%	0	0	0.41	37	0.000	0.006
1996	0%	0	0	1.8	150	0.006	0.02
1997	0%	0	0	1.8	149	0.006	0.02
1998	0%	0	0	2.2	192	0.008	0.03
1999	0%	0	0	4.1	291	0.01	0.05
2000	0%	0	0	9.0	641	0.02	0.10
2001	0%	0	0	6.6	476	0.02	0.07
2002	0%	0	0	4.6	338	0.01	0.05
2003	0%	0	0	3.5	425	0.01	0.07
2004	0%	0	0	3.0	421	0.01	0.07
2005	0%	0	0	5.1	719	0.02	0.11
2006	0%	0	0	6.9	972	0.03	0.15
2007	0%	0	0	9.5	1,454	0.03	0.23
2008	0%	0	0	13	2,417	0.02	0.38
2009	0%	0	0	16	3,080	0.03	0.48
2010	0%	0	0	13	2,653	0.02	0.42
2011	0%	0	0	10	3,166	0.01	0.50
2012	0%	0	0	19	6,724	0.01	1.1
2013	0%	0	0	14	5,397	0.010	0.85
2014	0%	0	0	12	5,525	0.01	0.87
2015	0%	0	0	14	7,779	0.02	1.2
2016	0%	0	0	22	12,488	0.02	2.0
2017	0%	0	0	6.6	3,944	0.008	0.62
2018	0%	0	0	5.9	3,720	0.007	0.58
2019	0%	0	0	5.6	3,844	0.007	0.60
2020	0%	0	0	3.3	2,461	0.004	0.39
2021	0%	0	0	1.1	575	0.002	0.09

Notes:

[1] EMFAC data shown here are obtained directly from EMFAC2017.

[2] Fleet mix percentages in this scenario are obtained directly from EMFAC2017.

[3] Population in each model year is calculated based on the fleet mix percentages for each HHDT type and the total population in the EMFAC data.

[4] Energy consumption is calculated based on EMFAC data, using the EER for each HHDT type shown in Table A-38.

[5] Emissions from vehicles in each model year are obtained directly from EMFAC2017 in this scenario.

[6] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CA Cert. - California certified
CH_4 - methane
CO_2 - carbon dioxide
DSL - diesel
EER - energy economy ratio
EMFAC2017 - Emission Factor Model
gal - gallon
HHDT - heavy heavy duty truck
MJ - megajoule
N_2O - nitrous oxide
NG - natural gas
NO_x - oxides of nitrogen
T7 SWCV - solid waste collection vehicles
TOTEX - total exhaust

Table A-3. NOx and GHG Tailpipe Emissions for Scenario 0 in Calendar Year 2023

Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Model Year	EMFAC2017 Output[1]						Conventional DSL		
	Population	NOx_TOTEX (tons/day)	CO2_TOTEX (tons/day)	CH4_TOTEX (tons/day)	N2O_TOTEX (tons/day)	Fuel Consumption (1000 gal/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)
1979	53	0.03	2.9	0.000	0.000	0.26	100%	53	35,019
1980	64	0.04	3.7	0.000	0.001	0.33	100%	64	44,086
1981	209	0.12	12	0.000	0.002	1.1	100%	209	142,790
1982	208	0.11	11	0.000	0.002	1.0	100%	208	134,214
1983	196	0.11	11	0.000	0.002	1.0	100%	196	131,088
1984	241	0.15	15	0.000	0.002	1.3	100%	241	176,822
1985	357	0.21	21	0.000	0.003	1.9	100%	357	252,082
1986	331	0.20	20	0.000	0.003	1.8	100%	331	243,579
1987	345	0.22	21	0.000	0.003	1.9	100%	345	253,082
1988	370	0.26	24	0.000	0.004	2.2	100%	370	290,997
1989	420	0.29	28	0.000	0.004	2.5	100%	420	332,355
1990	382	0.28	27	0.000	0.004	2.4	100%	382	319,401
1991	331	0.24	20	0.000	0.003	1.8	100%	331	238,471
1992	279	0.22	18	0.000	0.003	1.6	100%	279	214,037
1993	235	0.20	17	0.000	0.003	1.5	100%	235	202,566
1994	257	0.21	19	0.000	0.003	1.7	100%	257	228,163
1995	341	0.29	26	0.000	0.004	2.3	100%	341	308,497
1996	354	0.29	26	0.000	0.004	2.3	100%	354	309,827
1997	358	0.27	24	0.000	0.004	2.2	100%	358	292,799
1998	350	0.29	27	0.000	0.004	2.4	100%	350	324,850
1999	484	0.48	38	0.000	0.006	3.4	100%	484	458,610
2000	570	0.55	44	0.000	0.007	3.9	100%	570	522,449
2001	630	0.52	42	0.000	0.007	3.7	100%	630	502,288
2002	683	0.50	41	0.000	0.006	3.7	100%	683	490,906
2003	607	0.31	41	0.000	0.006	3.7	100%	607	491,836
2004	588	0.27	39	0.000	0.006	3.4	100%	588	462,594
2005	722	0.33	48	0.000	0.008	4.3	100%	722	579,188
2006	789	0.37	53	0.000	0.008	4.7	100%	789	635,640
2007	1,010	0.43	69	0.000	0.01	6.1	100%	1,010	822,391
2008	958	0.24	51	0.000	0.008	4.5	100%	958	608,971
2009	1,054	0.24	57	0.000	0.009	5.1	100%	1,054	681,595
2010	516	0.11	28	0.000	0.004	2.5	100%	516	336,250
2011	601	0.08	32	0.000	0.005	2.8	100%	601	381,333
2012	36,456	15	5,160	0.010	0.81	460	100%	36,456	61,840,416
2013	23,385	13	4,715	0.009	0.74	420	100%	23,385	56,503,770
2014	25,954	12	4,907	0.01	0.77	437	100%	25,954	58,805,403
2015	43,313	18	8,476	0.02	1.3	755	100%	43,313	101,582,009
2016	51,092	25	12,180	0.03	1.9	1,086	100%	51,092	145,975,230
2017	45,093	20	10,301	0.02	1.6	918	100%	45,093	123,455,483
2018	15,699	7.6	3,880	0.008	0.61	346	100%	15,699	46,494,284
2019	15,755	7.5	4,119	0.008	0.65	367	100%	15,755	49,364,115
2020	14,758	7.0	4,076	0.008	0.64	363	100%	14,758	48,851,177
2021	13,866	6.3	3,442	0.008	0.54	307	100%	13,866	41,250,943
2022	13,999	6.1	3,590	0.008	0.56	320	100%	13,999	43,027,237
2023	9,671	3.7	2,395	0.005	0.38	213	100%	9,671	28,707,076
2024	4,843	1.3	599	0.003	0.09	53	100%	4,843	7,172,863

Table A-3. NOx and GHG Tailpipe Emissions for Scenario 0 in Calendar Year 2023

	Federal Low NOx DSL			CA Cert. Low NOx DSL			Low NOx NG		
Model Year	**Fleet Mix[2] (%)**	**Population[3]**	**Energy Consumption[4] (MJ/day)**	**Fleet Mix[2] (%)**	**Population[3]**	**Energy Consumption[4] (MJ/day)**	**Fleet Mix[2] (%)**	**Population[3]**	**Energy Consumption[4] (MJ/day)**
1979	0%	0	0	0%	0	0	0%	0	0
1980	0%	0	0	0%	0	0	0%	0	0
1981	0%	0	0	0%	0	0	0%	0	0
1982	0%	0	0	0%	0	0	0%	0	0
1983	0%	0	0	0%	0	0	0%	0	0
1984	0%	0	0	0%	0	0	0%	0	0
1985	0%	0	0	0%	0	0	0%	0	0
1986	0%	0	0	0%	0	0	0%	0	0
1987	0%	0	0	0%	0	0	0%	0	0
1988	0%	0	0	0%	0	0	0%	0	0
1989	0%	0	0	0%	0	0	0%	0	0
1990	0%	0	0	0%	0	0	0%	0	0
1991	0%	0	0	0%	0	0	0%	0	0
1992	0%	0	0	0%	0	0	0%	0	0
1993	0%	0	0	0%	0	0	0%	0	0
1994	0%	0	0	0%	0	0	0%	0	0
1995	0%	0	0	0%	0	0	0%	0	0
1996	0%	0	0	0%	0	0	0%	0	0
1997	0%	0	0	0%	0	0	0%	0	0
1998	0%	0	0	0%	0	0	0%	0	0
1999	0%	0	0	0%	0	0	0%	0	0
2000	0%	0	0	0%	0	0	0%	0	0
2001	0%	0	0	0%	0	0	0%	0	0
2002	0%	0	0	0%	0	0	0%	0	0
2003	0%	0	0	0%	0	0	0%	0	0
2004	0%	0	0	0%	0	0	0%	0	0
2005	0%	0	0	0%	0	0	0%	0	0
2006	0%	0	0	0%	0	0	0%	0	0
2007	0%	0	0	0%	0	0	0%	0	0
2008	0%	0	0	0%	0	0	0%	0	0
2009	0%	0	0	0%	0	0	0%	0	0
2010	0%	0	0	0%	0	0	0%	0	0
2011	0%	0	0	0%	0	0	0%	0	0
2012	0%	0	0	0%	0	0	0%	0	0
2013	0%	0	0	0%	0	0	0%	0	0
2014	0%	0	0	0%	0	0	0%	0	0
2015	0%	0	0	0%	0	0	0%	0	0
2016	0%	0	0	0%	0	0	0%	0	0
2017	0%	0	0	0%	0	0	0%	0	0
2018	0%	0	0	0%	0	0	0%	0	0
2019	0%	0	0	0%	0	0	0%	0	0
2020	0%	0	0	0%	0	0	0%	0	0
2021	0%	0	0	0%	0	0	0%	0	0
2022	0%	0	0	0%	0	0	0%	0	0
2023	0%	0	0	0%	0	0	0%	0	0
2024	0%	0	0	0%	0	0	0%	0	0

Table A-3. NOx and GHG Tailpipe Emissions for Scenario 0 in Calendar Year 2023

Model Year	BEV			Tailpipe Emission Estimates[5] (tons/day)			
	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	NO_X	CO_2	CH_4	N_2O
1979	0%	0	0	0.03	2.9	0.000	0.000
1980	0%	0	0	0.04	3.7	0.000	0.001
1981	0%	0	0	0.12	12	0.000	0.002
1982	0%	0	0	0.11	11	0.000	0.002
1983	0%	0	0	0.11	11	0.000	0.002
1984	0%	0	0	0.15	15	0.000	0.002
1985	0%	0	0	0.21	21	0.000	0.003
1986	0%	0	0	0.20	20	0.000	0.003
1987	0%	0	0	0.22	21	0.000	0.003
1988	0%	0	0	0.26	24	0.000	0.004
1989	0%	0	0	0.29	28	0.000	0.004
1990	0%	0	0	0.28	27	0.000	0.004
1991	0%	0	0	0.24	20	0.000	0.003
1992	0%	0	0	0.22	18	0.000	0.003
1993	0%	0	0	0.20	17	0.000	0.003
1994	0%	0	0	0.21	19	0.000	0.003
1995	0%	0	0	0.29	26	0.000	0.004
1996	0%	0	0	0.29	26	0.000	0.004
1997	0%	0	0	0.27	24	0.000	0.004
1998	0%	0	0	0.29	27	0.000	0.004
1999	0%	0	0	0.48	38	0.000	0.006
2000	0%	0	0	0.55	44	0.000	0.007
2001	0%	0	0	0.52	42	0.000	0.007
2002	0%	0	0	0.50	41	0.000	0.006
2003	0%	0	0	0.31	41	0.000	0.006
2004	0%	0	0	0.27	39	0.000	0.006
2005	0%	0	0	0.33	48	0.000	0.008
2006	0%	0	0	0.37	53	0.000	0.008
2007	0%	0	0	0.43	69	0.000	0.01
2008	0%	0	0	0.24	51	0.000	0.008
2009	0%	0	0	0.24	57	0.000	0.009
2010	0%	0	0	0.11	28	0.000	0.004
2011	0%	0	0	0.08	32	0.000	0.005
2012	0%	0	0	15	5,160	0.010	0.81
2013	0%	0	0	13	4,715	0.009	0.74
2014	0%	0	0	12	4,907	0.01	0.77
2015	0%	0	0	18	8,476	0.02	1.3
2016	0%	0	0	25	12,180	0.03	1.9
2017	0%	0	0	20	10,301	0.02	1.6
2018	0%	0	0	7.6	3,880	0.008	0.61
2019	0%	0	0	7.5	4,119	0.008	0.65
2020	0%	0	0	7.0	4,076	0.008	0.64
2021	0%	0	0	6.3	3,442	0.008	0.54
2022	0%	0	0	6.1	3,590	0.008	0.56
2023	0%	0	0	3.7	2,395	0.005	0.38
2024	0%	0	0	1.3	599	0.003	0.09

Notes:

[1] EMFAC data shown here are obtained directly from EMFAC2017.

[2] Fleet mix percentages in this scenario are obtained directly from EMFAC2017.

[3] Population in each model year is calculated based on the fleet mix percentages for each HHDT type and the total population in the EMFAC data.

[4] Energy consumption is calculated based on EMFAC data, using the EER for each HHDT type shown in Table A-38.

[5] Emissions from vehicles in each model year are obtained directly from EMFAC2017 in this scenario.

[6] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CA Cert. - California certified
CH_4 - methane
CO_2 - carbon dioxide
DSL - diesel
EER - energy economy ratio
EMFAC2017 - Emission Factor Model
gal - gallon
HHDT - heavy heavy duty truck
MJ - megajoule
N_2O - nitrous oxide
NG - natural gas
NO_x - oxides of nitrogen
T7 SWCV - solid waste collection vehicles
TOTEX - total exhaust

Table A-4. NOx and GHG Tailpipe Emissions for Scenario 0 in Calendar Year 2031

Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

	EMFAC2017 Output[1]						Conventional DSL		
Model Year	Population	NOx_TOTEX (tons/day)	CO2_TOTEX (tons/day)	CH4_TOTEX (tons/day)	N2O_TOTEX (tons/day)	Fuel Consumption (1000 gal/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)
1987	175	0.10	9.4	0.000	0.001	0.84	100%	175	112,374
1988	235	0.13	13	0.000	0.002	1.1	100%	235	151,922
1989	294	0.17	16	0.000	0.002	1.4	100%	294	189,030
1990	270	0.16	15	0.000	0.002	1.3	100%	270	177,527
1991	233	0.15	12	0.000	0.002	1.1	100%	233	142,277
1992	183	0.12	10	0.000	0.002	0.87	100%	183	116,485
1993	140	0.09	7.9	0.000	0.001	0.71	100%	140	95,261
1994	138	0.09	8.0	0.000	0.001	0.71	100%	138	96,100
1995	170	0.11	10	0.000	0.002	0.91	100%	170	122,715
1996	167	0.11	10	0.000	0.002	0.90	100%	167	120,764
1997	163	0.11	10	0.000	0.002	0.85	100%	163	114,460
1998	153	0.11	10	0.000	0.002	0.90	100%	153	120,608
1999	208	0.18	14	0.000	0.002	1.3	100%	208	169,415
2000	246	0.21	17	0.000	0.003	1.5	100%	246	198,328
2001	281	0.21	17	0.000	0.003	1.5	100%	281	204,106
2002	317	0.22	18	0.000	0.003	1.6	100%	317	211,549
2003	287	0.14	18	0.000	0.003	1.6	100%	287	211,008
2004	291	0.12	18	0.000	0.003	1.6	100%	291	209,839
2005	372	0.16	23	0.000	0.004	2.0	100%	372	273,985
2006	425	0.19	27	0.000	0.004	2.4	100%	425	319,695
2007	573	0.24	37	0.000	0.006	3.3	100%	573	445,598
2008	595	0.15	31	0.000	0.005	2.8	100%	595	371,545
2009	690	0.15	36	0.000	0.006	3.2	100%	690	433,363
2010	356	0.07	19	0.000	0.003	1.7	100%	356	222,974
2011	441	0.05	22	0.000	0.004	2.0	100%	441	267,310
2012	19,805	6.6	2,242	0.004	0.35	200	100%	19,805	26,866,514
2013	11,462	5.5	2,037	0.003	0.32	182	100%	11,462	24,410,727
2014	13,052	5.1	2,102	0.004	0.33	187	100%	13,052	25,194,573
2015	23,841	8.4	3,662	0.007	0.58	326	100%	23,841	43,882,716
2016	26,961	10	4,078	0.01	0.64	363	100%	26,961	48,868,299
2017	31,181	10	4,244	0.009	0.67	378	100%	31,181	50,860,206
2018	10,710	4.0	1,675	0.004	0.26	149	100%	10,710	20,074,268
2019	12,144	4.7	1,963	0.005	0.31	175	100%	12,144	23,528,898
2020	13,758	5.7	2,379	0.006	0.37	212	100%	13,758	28,508,004
2021	15,079	6.5	2,397	0.006	0.38	214	100%	15,079	28,725,379
2022	17,317	8.0	2,991	0.008	0.47	267	100%	17,317	35,843,367
2023	23,269	12	4,495	0.01	0.71	401	100%	23,269	53,863,869
2024	20,136	10	3,698	0.01	0.58	330	100%	20,136	44,323,511
2025	20,975	11	4,195	0.01	0.66	374	100%	20,975	50,271,835
2026	20,497	11	4,412	0.01	0.69	393	100%	20,497	52,879,863
2027	20,024	11	4,331	0.01	0.68	386	100%	20,024	51,907,076
2028	18,309	9.4	4,128	0.01	0.65	368	100%	18,309	49,470,673
2029	17,211	8.4	3,970	0.010	0.62	354	100%	17,211	47,574,498
2030	16,613	7.6	3,900	0.010	0.61	348	100%	16,613	46,733,779
2031	10,661	4.3	2,402	0.006	0.38	214	100%	10,661	28,788,156
2032	5,437	1.4	644	0.003	0.10	57	100%	5,437	7,713,862

Table A-4. NOx and GHG Tailpipe Emissions for Scenario 0 in Calendar Year 2031
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Model Year	Federal Low NOx DSL			CA Cert. Low NOx DSL			Low NOx NG		
	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)
1987	0%	0	0	0%	0	0	0%	0	0
1988	0%	0	0	0%	0	0	0%	0	0
1989	0%	0	0	0%	0	0	0%	0	0
1990	0%	0	0	0%	0	0	0%	0	0
1991	0%	0	0	0%	0	0	0%	0	0
1992	0%	0	0	0%	0	0	0%	0	0
1993	0%	0	0	0%	0	0	0%	0	0
1994	0%	0	0	0%	0	0	0%	0	0
1995	0%	0	0	0%	0	0	0%	0	0
1996	0%	0	0	0%	0	0	0%	0	0
1997	0%	0	0	0%	0	0	0%	0	0
1998	0%	0	0	0%	0	0	0%	0	0
1999	0%	0	0	0%	0	0	0%	0	0
2000	0%	0	0	0%	0	0	0%	0	0
2001	0%	0	0	0%	0	0	0%	0	0
2002	0%	0	0	0%	0	0	0%	0	0
2003	0%	0	0	0%	0	0	0%	0	0
2004	0%	0	0	0%	0	0	0%	0	0
2005	0%	0	0	0%	0	0	0%	0	0
2006	0%	0	0	0%	0	0	0%	0	0
2007	0%	0	0	0%	0	0	0%	0	0
2008	0%	0	0	0%	0	0	0%	0	0
2009	0%	0	0	0%	0	0	0%	0	0
2010	0%	0	0	0%	0	0	0%	0	0
2011	0%	0	0	0%	0	0	0%	0	0
2012	0%	0	0	0%	0	0	0%	0	0
2013	0%	0	0	0%	0	0	0%	0	0
2014	0%	0	0	0%	0	0	0%	0	0
2015	0%	0	0	0%	0	0	0%	0	0
2016	0%	0	0	0%	0	0	0%	0	0
2017	0%	0	0	0%	0	0	0%	0	0
2018	0%	0	0	0%	0	0	0%	0	0
2019	0%	0	0	0%	0	0	0%	0	0
2020	0%	0	0	0%	0	0	0%	0	0
2021	0%	0	0	0%	0	0	0%	0	0
2022	0%	0	0	0%	0	0	0%	0	0
2023	0%	0	0	0%	0	0	0%	0	0
2024	0%	0	0	0%	0	0	0%	0	0
2025	0%	0	0	0%	0	0	0%	0	0
2026	0%	0	0	0%	0	0	0%	0	0
2027	0%	0	0	0%	0	0	0%	0	0
2028	0%	0	0	0%	0	0	0%	0	0
2029	0%	0	0	0%	0	0	0%	0	0
2030	0%	0	0	0%	0	0	0%	0	0
2031	0%	0	0	0%	0	0	0%	0	0
2032	0	0	0	0%	0	0	0%	0	0

Table A-4. NOx and GHG Tailpipe Emissions for Scenario 0 in Calendar Year 2031

	BEV			Tailpipe Emission Estimates[5] (tons/day)			
Model Year	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	NO_X	CO_2	CH_4	N_2O
1987	0%	0	0	0.10	9.4	0.000	0.001
1988	0%	0	0	0.13	13	0.000	0.002
1989	0%	0	0	0.17	16	0.000	0.002
1990	0%	0	0	0.16	15	0.000	0.002
1991	0%	0	0	0.15	12	0.000	0.002
1992	0%	0	0	0.12	10	0.000	0.002
1993	0%	0	0	0.09	7.9	0.000	0.001
1994	0%	0	0	0.09	8.0	0.000	0.001
1995	0%	0	0	0.11	10	0.000	0.002
1996	0%	0	0	0.11	10	0.000	0.002
1997	0%	0	0	0.11	10	0.000	0.002
1998	0%	0	0	0.11	10	0.000	0.002
1999	0%	0	0	0.18	14	0.000	0.002
2000	0%	0	0	0.21	17	0.000	0.003
2001	0%	0	0	0.21	17	0.000	0.003
2002	0%	0	0	0.22	18	0.000	0.003
2003	0%	0	0	0.14	18	0.000	0.003
2004	0%	0	0	0.12	18	0.000	0.003
2005	0%	0	0	0.16	23	0.000	0.004
2006	0%	0	0	0.19	27	0.000	0.004
2007	0%	0	0	0.24	37	0.000	0.006
2008	0%	0	0	0.15	31	0.000	0.005
2009	0%	0	0	0.15	36	0.000	0.006
2010	0%	0	0	0.07	19	0.000	0.003
2011	0%	0	0	0.05	22	0.000	0.004
2012	0%	0	0	6.6	2,242	0.004	0.35
2013	0%	0	0	5.5	2,037	0.003	0.32
2014	0%	0	0	5.1	2,102	0.004	0.33
2015	0%	0	0	8.4	3,662	0.007	0.58
2016	0%	0	0	10	4,078	0.01	0.64
2017	0%	0	0	10	4,244	0.009	0.67
2018	0%	0	0	4.0	1,675	0.004	0.26
2019	0%	0	0	4.7	1,963	0.005	0.31
2020	0%	0	0	5.7	2,379	0.006	0.37
2021	0%	0	0	6.5	2,397	0.006	0.38
2022	0%	0	0	8.0	2,991	0.008	0.47
2023	0%	0	0	12	4,495	0.01	0.71
2024	0%	0	0	10	3,698	0.01	0.58
2025	0%	0	0	11	4,195	0.01	0.66
2026	0%	0	0	11	4,412	0.01	0.69
2027	0%	0	0	11	4,331	0.01	0.68
2028	0%	0	0	9.4	4,128	0.01	0.65
2029	0%	0	0	8.4	3,970	0.010	0.62
2030	0%	0	0	7.6	3,900	0.010	0.61
2031	0%	0	0	4.3	2,402	0.006	0.38
2032	0%	0	0	1.4	644	0.003	0.10

Notes:

[1] EMFAC data shown here are obtained directly from EMFAC2017.

[2] Fleet mix percentages in this scenario are obtained directly from EMFAC2017.

[3] Population in each model year is calculated based on the fleet mix percentages for each HHDT type and the total population in the EMFAC data.

[4] Energy consumption is calculated based on EMFAC data, using the EER for each HHDT type shown in Table A-38.

[5] Emissions from vehicles in each model year are obtained directly from EMFAC2017 in this scenario.

[6] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CA Cert. - California certified
CH_4 - methane
CO_2 - carbon dioxide
DSL - diesel
EER - energy economy ratio
EMFAC2017 - Emission Factor Model
gal - gallon
HHDT - heavy heavy duty truck
MJ - megajoule
N_2O - nitrous oxide
NG - natural gas
NO_x - oxides of nitrogen
T7 SWCV - solid waste collection vehicles
TOTEX - total exhaust

Table A-5. NOx and GHG Tailpipe Emissions for Scenario 0 in Calendar Year 2037

Model Year	EMFAC2017 Output[1]						Conventional DSL		
	Population	NOx_TOTEX (tons/day)	CO2_TOTEX (tons/day)	CH4_TOTEX (tons/day)	N2O_TOTEX (tons/day)	Fuel Consumption (1000 gal/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)
1993	75	0.05	3.9	0.000	0.001	0.35	100%	75	47,317
1994	94	0.05	4.8	0.000	0.001	0.42	100%	94	57,084
1995	130	0.07	6.7	0.000	0.001	0.59	100%	130	79,873
1996	134	0.08	6.8	0.000	0.001	0.61	100%	134	81,980
1997	131	0.07	6.6	0.000	0.001	0.59	100%	131	79,331
1998	117	0.07	6.4	0.000	0.001	0.57	100%	117	76,415
1999	150	0.11	8.5	0.000	0.001	0.76	100%	150	101,977
2000	166	0.12	10	0.000	0.002	0.85	100%	166	114,626
2001	181	0.12	10	0.000	0.002	0.88	100%	181	118,851
2002	193	0.13	10	0.000	0.002	0.90	100%	193	121,512
2003	164	0.07	9.3	0.000	0.001	0.83	100%	164	111,673
2004	161	0.06	9.1	0.000	0.001	0.81	100%	161	108,865
2005	200	0.08	12	0.000	0.002	1.0	100%	200	139,150
2006	227	0.10	13	0.000	0.002	1.2	100%	227	160,976
2007	306	0.12	19	0.000	0.003	1.7	100%	306	225,401
2008	329	0.08	17	0.000	0.003	1.5	100%	329	201,692
2009	389	0.09	20	0.000	0.003	1.8	100%	389	239,857
2010	206	0.04	10	0.000	0.002	0.94	100%	206	125,743
2011	263	0.03	13	0.000	0.002	1.1	100%	263	153,971
2012	8,969	2.7	905	0.002	0.14	81	100%	8,969	10,850,749
2013	4,884	2.3	844	0.001	0.13	75	100%	4,884	10,111,625
2014	5,575	2.3	920	0.002	0.14	82	100%	5,575	11,024,466
2015	10,887	4.2	1,802	0.003	0.28	161	100%	10,887	21,597,772
2016	11,839	4.2	1,806	0.004	0.28	161	100%	11,839	21,639,565
2017	15,963	4.4	1,940	0.004	0.30	173	100%	15,963	23,245,601
2018	5,542	1.9	779	0.002	0.12	69	100%	5,542	9,330,010
2019	6,531	2.2	908	0.002	0.14	81	100%	6,531	10,880,678
2020	7,555	2.6	1,064	0.002	0.17	95	100%	7,555	12,750,708
2021	8,675	3.0	1,060	0.003	0.17	94	100%	8,675	12,701,740
2022	10,535	3.8	1,347	0.004	0.21	120	100%	10,535	16,143,648
2023	13,855	5.9	2,024	0.005	0.32	180	100%	13,855	24,261,600
2024	13,533	5.3	1,724	0.005	0.27	154	100%	13,533	20,662,715
2025	15,085	6.2	2,019	0.006	0.32	180	100%	15,085	24,194,862
2026	16,881	7.2	2,375	0.007	0.37	212	100%	16,881	28,459,718
2027	18,671	8.3	2,646	0.008	0.42	236	100%	18,671	31,706,518
2028	20,424	10	3,093	0.009	0.49	276	100%	20,424	37,072,964
2029	21,972	11	3,583	0.01	0.56	319	100%	21,972	42,935,501
2030	23,020	12	4,027	0.01	0.63	359	100%	23,020	48,263,523
2037	23,699	12	4,465	0.01	0.70	398	100%	23,699	53,515,434
2032	23,052	12	4,643	0.01	0.73	414	100%	23,052	55,644,560
2033	22,627	12	4,837	0.01	0.76	431	100%	22,627	57,966,231
2034	20,981	11	4,668	0.01	0.73	416	100%	20,981	55,937,866
2035	19,875	10	4,533	0.01	0.71	404	100%	19,875	54,328,050
2036	18,831	8.6	4,372	0.01	0.69	390	100%	18,831	52,390,503
2037	11,862	4.7	2,651	0.006	0.42	236	100%	11,862	31,768,688
2038	6,109	1.6	710	0.003	0.11	63	100%	6,109	8,512,215

	Federal Low NOx DSL			**CA Cert. Low NOx DSL**			**Low NOx NG**		
Model Year	**Fleet Mix[2] (%)**	**Population[3]**	**Energy Consumption[4] (MJ/day)**	**Fleet Mix[2] (%)**	**Population[3]**	**Energy Consumption[4] (MJ/day)**	**Fleet Mix[2] (%)**	**Population[3]**	**Energy Consumption[4] (MJ/day)**
1993	0%	0	0	0%	0	0	0%	0	0
1994	0%	0	0	0%	0	0	0%	0	0
1995	0%	0	0	0%	0	0	0%	0	0
1996	0%	0	0	0%	0	0	0%	0	0
1997	0%	0	0	0%	0	0	0%	0	0
1998	0%	0	0	0%	0	0	0%	0	0
1999	0%	0	0	0%	0	0	0%	0	0
2000	0%	0	0	0%	0	0	0%	0	0
2001	0%	0	0	0%	0	0	0%	0	0
2002	0%	0	0	0%	0	0	0%	0	0
2003	0%	0	0	0%	0	0	0%	0	0
2004	0%	0	0	0%	0	0	0%	0	0
2005	0%	0	0	0%	0	0	0%	0	0
2006	0%	0	0	0%	0	0	0%	0	0
2007	0%	0	0	0%	0	0	0%	0	0
2008	0%	0	0	0%	0	0	0%	0	0
2009	0%	0	0	0%	0	0	0%	0	0
2010	0%	0	0	0%	0	0	0%	0	0
2011	0%	0	0	0%	0	0	0%	0	0
2012	0%	0	0	0%	0	0	0%	0	0
2013	0%	0	0	0%	0	0	0%	0	0
2014	0%	0	0	0%	0	0	0%	0	0
2015	0%	0	0	0%	0	0	0%	0	0
2016	0%	0	0	0%	0	0	0%	0	0
2017	0%	0	0	0%	0	0	0%	0	0
2018	0%	0	0	0%	0	0	0%	0	0
2019	0%	0	0	0%	0	0	0%	0	0
2020	0%	0	0	0%	0	0	0%	0	0
2021	0%	0	0	0%	0	0	0%	0	0
2022	0%	0	0	0%	0	0	0%	0	0
2023	0%	0	0	0%	0	0	0%	0	0
2024	0%	0	0	0%	0	0	0%	0	0
2025	0%	0	0	0%	0	0	0%	0	0
2026	0%	0	0	0%	0	0	0%	0	0
2027	0%	0	0	0%	0	0	0%	0	0
2028	0%	0	0	0%	0	0	0%	0	0
2029	0%	0	0	0%	0	0	0%	0	0
2030	0%	0	0	0%	0	0	0%	0	0
2037	0%	0	0	0%	0	0	0%	0	0
2032	0%	0	0	0%	0	0	0%	0	0
2033	0%	0	0	0%	0	0	0%	0	0
2034	0%	0	0	0%	0	0	0%	0	0
2035	0%	0	0	0%	0	0	0%	0	0
2036	0%	0	0	0%	0	0	0%	0	0
2037	0%	0	0	0%	0	0	0%	0	0
2038	0%	0	0	0%	0	0	0%	0	0

	BEV			Tailpipe Emission Estimates[5] (tons/day)			
Model Year	**Fleet Mix[2] (%)**	**Population[3]**	**Energy Consumption[4] (MJ/day)**	**NO_X**	**CO_2**	**CH_4**	**N_2O**
1993	0%	0	0	0.05	3.9	0.000	0.001
1994	0%	0	0	0.05	4.8	0.000	0.001
1995	0%	0	0	0.07	6.7	0.000	0.001
1996	0%	0	0	0.08	6.8	0.000	0.001
1997	0%	0	0	0.07	6.6	0.000	0.001
1998	0%	0	0	0.07	6.4	0.000	0.001
1999	0%	0	0	0.11	8.5	0.000	0.001
2000	0%	0	0	0.12	10	0.000	0.002
2001	0%	0	0	0.12	10	0.000	0.002
2002	0%	0	0	0.13	10	0.000	0.002
2003	0%	0	0	0.07	9.3	0.000	0.001
2004	0%	0	0	0.06	9.1	0.000	0.001
2005	0%	0	0	0.08	12	0.000	0.002
2006	0%	0	0	0.10	13	0.000	0.002
2007	0%	0	0	0.12	19	0.000	0.003
2008	0%	0	0	0.08	17	0.000	0.003
2009	0%	0	0	0.09	20	0.000	0.003
2010	0%	0	0	0.04	10	0.000	0.002
2011	0%	0	0	0.03	13	0.000	0.002
2012	0%	0	0	2.7	905	0.002	0.14
2013	0%	0	0	2.3	844	0.001	0.13
2014	0%	0	0	2.3	920	0.002	0.14
2015	0%	0	0	4.2	1,802	0.003	0.28
2016	0%	0	0	4.2	1,806	0.004	0.28
2017	0%	0	0	4.4	1,940	0.004	0.30
2018	0%	0	0	1.9	779	0.002	0.12
2019	0%	0	0	2.2	908	0.002	0.14
2020	0%	0	0	2.6	1,064	0.002	0.17
2021	0%	0	0	3.0	1,060	0.003	0.17
2022	0%	0	0	3.8	1,347	0.004	0.21
2023	0%	0	0	5.9	2,024	0.005	0.32
2024	0%	0	0	5.3	1,724	0.005	0.27
2025	0%	0	0	6.2	2,019	0.006	0.32
2026	0%	0	0	7.2	2,375	0.007	0.37
2027	0%	0	0	8.3	2,646	0.008	0.42
2028	0%	0	0	10	3,093	0.009	0.49
2029	0%	0	0	11	3,583	0.01	0.56
2030	0%	0	0	12	4,027	0.01	0.63
2037	0%	0	0	12	4,465	0.01	0.70
2032	0%	0	0	12	4,643	0.01	0.73
2033	0%	0	0	12	4,837	0.01	0.76
2034	0%	0	0	11	4,668	0.01	0.73
2035	0%	0	0	10	4,533	0.01	0.71
2036	0%	0	0	8.6	4,372	0.01	0.69
2037	0%	0	0	4.7	2,651	0.006	0.42
2038	0%	0	0	1.6	710	0.003	0.11

Notes:

[1] EMFAC data shown here are obtained directly from EMFAC2017.

[2] Fleet mix percentages in this scenario are obtained directly from EMFAC2017.

[3] Population in each model year is calculated based on the fleet mix percentages for each HHDT type and the total population in the EMFAC data.

[4] Energy consumption is calculated based on EMFAC data, using the EER for each HHDT type shown in Table A-38.

[5] Emissions from vehicles in each model year are obtained directly from EMFAC2017 in this scenario.

[6] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CA Cert. - California certified
CH_4 - methane
CO_2 - carbon dioxide
DSL - diesel
EER - energy economy ratio
EMFAC2017 - Emission Factor Model
gal - gallon
HHDT - heavy heavy duty truck
MJ - megajoule
N_2O - nitrous oxide
NG - natural gas
NO_x - oxides of nitrogen
T7 SWCV - solid waste collection vehicles
TOTEX - total exhaust

Table A-6. NOx and GHG Tailpipe Emissions for Scenario 0 in Calendar Year 2045

Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Model Year	EMFAC2017 Output[1]						Conventional DSL		
	Population	NOx_TOTEX (tons/day)	CO2_TOTEX (tons/day)	CH4_TOTEX (tons/day)	N2O_TOTEX (tons/day)	Fuel Consumption (1000 gal/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)
2001	92	0.06	4.7	0.000	0.001	0.42	100%	92	55,864
2002	126	0.08	6.1	0.000	0.001	0.55	100%	126	73,692
2003	117	0.05	5.8	0.000	0.001	0.52	100%	117	69,583
2004	117	0.04	5.8	0.000	0.001	0.52	100%	117	69,938
2005	141	0.05	7.1	0.000	0.001	0.63	100%	141	84,978
2006	149	0.06	7.7	0.000	0.001	0.68	100%	149	91,926
2007	186	0.07	10	0.000	0.002	0.89	100%	186	119,191
2008	190	0.05	9.4	0.000	0.001	0.84	100%	190	113,113
2009	208	0.05	10	0.000	0.002	0.93	100%	208	124,512
2010	103	0.02	5.1	0.000	0.001	0.45	100%	103	60,761
2011	124	0.01	5.8	0.000	0.001	0.52	100%	124	69,981
2012	3,164	0.88	279	0.001	0.04	25	100%	3,164	3,344,913
2013	1,607	0.74	266	0.000	0.04	24	100%	1,607	3,183,366
2014	1,758	0.74	291	0.001	0.05	26	100%	1,758	3,492,142
2015	3,339	1.4	569	0.001	0.09	51	100%	3,339	6,824,423
2016	3,387	1.2	514	0.001	0.08	46	100%	3,387	6,158,622
2017	4,827	1.2	537	0.001	0.08	48	100%	4,827	6,430,112
2018	1,762	0.58	238	0.001	0.04	21	100%	1,762	2,851,512
2019	2,149	0.69	284	0.001	0.04	25	100%	2,149	3,404,717
2020	2,509	0.83	339	0.001	0.05	30	100%	2,509	4,060,186
2021	2,963	1.0	350	0.001	0.06	31	100%	2,963	4,200,368
2022	3,605	1.2	440	0.001	0.07	39	100%	3,605	5,271,072
2023	4,481	1.5	550	0.001	0.09	49	100%	4,481	6,596,556
2024	5,241	1.7	576	0.002	0.09	51	100%	5,241	6,908,530
2025	6,104	2.0	676	0.002	0.11	60	100%	6,104	8,100,000
2026	7,152	2.4	794	0.002	0.12	71	100%	7,152	9,515,611
2027	8,184	2.8	872	0.003	0.14	78	100%	8,184	10,447,069
2028	9,405	3.2	1,001	0.003	0.16	89	100%	9,405	11,995,147
2029	10,888	3.8	1,166	0.004	0.18	104	100%	10,888	13,973,007
2030	12,611	4.4	1,359	0.004	0.21	121	100%	12,611	16,288,180
2045	14,300	5.4	1,661	0.005	0.26	148	100%	14,300	19,910,222
2032	16,271	6.5	2,006	0.006	0.32	179	100%	16,271	24,038,562
2033	18,271	7.6	2,358	0.007	0.37	210	100%	18,271	28,256,371
2034	20,665	9.0	2,802	0.008	0.44	250	100%	20,665	33,577,632
2035	22,814	10	3,274	0.010	0.51	292	100%	22,814	39,232,932
2036	24,632	12	3,762	0.01	0.59	335	100%	24,632	45,082,949
2037	26,123	13	4,272	0.01	0.67	381	100%	26,123	51,193,009
2038	26,997	14	4,724	0.01	0.74	421	100%	26,997	56,619,599
2039	27,480	14	5,157	0.01	0.81	460	100%	27,480	61,800,167
2040	26,050	14	5,193	0.01	0.82	463	100%	26,050	62,236,336
2041	25,105	13	5,312	0.01	0.83	473	100%	25,105	63,663,029
2042	22,635	11	4,974	0.01	0.78	443	100%	22,635	59,613,985
2043	21,270	10	4,789	0.01	0.75	427	100%	21,270	57,388,548
2044	20,106	9.0	4,590	0.01	0.72	409	100%	20,106	55,011,066
2045	12,634	5.0	2,768	0.007	0.44	247	100%	12,634	33,169,181
2046	6,495	1.7	741	0.004	0.12	66	100%	6,495	8,884,377

Model Year	Federal Low NOx DSL			CA Cert. Low NOx DSL			Low NOx NG		
	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)
2001	0%	0	0	0%	0	0	0%	0	0
2002	0%	0	0	0%	0	0	0%	0	0
2003	0%	0	0	0%	0	0	0%	0	0
2004	0%	0	0	0%	0	0	0%	0	0
2005	0%	0	0	0%	0	0	0%	0	0
2006	0%	0	0	0%	0	0	0%	0	0
2007	0%	0	0	0%	0	0	0%	0	0
2008	0%	0	0	0%	0	0	0%	0	0
2009	0%	0	0	0%	0	0	0%	0	0
2010	0%	0	0	0%	0	0	0%	0	0
2011	0%	0	0	0%	0	0	0%	0	0
2012	0%	0	0	0%	0	0	0%	0	0
2013	0%	0	0	0%	0	0	0%	0	0
2014	0%	0	0	0%	0	0	0%	0	0
2015	0%	0	0	0%	0	0	0%	0	0
2016	0%	0	0	0%	0	0	0%	0	0
2017	0%	0	0	0%	0	0	0%	0	0
2018	0%	0	0	0%	0	0	0%	0	0
2019	0%	0	0	0%	0	0	0%	0	0
2020	0%	0	0	0%	0	0	0%	0	0
2021	0%	0	0	0%	0	0	0%	0	0
2022	0%	0	0	0%	0	0	0%	0	0
2023	0%	0	0	0%	0	0	0%	0	0
2024	0%	0	0	0%	0	0	0%	0	0
2025	0%	0	0	0%	0	0	0%	0	0
2026	0%	0	0	0%	0	0	0%	0	0
2027	0%	0	0	0%	0	0	0%	0	0
2028	0%	0	0	0%	0	0	0%	0	0
2029	0%	0	0	0%	0	0	0%	0	0
2030	0%	0	0	0%	0	0	0%	0	0
2045	0%	0	0	0%	0	0	0%	0	0
2032	0%	0	0	0%	0	0	0%	0	0
2033	0%	0	0	0%	0	0	0%	0	0
2034	0%	0	0	0%	0	0	0%	0	0
2035	0%	0	0	0%	0	0	0%	0	0
2036	0%	0	0	0%	0	0	0%	0	0
2037	0%	0	0	0%	0	0	0%	0	0
2038	0%	0	0	0%	0	0	0%	0	0
2039	0%	0	0	0%	0	0	0%	0	0
2040	0%	0	0	0%	0	0	0%	0	0
2041	0%	0	0	0%	0	0	0%	0	0
2042	0%	0	0	0%	0	0	0%	0	0
2043	0%	0	0	0%	0	0	0%	0	0
2044	0%	0	0	0%	0	0	0%	0	0
2045	0%	0	0	0%	0	0	0%	0	0
2046	0%	0	0	0%	0	0	0%	0	0

Table A-6. NOx and GHG Tailpipe Emissions for Scenario 0 in Calendar Year 2045

Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Model Year	BEV			Tailpipe Emission Estimates[5] (tons/day)			
	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	NO_X	CO_2	CH_4	N_2O
2001	0%	0	0	0.06	4.7	0.000	0.001
2002	0%	0	0	0.08	6.1	0.000	0.001
2003	0%	0	0	0.05	5.8	0.000	0.001
2004	0%	0	0	0.04	5.8	0.000	0.001
2005	0%	0	0	0.05	7.1	0.000	0.001
2006	0%	0	0	0.06	7.7	0.000	0.001
2007	0%	0	0	0.07	10	0.000	0.002
2008	0%	0	0	0.05	9.4	0.000	0.001
2009	0%	0	0	0.05	10	0.000	0.002
2010	0%	0	0	0.02	5.1	0.000	0.001
2011	0%	0	0	0.01	5.8	0.000	0.001
2012	0%	0	0	0.88	279	0.001	0.04
2013	0%	0	0	0.74	266	0.000	0.04
2014	0%	0	0	0.74	291	0.001	0.05
2015	0%	0	0	1.4	569	0.001	0.09
2016	0%	0	0	1.2	514	0.001	0.08
2017	0%	0	0	1.2	537	0.001	0.08
2018	0%	0	0	0.58	238	0.001	0.04
2019	0%	0	0	0.69	284	0.001	0.04
2020	0%	0	0	0.83	339	0.001	0.05
2021	0%	0	0	1.0	350	0.001	0.06
2022	0%	0	0	1.2	440	0.001	0.07
2023	0%	0	0	1.5	550	0.001	0.09
2024	0%	0	0	1.7	576	0.002	0.09
2025	0%	0	0	2.0	676	0.002	0.11
2026	0%	0	0	2.4	794	0.002	0.12
2027	0%	0	0	2.8	872	0.003	0.14
2028	0%	0	0	3.2	1,001	0.003	0.16
2029	0%	0	0	3.8	1,166	0.004	0.18
2030	0%	0	0	4.4	1,359	0.004	0.21
2045	0%	0	0	5.4	1,661	0.005	0.26
2032	0%	0	0	6.5	2,006	0.006	0.32
2033	0%	0	0	7.6	2,358	0.007	0.37
2034	0%	0	0	9.0	2,802	0.008	0.44
2035	0%	0	0	10	3,274	0.010	0.51
2036	0%	0	0	12	3,762	0.01	0.59
2037	0%	0	0	13	4,272	0.01	0.67
2038	0%	0	0	14	4,724	0.01	0.74
2039	0%	0	0	14	5,157	0.01	0.81
2040	0%	0	0	14	5,193	0.01	0.82
2041	0%	0	0	13	5,312	0.01	0.83
2042	0%	0	0	11	4,974	0.01	0.78
2043	0%	0	0	10	4,789	0.01	0.75
2044	0%	0	0	9.0	4,590	0.01	0.72
2045	0%	0	0	5.0	2,768	0.007	0.44
2046	0%	0	0	1.7	741	0.004	0.12

Notes:

[1] EMFAC data shown here are obtained directly from EMFAC2017.

[2] Fleet mix percentages in this scenario are obtained directly from EMFAC2017.

[3] Population in each model year is calculated based on the fleet mix percentages for each HHDT type and the total population in the EMFAC data.

[4] Energy consumption is calculated based on EMFAC data, using the EER for each HHDT type shown in Table A-38.

[5] Emissions from vehicles in each model year are obtained directly from EMFAC2017 in this scenario.

[6] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CA Cert. - California certified
CH_4 - methane
CO_2 - carbon dioxide
DSL - diesel
EER - energy economy ratio
EMFAC2017 - Emission Factor Model
gal - gallon
HHDT - heavy heavy duty truck
MJ - megajoule
N_2O - nitrous oxide
NG - natural gas
NO_x - oxides of nitrogen
T7 SWCV - solid waste collection vehicles
TOTEX - total exhaust

Table A-7. NOx and GHG Tailpipe Emissions for Scenario 0 in Calendar Year 2050

Model Year	EMFAC2017 Output[1]						Conventional DSL		
	Population	NOx_TOTEX (tons/day)	CO2_TOTEX (tons/day)	CH4_TOTEX (tons/day)	N2O_TOTEX (tons/day)	Fuel Consumption (1000 gal/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)
2006	82	0.03	4.1	0.000	0.001	0.37	100%	82	49,174
2007	132	0.04	6.6	0.000	0.001	0.59	100%	132	79,672
2008	156	0.04	7.6	0.000	0.001	0.68	100%	156	90,995
2009	181	0.04	8.9	0.000	0.001	0.79	100%	181	106,208
2010	90	0.02	4.4	0.000	0.001	0.39	100%	90	52,143
2011	106	0.01	4.8	0.000	0.001	0.43	100%	106	57,864
2012	1,478	0.33	101	0.000	0.02	9.0	100%	1,478	1,207,021
2013	750	0.28	99	0.000	0.02	8.9	100%	750	1,192,404
2014	777	0.30	115	0.000	0.02	10	100%	777	1,374,836
2015	1,536	0.62	252	0.000	0.04	22	100%	1,536	3,021,320
2016	1,630	0.59	241	0.001	0.04	21	100%	1,630	2,889,636
2017	2,386	0.59	251	0.001	0.04	22	100%	2,386	3,002,314
2018	887	0.29	116	0.000	0.02	10	100%	887	1,390,448
2019	1,087	0.35	139	0.000	0.02	12	100%	1,087	1,669,054
2020	1,265	0.41	166	0.000	0.03	15	100%	1,265	1,987,822
2021	1,465	0.48	169	0.000	0.03	15	100%	1,465	2,020,660
2022	1,760	0.59	209	0.001	0.03	19	100%	1,760	2,502,994
2023	2,161	0.73	259	0.001	0.04	23	100%	2,161	3,102,175
2024	2,493	0.83	270	0.001	0.04	24	100%	2,493	3,239,609
2025	2,909	1.0	317	0.001	0.05	28	100%	2,909	3,802,943
2026	3,483	1.1	378	0.001	0.06	34	100%	3,483	4,525,444
2027	4,089	1.3	422	0.001	0.07	38	100%	4,089	5,058,290
2028	4,861	1.6	505	0.001	0.08	45	100%	4,861	6,057,599
2029	5,793	1.9	607	0.002	0.10	54	100%	5,793	7,272,512
2030	6,787	2.3	713	0.002	0.11	64	100%	6,787	8,549,670
2050	7,893	2.7	837	0.002	0.13	75	100%	7,893	10,032,270
2032	9,119	3.1	976	0.003	0.15	87	100%	9,119	11,701,451
2033	10,570	3.6	1,130	0.003	0.18	101	100%	10,570	13,541,512
2034	12,402	4.3	1,331	0.004	0.21	119	100%	12,402	15,952,622
2035	14,345	5.1	1,555	0.005	0.24	139	100%	14,345	18,633,374
2036	16,120	6.1	1,885	0.006	0.30	168	100%	16,120	22,588,671
2037	17,993	7.2	2,237	0.007	0.35	199	100%	17,993	26,803,159
2038	19,907	8.4	2,593	0.008	0.41	231	100%	19,907	31,070,008
2039	22,021	10	3,013	0.009	0.47	269	100%	22,021	36,113,252
2040	24,085	11	3,476	0.01	0.55	310	100%	24,085	41,659,449
2041	26,029	12	3,991	0.01	0.63	356	100%	26,029	47,825,120
2042	27,606	14	4,519	0.01	0.71	403	100%	27,606	54,152,315
2043	28,488	15	4,980	0.01	0.78	444	100%	28,488	59,679,625
2044	28,931	15	5,411	0.02	0.85	482	100%	28,931	64,850,659
2045	27,286	14	5,420	0.02	0.85	483	100%	27,286	64,956,609
2046	26,307	14	5,542	0.01	0.87	494	100%	26,307	66,420,856
2047	23,687	12	5,184	0.01	0.81	462	100%	23,687	62,130,013
2048	22,283	11	5,001	0.01	0.79	446	100%	22,283	59,930,609
2049	21,009	9.4	4,781	0.01	0.75	426	100%	21,009	57,302,967
2050	13,154	5.2	2,874	0.007	0.45	256	100%	13,154	34,442,748
2051	6,775	1.8	1,178	0.004	0.19	105	100%	6,775	14,114,877

Model Year	Federal Low NOx DSL			CA Cert. Low NOx DSL			Low NOx NG		
	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)
2006	0%	0	0	0%	0	0	0%	0	0
2007	0%	0	0	0%	0	0	0%	0	0
2008	0%	0	0	0%	0	0	0%	0	0
2009	0%	0	0	0%	0	0	0%	0	0
2010	0%	0	0	0%	0	0	0%	0	0
2011	0%	0	0	0%	0	0	0%	0	0
2012	0%	0	0	0%	0	0	0%	0	0
2013	0%	0	0	0%	0	0	0%	0	0
2014	0%	0	0	0%	0	0	0%	0	0
2015	0%	0	0	0%	0	0	0%	0	0
2016	0%	0	0	0%	0	0	0%	0	0
2017	0%	0	0	0%	0	0	0%	0	0
2018	0%	0	0	0%	0	0	0%	0	0
2019	0%	0	0	0%	0	0	0%	0	0
2020	0%	0	0	0%	0	0	0%	0	0
2021	0%	0	0	0%	0	0	0%	0	0
2022	0%	0	0	0%	0	0	0%	0	0
2023	0%	0	0	0%	0	0	0%	0	0
2024	0%	0	0	0%	0	0	0%	0	0
2025	0%	0	0	0%	0	0	0%	0	0
2026	0%	0	0	0%	0	0	0%	0	0
2027	0%	0	0	0%	0	0	0%	0	0
2028	0%	0	0	0%	0	0	0%	0	0
2029	0%	0	0	0%	0	0	0%	0	0
2030	0%	0	0	0%	0	0	0%	0	0
2050	0%	0	0	0%	0	0	0%	0	0
2032	0%	0	0	0%	0	0	0%	0	0
2033	0%	0	0	0%	0	0	0%	0	0
2034	0%	0	0	0%	0	0	0%	0	0
2035	0%	0	0	0%	0	0	0%	0	0
2036	0%	0	0	0%	0	0	0%	0	0
2037	0%	0	0	0%	0	0	0%	0	0
2038	0%	0	0	0%	0	0	0%	0	0
2039	0%	0	0	0%	0	0	0%	0	0
2040	0%	0	0	0%	0	0	0%	0	0
2041	0%	0	0	0%	0	0	0%	0	0
2042	0%	0	0	0%	0	0	0%	0	0
2043	0%	0	0	0%	0	0	0%	0	0
2044	0%	0	0	0%	0	0	0%	0	0
2045	0%	0	0	0%	0	0	0%	0	0
2046	0%	0	0	0%	0	0	0%	0	0
2047	0%	0	0	0%	0	0	0%	0	0
2048	0%	0	0	0%	0	0	0%	0	0
2049	0%	0	0	0%	0	0	0%	0	0
2050	0%	0	0	0%	0	0	0%	0	0
2051	0%	0	0	0%	0	0	0%	0	0

Table A-7. NOx and GHG Tailpipe Emissions for Scenario 0 in Calendar Year 2050

Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

	BEV			Tailpipe Emission Estimates[5] (tons/day)			
Model Year	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	NO_X	CO_2	CH_4	N_2O
2006	0%	0	0	0.03	4.1	0.000	0.001
2007	0%	0	0	0.04	6.6	0.000	0.001
2008	0%	0	0	0.04	7.6	0.000	0.001
2009	0%	0	0	0.04	8.9	0.000	0.001
2010	0%	0	0	0.02	4.4	0.000	0.001
2011	0%	0	0	0.01	4.8	0.000	0.001
2012	0%	0	0	0.33	101	0.000	0.02
2013	0%	0	0	0.28	99	0.000	0.02
2014	0%	0	0	0.30	115	0.000	0.02
2015	0%	0	0	0.62	252	0.000	0.04
2016	0%	0	0	0.59	241	0.001	0.04
2017	0%	0	0	0.59	251	0.001	0.04
2018	0%	0	0	0.29	116	0.000	0.02
2019	0%	0	0	0.35	139	0.000	0.02
2020	0%	0	0	0.41	166	0.000	0.03
2021	0%	0	0	0.48	169	0.000	0.03
2022	0%	0	0	0.59	209	0.001	0.03
2023	0%	0	0	0.73	259	0.001	0.04
2024	0%	0	0	0.83	270	0.001	0.04
2025	0%	0	0	1.0	317	0.001	0.05
2026	0%	0	0	1.1	378	0.001	0.06
2027	0%	0	0	1.3	422	0.001	0.07
2028	0%	0	0	1.6	505	0.001	0.08
2029	0%	0	0	1.9	607	0.002	0.10
2030	0%	0	0	2.3	713	0.002	0.11
2050	0%	0	0	2.7	837	0.002	0.13
2032	0%	0	0	3.1	976	0.003	0.15
2033	0%	0	0	3.6	1,130	0.003	0.18
2034	0%	0	0	4.3	1,331	0.004	0.21
2035	0%	0	0	5.1	1,555	0.005	0.24
2036	0%	0	0	6.1	1,885	0.006	0.30
2037	0%	0	0	7.2	2,237	0.007	0.35
2038	0%	0	0	8.4	2,593	0.008	0.41
2039	0%	0	0	10	3,013	0.009	0.47
2040	0%	0	0	11	3,476	0.01	0.55
2041	0%	0	0	12	3,991	0.01	0.63
2042	0%	0	0	14	4,519	0.01	0.71
2043	0%	0	0	15	4,980	0.01	0.78
2044	0%	0	0	15	5,411	0.02	0.85
2045	0%	0	0	14	5,420	0.02	0.85
2046	0%	0	0	14	5,542	0.01	0.87
2047	0%	0	0	12	5,184	0.01	0.81
2048	0%	0	0	11	5,001	0.01	0.79
2049	0%	0	0	9.4	4,781	0.01	0.75
2050	0%	0	0	5.2	2,874	0.007	0.45
2051	0%	0	0	1.8	1,178	0.004	0.19

Notes:

[1] EMFAC data shown here are obtained directly from EMFAC2017.

[2] Fleet mix percentages in this scenario are obtained directly from EMFAC2017.

[3] Population in each model year is calculated based on the fleet mix percentages for each HHDT type and the total population in the EMFAC data.

[4] Energy consumption is calculated based on EMFAC data, using the EER for each HHDT type shown in Table A-38.

[5] Emissions from vehicles in each model year are obtained directly from EMFAC2017 in this scenario.

[6] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CA Cert. - California certified
CH_4 - methane
CO_2 - carbon dioxide
DSL - diesel
EER - energy economy ratio
EMFAC2017 - Emission Factor Model
gal - gallon
HHDT - heavy heavy duty truck
MJ - megajoule
N_2O - nitrous oxide
NG - natural gas
NO_x - oxides of nitrogen
T7 SWCV - solid waste collection vehicles
TOTEX - total exhaust

Table A-8. NOx and GHG Tailpipe Emissions for Scenario 1 in Calendar Year 2020

	Adjusted EMFAC2017 Output[1]						**Conventional DSL**		
Model Year	**Population**	**NOx_TOTEX (tons/day)**	**CO2_TOTEX (tons/day)**	**CH4_TOTEX (tons/day)**	**N2O_TOTEX (tons/day)**	**Fuel Consumption (1000 gal/day)**	**Fleet Mix[2] (%)**	**Population[3]**	**Energy Consumption[4] (MJ/day)**
1976	29	0.02	1.7	0.000	0.000	0.15	100%	29	19,871
1977	34	0.02	2.3	0.000	0.000	0.20	100%	34	27,331
1978	66	0.04	3.9	0.000	0.001	0.35	100%	66	47,207
1979	94	0.05	5.0	0.000	0.001	0.44	100%	94	59,761
1980	87	0.05	5.1	0.000	0.001	0.45	100%	87	61,143
1981	258	0.15	15	0.000	0.002	1.3	100%	258	180,361
1982	236	0.13	13	0.000	0.002	1.2	100%	236	156,209
1983	219	0.13	13	0.000	0.002	1.1	100%	219	151,257
1984	274	0.18	18	0.000	0.003	1.6	100%	274	214,575
1985	404	0.25	25	0.000	0.004	2.2	100%	404	301,188
1986	396	0.25	25	0.000	0.004	2.2	100%	396	301,092
1987	426	0.29	27	0.000	0.004	2.4	100%	426	324,223
1988	484	0.34	32	0.000	0.005	2.9	100%	484	387,591
1989	567	0.40	38	0.000	0.006	3.4	100%	567	454,438
1990	539	0.39	37	0.000	0.006	3.3	100%	539	446,862
1991	475	0.34	28	0.000	0.004	2.5	100%	475	335,098
1992	399	0.31	25	0.000	0.004	2.2	100%	399	301,877
1993	363	0.29	25	0.000	0.004	2.2	100%	363	295,585
1994	379	0.31	28	0.000	0.004	2.5	100%	379	330,512
1995	507	0.41	37	0.000	0.006	3.3	100%	507	443,837
1996	1,142	1.8	150	0.006	0.02	13	100%	1,142	1,800,897
1997	1,167	1.8	149	0.006	0.02	13	100%	1,167	1,790,241
1998	1,370	2.2	192	0.008	0.03	17	100%	1,370	2,305,455
1999	1,972	4.1	291	0.01	0.05	26	100%	1,972	3,484,066
2000	4,067	9.0	641	0.02	0.10	57	100%	4,067	7,683,603
2001	3,153	6.6	476	0.02	0.07	42	100%	3,153	5,706,180
2002	2,427	4.6	338	0.01	0.05	30	100%	2,427	4,046,083
2003	2,907	3.5	425	0.01	0.07	38	100%	2,907	5,088,912
2004	2,913	3.0	421	0.01	0.07	38	100%	2,913	5,047,803
2005	4,812	5.1	719	0.02	0.11	64	100%	4,812	8,613,212
2006	5,968	6.9	972	0.03	0.15	87	100%	5,968	11,650,876
2007	8,303	9.5	1,454	0.03	0.23	130	100%	8,303	17,419,576
2008	12,274	13	2,417	0.02	0.38	215	100%	12,274	28,960,284
2009	14,354	16	3,080	0.03	0.48	275	100%	14,354	36,913,677
2010	11,383	13	2,653	0.02	0.42	236	100%	11,383	31,795,323
2011	13,627	10	3,166	0.01	0.50	282	100%	13,627	37,940,166
2012	39,297	19	6,724	0.01	1.1	599	100%	39,297	80,581,115
2013	21,084	14	5,397	0.010	0.85	481	100%	21,084	64,680,893
2014	23,061	12	5,525	0.01	0.87	492	100%	23,061	66,207,976
2015	28,916	14	7,779	0.02	1.2	693	100%	28,916	93,222,050
2016	41,998	22	12,488	0.02	2.0	1,113	100%	41,998	149,658,452
2017	16,101	6.6	3,944	0.008	0.62	351	100%	16,101	47,265,405
2018	12,688	5.9	3,720	0.007	0.58	332	100%	12,688	44,579,225
2019	12,851	5.6	3,844	0.007	0.60	343	100%	12,851	46,069,473
2020	8,537	3.3	2,461	0.004	0.39	219	100%	8,537	29,496,897
2021	4,246	1.1	575	0.002	0.09	51	100%	4,246	6,891,960

Model Year	Federal Low NOx DSL			CA Cert. Low NOx DSL			Low NOx NG		
	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)
1976	0%	0	0	0%	0	0	0%	0	0
1977	0%	0	0	0%	0	0	0%	0	0
1978	0%	0	0	0%	0	0	0%	0	0
1979	0%	0	0	0%	0	0	0%	0	0
1980	0%	0	0	0%	0	0	0%	0	0
1981	0%	0	0	0%	0	0	0%	0	0
1982	0%	0	0	0%	0	0	0%	0	0
1983	0%	0	0	0%	0	0	0%	0	0
1984	0%	0	0	0%	0	0	0%	0	0
1985	0%	0	0	0%	0	0	0%	0	0
1986	0%	0	0	0%	0	0	0%	0	0
1987	0%	0	0	0%	0	0	0%	0	0
1988	0%	0	0	0%	0	0	0%	0	0
1989	0%	0	0	0%	0	0	0%	0	0
1990	0%	0	0	0%	0	0	0%	0	0
1991	0%	0	0	0%	0	0	0%	0	0
1992	0%	0	0	0%	0	0	0%	0	0
1993	0%	0	0	0%	0	0	0%	0	0
1994	0%	0	0	0%	0	0	0%	0	0
1995	0%	0	0	0%	0	0	0%	0	0
1996	0%	0	0	0%	0	0	0%	0	0
1997	0%	0	0	0%	0	0	0%	0	0
1998	0%	0	0	0%	0	0	0%	0	0
1999	0%	0	0	0%	0	0	0%	0	0
2000	0%	0	0	0%	0	0	0%	0	0
2001	0%	0	0	0%	0	0	0%	0	0
2002	0%	0	0	0%	0	0	0%	0	0
2003	0%	0	0	0%	0	0	0%	0	0
2004	0%	0	0	0%	0	0	0%	0	0
2005	0%	0	0	0%	0	0	0%	0	0
2006	0%	0	0	0%	0	0	0%	0	0
2007	0%	0	0	0%	0	0	0%	0	0
2008	0%	0	0	0%	0	0	0%	0	0
2009	0%	0	0	0%	0	0	0%	0	0
2010	0%	0	0	0%	0	0	0%	0	0
2011	0%	0	0	0%	0	0	0%	0	0
2012	0%	0	0	0%	0	0	0%	0	0
2013	0%	0	0	0%	0	0	0%	0	0
2014	0%	0	0	0%	0	0	0%	0	0
2015	0%	0	0	0%	0	0	0%	0	0
2016	0%	0	0	0%	0	0	0%	0	0
2017	0%	0	0	0%	0	0	0%	0	0
2018	0%	0	0	0%	0	0	0%	0	0
2019	0%	0	0	0%	0	0	0%	0	0
2020	0%	0	0	0%	0	0	0%	0	0
2021	0%	0	0	0%	0	0	0%	0	0

Table A-8. NOx and GHG Tailpipe Emissions for Scenario 1 in Calendar Year 2020

	BEV			Tailpipe Emission Estimates[5] (tons/day)			
Model Year	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	NO_X	CO_2	CH_4	N_2O
1976	0%	0	0	0.02	1.7	0.000	0.000
1977	0%	0	0	0.02	2.3	0.000	0.000
1978	0%	0	0	0.04	3.9	0.000	0.001
1979	0%	0	0	0.05	5.0	0.000	0.001
1980	0%	0	0	0.05	5.1	0.000	0.001
1981	0%	0	0	0.15	15	0.000	0.002
1982	0%	0	0	0.13	13	0.000	0.002
1983	0%	0	0	0.13	13	0.000	0.002
1984	0%	0	0	0.18	18	0.000	0.003
1985	0%	0	0	0.25	25	0.000	0.004
1986	0%	0	0	0.25	25	0.000	0.004
1987	0%	0	0	0.29	27	0.000	0.004
1988	0%	0	0	0.34	32	0.000	0.005
1989	0%	0	0	0.40	38	0.000	0.006
1990	0%	0	0	0.39	37	0.000	0.006
1991	0%	0	0	0.34	28	0.000	0.004
1992	0%	0	0	0.31	25	0.000	0.004
1993	0%	0	0	0.29	25	0.000	0.004
1994	0%	0	0	0.31	28	0.000	0.004
1995	0%	0	0	0.41	37	0.000	0.006
1996	0%	0	0	1.8	150	0.006	0.02
1997	0%	0	0	1.8	149	0.006	0.02
1998	0%	0	0	2.2	192	0.008	0.03
1999	0%	0	0	4.1	291	0.01	0.05
2000	0%	0	0	9.0	641	0.02	0.10
2001	0%	0	0	6.6	476	0.02	0.07
2002	0%	0	0	4.6	338	0.01	0.05
2003	0%	0	0	3.5	425	0.01	0.07
2004	0%	0	0	3.0	421	0.01	0.07
2005	0%	0	0	5.1	719	0.02	0.11
2006	0%	0	0	6.9	972	0.03	0.15
2007	0%	0	0	9.5	1,454	0.03	0.23
2008	0%	0	0	13	2,417	0.02	0.38
2009	0%	0	0	16	3,080	0.03	0.48
2010	0%	0	0	13	2,653	0.02	0.42
2011	0%	0	0	10	3,166	0.01	0.50
2012	0%	0	0	19	6,724	0.01	1.1
2013	0%	0	0	14	5,397	0.010	0.85
2014	0%	0	0	12	5,525	0.01	0.87
2015	0%	0	0	14	7,779	0.02	1.2
2016	0%	0	0	22	12,488	0.02	2.0
2017	0%	0	0	6.6	3,944	0.008	0.62
2018	0%	0	0	5.9	3,720	0.007	0.58
2019	0%	0	0	5.6	3,844	0.007	0.60
2020	0%	0	0	3.3	2,461	0.004	0.39
2021	0%	0	0	1.1	575	0.002	0.09

Notes:

[1] EMFAC data shown here are adjusted by subtracting data for T7 SWCVs from corresponding data for all HHDTs as described in Appendix A. Accelerated turnover adjustments are included in calendar years 2031, 2037, 2045, and 2050 as described in Appendix A.

[2] Fleet mix percentages for each alternative HHDT technology type are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[3] Population in each model year is calculated based on the fleet mix percentages for each HHDT type and the total population in the adjusted EMFAC data.

[4] Energy consumption is calculated based on adjusted EMFAC data, using the EER for each HHDT type shown in Table A-38.

[5] Emissions from vehicles in each model year are calculated based on the fleet mix composition and the reduction in tailpipe NOx emissions achieved by each HHDT type shown in Table 3-2. Total emissions in each calendar year are calculated as the sum of tailpipe emissions across all HHDT types and all model years in each calendar year.

[6] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CA Cert. - California certified
CH_4 - methane
CO_2 - carbon dioxide
DSL - diesel
EER - energy economy ratio
EMFAC2017 - Emission Factor Model
gal - gallon
HHDT - heavy heavy duty truck
MJ - megajoule
N_2O - nitrous oxide
NG - natural gas
NO_x - oxides of nitrogen
T7 SWCV - solid waste collection vehicles
TOTEX - total exhaust

Table A-9. NOx and GHG Tailpipe Emissions for Scenario 1 in Calendar Year 2023

	Adjusted EMFAC2017 Output[1]						Conventional DSL		
Model Year	Population	NOx_TOTEX (tons/day)	CO2_TOTEX (tons/day)	CH4_TOTEX (tons/day)	N2O_TOTEX (tons/day)	Fuel Consumption (1000 gal/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)
1979	53	0.03	2.9	0.000	0.000	0.26	100%	53	35,019
1980	64	0.04	3.7	0.000	0.001	0.33	100%	64	44,086
1981	209	0.12	12	0.000	0.002	1.1	100%	209	142,790
1982	208	0.11	11	0.000	0.002	1.0	100%	208	134,214
1983	196	0.11	11	0.000	0.002	1.0	100%	196	131,088
1984	241	0.15	15	0.000	0.002	1.3	100%	241	176,822
1985	357	0.21	21	0.000	0.003	1.9	100%	357	252,082
1986	331	0.20	20	0.000	0.003	1.8	100%	331	243,579
1987	345	0.22	21	0.000	0.003	1.9	100%	345	253,082
1988	370	0.26	24	0.000	0.004	2.2	100%	370	290,997
1989	420	0.29	28	0.000	0.004	2.5	100%	420	332,355
1990	382	0.28	27	0.000	0.004	2.4	100%	382	319,401
1991	331	0.24	20	0.000	0.003	1.8	100%	331	238,471
1992	279	0.22	18	0.000	0.003	1.6	100%	279	214,037
1993	235	0.20	17	0.000	0.003	1.5	100%	235	202,566
1994	257	0.21	19	0.000	0.003	1.7	100%	257	228,163
1995	341	0.29	26	0.000	0.004	2.3	100%	341	308,497
1996	354	0.29	26	0.000	0.004	2.3	100%	354	309,827
1997	358	0.27	24	0.000	0.004	2.2	100%	358	292,799
1998	350	0.29	27	0.000	0.004	2.4	100%	350	324,850
1999	484	0.48	38	0.000	0.006	3.4	100%	484	458,610
2000	570	0.55	44	0.000	0.007	3.9	100%	570	522,449
2001	630	0.52	42	0.000	0.007	3.7	100%	630	502,288
2002	683	0.50	41	0.000	0.006	3.7	100%	683	490,906
2003	607	0.31	41	0.000	0.006	3.7	100%	607	491,836
2004	588	0.27	39	0.000	0.006	3.4	100%	588	462,594
2005	722	0.33	48	0.000	0.008	4.3	100%	722	579,188
2006	789	0.37	53	0.000	0.008	4.7	100%	789	635,640
2007	1,010	0.43	69	0.000	0.01	6.1	100%	1,010	822,391
2008	958	0.24	51	0.000	0.008	4.5	100%	958	608,971
2009	1,054	0.24	57	0.000	0.009	5.1	100%	1,054	681,595
2010	516	0.11	28	0.000	0.004	2.5	100%	516	336,250
2011	601	0.08	32	0.000	0.005	2.8	100%	601	381,333
2012	36,456	15	5,160	0.010	0.81	460	100%	36,456	61,840,416
2013	23,385	13	4,715	0.009	0.74	420	100%	23,385	56,503,770
2014	25,954	12	4,907	0.01	0.77	437	100%	25,954	58,805,403
2015	43,313	18	8,476	0.02	1.3	755	100%	43,313	101,582,009
2016	51,092	25	12,180	0.03	1.9	1,086	100%	51,092	145,975,230
2017	45,093	20	10,301	0.02	1.6	918	100%	45,093	123,455,483
2018	15,699	7.6	3,880	0.008	0.61	346	100%	15,699	46,494,284
2019	15,755	7.5	4,119	0.008	0.65	367	100%	15,755	49,364,115
2020	14,758	7.0	4,076	0.008	0.64	363	100%	14,758	48,851,177
2021	13,866	6.3	3,442	0.008	0.54	307	100%	13,866	41,250,943
2022	13,999	6.1	3,590	0.008	0.56	320	100%	13,999	43,027,237
2023	9,671	3.7	2,395	0.005	0.38	213	100%	9,671	28,707,076
2024	4,843	1.3	599	0.003	0.09	53	0%	0	0

Table A-9. NOx and GHG Tailpipe Emissions for Scenario 1 in Calendar Year 2023
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

	Federal Low NOx DSL			CA Cert. Low NOx DSL			Low NOx NG		
Model Year	**Fleet Mix[2] (%)**	**Population[3]**	**Energy Consumption[4] (MJ/day)**	**Fleet Mix[2] (%)**	**Population[3]**	**Energy Consumption[4] (MJ/day)**	**Fleet Mix[2] (%)**	**Population[3]**	**Energy Consumption[4] (MJ/day)**
1979	0%	0	0	0%	0	0	0%	0	0
1980	0%	0	0	0%	0	0	0%	0	0
1981	0%	0	0	0%	0	0	0%	0	0
1982	0%	0	0	0%	0	0	0%	0	0
1983	0%	0	0	0%	0	0	0%	0	0
1984	0%	0	0	0%	0	0	0%	0	0
1985	0%	0	0	0%	0	0	0%	0	0
1986	0%	0	0	0%	0	0	0%	0	0
1987	0%	0	0	0%	0	0	0%	0	0
1988	0%	0	0	0%	0	0	0%	0	0
1989	0%	0	0	0%	0	0	0%	0	0
1990	0%	0	0	0%	0	0	0%	0	0
1991	0%	0	0	0%	0	0	0%	0	0
1992	0%	0	0	0%	0	0	0%	0	0
1993	0%	0	0	0%	0	0	0%	0	0
1994	0%	0	0	0%	0	0	0%	0	0
1995	0%	0	0	0%	0	0	0%	0	0
1996	0%	0	0	0%	0	0	0%	0	0
1997	0%	0	0	0%	0	0	0%	0	0
1998	0%	0	0	0%	0	0	0%	0	0
1999	0%	0	0	0%	0	0	0%	0	0
2000	0%	0	0	0%	0	0	0%	0	0
2001	0%	0	0	0%	0	0	0%	0	0
2002	0%	0	0	0%	0	0	0%	0	0
2003	0%	0	0	0%	0	0	0%	0	0
2004	0%	0	0	0%	0	0	0%	0	0
2005	0%	0	0	0%	0	0	0%	0	0
2006	0%	0	0	0%	0	0	0%	0	0
2007	0%	0	0	0%	0	0	0%	0	0
2008	0%	0	0	0%	0	0	0%	0	0
2009	0%	0	0	0%	0	0	0%	0	0
2010	0%	0	0	0%	0	0	0%	0	0
2011	0%	0	0	0%	0	0	0%	0	0
2012	0%	0	0	0%	0	0	0%	0	0
2013	0%	0	0	0%	0	0	0%	0	0
2014	0%	0	0	0%	0	0	0%	0	0
2015	0%	0	0	0%	0	0	0%	0	0
2016	0%	0	0	0%	0	0	0%	0	0
2017	0%	0	0	0%	0	0	0%	0	0
2018	0%	0	0	0%	0	0	0%	0	0
2019	0%	0	0	0%	0	0	0%	0	0
2020	0%	0	0	0%	0	0	0%	0	0
2021	0%	0	0	0%	0	0	0%	0	0
2022	0%	0	0	0%	0	0	0%	0	0
2023	0%	0	0	0%	0	0	0%	0	0
2024	10%	484	717,286	25%	1,211	1,793,216	0%	0	0

Table A-9. NOx and GHG Tailpipe Emissions for Scenario 1 in Calendar Year 2023

	BEV			Tailpipe Emission Estimates[5] (tons/day)			
Model Year	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	NO_X	CO_2	CH_4	N_2O
1979	0%	0	0	0.03	2.9	0.000	0.000
1980	0%	0	0	0.04	3.7	0.000	0.001
1981	0%	0	0	0.12	12	0.000	0.002
1982	0%	0	0	0.11	11	0.000	0.002
1983	0%	0	0	0.11	11	0.000	0.002
1984	0%	0	0	0.15	15	0.000	0.002
1985	0%	0	0	0.21	21	0.000	0.003
1986	0%	0	0	0.20	20	0.000	0.003
1987	0%	0	0	0.22	21	0.000	0.003
1988	0%	0	0	0.26	24	0.000	0.004
1989	0%	0	0	0.29	28	0.000	0.004
1990	0%	0	0	0.28	27	0.000	0.004
1991	0%	0	0	0.24	20	0.000	0.003
1992	0%	0	0	0.22	18	0.000	0.003
1993	0%	0	0	0.20	17	0.000	0.003
1994	0%	0	0	0.21	19	0.000	0.003
1995	0%	0	0	0.29	26	0.000	0.004
1996	0%	0	0	0.29	26	0.000	0.004
1997	0%	0	0	0.27	24	0.000	0.004
1998	0%	0	0	0.29	27	0.000	0.004
1999	0%	0	0	0.48	38	0.000	0.006
2000	0%	0	0	0.55	44	0.000	0.007
2001	0%	0	0	0.52	42	0.000	0.007
2002	0%	0	0	0.50	41	0.000	0.006
2003	0%	0	0	0.31	41	0.000	0.006
2004	0%	0	0	0.27	39	0.000	0.006
2005	0%	0	0	0.33	48	0.000	0.008
2006	0%	0	0	0.37	53	0.000	0.008
2007	0%	0	0	0.43	69	0.000	0.01
2008	0%	0	0	0.24	51	0.000	0.008
2009	0%	0	0	0.24	57	0.000	0.009
2010	0%	0	0	0.11	28	0.000	0.004
2011	0%	0	0	0.08	32	0.000	0.005
2012	0%	0	0	15	5,160	0.010	0.81
2013	0%	0	0	13	4,715	0.009	0.74
2014	0%	0	0	12	4,907	0.01	0.77
2015	0%	0	0	18	8,476	0.02	1.3
2016	0%	0	0	25	12,180	0.03	1.9
2017	0%	0	0	20	10,301	0.02	1.6
2018	0%	0	0	7.6	3,880	0.008	0.61
2019	0%	0	0	7.5	4,119	0.008	0.65
2020	0%	0	0	7.0	4,076	0.008	0.64
2021	0%	0	0	6.3	3,442	0.008	0.54
2022	0%	0	0	6.1	3,590	0.008	0.56
2023	0%	0	0	3.7	2,395	0.005	0.38
2024	65%	3,148	1,539,490	0.11	209	0.001	0.03

Notes:

[1] EMFAC data shown here are adjusted by subtracting data for T7 SWCVs from corresponding data for all HHDTs as described in Appendix A. Accelerated turnover adjustments are included in calendar years 2031, 2037, 2045, and 2050 as described in Appendix A.

[2] Fleet mix percentages for each alternative HHDT technology type are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[3] Population in each model year is calculated based on the fleet mix percentages for each HHDT type and the total population in the adjusted EMFAC data.

[4] Energy consumption is calculated based on adjusted EMFAC data, using the EER for each HHDT type shown in Table A-38.

[5] Emissions from vehicles in each model year are calculated based on the fleet mix composition and the reduction in tailpipe NOx emissions achieved by each HHDT type shown in Table 3-2. Total emissions in each calendar year are calculated as the sum of tailpipe emissions across all HHDT types and all model years in each calendar year.

[6] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CA Cert. - California certified
CH_4 - methane
CO_2 - carbon dioxide
DSL - diesel
EER - energy economy ratio
EMFAC2017 - Emission Factor Model
gal - gallon
HHDT - heavy heavy duty truck
MJ - megajoule
N_2O - nitrous oxide
NG - natural gas
NO_x - oxides of nitrogen
T7 SWCV - solid waste collection vehicles
TOTEX - total exhaust

Table A-10. NOx and GHG Tailpipe Emissions for Scenario 1 in Calendar Year 2031

	Adjusted EMFAC2017 Output[1]						Conventional DSL		
Model Year	**Population**	**NOx_TOTEX (tons/day)**	**CO2_TOTEX (tons/day)**	**CH4_TOTEX (tons/day)**	**N2O_TOTEX (tons/day)**	**Fuel Consumption (1000 gal/day)**	**Fleet Mix[2] (%)**	**Population[3]**	**Energy Consumption[4] (MJ/day)**
1987	166	0.09	8.9	0.000	0.001	0.79	100%	166	106,532
1988	223	0.13	12	0.000	0.002	1.1	100%	223	144,024
1989	279	0.16	15	0.000	0.002	1.3	100%	279	179,202
1990	256	0.15	14	0.000	0.002	1.3	100%	256	168,297
1991	221	0.14	11	0.000	0.002	1.0	100%	221	134,880
1992	173	0.11	9.2	0.000	0.001	0.82	100%	173	110,429
1993	132	0.09	7.5	0.000	0.001	0.67	100%	132	90,308
1994	131	0.08	7.6	0.000	0.001	0.68	100%	131	91,104
1995	161	0.11	10	0.000	0.002	0.87	100%	161	116,335
1996	159	0.11	10	0.000	0.002	0.85	100%	159	114,485
1997	155	0.10	9.1	0.000	0.001	0.81	100%	155	108,509
1998	145	0.10	10	0.000	0.001	0.85	100%	145	114,337
1999	197	0.17	13	0.000	0.002	1.2	100%	197	160,607
2000	233	0.20	16	0.000	0.002	1.4	100%	233	188,016
2001	267	0.20	16	0.000	0.003	1.4	100%	267	193,494
2002	300	0.21	17	0.000	0.003	1.5	100%	300	200,551
2003	272	0.13	17	0.000	0.003	1.5	100%	272	200,037
2004	276	0.12	17	0.000	0.003	1.5	100%	276	198,929
2005	353	0.15	22	0.000	0.003	1.9	100%	353	259,740
2006	403	0.18	25	0.000	0.004	2.3	100%	403	303,073
2007	543	0.22	35	0.000	0.006	3.1	100%	543	422,431
2008	564	0.14	29	0.000	0.005	2.6	100%	564	352,228
2009	654	0.15	34	0.000	0.005	3.1	100%	654	410,832
2010	337	0.07	18	0.000	0.003	1.6	100%	337	211,381
2011	419	0.05	21	0.000	0.003	1.9	100%	419	253,413
2012	18,775	6.3	2,125	0.004	0.33	189	100%	18,775	25,469,698
2013	10,866	5.2	1,931	0.003	0.30	172	100%	10,866	23,141,590
2014	12,373	4.9	1,993	0.004	0.31	178	100%	12,373	23,884,682
2015	22,601	8.0	3,471	0.007	0.55	309	100%	22,601	41,601,211
2016	25,559	9.1	3,866	0.010	0.61	345	100%	25,559	46,327,589
2017	29,560	9.2	4,023	0.009	0.63	359	100%	29,560	48,215,934
2018	10,153	3.8	1,588	0.004	0.25	142	100%	10,153	19,030,587
2019	11,512	4.5	1,861	0.004	0.29	166	100%	11,512	22,305,607
2020	13,043	5.4	2,255	0.005	0.35	201	100%	13,043	27,025,846
2021	14,295	6.2	2,272	0.006	0.36	203	100%	14,295	27,231,919
2022	16,417	7.5	2,835	0.007	0.45	253	100%	16,417	33,979,835
2023	22,059	12	4,261	0.010	0.67	380	100%	22,059	51,063,434
2024	21,715	11	3,988	0.01	0.63	355	0%	0	0
2025	22,619	12	4,524	0.01	0.71	403	0%	0	0
2026	22,104	12	4,758	0.01	0.75	424	0%	0	0
2027	21,594	11	4,671	0.01	0.73	416	0%	0	0
2028	19,744	10	4,452	0.01	0.70	397	0%	0	0
2029	18,560	9.0	4,281	0.01	0.67	382	0%	0	0
2030	17,915	8.2	4,205	0.01	0.66	375	0%	0	0
2031	11,497	4.6	2,590	0.006	0.41	231	0%	0	0
2032	5,864	1.6	694	0.003	0.11	62	0%	0	0

Table A-10. NOx and GHG Tailpipe Emissions for Scenario 1 in Calendar Year 2031

Model Year	Federal Low NOx DSL			CA Cert. Low NOx DSL			Low NOx NG		
	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)
1987	0%	0	0	0%	0	0	0%	0	0
1988	0%	0	0	0%	0	0	0%	0	0
1989	0%	0	0	0%	0	0	0%	0	0
1990	0%	0	0	0%	0	0	0%	0	0
1991	0%	0	0	0%	0	0	0%	0	0
1992	0%	0	0	0%	0	0	0%	0	0
1993	0%	0	0	0%	0	0	0%	0	0
1994	0%	0	0	0%	0	0	0%	0	0
1995	0%	0	0	0%	0	0	0%	0	0
1996	0%	0	0	0%	0	0	0%	0	0
1997	0%	0	0	0%	0	0	0%	0	0
1998	0%	0	0	0%	0	0	0%	0	0
1999	0%	0	0	0%	0	0	0%	0	0
2000	0%	0	0	0%	0	0	0%	0	0
2001	0%	0	0	0%	0	0	0%	0	0
2002	0%	0	0	0%	0	0	0%	0	0
2003	0%	0	0	0%	0	0	0%	0	0
2004	0%	0	0	0%	0	0	0%	0	0
2005	0%	0	0	0%	0	0	0%	0	0
2006	0%	0	0	0%	0	0	0%	0	0
2007	0%	0	0	0%	0	0	0%	0	0
2008	0%	0	0	0%	0	0	0%	0	0
2009	0%	0	0	0%	0	0	0%	0	0
2010	0%	0	0	0%	0	0	0%	0	0
2011	0%	0	0	0%	0	0	0%	0	0
2012	0%	0	0	0%	0	0	0%	0	0
2013	0%	0	0	0%	0	0	0%	0	0
2014	0%	0	0	0%	0	0	0%	0	0
2015	0%	0	0	0%	0	0	0%	0	0
2016	0%	0	0	0%	0	0	0%	0	0
2017	0%	0	0	0%	0	0	0%	0	0
2018	0%	0	0	0%	0	0	0%	0	0
2019	0%	0	0	0%	0	0	0%	0	0
2020	0%	0	0	0%	0	0	0%	0	0
2021	0%	0	0	0%	0	0	0%	0	0
2022	0%	0	0	0%	0	0	0%	0	0
2023	0%	0	0	0%	0	0	0%	0	0
2024	10%	2,171	4,779,835	25%	5,429	11,949,588	0%	0	0
2025	10%	2,262	5,421,301	30%	6,786	16,263,902	0%	0	0
2026	10%	2,210	5,702,550	35%	7,736	19,958,924	0%	0	0
2027	15%	3,239	8,396,467	35%	7,558	19,591,756	0%	0	0
2028	15%	2,962	8,002,355	40%	7,898	21,339,614	0%	0	0
2029	20%	3,712	10,260,841	45%	8,352	23,086,893	0%	0	0
2030	20%	3,583	10,079,515	50%	8,958	25,198,789	0%	0	0
2031	20%	2,299	6,209,013	45%	5,174	13,970,280	0%	0	0
2032	10%	586	831,861	40%	2,345	3,327,443	0%	0	0

Table A-10. NOx and GHG Tailpipe Emissions for Scenario 1 in Calendar Year 2031

	BEV			Tailpipe Emission Estimates[5] (tons/day)			
Model Year	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	NO_X	CO_2	CH_4	N_2O
1987	0%	0	0	0.09	8.9	0.000	0.001
1988	0%	0	0	0.13	12	0.000	0.002
1989	0%	0	0	0.16	15	0.000	0.002
1990	0%	0	0	0.15	14	0.000	0.002
1991	0%	0	0	0.14	11	0.000	0.002
1992	0%	0	0	0.11	9.2	0.000	0.001
1993	0%	0	0	0.09	7.5	0.000	0.001
1994	0%	0	0	0.08	7.6	0.000	0.001
1995	0%	0	0	0.11	10	0.000	0.002
1996	0%	0	0	0.11	10	0.000	0.002
1997	0%	0	0	0.10	9.1	0.000	0.001
1998	0%	0	0	0.10	10	0.000	0.001
1999	0%	0	0	0.17	13	0.000	0.002
2000	0%	0	0	0.20	16	0.000	0.002
2001	0%	0	0	0.20	16	0.000	0.003
2002	0%	0	0	0.21	17	0.000	0.003
2003	0%	0	0	0.13	17	0.000	0.003
2004	0%	0	0	0.12	17	0.000	0.003
2005	0%	0	0	0.15	22	0.000	0.003
2006	0%	0	0	0.18	25	0.000	0.004
2007	0%	0	0	0.22	35	0.000	0.006
2008	0%	0	0	0.14	29	0.000	0.005
2009	0%	0	0	0.15	34	0.000	0.005
2010	0%	0	0	0.07	18	0.000	0.003
2011	0%	0	0	0.05	21	0.000	0.003
2012	0%	0	0	6.3	2,125	0.004	0.33
2013	0%	0	0	5.2	1,931	0.003	0.30
2014	0%	0	0	4.9	1,993	0.004	0.31
2015	0%	0	0	8.0	3,471	0.007	0.55
2016	0%	0	0	9.1	3,866	0.010	0.61
2017	0%	0	0	9.2	4,023	0.009	0.63
2018	0%	0	0	3.8	1,588	0.004	0.25
2019	0%	0	0	4.5	1,861	0.004	0.29
2020	0%	0	0	5.4	2,255	0.005	0.35
2021	0%	0	0	6.2	2,272	0.006	0.36
2022	0%	0	0	7.5	2,835	0.007	0.45
2023	0%	0	0	12	4,261	0.010	0.67
2024	65%	14,114	10,258,817	1.0	1,396	0.004	0.22
2025	60%	13,572	10,740,531	1.2	1,809	0.005	0.28
2026	55%	12,157	10,356,256	1.3	2,141	0.006	0.34
2027	50%	10,797	9,241,582	1.4	2,335	0.006	0.37
2028	45%	8,885	7,927,023	1.4	2,448	0.006	0.38
2029	35%	6,496	5,929,144	1.5	2,783	0.007	0.44
2030	30%	5,375	4,992,314	1.4	2,944	0.007	0.46
2031	35%	4,024	3,587,828	0.75	1,684	0.004	0.26
2032	50%	2,932	1,373,383	0.19	347	0.002	0.05

Notes:

[1] EMFAC data shown here are adjusted by subtracting data for T7 SWCVs from corresponding data for all HHDTs as described in Appendix A. Accelerated turnover adjustments are included in calendar years 2031, 2037, 2045, and 2050 as described in Appendix A.

[2] Fleet mix percentages for each alternative HHDT technology type are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[3] Population in each model year is calculated based on the fleet mix percentages for each HHDT type and the total population in the adjusted EMFAC data.

[4] Energy consumption is calculated based on adjusted EMFAC data, using the EER for each HHDT type shown in Table A-38.

[5] Emissions from vehicles in each model year are calculated based on the fleet mix composition and the reduction in tailpipe NOx emissions achieved by each HHDT type shown in Table 3-2. Total emissions in each calendar year are calculated as the sum of tailpipe emissions across all HHDT types and all model years in each calendar year.

[6] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle	EER - energy economy ratio	N_2O - nitrous oxide
CA Cert. - California certified	EMFAC2017 - Emission Factor Model	NG - natural gas
CH_4 - methane	gal - gallon	NO_x - oxides of nitrogen
CO_2 - carbon dioxide	HHDT - heavy heavy duty truck	T7 SWCV - solid waste collection vehicles
DSL - diesel	MJ - megajoule	TOTEX - total exhaust

Table A-11. NOx and GHG Tailpipe Emissions for Scenario 1 in Calendar Year 2037

	Adjusted EMFAC2017 Output[1]						Conventional DSL		
Model Year	**Population**	**NOx_TOTEX (tons/day)**	**CO2_TOTEX (tons/day)**	**CH4_TOTEX (tons/day)**	**N2O_TOTEX (tons/day)**	**Fuel Consumption (1000 gal/day)**	**Fleet Mix[2] (%)**	**Population[3]**	**Energy Consumption[4] (MJ/day)**
1993	66	0.04	3.5	0.000	0.001	0.31	100%	66	42,043
1994	83	0.05	4.2	0.000	0.001	0.38	100%	83	50,721
1995	115	0.07	5.9	0.000	0.001	0.53	100%	115	70,970
1996	119	0.07	6.1	0.000	0.001	0.54	100%	119	72,842
1997	117	0.06	5.9	0.000	0.001	0.52	100%	117	70,488
1998	104	0.06	5.7	0.000	0.001	0.50	100%	104	67,898
1999	133	0.10	7.6	0.000	0.001	0.67	100%	133	90,610
2000	147	0.11	8.5	0.000	0.001	0.76	100%	147	101,850
2001	161	0.11	8.8	0.000	0.001	0.79	100%	161	105,603
2002	172	0.11	9.0	0.000	0.001	0.80	100%	172	107,968
2003	146	0.06	8.3	0.000	0.001	0.74	100%	146	99,226
2004	143	0.06	8.1	0.000	0.001	0.72	100%	143	96,731
2005	178	0.07	10	0.000	0.002	0.92	100%	178	123,640
2006	202	0.09	12	0.000	0.002	1.1	100%	202	143,033
2007	272	0.11	17	0.000	0.003	1.5	100%	272	200,277
2008	292	0.07	15	0.000	0.002	1.3	100%	292	179,211
2009	346	0.08	18	0.000	0.003	1.6	100%	346	213,122
2010	183	0.04	9.3	0.000	0.001	0.83	100%	183	111,727
2011	234	0.03	11	0.000	0.002	1.0	100%	234	136,809
2012	7,969	2.4	804	0.002	0.13	72	100%	7,969	9,641,296
2013	4,340	2.0	750	0.001	0.12	67	100%	4,340	8,984,556
2014	4,954	2.0	817	0.001	0.13	73	100%	4,954	9,795,650
2015	9,674	3.7	1,601	0.003	0.25	143	100%	9,674	19,190,427
2016	10,519	3.7	1,604	0.004	0.25	143	100%	10,519	19,227,562
2017	14,184	3.9	1,723	0.004	0.27	154	100%	14,184	20,654,585
2018	4,924	1.7	692	0.002	0.11	62	100%	4,924	8,290,062
2019	5,803	1.9	807	0.002	0.13	72	100%	5,803	9,667,889
2020	6,713	2.3	945	0.002	0.15	84	100%	6,713	11,329,480
2021	7,708	2.6	942	0.003	0.15	84	100%	7,708	11,285,971
2022	9,361	3.4	1,197	0.003	0.19	107	100%	9,361	14,344,235
2023	12,311	5.2	1,799	0.004	0.28	160	100%	12,311	21,557,339
2024	14,157	5.5	1,804	0.005	0.28	161	0%	0	0
2025	15,781	6.4	2,112	0.006	0.33	188	0%	0	0
2026	17,659	7.5	2,484	0.007	0.39	221	0%	0	0
2027	19,532	8.7	2,768	0.008	0.44	247	0%	0	0
2028	21,365	10	3,236	0.010	0.51	288	0%	0	0
2029	22,985	11	3,748	0.01	0.59	334	0%	0	0
2030	24,081	12	4,213	0.01	0.66	375	0%	0	0
2037	24,791	13	4,671	0.01	0.73	416	0%	0	0
2032	24,114	13	4,857	0.01	0.76	433	0%	0	0
2033	23,670	12	5,060	0.01	0.80	451	0%	0	0
2034	21,948	11	4,883	0.01	0.77	435	0%	0	0
2035	20,791	10	4,742	0.01	0.75	423	0%	0	0
2036	19,699	9.0	4,573	0.01	0.72	408	0%	0	0
2037	12,409	5.0	2,773	0.007	0.44	247	0%	0	0
2038	6,391	1.7	743	0.003	0.12	66	0%	0	0

Table A-11. NOx and GHG Tailpipe Emissions for Scenario 1 in Calendar Year 2037

Model Year	Federal Low NOx DSL			CA Cert. Low NOx DSL			Low NOx NG		
	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)
1993	0%	0	0	0%	0	0	0%	0	0
1994	0%	0	0	0%	0	0	0%	0	0
1995	0%	0	0	0%	0	0	0%	0	0
1996	0%	0	0	0%	0	0	0%	0	0
1997	0%	0	0	0%	0	0	0%	0	0
1998	0%	0	0	0%	0	0	0%	0	0
1999	0%	0	0	0%	0	0	0%	0	0
2000	0%	0	0	0%	0	0	0%	0	0
2001	0%	0	0	0%	0	0	0%	0	0
2002	0%	0	0	0%	0	0	0%	0	0
2003	0%	0	0	0%	0	0	0%	0	0
2004	0%	0	0	0%	0	0	0%	0	0
2005	0%	0	0	0%	0	0	0%	0	0
2006	0%	0	0	0%	0	0	0%	0	0
2007	0%	0	0	0%	0	0	0%	0	0
2008	0%	0	0	0%	0	0	0%	0	0
2009	0%	0	0	0%	0	0	0%	0	0
2010	0%	0	0	0%	0	0	0%	0	0
2011	0%	0	0	0%	0	0	0%	0	0
2012	0%	0	0	0%	0	0	0%	0	0
2013	0%	0	0	0%	0	0	0%	0	0
2014	0%	0	0	0%	0	0	0%	0	0
2015	0%	0	0	0%	0	0	0%	0	0
2016	0%	0	0	0%	0	0	0%	0	0
2017	0%	0	0	0%	0	0	0%	0	0
2018	0%	0	0	0%	0	0	0%	0	0
2019	0%	0	0	0%	0	0	0%	0	0
2020	0%	0	0	0%	0	0	0%	0	0
2021	0%	0	0	0%	0	0	0%	0	0
2022	0%	0	0	0%	0	0	0%	0	0
2023	0%	0	0	0%	0	0	0%	0	0
2024	10%	1,416	2,161,542	25%	3,539	5,403,855	0%	0	0
2025	10%	1,578	2,531,043	30%	4,734	7,593,128	0%	0	0
2026	10%	1,766	2,977,192	35%	6,181	10,420,173	0%	0	0
2027	15%	2,930	4,975,264	35%	6,836	11,608,949	0%	0	0
2028	15%	3,205	5,817,346	40%	8,546	15,512,922	0%	0	0
2029	20%	4,597	8,983,030	45%	10,343	20,211,817	0%	0	0
2030	20%	4,816	10,097,767	50%	12,040	25,244,417	0%	0	0
2037	12%	2,975	6,717,948	5%	1,240	2,799,145	0%	0	0
2032	10%	2,411	5,821,019	40%	9,646	23,284,077	0%	0	0
2033	10%	2,367	6,063,891	35%	8,285	21,223,618	0%	0	0
2034	10%	2,195	5,851,702	30%	6,585	17,555,106	0%	0	0
2035	12%	2,495	6,819,958	5%	1,040	2,841,649	0%	0	0
2036	12%	2,364	6,576,732	5%	985	2,740,305	0%	0	0
2037	12%	1,489	3,988,015	5%	620	1,661,673	0%	0	0
2038	12%	767	1,068,563	5%	320	445,235	0%	0	0

Table A-11. NOx and GHG Tailpipe Emissions for Scenario 1 in Calendar Year 2037

Model Year	BEV			Tailpipe Emission Estimates[5] (tons/day)			
	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	NO_X	CO_2	CH_4	N_2O
1993	0%	0	0	0.04	3.5	0.000	0.001
1994	0%	0	0	0.05	4.2	0.000	0.001
1995	0%	0	0	0.07	5.9	0.000	0.001
1996	0%	0	0	0.07	6.1	0.000	0.001
1997	0%	0	0	0.06	5.9	0.000	0.001
1998	0%	0	0	0.06	5.7	0.000	0.001
1999	0%	0	0	0.10	7.6	0.000	0.001
2000	0%	0	0	0.11	8.5	0.000	0.001
2001	0%	0	0	0.11	8.8	0.000	0.001
2002	0%	0	0	0.11	9.0	0.000	0.001
2003	0%	0	0	0.06	8.3	0.000	0.001
2004	0%	0	0	0.06	8.1	0.000	0.001
2005	0%	0	0	0.07	10	0.000	0.002
2006	0%	0	0	0.09	12	0.000	0.002
2007	0%	0	0	0.11	17	0.000	0.003
2008	0%	0	0	0.07	15	0.000	0.002
2009	0%	0	0	0.08	18	0.000	0.003
2010	0%	0	0	0.04	9.3	0.000	0.001
2011	0%	0	0	0.03	11	0.000	0.002
2012	0%	0	0	2.4	804	0.002	0.13
2013	0%	0	0	2.0	750	0.001	0.12
2014	0%	0	0	2.0	817	0.001	0.13
2015	0%	0	0	3.7	1,601	0.003	0.25
2016	0%	0	0	3.7	1,604	0.004	0.25
2017	0%	0	0	3.9	1,723	0.004	0.27
2018	0%	0	0	1.7	692	0.002	0.11
2019	0%	0	0	1.9	807	0.002	0.13
2020	0%	0	0	2.3	945	0.002	0.15
2021	0%	0	0	2.6	942	0.003	0.15
2022	0%	0	0	3.4	1,197	0.003	0.19
2023	0%	0	0	5.2	1,799	0.004	0.28
2024	65%	9,202	4,639,253	0.48	631	0.002	0.10
2025	60%	9,469	5,014,432	0.64	845	0.002	0.13
2026	55%	9,712	5,406,804	0.85	1,118	0.003	0.18
2027	50%	9,766	5,476,031	1.1	1,384	0.004	0.22
2028	45%	9,614	5,762,582	1.4	1,780	0.005	0.28
2029	35%	8,045	5,190,771	1.8	2,436	0.007	0.38
2030	30%	7,224	5,001,354	2.1	2,949	0.008	0.46
2037	83%	20,577	15,342,795	0.55	794	0.002	0.12
2032	50%	12,057	9,610,369	1.6	2,429	0.007	0.38
2033	55%	13,019	11,012,479	1.4	2,277	0.006	0.36
2034	60%	13,169	11,593,231	1.1	1,953	0.005	0.31
2035	83%	17,257	15,575,770	0.43	806	0.002	0.13
2036	83%	16,350	15,020,279	0.38	777	0.002	0.12
2037	83%	10,300	9,108,035	0.21	471	0.001	0.07
2038	83%	5,305	2,440,439	0.07	126	0.001	0.02

Notes:

[1] EMFAC data shown here are adjusted by subtracting data for T7 SWCVs from corresponding data for all HHDTs as described in Appendix A. Accelerated turnover adjustments are included in calendar years 2031, 2037, 2045, and 2050 as described in Appendix A.

[2] Fleet mix percentages for each alternative HHDT technology type are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[3] Population in each model year is calculated based on the fleet mix percentages for each HHDT type and the total population in the adjusted EMFAC data.

[4] Energy consumption is calculated based on adjusted EMFAC data, using the EER for each HHDT type shown in Table A-38.

[5] Emissions from vehicles in each model year are calculated based on the fleet mix composition and the reduction in tailpipe NOx emissions achieved by each HHDT type shown in Table 3-2. Total emissions in each calendar year are calculated as the sum of tailpipe emissions across all HHDT types and all model years in each calendar year.

[6] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CA Cert. - California certified
CH_4 - methane
CO_2 - carbon dioxide
DSL - diesel
EER - energy economy ratio
EMFAC2017 - Emission Factor Model
gal - gallon
HHDT - heavy heavy duty truck
MJ - megajoule
N_2O - nitrous oxide
NG - natural gas
NO_x - oxides of nitrogen
T7 SWCV - solid waste collection vehicles
TOTEX - total exhaust

Table A-12. NOx and GHG Tailpipe Emissions for Scenario 1 in Calendar Year 2045

	Adjusted EMFAC2017 Output[1]						Conventional DSL		
Model Year	Population	NOx_TOTEX (tons/day)	CO2_TOTEX (tons/day)	CH4_TOTEX (tons/day)	N2O_TOTEX (tons/day)	Fuel Consumption (1000 gal/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)
2001	0	0	0	0	0	0	0%	0	0
2002	0	0	0	0	0	0	0%	0	0
2003	0	0	0	0	0	0	0%	0	0
2004	0	0	0	0	0	0	0%	0	0
2005	0	0	0	0	0	0	0%	0	0
2006	0	0	0	0	0	0	0%	0	0
2007	0	0	0	0	0	0	0%	0	0
2008	0	0	0	0	0	0	0%	0	0
2009	0	0	0	0	0	0	0%	0	0
2010	0	0	0	0	0	0	0%	0	0
2011	0	0	0	0	0	0	0%	0	0
2012	0	0	0	0	0	0	0%	0	0
2013	0	0	0	0	0	0	0%	0	0
2014	0	0	0	0	0	0	0%	0	0
2015	0	0	0	0	0	0	0%	0	0
2016	0	0	0	0	0	0	0%	0	0
2017	0	0	0	0	0	0	0%	0	0
2018	0	0	0	0	0	0	0%	0	0
2019	0	0	0	0	0	0	0%	0	0
2020	0	0	0	0	0	0	0%	0	0
2021	0	0	0	0	0	0	0%	0	0
2022	0	0	0	0	0	0	0%	0	0
2023	0	0	0	0	0	0	0%	0	0
2024	5,738	1.9	631	0.002	0.10	56	0%	0	0
2025	6,682	2.2	740	0.002	0.12	66	0%	0	0
2026	7,830	2.6	869	0.002	0.14	77	0%	0	0
2027	8,960	3.0	954	0.003	0.15	85	0%	0	0
2028	10,297	3.5	1,096	0.003	0.17	98	0%	0	0
2029	11,921	4.1	1,276	0.004	0.20	114	0%	0	0
2030	13,807	4.8	1,488	0.005	0.23	133	0%	0	0
2045	15,655	5.9	1,819	0.006	0.29	162	0%	0	0
2032	17,813	7.1	2,196	0.007	0.35	196	0%	0	0
2033	20,003	8.3	2,581	0.008	0.41	230	0%	0	0
2034	22,623	10	3,067	0.009	0.48	273	0%	0	0
2035	24,976	11	3,584	0.01	0.56	319	0%	0	0
2036	26,967	13	4,118	0.01	0.65	367	0%	0	0
2037	28,599	14	4,677	0.01	0.74	417	0%	0	0
2038	29,556	15	5,172	0.01	0.81	461	0%	0	0
2039	30,085	16	5,646	0.02	0.89	503	0%	0	0
2040	28,520	15	5,685	0.02	0.89	507	0%	0	0
2041	27,485	14	5,816	0.02	0.91	518	0%	0	0
2042	24,780	12	5,446	0.01	0.86	485	0%	0	0
2043	23,286	11	5,243	0.01	0.82	467	0%	0	0
2044	22,012	10	5,025	0.01	0.79	448	0%	0	0
2045	13,831	5.5	3,030	0.007	0.48	270	0%	0	0
2046	7,111	1.9	812	0.004	0.13	72	0%	0	0

Table A-12. NOx and GHG Tailpipe Emissions for Scenario 1 in Calendar Year 2045

Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

	Federal Low NOx DSL			CA Cert. Low NOx DSL			Low NOx NG		
Model Year	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)
2001	0%	0	0	0%	0	0	0%	0	0
2002	0%	0	0	0%	0	0	0%	0	0
2003	0%	0	0	0%	0	0	0%	0	0
2004	0%	0	0	0%	0	0	0%	0	0
2005	0%	0	0	0%	0	0	0%	0	0
2006	0%	0	0	0%	0	0	0%	0	0
2007	0%	0	0	0%	0	0	0%	0	0
2008	0%	0	0	0%	0	0	0%	0	0
2009	0%	0	0	0%	0	0	0%	0	0
2010	0%	0	0	0%	0	0	0%	0	0
2011	0%	0	0	0%	0	0	0%	0	0
2012	0%	0	0	0%	0	0	0%	0	0
2013	0%	0	0	0%	0	0	0%	0	0
2014	0%	0	0	0%	0	0	0%	0	0
2015	0%	0	0	0%	0	0	0%	0	0
2016	0%	0	0	0%	0	0	0%	0	0
2017	0%	0	0	0%	0	0	0%	0	0
2018	0%	0	0	0%	0	0	0%	0	0
2019	0%	0	0	0%	0	0	0%	0	0
2020	0%	0	0	0%	0	0	0%	0	0
2021	0%	0	0	0%	0	0	0%	0	0
2022	0%	0	0	0%	0	0	0%	0	0
2023	0%	0	0	0%	0	0	0%	0	0
2024	10%	574	756,340	25%	1,434	1,890,850	0%	0	0
2025	10%	668	886,781	30%	2,005	2,660,344	0%	0	0
2026	10%	783	1,041,761	35%	2,741	3,646,164	0%	0	0
2027	15%	1,344	1,715,605	35%	3,136	4,003,078	0%	0	0
2028	15%	1,544	1,969,828	40%	4,119	5,252,875	0%	0	0
2029	20%	2,384	3,059,507	45%	5,364	6,883,890	0%	0	0
2030	20%	2,761	3,566,433	50%	6,903	8,916,082	0%	0	0
2045	12%	1,879	2,615,706	5%	783	1,089,877	0%	0	0
2032	10%	1,781	2,631,722	40%	7,125	10,526,888	0%	0	0
2033	10%	2,000	3,093,484	35%	7,001	10,827,195	0%	0	0
2034	10%	2,262	3,676,051	30%	6,787	11,028,154	0%	0	0
2035	12%	2,997	5,154,227	5%	1,249	2,147,595	0%	0	0
2036	12%	3,236	5,922,773	5%	1,348	2,467,822	0%	0	0
2037	12%	3,432	6,725,482	5%	1,430	2,802,284	0%	0	0
2038	12%	3,547	7,438,400	5%	1,478	3,099,333	0%	0	0
2039	12%	3,610	8,118,998	5%	1,504	3,382,916	0%	0	0
2040	12%	3,422	8,176,299	5%	1,426	3,406,791	0%	0	0
2041	12%	3,298	8,363,731	5%	1,374	3,484,888	0%	0	0
2042	12%	2,974	7,831,788	5%	1,239	3,263,245	0%	0	0
2043	12%	2,794	7,539,421	5%	1,164	3,141,425	0%	0	0
2044	12%	2,641	7,227,079	5%	1,101	3,011,283	0%	0	0
2045	12%	1,660	4,357,601	5%	692	1,815,667	0%	0	0
2046	12%	853	1,167,185	5%	356	486,327	0%	0	0

Table A-12. NOx and GHG Tailpipe Emissions for Scenario 1 in Calendar Year 2045

	BEV			Tailpipe Emission Estimates[5] (tons/day)			
Model Year	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	NO_X	CO_2	CH_4	N_2O
2001	0%	0	0	0	0	0	0
2002	0%	0	0	0	0	0	0
2003	0%	0	0	0	0	0	0
2004	0%	0	0	0	0	0	0
2005	0%	0	0	0	0	0	0
2006	0%	0	0	0	0	0	0
2007	0%	0	0	0	0	0	0
2008	0%	0	0	0	0	0	0
2009	0%	0	0	0	0	0	0
2010	0%	0	0	0	0	0	0
2011	0%	0	0	0	0	0	0
2012	0%	0	0	0	0	0	0
2013	0%	0	0	0	0	0	0
2014	0%	0	0	0	0	0	0
2015	0%	0	0	0	0	0	0
2016	0%	0	0	0	0	0	0
2017	0%	0	0	0	0	0	0
2018	0%	0	0	0	0	0	0
2019	0%	0	0	0	0	0	0
2020	0%	0	0	0	0	0	0
2021	0%	0	0	0	0	0	0
2022	0%	0	0	0	0	0	0
2023	0%	0	0	0	0	0	0
2024	65%	3,730	1,623,310	0.17	221	0.001	0.03
2025	60%	4,009	1,756,867	0.22	296	0.001	0.05
2026	55%	4,307	1,891,916	0.30	391	0.001	0.06
2027	50%	4,480	1,888,283	0.38	477	0.001	0.08
2028	45%	4,633	1,951,285	0.48	603	0.002	0.09
2029	35%	4,172	1,767,911	0.67	830	0.003	0.13
2030	30%	4,142	1,766,430	0.85	1,042	0.003	0.16
2045	83%	12,994	5,973,883	0.25	309	0.001	0.05
2032	50%	8,906	4,344,912	0.89	1,098	0.003	0.17
2033	55%	11,002	5,617,998	0.94	1,162	0.003	0.18
2034	60%	13,574	7,282,892	1.0	1,227	0.004	0.19
2035	83%	20,730	11,771,489	0.48	609	0.002	0.10
2036	83%	22,383	13,526,734	0.54	700	0.002	0.11
2037	83%	23,737	15,360,002	0.60	795	0.002	0.12
2038	83%	24,531	16,988,202	0.64	879	0.002	0.14
2039	83%	24,971	18,542,585	0.66	960	0.003	0.15
2040	83%	23,671	18,673,453	0.63	967	0.003	0.15
2041	83%	22,813	19,101,520	0.60	989	0.003	0.16
2042	83%	20,568	17,886,641	0.53	926	0.002	0.15
2043	83%	19,327	17,218,918	0.47	891	0.002	0.14
2044	83%	18,270	16,505,576	0.42	854	0.002	0.13
2045	83%	11,480	9,952,115	0.23	515	0.001	0.08
2046	83%	5,902	2,665,677	0.08	138	0.001	0.02

Notes:

[1] EMFAC data shown here are adjusted by subtracting data for T7 SWCVs from corresponding data for all HHDTs as described in Appendix A. Accelerated turnover adjustments are included in calendar years 2031, 2037, 2045, and 2050 as described in Appendix A.

[2] Fleet mix percentages for each alternative HHDT technology type are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[3] Population in each model year is calculated based on the fleet mix percentages for each HHDT type and the total population in the adjusted EMFAC data.

[4] Energy consumption is calculated based on adjusted EMFAC data, using the EER for each HHDT type shown in Table A-38.

[5] Emissions from vehicles in each model year are calculated based on the fleet mix composition and the reduction in tailpipe NOx emissions achieved by each HHDT type shown in Table 3-2. Total emissions in each calendar year are calculated as the sum of tailpipe emissions across all HHDT types and all model years in each calendar year.

[6] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CA Cert. - California certified
CH_4 - methane
CO_2 - carbon dioxide
DSL - diesel
EER - energy economy ratio
EMFAC2017 - Emission Factor Model
gal - gallon
HHDT - heavy heavy duty truck
MJ - megajoule
N_2O - nitrous oxide
NG - natural gas
NO_x - oxides of nitrogen
T7 SWCV - solid waste collection vehicles
TOTEX - total exhaust

	Adjusted EMFAC2017 Output[1]						**Conventional DSL**		
Model Year	**Population**	**NOx_TOTEX (tons/day)**	**CO2_TOTEX (tons/day)**	**CH4_TOTEX (tons/day)**	**N2O_TOTEX (tons/day)**	**Fuel Consumption (1000 gal/day)**	**Fleet Mix[2] (%)**	**Population[3]**	**Energy Consumption[4] (MJ/day)**
2006	0	0	0	0	0	0	0%	0	0
2007	0	0	0	0	0	0	0%	0	0
2008	0	0	0	0	0	0	0%	0	0
2009	0	0	0	0	0	0	0%	0	0
2010	0	0	0	0	0	0	0%	0	0
2011	0	0	0	0	0	0	0%	0	0
2012	0	0	0	0	0	0	0%	0	0
2013	0	0	0	0	0	0	0%	0	0
2014	0	0	0	0	0	0	0%	0	0
2015	0	0	0	0	0	0	0%	0	0
2016	0	0	0	0	0	0	0%	0	0
2017	0	0	0	0	0	0	0%	0	0
2018	0	0	0	0	0	0	0%	0	0
2019	0	0	0	0	0	0	0%	0	0
2020	0	0	0	0	0	0	0%	0	0
2021	0	0	0	0	0	0	0%	0	0
2022	0	0	0	0	0	0	0%	0	0
2023	0	0	0	0	0	0	0%	0	0
2024	2,595	0.86	281	0.001	0.04	25	0%	0	0
2025	3,028	1.0	330	0.001	0.05	29	0%	0	0
2026	3,626	1.2	393	0.001	0.06	35	0%	0	0
2027	4,257	1.4	439	0.001	0.07	39	0%	0	0
2028	5,060	1.7	526	0.001	0.08	47	0%	0	0
2029	6,031	2.0	632	0.002	0.10	56	0%	0	0
2030	7,066	2.4	743	0.002	0.12	66	0%	0	0
2050	8,217	2.8	872	0.003	0.14	78	0%	0	0
2032	9,494	3.2	1,017	0.003	0.16	91	0%	0	0
2033	11,004	3.8	1,176	0.004	0.18	105	0%	0	0
2034	12,911	4.5	1,386	0.004	0.22	124	0%	0	0
2035	14,935	5.3	1,619	0.005	0.25	144	0%	0	0
2036	16,783	6.4	1,962	0.006	0.31	175	0%	0	0
2037	18,732	7.5	2,328	0.007	0.37	208	0%	0	0
2038	20,725	8.7	2,699	0.008	0.42	241	0%	0	0
2039	22,925	10	3,137	0.009	0.49	280	0%	0	0
2040	25,074	11	3,619	0.01	0.57	323	0%	0	0
2041	27,099	13	4,155	0.01	0.65	370	0%	0	0
2042	28,740	14	4,704	0.01	0.74	419	0%	0	0
2043	29,658	15	5,184	0.01	0.81	462	0%	0	0
2044	30,119	16	5,634	0.02	0.89	502	0%	0	0
2045	28,407	15	5,643	0.02	0.89	503	0%	0	0
2046	27,387	14	5,770	0.02	0.91	514	0%	0	0
2047	24,660	12	5,397	0.01	0.85	481	0%	0	0
2048	23,198	11	5,206	0.01	0.82	464	0%	0	0
2049	21,872	10	4,978	0.01	0.78	444	0%	0	0
2050	13,695	5.4	2,992	0.007	0.47	267	0%	0	0
2051	7,053	1.8	1,226	0.004	0.19	109	0%	0	0

Table A-13. NOx and GHG Tailpipe Emissions for Scenario 1 in Calendar Year 2050

Model Year	Federal Low NOx DSL			CA Cert. Low NOx DSL			Low NOx NG		
	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)
2006	0%	0	0	0%	0	0	0%	0	0
2007	0%	0	0	0%	0	0	0%	0	0
2008	0%	0	0	0%	0	0	0%	0	0
2009	0%	0	0	0%	0	0	0%	0	0
2010	0%	0	0	0%	0	0	0%	0	0
2011	0%	0	0	0%	0	0	0%	0	0
2012	0%	0	0	0%	0	0	0%	0	0
2013	0%	0	0	0%	0	0	0%	0	0
2014	0%	0	0	0%	0	0	0%	0	0
2015	0%	0	0	0%	0	0	0%	0	0
2016	0%	0	0	0%	0	0	0%	0	0
2017	0%	0	0	0%	0	0	0%	0	0
2018	0%	0	0	0%	0	0	0%	0	0
2019	0%	0	0	0%	0	0	0%	0	0
2020	0%	0	0	0%	0	0	0%	0	0
2021	0%	0	0	0%	0	0	0%	0	0
2022	0%	0	0	0%	0	0	0%	0	0
2023	0%	0	0	0%	0	0	0%	0	0
2024	10%	260	337,270	25%	649	843,175	0%	0	0
2025	10%	303	395,918	30%	908	1,187,754	0%	0	0
2026	10%	363	471,136	35%	1,269	1,648,977	0%	0	0
2027	15%	639	789,915	35%	1,490	1,843,135	0%	0	0
2028	15%	759	945,969	40%	2,024	2,522,585	0%	0	0
2029	20%	1,206	1,514,257	45%	2,714	3,407,079	0%	0	0
2030	20%	1,413	1,780,183	50%	3,533	4,450,457	0%	0	0
2050	12%	986	1,253,331	5%	411	522,221	0%	0	0
2032	10%	949	1,218,218	40%	3,797	4,872,872	0%	0	0
2033	10%	1,100	1,409,784	35%	3,851	4,934,242	0%	0	0
2034	10%	1,291	1,660,800	30%	3,873	4,982,400	0%	0	0
2035	12%	1,792	2,327,866	5%	747	969,944	0%	0	0
2036	12%	2,014	2,822,001	5%	839	1,175,834	0%	0	0
2037	12%	2,248	3,348,517	5%	937	1,395,215	0%	0	0
2038	12%	2,487	3,881,574	5%	1,036	1,617,323	0%	0	0
2039	12%	2,751	4,511,626	5%	1,146	1,879,844	0%	0	0
2040	12%	3,009	5,204,512	5%	1,254	2,168,547	0%	0	0
2041	12%	3,252	5,974,789	5%	1,355	2,489,495	0%	0	0
2042	12%	3,449	6,765,245	5%	1,437	2,818,852	0%	0	0
2043	12%	3,559	7,455,772	5%	1,483	3,106,572	0%	0	0
2044	12%	3,614	8,101,789	5%	1,506	3,375,745	0%	0	0
2045	12%	3,409	8,115,025	5%	1,420	3,381,260	0%	0	0
2046	12%	3,286	8,297,953	5%	1,369	3,457,480	0%	0	0
2047	12%	2,959	7,761,898	5%	1,233	3,234,124	0%	0	0
2048	12%	2,784	7,487,127	5%	1,160	3,119,636	0%	0	0
2049	12%	2,625	7,158,856	5%	1,094	2,982,857	0%	0	0
2050	12%	1,643	4,302,930	5%	685	1,792,888	0%	0	0
2051	12%	846	1,763,371	5%	353	734,738	0%	0	0

Table A-13. NOx and GHG Tailpipe Emissions for Scenario 1 in Calendar Year 2050

	BEV			Tailpipe Emission Estimates[5] (tons/day)			
Model Year	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	NO_X	CO_2	CH_4	N_2O
2006	0%	0	0	0	0	0	0
2007	0%	0	0	0	0	0	0
2008	0%	0	0	0	0	0	0
2009	0%	0	0	0	0	0	0
2010	0%	0	0	0	0	0	0
2011	0%	0	0	0	0	0	0
2012	0%	0	0	0	0	0	0
2013	0%	0	0	0	0	0	0
2014	0%	0	0	0	0	0	0
2015	0%	0	0	0	0	0	0
2016	0%	0	0	0	0	0	0
2017	0%	0	0	0	0	0	0
2018	0%	0	0	0	0	0	0
2019	0%	0	0	0	0	0	0
2020	0%	0	0	0	0	0	0
2021	0%	0	0	0	0	0	0
2022	0%	0	0	0	0	0	0
2023	0%	0	0	0	0	0	0
2024	65%	1,687	723,873	0.08	98	0.000	0.02
2025	60%	1,817	784,381	0.10	132	0.000	0.02
2026	55%	1,994	855,619	0.13	177	0.000	0.03
2027	50%	2,128	869,421	0.18	220	0.001	0.03
2028	45%	2,277	937,064	0.23	289	0.001	0.05
2029	35%	2,111	875,001	0.33	411	0.001	0.06
2030	30%	2,120	881,712	0.41	520	0.001	0.08
2050	83%	6,820	2,862,421	0.12	148	0.000	0.02
2032	50%	4,747	2,011,250	0.40	508	0.001	0.08
2033	55%	6,052	2,560,272	0.42	529	0.002	0.08
2034	60%	7,747	3,290,331	0.45	554	0.002	0.09
2035	83%	12,396	5,316,501	0.22	275	0.001	0.04
2036	83%	13,929	6,445,032	0.27	334	0.001	0.05
2037	83%	15,547	7,647,515	0.32	396	0.001	0.06
2038	83%	17,202	8,864,939	0.37	459	0.001	0.07
2039	83%	19,028	10,303,884	0.43	533	0.002	0.08
2040	83%	20,812	11,886,333	0.49	615	0.002	0.10
2041	83%	22,492	13,645,531	0.55	706	0.002	0.11
2042	83%	23,855	15,450,815	0.61	800	0.002	0.13
2043	83%	24,616	17,027,875	0.64	881	0.002	0.14
2044	83%	24,999	18,503,282	0.66	958	0.003	0.15
2045	83%	23,578	18,533,512	0.63	959	0.003	0.15
2046	83%	22,732	18,951,293	0.60	981	0.003	0.15
2047	83%	20,468	17,727,023	0.52	918	0.002	0.14
2048	83%	19,254	17,099,486	0.47	885	0.002	0.14
2049	83%	18,154	16,349,764	0.42	846	0.002	0.13
2050	83%	11,367	9,827,254	0.23	509	0.001	0.08
2051	83%	5,854	4,027,277	0.08	208	0.001	0.03

Notes:

[1] EMFAC data shown here are adjusted by subtracting data for T7 SWCVs from corresponding data for all HHDTs as described in Appendix A. Accelerated turnover adjustments are included in calendar years 2031, 2037, 2045, and 2050 as described in Appendix A.

[2] Fleet mix percentages for each alternative HHDT technology type are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[3] Population in each model year is calculated based on the fleet mix percentages for each HHDT type and the total population in the adjusted EMFAC data.

[4] Energy consumption is calculated based on adjusted EMFAC data, using the EER for each HHDT type shown in Table A-38.

[5] Emissions from vehicles in each model year are calculated based on the fleet mix composition and the reduction in tailpipe NOx emissions achieved by each HHDT type shown in Table 3-2. Total emissions in each calendar year are calculated as the sum of tailpipe emissions across all HHDT types and all model years in each calendar year.

[6] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CA Cert. - California certified
CH_4 - methane
CO_2 - carbon dioxide
DSL - diesel
EER - energy economy ratio
EMFAC2017 - Emission Factor Model
gal - gallon
HHDT - heavy heavy duty truck
MJ - megajoule
N_2O - nitrous oxide
NG - natural gas
NO_x - oxides of nitrogen
T7 SWCV - solid waste collection vehicles
TOTEX - total exhaust

Table A-14. NOx and GHG Tailpipe Emissions for Scenario 2 in Calendar Year 2020

Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

	Adjusted EMFAC2017 Output[1]						Conventional DSL		
Model Year	**Population**	**NOx_TOTEX (tons/day)**	**CO2_TOTEX (tons/day)**	**CH4_TOTEX (tons/day)**	**N2O_TOTEX (tons/day)**	**Fuel Consumption (1000 gal/day)**	**Fleet Mix[2] (%)**	**Population[3]**	**Energy Consumption[4] (MJ/day)**
1976	29	0.02	1.7	0.000	0.000	0.15	100%	29	19,871
1977	34	0.02	2.3	0.000	0.000	0.20	100%	34	27,331
1978	66	0.04	3.9	0.000	0.001	0.35	100%	66	47,207
1979	94	0.05	5.0	0.000	0.001	0.44	100%	94	59,761
1980	87	0.05	5.1	0.000	0.001	0.45	100%	87	61,143
1981	258	0.15	15	0.000	0.002	1.3	100%	258	180,361
1982	236	0.13	13	0.000	0.002	1.2	100%	236	156,209
1983	219	0.13	13	0.000	0.002	1.1	100%	219	151,257
1984	274	0.18	18	0.000	0.003	1.6	100%	274	214,575
1985	404	0.25	25	0.000	0.004	2.2	100%	404	301,188
1986	396	0.25	25	0.000	0.004	2.2	100%	396	301,092
1987	426	0.29	27	0.000	0.004	2.4	100%	426	324,223
1988	484	0.34	32	0.000	0.005	2.9	100%	484	387,591
1989	567	0.40	38	0.000	0.006	3.4	100%	567	454,438
1990	539	0.39	37	0.000	0.006	3.3	100%	539	446,862
1991	475	0.34	28	0.000	0.004	2.5	100%	475	335,098
1992	399	0.31	25	0.000	0.004	2.2	100%	399	301,877
1993	363	0.29	25	0.000	0.004	2.2	100%	363	295,585
1994	379	0.31	28	0.000	0.004	2.5	100%	379	330,512
1995	507	0.41	37	0.000	0.006	3.3	100%	507	443,837
1996	1,142	1.8	150	0.006	0.02	13	100%	1,142	1,800,897
1997	1,167	1.8	149	0.006	0.02	13	100%	1,167	1,790,241
1998	1,370	2.2	192	0.008	0.03	17	100%	1,370	2,305,455
1999	1,972	4.1	291	0.01	0.05	26	100%	1,972	3,484,066
2000	4,067	9.0	641	0.02	0.10	57	100%	4,067	7,683,603
2001	3,153	6.6	476	0.02	0.07	42	100%	3,153	5,706,180
2002	2,427	4.6	338	0.01	0.05	30	100%	2,427	4,046,083
2003	2,907	3.5	425	0.01	0.07	38	100%	2,907	5,088,912
2004	2,913	3.0	421	0.01	0.07	38	100%	2,913	5,047,803
2005	4,812	5.1	719	0.02	0.11	64	100%	4,812	8,613,212
2006	5,968	6.9	972	0.03	0.15	87	100%	5,968	11,650,876
2007	8,303	9.5	1,454	0.03	0.23	130	100%	8,303	17,419,576
2008	12,274	13	2,417	0.02	0.38	215	100%	12,274	28,960,284
2009	14,354	16	3,080	0.03	0.48	275	100%	14,354	36,913,677
2010	11,383	13	2,653	0.02	0.42	236	100%	11,383	31,795,323
2011	13,627	10	3,166	0.01	0.50	282	100%	13,627	37,940,166
2012	39,297	19	6,724	0.01	1.1	599	100%	39,297	80,581,115
2013	21,084	14	5,397	0.010	0.85	481	100%	21,084	64,680,893
2014	23,061	12	5,525	0.01	0.87	492	100%	23,061	66,207,976
2015	28,916	14	7,779	0.02	1.2	693	100%	28,916	93,222,050
2016	41,998	22	12,488	0.02	2.0	1,113	100%	41,998	149,658,452
2017	16,101	6.6	3,944	0.008	0.62	351	100%	16,101	47,265,405
2018	12,688	5.9	3,720	0.007	0.58	332	100%	12,688	44,579,225
2019	12,851	5.6	3,844	0.007	0.60	343	100%	12,851	46,069,473
2020	8,537	3.3	2,461	0.004	0.39	219	100%	8,537	29,496,897
2021	4,246	1.1	575	0.002	0.09	51	100%	4,246	6,891,960

Table A-14. NOx and GHG Tailpipe Emissions for Scenario 2 in Calendar Year 2020

Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

	Federal Low NOx DSL			**CA Cert. Low NOx DSL**			**Low NOx NG**		
Model Year	**Fleet Mix[2] (%)**	**Population[3]**	**Energy Consumption[4] (MJ/day)**	**Fleet Mix[2] (%)**	**Population[3]**	**Energy Consumption[4] (MJ/day)**	**Fleet Mix[2] (%)**	**Population[3]**	**Energy Consumption[4] (MJ/day)**
1976	0%	0	0	0%	0	0	0%	0	0
1977	0%	0	0	0%	0	0	0%	0	0
1978	0%	0	0	0%	0	0	0%	0	0
1979	0%	0	0	0%	0	0	0%	0	0
1980	0%	0	0	0%	0	0	0%	0	0
1981	0%	0	0	0%	0	0	0%	0	0
1982	0%	0	0	0%	0	0	0%	0	0
1983	0%	0	0	0%	0	0	0%	0	0
1984	0%	0	0	0%	0	0	0%	0	0
1985	0%	0	0	0%	0	0	0%	0	0
1986	0%	0	0	0%	0	0	0%	0	0
1987	0%	0	0	0%	0	0	0%	0	0
1988	0%	0	0	0%	0	0	0%	0	0
1989	0%	0	0	0%	0	0	0%	0	0
1990	0%	0	0	0%	0	0	0%	0	0
1991	0%	0	0	0%	0	0	0%	0	0
1992	0%	0	0	0%	0	0	0%	0	0
1993	0%	0	0	0%	0	0	0%	0	0
1994	0%	0	0	0%	0	0	0%	0	0
1995	0%	0	0	0%	0	0	0%	0	0
1996	0%	0	0	0%	0	0	0%	0	0
1997	0%	0	0	0%	0	0	0%	0	0
1998	0%	0	0	0%	0	0	0%	0	0
1999	0%	0	0	0%	0	0	0%	0	0
2000	0%	0	0	0%	0	0	0%	0	0
2001	0%	0	0	0%	0	0	0%	0	0
2002	0%	0	0	0%	0	0	0%	0	0
2003	0%	0	0	0%	0	0	0%	0	0
2004	0%	0	0	0%	0	0	0%	0	0
2005	0%	0	0	0%	0	0	0%	0	0
2006	0%	0	0	0%	0	0	0%	0	0
2007	0%	0	0	0%	0	0	0%	0	0
2008	0%	0	0	0%	0	0	0%	0	0
2009	0%	0	0	0%	0	0	0%	0	0
2010	0%	0	0	0%	0	0	0%	0	0
2011	0%	0	0	0%	0	0	0%	0	0
2012	0%	0	0	0%	0	0	0%	0	0
2013	0%	0	0	0%	0	0	0%	0	0
2014	0%	0	0	0%	0	0	0%	0	0
2015	0%	0	0	0%	0	0	0%	0	0
2016	0%	0	0	0%	0	0	0%	0	0
2017	0%	0	0	0%	0	0	0%	0	0
2018	0%	0	0	0%	0	0	0%	0	0
2019	0%	0	0	0%	0	0	0%	0	0
2020	0%	0	0	0%	0	0	0%	0	0
2021	0%	0	0	0%	0	0	0%	0	0

Table A-14. NOx and GHG Tailpipe Emissions for Scenario 2 in Calendar Year 2020

	BEV			Tailpipe Emission Estimates[5] (tons/day)			
Model Year	**Fleet Mix[2] (%)**	**Population[3]**	**Energy Consumption[4] (MJ/day)**	**NO$_X$**	**CO$_2$**	**CH$_4$**	**N$_2$O**
1976	0%	0	0	0.02	1.7	0.000	0.000
1977	0%	0	0	0.02	2.3	0.000	0.000
1978	0%	0	0	0.04	3.9	0.000	0.001
1979	0%	0	0	0.05	5.0	0.000	0.001
1980	0%	0	0	0.05	5.1	0.000	0.001
1981	0%	0	0	0.15	15	0.000	0.002
1982	0%	0	0	0.13	13	0.000	0.002
1983	0%	0	0	0.13	13	0.000	0.002
1984	0%	0	0	0.18	18	0.000	0.003
1985	0%	0	0	0.25	25	0.000	0.004
1986	0%	0	0	0.25	25	0.000	0.004
1987	0%	0	0	0.29	27	0.000	0.004
1988	0%	0	0	0.34	32	0.000	0.005
1989	0%	0	0	0.40	38	0.000	0.006
1990	0%	0	0	0.39	37	0.000	0.006
1991	0%	0	0	0.34	28	0.000	0.004
1992	0%	0	0	0.31	25	0.000	0.004
1993	0%	0	0	0.29	25	0.000	0.004
1994	0%	0	0	0.31	28	0.000	0.004
1995	0%	0	0	0.41	37	0.000	0.006
1996	0%	0	0	1.8	150	0.006	0.02
1997	0%	0	0	1.8	149	0.006	0.02
1998	0%	0	0	2.2	192	0.008	0.03
1999	0%	0	0	4.1	291	0.01	0.05
2000	0%	0	0	9.0	641	0.02	0.10
2001	0%	0	0	6.6	476	0.02	0.07
2002	0%	0	0	4.6	338	0.01	0.05
2003	0%	0	0	3.5	425	0.01	0.07
2004	0%	0	0	3.0	421	0.01	0.07
2005	0%	0	0	5.1	719	0.02	0.11
2006	0%	0	0	6.9	972	0.03	0.15
2007	0%	0	0	9.5	1,454	0.03	0.23
2008	0%	0	0	13	2,417	0.02	0.38
2009	0%	0	0	16	3,080	0.03	0.48
2010	0%	0	0	13	2,653	0.02	0.42
2011	0%	0	0	10	3,166	0.01	0.50
2012	0%	0	0	19	6,724	0.01	1.1
2013	0%	0	0	14	5,397	0.010	0.85
2014	0%	0	0	12	5,525	0.01	0.87
2015	0%	0	0	14	7,779	0.02	1.2
2016	0%	0	0	22	12,488	0.02	2.0
2017	0%	0	0	6.6	3,944	0.008	0.62
2018	0%	0	0	5.9	3,720	0.007	0.58
2019	0%	0	0	5.6	3,844	0.007	0.60
2020	0%	0	0	3.3	2,461	0.004	0.39
2021	0%	0	0	1.1	575	0.002	0.09

Notes:

[1] EMFAC data shown here are adjusted by subtracting data for T7 SWCVs from corresponding data for all HHDTs as described in Appendix A. Accelerated turnover adjustments are included in calendar years 2031, 2037, 2045, and 2050 as described in Appendix A.

[2] Fleet mix percentages for each alternative HHDT technology type are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[3] Population in each model year is calculated based on the fleet mix percentages for each HHDT type and the total population in the adjusted EMFAC data.

[4] Energy consumption is calculated based on adjusted EMFAC data, using the EER for each HHDT type shown in Table A-38.

[5] Emissions from vehicles in each model year are calculated based on the fleet mix composition and the reduction in tailpipe NOx emissions achieved by each HHDT type shown in Table 3-2. Total emissions in each calendar year are calculated as the sum of tailpipe emissions across all HHDT types and all model years in each calendar year.

[6] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CA Cert. - California certified
CH$_4$ - methane
CO$_2$ - carbon dioxide
DSL - diesel
EER - energy economy ratio
EMFAC2017 - Emission Factor Model
gal - gallon
HHDT - heavy heavy duty truck
MJ - megajoule
N$_2$O - nitrous oxide
NG - natural gas
NO$_x$ - oxides of nitrogen
T7 SWCV - solid waste collection vehicles
TOTEX - total exhaust

Table A-15. NOx and GHG Tailpipe Emissions for Scenario 2 in Calendar Year 2023

Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Model Year	Adjusted EMFAC2017 Output[1]						Conventional DSL		
	Population	NOx_TOTEX (tons/day)	CO2_TOTEX (tons/day)	CH4_TOTEX (tons/day)	N2O_TOTEX (tons/day)	Fuel Consumption (1000 gal/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)
1979	53	0.03	2.9	0.000	0.000	0.26	100%	53	35,019
1980	64	0.04	3.7	0.000	0.001	0.33	100%	64	44,086
1981	209	0.12	12	0.000	0.002	1.1	100%	209	142,790
1982	208	0.11	11	0.000	0.002	1.0	100%	208	134,214
1983	196	0.11	11	0.000	0.002	1.0	100%	196	131,088
1984	241	0.15	15	0.000	0.002	1.3	100%	241	176,822
1985	357	0.21	21	0.000	0.003	1.9	100%	357	252,082
1986	331	0.20	20	0.000	0.003	1.8	100%	331	243,579
1987	345	0.22	21	0.000	0.003	1.9	100%	345	253,082
1988	370	0.26	24	0.000	0.004	2.2	100%	370	290,997
1989	420	0.29	28	0.000	0.004	2.5	100%	420	332,355
1990	382	0.28	27	0.000	0.004	2.4	100%	382	319,401
1991	331	0.24	20	0.000	0.003	1.8	100%	331	238,471
1992	279	0.22	18	0.000	0.003	1.6	100%	279	214,037
1993	235	0.20	17	0.000	0.003	1.5	100%	235	202,566
1994	257	0.21	19	0.000	0.003	1.7	100%	257	228,163
1995	341	0.29	26	0.000	0.004	2.3	100%	341	308,497
1996	354	0.29	26	0.000	0.004	2.3	100%	354	309,827
1997	358	0.27	24	0.000	0.004	2.2	100%	358	292,799
1998	350	0.29	27	0.000	0.004	2.4	100%	350	324,850
1999	484	0.48	38	0.000	0.006	3.4	100%	484	458,610
2000	570	0.55	44	0.000	0.007	3.9	100%	570	522,449
2001	630	0.52	42	0.000	0.007	3.7	100%	630	502,288
2002	683	0.50	41	0.000	0.006	3.7	100%	683	490,906
2003	607	0.31	41	0.000	0.006	3.7	100%	607	491,836
2004	588	0.27	39	0.000	0.006	3.4	100%	588	462,594
2005	722	0.33	48	0.000	0.008	4.3	100%	722	579,188
2006	789	0.37	53	0.000	0.008	4.7	100%	789	635,640
2007	1,010	0.43	69	0.000	0.01	6.1	100%	1,010	822,391
2008	958	0.24	51	0.000	0.008	4.5	100%	958	608,971
2009	1,054	0.24	57	0.000	0.009	5.1	100%	1,054	681,595
2010	516	0.11	28	0.000	0.004	2.5	100%	516	336,250
2011	601	0.08	32	0.000	0.005	2.8	100%	601	381,333
2012	36,456	15	5,160	0.010	0.81	460	100%	36,456	61,840,416
2013	23,385	13	4,715	0.009	0.74	420	100%	23,385	56,503,770
2014	25,954	12	4,907	0.01	0.77	437	100%	25,954	58,805,403
2015	43,313	18	8,476	0.02	1.3	755	100%	43,313	101,582,009
2016	51,092	25	12,180	0.03	1.9	1,086	100%	51,092	145,975,230
2017	45,093	20	10,301	0.02	1.6	918	100%	45,093	123,455,483
2018	15,699	7.6	3,880	0.008	0.61	346	100%	15,699	46,494,284
2019	15,755	7.5	4,119	0.008	0.65	367	100%	15,755	49,364,115
2020	14,758	7.0	4,076	0.008	0.64	363	100%	14,758	48,851,177
2021	13,866	6.3	3,442	0.008	0.54	307	100%	13,866	41,250,943
2022	13,999	6.1	3,590	0.008	0.56	320	100%	13,999	43,027,237
2023	9,671	3.7	2,395	0.005	0.38	213	100%	9,671	28,707,076
2024	4,843	1.3	599	0.003	0.09	53	0%	0	0

Table A-15. NOx and GHG Tailpipe Emissions for Scenario 2 in Calendar Year 2023

Model Year	Federal Low NOx DSL			CA Cert. Low NOx DSL			Low NOx NG		
	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)
1979	0%	0	0	0%	0	0	0%	0	0
1980	0%	0	0	0%	0	0	0%	0	0
1981	0%	0	0	0%	0	0	0%	0	0
1982	0%	0	0	0%	0	0	0%	0	0
1983	0%	0	0	0%	0	0	0%	0	0
1984	0%	0	0	0%	0	0	0%	0	0
1985	0%	0	0	0%	0	0	0%	0	0
1986	0%	0	0	0%	0	0	0%	0	0
1987	0%	0	0	0%	0	0	0%	0	0
1988	0%	0	0	0%	0	0	0%	0	0
1989	0%	0	0	0%	0	0	0%	0	0
1990	0%	0	0	0%	0	0	0%	0	0
1991	0%	0	0	0%	0	0	0%	0	0
1992	0%	0	0	0%	0	0	0%	0	0
1993	0%	0	0	0%	0	0	0%	0	0
1994	0%	0	0	0%	0	0	0%	0	0
1995	0%	0	0	0%	0	0	0%	0	0
1996	0%	0	0	0%	0	0	0%	0	0
1997	0%	0	0	0%	0	0	0%	0	0
1998	0%	0	0	0%	0	0	0%	0	0
1999	0%	0	0	0%	0	0	0%	0	0
2000	0%	0	0	0%	0	0	0%	0	0
2001	0%	0	0	0%	0	0	0%	0	0
2002	0%	0	0	0%	0	0	0%	0	0
2003	0%	0	0	0%	0	0	0%	0	0
2004	0%	0	0	0%	0	0	0%	0	0
2005	0%	0	0	0%	0	0	0%	0	0
2006	0%	0	0	0%	0	0	0%	0	0
2007	0%	0	0	0%	0	0	0%	0	0
2008	0%	0	0	0%	0	0	0%	0	0
2009	0%	0	0	0%	0	0	0%	0	0
2010	0%	0	0	0%	0	0	0%	0	0
2011	0%	0	0	0%	0	0	0%	0	0
2012	0%	0	0	0%	0	0	0%	0	0
2013	0%	0	0	0%	0	0	0%	0	0
2014	0%	0	0	0%	0	0	0%	0	0
2015	0%	0	0	0%	0	0	0%	0	0
2016	0%	0	0	0%	0	0	0%	0	0
2017	0%	0	0	0%	0	0	0%	0	0
2018	0%	0	0	0%	0	0	0%	0	0
2019	0%	0	0	0%	0	0	0%	0	0
2020	0%	0	0	0%	0	0	0%	0	0
2021	0%	0	0	0%	0	0	0%	0	0
2022	0%	0	0	0%	0	0	0%	0	0
2023	0%	0	0	0%	0	0	0%	0	0
2024	10%	484	717,286	0%	0	0	86%	4,141	6,814,220

Table A-15. NOx and GHG Tailpipe Emissions for Scenario 2 in Calendar Year 2023

Model Year	BEV			Tailpipe Emission Estimates[5] (tons/day)			
	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	NO_X	CO_2	CH_4	N_2O
1979	0%	0	0	0.03	2.9	0.000	0.000
1980	0%	0	0	0.04	3.7	0.000	0.001
1981	0%	0	0	0.12	12	0.000	0.002
1982	0%	0	0	0.11	11	0.000	0.002
1983	0%	0	0	0.11	11	0.000	0.002
1984	0%	0	0	0.15	15	0.000	0.002
1985	0%	0	0	0.21	21	0.000	0.003
1986	0%	0	0	0.20	20	0.000	0.003
1987	0%	0	0	0.22	21	0.000	0.003
1988	0%	0	0	0.26	24	0.000	0.004
1989	0%	0	0	0.29	28	0.000	0.004
1990	0%	0	0	0.28	27	0.000	0.004
1991	0%	0	0	0.24	20	0.000	0.003
1992	0%	0	0	0.22	18	0.000	0.003
1993	0%	0	0	0.20	17	0.000	0.003
1994	0%	0	0	0.21	19	0.000	0.003
1995	0%	0	0	0.29	26	0.000	0.004
1996	0%	0	0	0.29	26	0.000	0.004
1997	0%	0	0	0.27	24	0.000	0.004
1998	0%	0	0	0.29	27	0.000	0.004
1999	0%	0	0	0.48	38	0.000	0.006
2000	0%	0	0	0.55	44	0.000	0.007
2001	0%	0	0	0.52	42	0.000	0.007
2002	0%	0	0	0.50	41	0.000	0.006
2003	0%	0	0	0.31	41	0.000	0.006
2004	0%	0	0	0.27	39	0.000	0.006
2005	0%	0	0	0.33	48	0.000	0.008
2006	0%	0	0	0.37	53	0.000	0.008
2007	0%	0	0	0.43	69	0.000	0.01
2008	0%	0	0	0.24	51	0.000	0.008
2009	0%	0	0	0.24	57	0.000	0.009
2010	0%	0	0	0.11	28	0.000	0.004
2011	0%	0	0	0.08	32	0.000	0.005
2012	0%	0	0	15	5,160	0.010	0.81
2013	0%	0	0	13	4,715	0.009	0.74
2014	0%	0	0	12	4,907	0.01	0.77
2015	0%	0	0	18	8,476	0.02	1.3
2016	0%	0	0	25	12,180	0.03	1.9
2017	0%	0	0	20	10,301	0.02	1.6
2018	0%	0	0	7.6	3,880	0.008	0.61
2019	0%	0	0	7.5	4,119	0.008	0.65
2020	0%	0	0	7.0	4,076	0.008	0.64
2021	0%	0	0	6.3	3,442	0.008	0.54
2022	0%	0	0	6.1	3,590	0.008	0.56
2023	0%	0	0	3.7	2,395	0.005	0.38
2024	5%	218	106,580	0.14	572	0.002	0.09

Notes:

[1] EMFAC data shown here are adjusted by subtracting data for T7 SWCVs from corresponding data for all HHDTs as described in Appendix A. Accelerated turnover adjustments are included in calendar years 2031, 2037, 2045, and 2050 as described in Appendix A.

[2] Fleet mix percentages for each alternative HHDT technology type are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[3] Population in each model year is calculated based on the fleet mix percentages for each HHDT type and the total population in the adjusted EMFAC data.

[4] Energy consumption is calculated based on adjusted EMFAC data, using the EER for each HHDT type shown in Table A-38.

[5] Emissions from vehicles in each model year are calculated based on the fleet mix composition and the reduction in tailpipe NOx emissions achieved by each HHDT type shown in Table 3-2. Total emissions in each calendar year are calculated as the sum of tailpipe emissions across all HHDT types and all model years in each calendar year.

[6] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CA Cert. - California certified
CH_4 - methane
CO_2 - carbon dioxide
DSL - diesel
EER - energy economy ratio
EMFAC2017 - Emission Factor Model
gal - gallon
HHDT - heavy heavy duty truck
MJ - megajoule
N_2O - nitrous oxide
NG - natural gas
NO_x - oxides of nitrogen
T7 SWCV - solid waste collection vehicles
TOTEX - total exhaust

Table A-16. NOx and GHG Tailpipe Emissions for Scenario 2 in Calendar Year 2031

	Adjusted EMFAC2017 Output[1]						Conventional DSL		
Model Year	Population	NOx_TOTEX (tons/day)	CO2_TOTEX (tons/day)	CH4_TOTEX (tons/day)	N2O_TOTEX (tons/day)	Fuel Consumption (1000 gal/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)
1987	166	0.09	8.9	0.000	0.001	0.79	100%	166	106,532
1988	223	0.13	12	0.000	0.002	1.1	100%	223	144,024
1989	279	0.16	15	0.000	0.002	1.3	100%	279	179,202
1990	256	0.15	14	0.000	0.002	1.3	100%	256	168,297
1991	221	0.14	11	0.000	0.002	1.0	100%	221	134,880
1992	173	0.11	9.2	0.000	0.001	0.82	100%	173	110,429
1993	132	0.09	7.5	0.000	0.001	0.67	100%	132	90,308
1994	131	0.08	7.6	0.000	0.001	0.68	100%	131	91,104
1995	161	0.11	10	0.000	0.002	0.87	100%	161	116,335
1996	159	0.11	10	0.000	0.002	0.85	100%	159	114,485
1997	155	0.10	9.1	0.000	0.001	0.81	100%	155	108,509
1998	145	0.10	10	0.000	0.001	0.85	100%	145	114,337
1999	197	0.17	13	0.000	0.002	1.2	100%	197	160,607
2000	233	0.20	16	0.000	0.002	1.4	100%	233	188,016
2001	267	0.20	16	0.000	0.003	1.4	100%	267	193,494
2002	300	0.21	17	0.000	0.003	1.5	100%	300	200,551
2003	272	0.13	17	0.000	0.003	1.5	100%	272	200,037
2004	276	0.12	17	0.000	0.003	1.5	100%	276	198,929
2005	353	0.15	22	0.000	0.003	1.9	100%	353	259,740
2006	403	0.18	25	0.000	0.004	2.3	100%	403	303,073
2007	543	0.22	35	0.000	0.006	3.1	100%	543	422,431
2008	564	0.14	29	0.000	0.005	2.6	100%	564	352,228
2009	654	0.15	34	0.000	0.005	3.1	100%	654	410,832
2010	337	0.07	18	0.000	0.003	1.6	100%	337	211,381
2011	419	0.05	21	0.000	0.003	1.9	100%	419	253,413
2012	18,775	6.3	2,125	0.004	0.33	189	100%	18,775	25,469,698
2013	10,866	5.2	1,931	0.003	0.30	172	100%	10,866	23,141,590
2014	12,373	4.9	1,993	0.004	0.31	178	100%	12,373	23,884,682
2015	22,601	8.0	3,471	0.007	0.55	309	100%	22,601	41,601,211
2016	25,559	9.1	3,866	0.010	0.61	345	100%	25,559	46,327,589
2017	29,560	9.2	4,023	0.009	0.63	359	100%	29,560	48,215,934
2018	10,153	3.8	1,588	0.004	0.25	142	100%	10,153	19,030,587
2019	11,512	4.5	1,861	0.004	0.29	166	100%	11,512	22,305,607
2020	13,043	5.4	2,255	0.005	0.35	201	100%	13,043	27,025,846
2021	14,295	6.2	2,272	0.006	0.36	203	100%	14,295	27,231,919
2022	16,417	7.5	2,835	0.007	0.45	253	100%	16,417	33,979,835
2023	22,059	12	4,261	0.010	0.67	380	100%	22,059	51,063,434
2024	21,715	11	3,988	0.01	0.63	355	0%	0	0
2025	22,619	12	4,524	0.01	0.71	403	0%	0	0
2026	22,104	12	4,758	0.01	0.75	424	0%	0	0
2027	21,594	11	4,671	0.01	0.73	416	0%	0	0
2028	19,744	10	4,452	0.01	0.70	397	0%	0	0
2029	18,560	9.0	4,281	0.01	0.67	382	0%	0	0
2030	17,915	8.2	4,205	0.01	0.66	375	0%	0	0
2031	11,497	4.6	2,590	0.006	0.41	231	0%	0	0
2032	5,864	1.6	694	0.003	0.11	62	0%	0	0

Table A-16. NOx and GHG Tailpipe Emissions for Scenario 2 in Calendar Year 2031

Model Year	Federal Low NOx DSL			CA Cert. Low NOx DSL			Low NOx NG		
	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)
1987	0%	0	0	0%	0	0	0%	0	0
1988	0%	0	0	0%	0	0	0%	0	0
1989	0%	0	0	0%	0	0	0%	0	0
1990	0%	0	0	0%	0	0	0%	0	0
1991	0%	0	0	0%	0	0	0%	0	0
1992	0%	0	0	0%	0	0	0%	0	0
1993	0%	0	0	0%	0	0	0%	0	0
1994	0%	0	0	0%	0	0	0%	0	0
1995	0%	0	0	0%	0	0	0%	0	0
1996	0%	0	0	0%	0	0	0%	0	0
1997	0%	0	0	0%	0	0	0%	0	0
1998	0%	0	0	0%	0	0	0%	0	0
1999	0%	0	0	0%	0	0	0%	0	0
2000	0%	0	0	0%	0	0	0%	0	0
2001	0%	0	0	0%	0	0	0%	0	0
2002	0%	0	0	0%	0	0	0%	0	0
2003	0%	0	0	0%	0	0	0%	0	0
2004	0%	0	0	0%	0	0	0%	0	0
2005	0%	0	0	0%	0	0	0%	0	0
2006	0%	0	0	0%	0	0	0%	0	0
2007	0%	0	0	0%	0	0	0%	0	0
2008	0%	0	0	0%	0	0	0%	0	0
2009	0%	0	0	0%	0	0	0%	0	0
2010	0%	0	0	0%	0	0	0%	0	0
2011	0%	0	0	0%	0	0	0%	0	0
2012	0%	0	0	0%	0	0	0%	0	0
2013	0%	0	0	0%	0	0	0%	0	0
2014	0%	0	0	0%	0	0	0%	0	0
2015	0%	0	0	0%	0	0	0%	0	0
2016	0%	0	0	0%	0	0	0%	0	0
2017	0%	0	0	0%	0	0	0%	0	0
2018	0%	0	0	0%	0	0	0%	0	0
2019	0%	0	0	0%	0	0	0%	0	0
2020	0%	0	0	0%	0	0	0%	0	0
2021	0%	0	0	0%	0	0	0%	0	0
2022	0%	0	0	0%	0	0	0%	0	0
2023	0%	0	0	0%	0	0	0%	0	0
2024	10%	2,171	4,779,835	0%	0	0	86%	18,566	45,408,434
2025	10%	2,262	5,421,301	0%	0	0	84%	18,932	50,418,096
2026	10%	2,210	5,702,550	0%	0	0	81%	17,904	51,322,947
2027	15%	3,239	8,396,467	0%	0	0	72%	15,602	44,936,647
2028	15%	2,962	8,002,355	0%	0	0	68%	13,426	40,308,160
2029	20%	3,712	10,260,841	0%	0	0	60%	11,136	34,202,804
2030	20%	3,583	10,079,515	0%	0	0	56%	10,032	31,358,493
2031	20%	2,299	6,209,013	0%	0	0	52%	5,979	17,937,150
2032	10%	586	831,861	0%	0	0	54%	3,166	4,991,164

Table A-16. NOx and GHG Tailpipe Emissions for Scenario 2 in Calendar Year 2031

Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Model Year	BEV			Tailpipe Emission Estimates[5] (tons/day)			
	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	NO_X	CO_2	CH_4	N_2O
1987	0%	0	0	0.09	8.9	0.000	0.001
1988	0%	0	0	0.13	12	0.000	0.002
1989	0%	0	0	0.16	15	0.000	0.002
1990	0%	0	0	0.15	14	0.000	0.002
1991	0%	0	0	0.14	11	0.000	0.002
1992	0%	0	0	0.11	9.2	0.000	0.001
1993	0%	0	0	0.09	7.5	0.000	0.001
1994	0%	0	0	0.08	7.6	0.000	0.001
1995	0%	0	0	0.11	10	0.000	0.002
1996	0%	0	0	0.11	10	0.000	0.002
1997	0%	0	0	0.10	9.1	0.000	0.001
1998	0%	0	0	0.10	10	0.000	0.001
1999	0%	0	0	0.17	13	0.000	0.002
2000	0%	0	0	0.20	16	0.000	0.002
2001	0%	0	0	0.20	16	0.000	0.003
2002	0%	0	0	0.21	17	0.000	0.003
2003	0%	0	0	0.13	17	0.000	0.003
2004	0%	0	0	0.12	17	0.000	0.003
2005	0%	0	0	0.15	22	0.000	0.003
2006	0%	0	0	0.18	25	0.000	0.004
2007	0%	0	0	0.22	35	0.000	0.006
2008	0%	0	0	0.14	29	0.000	0.005
2009	0%	0	0	0.15	34	0.000	0.005
2010	0%	0	0	0.07	18	0.000	0.003
2011	0%	0	0	0.05	21	0.000	0.003
2012	0%	0	0	6.3	2,125	0.004	0.33
2013	0%	0	0	5.2	1,931	0.003	0.30
2014	0%	0	0	4.9	1,993	0.004	0.31
2015	0%	0	0	8.0	3,471	0.007	0.55
2016	0%	0	0	9.1	3,866	0.010	0.61
2017	0%	0	0	9.2	4,023	0.009	0.63
2018	0%	0	0	3.8	1,588	0.004	0.25
2019	0%	0	0	4.5	1,861	0.004	0.29
2020	0%	0	0	5.4	2,255	0.005	0.35
2021	0%	0	0	6.2	2,272	0.006	0.36
2022	0%	0	0	7.5	2,835	0.007	0.45
2023	0%	0	0	12	4,261	0.010	0.67
2024	5%	977	710,226	1.2	3,809	0.01	0.60
2025	6%	1,425	1,127,756	1.3	4,239	0.01	0.67
2026	9%	1,989	1,694,660	1.2	4,330	0.01	0.68
2027	13%	2,753	2,356,604	1.2	4,075	0.01	0.64
2028	17%	3,357	2,994,653	1.1	3,695	0.009	0.58
2029	20%	3,712	3,388,083	1.0	3,425	0.009	0.54
2030	24%	4,300	3,993,852	0.87	3,196	0.008	0.50
2031	28%	3,219	2,870,263	0.47	1,865	0.004	0.29
2032	36%	2,111	988,836	0.12	444	0.002	0.07

Notes:

[1] EMFAC data shown here are adjusted by subtracting data for T7 SWCVs from corresponding data for all HHDTs as described in Appendix A. Accelerated turnover adjustments are included in calendar years 2031, 2037, 2045, and 2050 as described in Appendix A.

[2] Fleet mix percentages for each alternative HHDT technology type are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[3] Population in each model year is calculated based on the fleet mix percentages for each HHDT type and the total population in the adjusted EMFAC data.

[4] Energy consumption is calculated based on adjusted EMFAC data, using the EER for each HHDT type shown in Table A-38.

[5] Emissions from vehicles in each model year are calculated based on the fleet mix composition and the reduction in tailpipe NOx emissions achieved by each HHDT type shown in Table 3-2. Total emissions in each calendar year are calculated as the sum of tailpipe emissions across all HHDT types and all model years in each calendar year.

[6] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CA Cert. - California certified
CH_4 - methane
CO_2 - carbon dioxide
DSL - diesel
EER - energy economy ratio
EMFAC2017 - Emission Factor Model
gal - gallon
HHDT - heavy heavy duty truck
MJ - megajoule
N_2O - nitrous oxide
NG - natural gas
NO_x - oxides of nitrogen
T7 SWCV - solid waste collection vehicles
TOTEX - total exhaust

Table A-17. NOx and GHG Tailpipe Emissions for Scenario 2 in Calendar Year 2037

Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

	Adjusted EMFAC2017 Output[1]						**Conventional DSL**		
Model Year	**Population**	**NOx_TOTEX (tons/day)**	**CO2_TOTEX (tons/day)**	**CH4_TOTEX (tons/day)**	**N2O_TOTEX (tons/day)**	**Fuel Consumption (1000 gal/day)**	**Fleet Mix**[2] **(%)**	**Population**[3]	**Energy Consumption**[4] **(MJ/day)**
1993	66	0.04	3.5	0.000	0.001	0.31	100%	66	42,043
1994	83	0.05	4.2	0.000	0.001	0.38	100%	83	50,721
1995	115	0.07	5.9	0.000	0.001	0.53	100%	115	70,970
1996	119	0.07	6.1	0.000	0.001	0.54	100%	119	72,842
1997	117	0.06	5.9	0.000	0.001	0.52	100%	117	70,488
1998	104	0.06	5.7	0.000	0.001	0.50	100%	104	67,898
1999	133	0.10	7.6	0.000	0.001	0.67	100%	133	90,610
2000	147	0.11	8.5	0.000	0.001	0.76	100%	147	101,850
2001	161	0.11	8.8	0.000	0.001	0.79	100%	161	105,603
2002	172	0.11	9.0	0.000	0.001	0.80	100%	172	107,968
2003	146	0.06	8.3	0.000	0.001	0.74	100%	146	99,226
2004	143	0.06	8.1	0.000	0.001	0.72	100%	143	96,731
2005	178	0.07	10	0.000	0.002	0.92	100%	178	123,640
2006	202	0.09	12	0.000	0.002	1.1	100%	202	143,033
2007	272	0.11	17	0.000	0.003	1.5	100%	272	200,277
2008	292	0.07	15	0.000	0.002	1.3	100%	292	179,211
2009	346	0.08	18	0.000	0.003	1.6	100%	346	213,122
2010	183	0.04	9.3	0.000	0.001	0.83	100%	183	111,727
2011	234	0.03	11	0.000	0.002	1.0	100%	234	136,809
2012	7,969	2.4	804	0.002	0.13	72	100%	7,969	9,641,296
2013	4,340	2.0	750	0.001	0.12	67	100%	4,340	8,984,556
2014	4,954	2.0	817	0.001	0.13	73	100%	4,954	9,795,650
2015	9,674	3.7	1,601	0.003	0.25	143	100%	9,674	19,190,427
2016	10,519	3.7	1,604	0.004	0.25	143	100%	10,519	19,227,562
2017	14,184	3.9	1,723	0.004	0.27	154	100%	14,184	20,654,585
2018	4,924	1.7	692	0.002	0.11	62	100%	4,924	8,290,062
2019	5,803	1.9	807	0.002	0.13	72	100%	5,803	9,667,889
2020	6,713	2.3	945	0.002	0.15	84	100%	6,713	11,329,480
2021	7,708	2.6	942	0.003	0.15	84	100%	7,708	11,285,971
2022	9,361	3.4	1,197	0.003	0.19	107	100%	9,361	14,344,235
2023	12,311	5.2	1,799	0.004	0.28	160	100%	12,311	21,557,339
2024	14,157	5.5	1,804	0.005	0.28	161	0%	0	0
2025	15,781	6.4	2,112	0.006	0.33	188	0%	0	0
2026	17,659	7.5	2,484	0.007	0.39	221	0%	0	0
2027	19,532	8.7	2,768	0.008	0.44	247	0%	0	0
2028	21,365	10	3,236	0.010	0.51	288	0%	0	0
2029	22,985	11	3,748	0.01	0.59	334	0%	0	0
2030	24,081	12	4,213	0.01	0.66	375	0%	0	0
2037	24,791	13	4,671	0.01	0.73	416	0%	0	0
2032	24,114	13	4,857	0.01	0.76	433	0%	0	0
2033	23,670	12	5,060	0.01	0.80	451	0%	0	0
2034	21,948	11	4,883	0.01	0.77	435	0%	0	0
2035	20,791	10	4,742	0.01	0.75	423	0%	0	0
2036	19,699	9.0	4,573	0.01	0.72	408	0%	0	0
2037	12,409	5.0	2,773	0.007	0.44	247	0%	0	0
2038	6,391	1.7	743	0.003	0.12	66	0%	0	0

	Federal Low NOx DSL			**CA Cert. Low NOx DSL**			**Low NOx NG**		
Model Year	**Fleet Mix[2] (%)**	**Population[3]**	**Energy Consumption[4] (MJ/day)**	**Fleet Mix[2] (%)**	**Population[3]**	**Energy Consumption[4] (MJ/day)**	**Fleet Mix[2] (%)**	**Population[3]**	**Energy Consumption[4] (MJ/day)**
1993	0%	0	0	0%	0	0	0%	0	0
1994	0%	0	0	0%	0	0	0%	0	0
1995	0%	0	0	0%	0	0	0%	0	0
1996	0%	0	0	0%	0	0	0%	0	0
1997	0%	0	0	0%	0	0	0%	0	0
1998	0%	0	0	0%	0	0	0%	0	0
1999	0%	0	0	0%	0	0	0%	0	0
2000	0%	0	0	0%	0	0	0%	0	0
2001	0%	0	0	0%	0	0	0%	0	0
2002	0%	0	0	0%	0	0	0%	0	0
2003	0%	0	0	0%	0	0	0%	0	0
2004	0%	0	0	0%	0	0	0%	0	0
2005	0%	0	0	0%	0	0	0%	0	0
2006	0%	0	0	0%	0	0	0%	0	0
2007	0%	0	0	0%	0	0	0%	0	0
2008	0%	0	0	0%	0	0	0%	0	0
2009	0%	0	0	0%	0	0	0%	0	0
2010	0%	0	0	0%	0	0	0%	0	0
2011	0%	0	0	0%	0	0	0%	0	0
2012	0%	0	0	0%	0	0	0%	0	0
2013	0%	0	0	0%	0	0	0%	0	0
2014	0%	0	0	0%	0	0	0%	0	0
2015	0%	0	0	0%	0	0	0%	0	0
2016	0%	0	0	0%	0	0	0%	0	0
2017	0%	0	0	0%	0	0	0%	0	0
2018	0%	0	0	0%	0	0	0%	0	0
2019	0%	0	0	0%	0	0	0%	0	0
2020	0%	0	0	0%	0	0	0%	0	0
2021	0%	0	0	0%	0	0	0%	0	0
2022	0%	0	0	0%	0	0	0%	0	0
2023	0%	0	0	0%	0	0	0%	0	0
2024	10%	1,416	2,161,542	0%	0	0	86%	12,104	20,534,650
2025	10%	1,578	2,531,043	0%	0	0	84%	13,209	23,538,696
2026	10%	1,766	2,977,192	0%	0	0	81%	14,304	26,794,732
2027	15%	2,930	4,975,264	0%	0	0	72%	14,112	26,626,876
2028	15%	3,205	5,817,346	0%	0	0	68%	14,528	29,302,186
2029	20%	4,597	8,983,030	0%	0	0	60%	13,791	29,943,433
2030	20%	4,816	10,097,767	0%	0	0	56%	13,485	31,415,274
2037	12%	2,975	6,717,948	0%	0	0	53%	13,090	32,843,299
2032	10%	2,411	5,821,019	0%	0	0	54%	13,022	34,926,115
2033	10%	2,367	6,063,891	0%	0	0	54%	12,782	36,383,345
2034	10%	2,195	5,851,702	0%	0	0	54%	11,852	35,110,212
2035	12%	2,495	6,819,958	0%	0	0	53%	10,978	33,342,015
2036	12%	2,364	6,576,732	0%	0	0	53%	10,401	32,152,911
2037	12%	1,489	3,988,015	0%	0	0	53%	6,552	19,496,964
2038	12%	767	1,068,563	0%	0	0	53%	3,375	5,224,086

Model Year	BEV			Tailpipe Emission Estimates[5] (tons/day)			
	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	NO_X	CO_2	CH_4	N_2O
1993	0%	0	0	0.04	3.5	0.000	0.001
1994	0%	0	0	0.05	4.2	0.000	0.001
1995	0%	0	0	0.07	5.9	0.000	0.001
1996	0%	0	0	0.07	6.1	0.000	0.001
1997	0%	0	0	0.06	5.9	0.000	0.001
1998	0%	0	0	0.06	5.7	0.000	0.001
1999	0%	0	0	0.10	7.6	0.000	0.001
2000	0%	0	0	0.11	8.5	0.000	0.001
2001	0%	0	0	0.11	8.8	0.000	0.001
2002	0%	0	0	0.11	9.0	0.000	0.001
2003	0%	0	0	0.06	8.3	0.000	0.001
2004	0%	0	0	0.06	8.1	0.000	0.001
2005	0%	0	0	0.07	10	0.000	0.002
2006	0%	0	0	0.09	12	0.000	0.002
2007	0%	0	0	0.11	17	0.000	0.003
2008	0%	0	0	0.07	15	0.000	0.002
2009	0%	0	0	0.08	18	0.000	0.003
2010	0%	0	0	0.04	9.3	0.000	0.001
2011	0%	0	0	0.03	11	0.000	0.002
2012	0%	0	0	2.4	804	0.002	0.13
2013	0%	0	0	2.0	750	0.001	0.12
2014	0%	0	0	2.0	817	0.001	0.13
2015	0%	0	0	3.7	1,601	0.003	0.25
2016	0%	0	0	3.7	1,604	0.004	0.25
2017	0%	0	0	3.9	1,723	0.004	0.27
2018	0%	0	0	1.7	692	0.002	0.11
2019	0%	0	0	1.9	807	0.002	0.13
2020	0%	0	0	2.3	945	0.002	0.15
2021	0%	0	0	2.6	942	0.003	0.15
2022	0%	0	0	3.4	1,197	0.003	0.19
2023	0%	0	0	5.2	1,799	0.004	0.28
2024	5%	637	321,179	0.61	1,722	0.005	0.27
2025	6%	994	526,515	0.70	1,979	0.006	0.31
2026	9%	1,589	884,750	0.80	2,261	0.007	0.36
2027	13%	2,490	1,396,388	1.0	2,415	0.007	0.38
2028	17%	3,632	2,176,976	1.1	2,686	0.008	0.42
2029	20%	4,597	2,966,155	1.2	2,998	0.009	0.47
2030	24%	5,779	4,001,083	1.3	3,202	0.009	0.50
2037	35%	8,727	6,506,824	1.1	3,027	0.008	0.48
2032	36%	8,681	6,919,465	1.0	3,109	0.009	0.49
2033	36%	8,521	7,208,168	1.0	3,238	0.008	0.51
2034	36%	7,901	6,955,938	0.88	3,125	0.008	0.49
2035	35%	7,318	6,605,628	0.83	3,073	0.008	0.48
2036	35%	6,934	6,370,046	0.74	2,963	0.007	0.47
2037	35%	4,368	3,862,685	0.41	1,797	0.004	0.28
2038	35%	2,250	1,034,981	0.14	481	0.002	0.08

Notes:

[1] EMFAC data shown here are adjusted by subtracting data for T7 SWCVs from corresponding data for all HHDTs as described in Appendix A. Accelerated turnover adjustments are included in calendar years 2031, 2037, 2045, and 2050 as described in Appendix A.

[2] Fleet mix percentages for each alternative HHDT technology type are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[3] Population in each model year is calculated based on the fleet mix percentages for each HHDT type and the total population in the adjusted EMFAC data.

[4] Energy consumption is calculated based on adjusted EMFAC data, using the EER for each HHDT type shown in Table A-38.

[5] Emissions from vehicles in each model year are calculated based on the fleet mix composition and the reduction in tailpipe NOx emissions achieved by each HHDT type shown in Table 3-2. Total emissions in each calendar year are calculated as the sum of tailpipe emissions across all HHDT types and all model years in each calendar year.

[6] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CA Cert. - California certified
CH_4 - methane
CO_2 - carbon dioxide
DSL - diesel
EER - energy economy ratio
EMFAC2017 - Emission Factor Model
gal - gallon
HHDT - heavy heavy duty truck
MJ - megajoule
N_2O - nitrous oxide
NG - natural gas
NO_x - oxides of nitrogen
T7 SWCV - solid waste collection vehicles
TOTEX - total exhaust

Table A-18. NOx and GHG Tailpipe Emissions for Scenario 2 in Calendar Year 2045

	Adjusted EMFAC2017 Output[1]						Conventional DSL		
Model Year	Population	NOx_TOTEX (tons/day)	CO2_TOTEX (tons/day)	CH4_TOTEX (tons/day)	N2O_TOTEX (tons/day)	Fuel Consumption (1000 gal/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)
2001	0	0	0	0	0	0	0%	0	0
2002	0	0	0	0	0	0	0%	0	0
2003	0	0	0	0	0	0	0%	0	0
2004	0	0	0	0	0	0	0%	0	0
2005	0	0	0	0	0	0	0%	0	0
2006	0	0	0	0	0	0	0%	0	0
2007	0	0	0	0	0	0	0%	0	0
2008	0	0	0	0	0	0	0%	0	0
2009	0	0	0	0	0	0	0%	0	0
2010	0	0	0	0	0	0	0%	0	0
2011	0	0	0	0	0	0	0%	0	0
2012	0	0	0	0	0	0	0%	0	0
2013	0	0	0	0	0	0	0%	0	0
2014	0	0	0	0	0	0	0%	0	0
2015	0	0	0	0	0	0	0%	0	0
2016	0	0	0	0	0	0	0%	0	0
2017	0	0	0	0	0	0	0%	0	0
2018	0	0	0	0	0	0	0%	0	0
2019	0	0	0	0	0	0	0%	0	0
2020	0	0	0	0	0	0	0%	0	0
2021	0	0	0	0	0	0	0%	0	0
2022	0	0	0	0	0	0	0%	0	0
2023	0	0	0	0	0	0	0%	0	0
2024	5,738	1.9	631	0.002	0.10	56	0%	0	0
2025	6,682	2.2	740	0.002	0.12	66	0%	0	0
2026	7,830	2.6	869	0.002	0.14	77	0%	0	0
2027	8,960	3.0	954	0.003	0.15	85	0%	0	0
2028	10,297	3.5	1,096	0.003	0.17	98	0%	0	0
2029	11,921	4.1	1,276	0.004	0.20	114	0%	0	0
2030	13,807	4.8	1,488	0.005	0.23	133	0%	0	0
2045	15,655	5.9	1,819	0.006	0.29	162	0%	0	0
2032	17,813	7.1	2,196	0.007	0.35	196	0%	0	0
2033	20,003	8.3	2,581	0.008	0.41	230	0%	0	0
2034	22,623	10	3,067	0.009	0.48	273	0%	0	0
2035	24,976	11	3,584	0.01	0.56	319	0%	0	0
2036	26,967	13	4,118	0.01	0.65	367	0%	0	0
2037	28,599	14	4,677	0.01	0.74	417	0%	0	0
2038	29,556	15	5,172	0.01	0.81	461	0%	0	0
2039	30,085	16	5,646	0.02	0.89	503	0%	0	0
2040	28,520	15	5,685	0.02	0.89	507	0%	0	0
2041	27,485	14	5,816	0.02	0.91	518	0%	0	0
2042	24,780	12	5,446	0.01	0.86	485	0%	0	0
2043	23,286	11	5,243	0.01	0.82	467	0%	0	0
2044	22,012	10	5,025	0.01	0.79	448	0%	0	0
2045	13,831	5.5	3,030	0.007	0.48	270	0%	0	0
2046	7,111	1.9	812	0.004	0.13	72	0%	0	0

Table A-18. NOx and GHG Tailpipe Emissions for Scenario 2 in Calendar Year 2045

Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

	Federal Low NOx DSL			CA Cert. Low NOx DSL			Low NOx NG		
Model Year	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)
2001	0%	0	0	0%	0	0	0%	0	0
2002	0%	0	0	0%	0	0	0%	0	0
2003	0%	0	0	0%	0	0	0%	0	0
2004	0%	0	0	0%	0	0	0%	0	0
2005	0%	0	0	0%	0	0	0%	0	0
2006	0%	0	0	0%	0	0	0%	0	0
2007	0%	0	0	0%	0	0	0%	0	0
2008	0%	0	0	0%	0	0	0%	0	0
2009	0%	0	0	0%	0	0	0%	0	0
2010	0%	0	0	0%	0	0	0%	0	0
2011	0%	0	0	0%	0	0	0%	0	0
2012	0%	0	0	0%	0	0	0%	0	0
2013	0%	0	0	0%	0	0	0%	0	0
2014	0%	0	0	0%	0	0	0%	0	0
2015	0%	0	0	0%	0	0	0%	0	0
2016	0%	0	0	0%	0	0	0%	0	0
2017	0%	0	0	0%	0	0	0%	0	0
2018	0%	0	0	0%	0	0	0%	0	0
2019	0%	0	0	0%	0	0	0%	0	0
2020	0%	0	0	0%	0	0	0%	0	0
2021	0%	0	0	0%	0	0	0%	0	0
2022	0%	0	0	0%	0	0	0%	0	0
2023	0%	0	0	0%	0	0	0%	0	0
2024	10%	574	756,340	0%	0	0	86%	4,906	7,185,231
2025	10%	668	886,781	0%	0	0	84%	5,593	8,247,067
2026	10%	783	1,041,761	0%	0	0	81%	6,343	9,375,851
2027	15%	1,344	1,715,605	0%	0	0	72%	6,474	9,181,662
2028	15%	1,544	1,969,828	0%	0	0	68%	7,002	9,922,098
2029	20%	2,384	3,059,507	0%	0	0	60%	7,152	10,198,356
2030	20%	2,761	3,566,433	0%	0	0	56%	7,732	11,095,569
2045	12%	1,879	2,615,706	0%	0	0	53%	8,266	12,787,894
2032	10%	1,781	2,631,722	0%	0	0	54%	9,619	15,790,332
2033	10%	2,000	3,093,484	0%	0	0	54%	10,802	18,560,905
2034	10%	2,262	3,676,051	0%	0	0	54%	12,217	22,056,309
2035	12%	2,997	5,154,227	0%	0	0	53%	13,188	25,198,442
2036	12%	3,236	5,922,773	0%	0	0	53%	14,239	28,955,778
2037	12%	3,432	6,725,482	0%	0	0	53%	15,100	32,880,135
2038	12%	3,547	7,438,400	0%	0	0	53%	15,606	36,365,513
2039	12%	3,610	8,118,998	0%	0	0	53%	15,885	39,692,877
2040	12%	3,422	8,176,299	0%	0	0	53%	15,058	39,973,018
2041	12%	3,298	8,363,731	0%	0	0	53%	14,512	40,889,352
2042	12%	2,974	7,831,788	0%	0	0	53%	13,084	38,288,741
2043	12%	2,794	7,539,421	0%	0	0	53%	12,295	36,859,392
2044	12%	2,641	7,227,079	0%	0	0	53%	11,622	35,332,388
2045	12%	1,660	4,357,601	0%	0	0	53%	7,303	21,303,829
2046	12%	853	1,167,185	0%	0	0	53%	3,755	5,706,238

Table A-18. NOx and GHG Tailpipe Emissions for Scenario 2 in Calendar Year 2045

Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

	BEV			Tailpipe Emission Estimates[5] (tons/day)			
Model Year	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	NO_X	CO_2	CH_4	N_2O
2001	0%	0	0	0	0	0	0
2002	0%	0	0	0	0	0	0
2003	0%	0	0	0	0	0	0
2004	0%	0	0	0	0	0	0
2005	0%	0	0	0	0	0	0
2006	0%	0	0	0	0	0	0
2007	0%	0	0	0	0	0	0
2008	0%	0	0	0	0	0	0
2009	0%	0	0	0	0	0	0
2010	0%	0	0	0	0	0	0
2011	0%	0	0	0	0	0	0
2012	0%	0	0	0	0	0	0
2013	0%	0	0	0	0	0	0
2014	0%	0	0	0	0	0	0
2015	0%	0	0	0	0	0	0
2016	0%	0	0	0	0	0	0
2017	0%	0	0	0	0	0	0
2018	0%	0	0	0	0	0	0
2019	0%	0	0	0	0	0	0
2020	0%	0	0	0	0	0	0
2021	0%	0	0	0	0	0	0
2022	0%	0	0	0	0	0	0
2023	0%	0	0	0	0	0	0
2024	5%	258	112,383	0.21	603	0.002	0.09
2025	6%	421	184,471	0.24	693	0.002	0.11
2026	9%	705	309,586	0.28	791	0.002	0.12
2027	13%	1,142	481,512	0.33	833	0.002	0.13
2028	17%	1,750	737,152	0.37	909	0.003	0.14
2029	20%	2,384	1,010,235	0.45	1,021	0.003	0.16
2030	24%	3,314	1,413,144	0.51	1,131	0.003	0.18
2045	35%	5,511	2,533,502	0.49	1,179	0.004	0.19
2032	36%	6,413	3,128,337	0.56	1,405	0.004	0.22
2033	36%	7,201	3,677,235	0.66	1,652	0.005	0.26
2034	36%	8,144	4,369,735	0.78	1,963	0.006	0.31
2035	35%	8,792	4,992,246	0.94	2,322	0.007	0.37
2036	35%	9,493	5,736,639	1.1	2,669	0.008	0.42
2037	35%	10,067	6,514,121	1.2	3,030	0.009	0.48
2038	35%	10,404	7,204,635	1.2	3,352	0.009	0.53
2039	35%	10,590	7,863,843	1.3	3,658	0.01	0.58
2040	35%	10,039	7,919,344	1.2	3,684	0.01	0.58
2041	35%	9,675	8,100,885	1.2	3,769	0.010	0.59
2042	35%	8,723	7,585,660	1.0	3,529	0.009	0.55
2043	35%	8,197	7,302,481	0.92	3,397	0.008	0.53
2044	35%	7,748	6,999,955	0.82	3,256	0.008	0.51
2045	35%	4,869	4,220,656	0.45	1,963	0.005	0.31
2046	35%	2,503	1,130,504	0.15	526	0.002	0.08

Notes:

[1] EMFAC data shown here are adjusted by subtracting data for T7 SWCVs from corresponding data for all HHDTs as described in Appendix A. Accelerated turnover adjustments are included in calendar years 2031, 2037, 2045, and 2050 as described in Appendix A.

[2] Fleet mix percentages for each alternative HHDT technology type are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[3] Population in each model year is calculated based on the fleet mix percentages for each HHDT type and the total population in the adjusted EMFAC data.

[4] Energy consumption is calculated based on adjusted EMFAC data, using the EER for each HHDT type shown in Table A-38.

[5] Emissions from vehicles in each model year are calculated based on the fleet mix composition and the reduction in tailpipe NOx emissions achieved by each HHDT type shown in Table 3-2. Total emissions in each calendar year are calculated as the sum of tailpipe emissions across all HHDT types and all model years in each calendar year.

[6] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CA Cert. - California certified
CH_4 - methane
CO_2 - carbon dioxide
DSL - diesel
EER - energy economy ratio
EMFAC2017 - Emission Factor Model
gal - gallon
HHDT - heavy heavy duty truck
MJ - megajoule
N_2O - nitrous oxide
NG - natural gas
NO_x - oxides of nitrogen
T7 SWCV - solid waste collection vehicles
TOTEX - total exhaust

Table A-19. NOx and GHG Tailpipe Emissions for Scenario 2 in Calendar Year 2050

Model Year	Adjusted EMFAC2017 Output[1]						Conventional DSL		
	Population	NOx_TOTEX (tons/day)	CO2_TOTEX (tons/day)	CH4_TOTEX (tons/day)	N2O_TOTEX (tons/day)	Fuel Consumption (1000 gal/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)
2006	0	0	0	0	0	0	0%	0	0
2007	0	0	0	0	0	0	0%	0	0
2008	0	0	0	0	0	0	0%	0	0
2009	0	0	0	0	0	0	0%	0	0
2010	0	0	0	0	0	0	0%	0	0
2011	0	0	0	0	0	0	0%	0	0
2012	0	0	0	0	0	0	0%	0	0
2013	0	0	0	0	0	0	0%	0	0
2014	0	0	0	0	0	0	0%	0	0
2015	0	0	0	0	0	0	0%	0	0
2016	0	0	0	0	0	0	0%	0	0
2017	0	0	0	0	0	0	0%	0	0
2018	0	0	0	0	0	0	0%	0	0
2019	0	0	0	0	0	0	0%	0	0
2020	0	0	0	0	0	0	0%	0	0
2021	0	0	0	0	0	0	0%	0	0
2022	0	0	0	0	0	0	0%	0	0
2023	0	0	0	0	0	0	0%	0	0
2024	2,595	0.86	281	0.001	0.04	25	0%	0	0
2025	3,028	1.0	330	0.001	0.05	29	0%	0	0
2026	3,626	1.2	393	0.001	0.06	35	0%	0	0
2027	4,257	1.4	439	0.001	0.07	39	0%	0	0
2028	5,060	1.7	526	0.001	0.08	47	0%	0	0
2029	6,031	2.0	632	0.002	0.10	56	0%	0	0
2030	7,066	2.4	743	0.002	0.12	66	0%	0	0
2050	8,217	2.8	872	0.003	0.14	78	0%	0	0
2032	9,494	3.2	1,017	0.003	0.16	91	0%	0	0
2033	11,004	3.8	1,176	0.004	0.18	105	0%	0	0
2034	12,911	4.5	1,386	0.004	0.22	124	0%	0	0
2035	14,935	5.3	1,619	0.005	0.25	144	0%	0	0
2036	16,783	6.4	1,962	0.006	0.31	175	0%	0	0
2037	18,732	7.5	2,328	0.007	0.37	208	0%	0	0
2038	20,725	8.7	2,699	0.008	0.42	241	0%	0	0
2039	22,925	10	3,137	0.009	0.49	280	0%	0	0
2040	25,074	11	3,619	0.01	0.57	323	0%	0	0
2041	27,099	13	4,155	0.01	0.65	370	0%	0	0
2042	28,740	14	4,704	0.01	0.74	419	0%	0	0
2043	29,658	15	5,184	0.01	0.81	462	0%	0	0
2044	30,119	16	5,634	0.02	0.89	502	0%	0	0
2045	28,407	15	5,643	0.02	0.89	503	0%	0	0
2046	27,387	14	5,770	0.02	0.91	514	0%	0	0
2047	24,660	12	5,397	0.01	0.85	481	0%	0	0
2048	23,198	11	5,206	0.01	0.82	464	0%	0	0
2049	21,872	10	4,978	0.01	0.78	444	0%	0	0
2050	13,695	5.4	2,992	0.007	0.47	267	0%	0	0
2051	7,053	1.8	1,226	0.004	0.19	109	0%	0	0

Model Year	Federal Low NOx DSL			CA Cert. Low NOx DSL			Low NOx NG		
	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)
2006	0%	0	0	0%	0	0	0%	0	0
2007	0%	0	0	0%	0	0	0%	0	0
2008	0%	0	0	0%	0	0	0%	0	0
2009	0%	0	0	0%	0	0	0%	0	0
2010	0%	0	0	0%	0	0	0%	0	0
2011	0%	0	0	0%	0	0	0%	0	0
2012	0%	0	0	0%	0	0	0%	0	0
2013	0%	0	0	0%	0	0	0%	0	0
2014	0%	0	0	0%	0	0	0%	0	0
2015	0%	0	0	0%	0	0	0%	0	0
2016	0%	0	0	0%	0	0	0%	0	0
2017	0%	0	0	0%	0	0	0%	0	0
2018	0%	0	0	0%	0	0	0%	0	0
2019	0%	0	0	0%	0	0	0%	0	0
2020	0%	0	0	0%	0	0	0%	0	0
2021	0%	0	0	0%	0	0	0%	0	0
2022	0%	0	0	0%	0	0	0%	0	0
2023	0%	0	0	0%	0	0	0%	0	0
2024	10%	260	337,270	0%	0	0	86%	2,219	3,204,066
2025	10%	303	395,918	0%	0	0	84%	2,534	3,682,036
2026	10%	363	471,136	0%	0	0	81%	2,937	4,240,226
2027	15%	639	789,915	0%	0	0	72%	3,076	4,227,507
2028	15%	759	945,969	0%	0	0	68%	3,441	4,764,882
2029	20%	1,206	1,514,257	0%	0	0	60%	3,619	5,047,525
2030	20%	1,413	1,780,183	0%	0	0	56%	3,957	5,538,347
2050	12%	986	1,253,331	0%	0	0	53%	4,339	6,127,395
2032	10%	949	1,218,218	0%	0	0	54%	5,127	7,309,307
2033	10%	1,100	1,409,784	0%	0	0	54%	5,942	8,458,701
2034	10%	1,291	1,660,800	0%	0	0	54%	6,972	9,964,800
2035	12%	1,792	2,327,866	0%	0	0	53%	7,885	11,380,679
2036	12%	2,014	2,822,001	0%	0	0	53%	8,861	13,796,450
2037	12%	2,248	3,348,517	0%	0	0	53%	9,890	16,370,527
2038	12%	2,487	3,881,574	0%	0	0	53%	10,943	18,976,585
2039	12%	2,751	4,511,626	0%	0	0	53%	12,105	22,056,839
2040	12%	3,009	5,204,512	0%	0	0	53%	13,239	25,444,282
2041	12%	3,252	5,974,789	0%	0	0	53%	14,308	29,210,080
2042	12%	3,449	6,765,245	0%	0	0	53%	15,175	33,074,532
2043	12%	3,559	7,455,772	0%	0	0	53%	15,660	36,450,439
2044	12%	3,614	8,101,789	0%	0	0	53%	15,903	39,608,744
2045	12%	3,409	8,115,025	0%	0	0	53%	14,999	39,673,455
2046	12%	3,286	8,297,953	0%	0	0	53%	14,461	40,567,771
2047	12%	2,959	7,761,898	0%	0	0	53%	13,021	37,947,059
2048	12%	2,784	7,487,127	0%	0	0	53%	12,249	36,603,732
2049	12%	2,625	7,158,856	0%	0	0	53%	11,549	34,998,851
2050	12%	1,643	4,302,930	0%	0	0	53%	7,231	21,036,548
2051	12%	846	1,763,371	0%	0	0	53%	3,724	8,620,923

Table A-19. NOx and GHG Tailpipe Emissions for Scenario 2 in Calendar Year 2050

Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

	BEV			Tailpipe Emission Estimates[5] (tons/day)			
Model Year	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	NO_X	CO_2	CH_4	N_2O
2006	0%	0	0	0	0	0	0
2007	0%	0	0	0	0	0	0
2008	0%	0	0	0	0	0	0
2009	0%	0	0	0	0	0	0
2010	0%	0	0	0	0	0	0
2011	0%	0	0	0	0	0	0
2012	0%	0	0	0	0	0	0
2013	0%	0	0	0	0	0	0
2014	0%	0	0	0	0	0	0
2015	0%	0	0	0	0	0	0
2016	0%	0	0	0	0	0	0
2017	0%	0	0	0	0	0	0
2018	0%	0	0	0	0	0	0
2019	0%	0	0	0	0	0	0
2020	0%	0	0	0	0	0	0
2021	0%	0	0	0	0	0	0
2022	0%	0	0	0	0	0	0
2023	0%	0	0	0	0	0	0
2024	5%	117	50,114	0.10	269	0.001	0.04
2025	6%	191	82,360	0.11	310	0.001	0.05
2026	9%	326	140,010	0.13	358	0.001	0.06
2027	13%	543	221,702	0.15	383	0.001	0.06
2028	17%	860	354,002	0.18	437	0.001	0.07
2029	20%	1,206	500,001	0.22	505	0.001	0.08
2030	24%	1,696	705,370	0.25	564	0.002	0.09
2050	35%	2,892	1,213,943	0.23	565	0.002	0.09
2032	36%	3,418	1,448,100	0.26	651	0.002	0.10
2033	36%	3,961	1,675,814	0.30	753	0.002	0.12
2034	36%	4,648	1,974,199	0.35	887	0.003	0.14
2035	35%	5,257	2,254,709	0.44	1,049	0.003	0.16
2036	35%	5,907	2,733,315	0.53	1,272	0.004	0.20
2037	35%	6,594	3,243,284	0.62	1,509	0.005	0.24
2038	35%	7,295	3,759,589	0.72	1,749	0.005	0.27
2039	35%	8,070	4,369,840	0.84	2,033	0.006	0.32
2040	35%	8,826	5,040,951	1.0	2,345	0.007	0.37
2041	35%	9,539	5,787,020	1.1	2,692	0.008	0.42
2042	35%	10,117	6,552,635	1.2	3,048	0.009	0.48
2043	35%	10,440	7,221,460	1.3	3,359	0.009	0.53
2044	35%	10,602	7,847,175	1.3	3,651	0.01	0.57
2045	35%	9,999	7,859,995	1.2	3,657	0.01	0.57
2046	35%	9,640	8,037,175	1.2	3,739	0.010	0.59
2047	35%	8,680	7,517,967	1.0	3,497	0.009	0.55
2048	35%	8,166	7,251,830	0.91	3,374	0.008	0.53
2049	35%	7,699	6,933,876	0.81	3,226	0.008	0.51
2050	35%	4,821	4,167,703	0.45	1,939	0.005	0.30
2051	35%	2,483	1,707,953	0.15	795	0.002	0.12

Notes:

[1] EMFAC data shown here are adjusted by subtracting data for T7 SWCVs from corresponding data for all HHDTs as described in Appendix A. Accelerated turnover adjustments are included in calendar years 2031, 2037, 2045, and 2050 as described in Appendix A.

[2] Fleet mix percentages for each alternative HHDT technology type are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[3] Population in each model year is calculated based on the fleet mix percentages for each HHDT type and the total population in the adjusted EMFAC data.

[4] Energy consumption is calculated based on adjusted EMFAC data, using the EER for each HHDT type shown in Table A-38.

[5] Emissions from vehicles in each model year are calculated based on the fleet mix composition and the reduction in tailpipe NOx emissions achieved by each HHDT type shown in Table 3-2. Total emissions in each calendar year are calculated as the sum of tailpipe emissions across all HHDT types and all model years in each calendar year.

[6] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CA Cert. - California certified
CH_4 - methane
CO_2 - carbon dioxide
DSL - diesel

EER - energy economy ratio
EMFAC2017 - Emission Factor Model
gal - gallon
HHDT - heavy heavy duty truck
MJ - megajoule

N_2O - nitrous oxide
NG - natural gas
NO_x - oxides of nitrogen
T7 SWCV - solid waste collection vehicles
TOTEX - total exhaust

Table A-20. NOx and GHG Tailpipe Emissions for Scenario 3 in Calendar Year 2020

Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

	Adjusted EMFAC2017 Output[1]						**Conventional DSL**		
Model Year	**Population**	**NOx_TOTEX (tons/day)**	**CO2_TOTEX (tons/day)**	**CH4_TOTEX (tons/day)**	**N2O_TOTEX (tons/day)**	**Fuel Consumption (1000 gal/day)**	**Fleet Mix[2] (%)**	**Population[3]**	**Energy Consumption[4] (MJ/day)**
1976	29	0.02	1.7	0.000	0.000	0.15	100%	29	19,871
1977	34	0.02	2.3	0.000	0.000	0.20	100%	34	27,331
1978	66	0.04	3.9	0.000	0.001	0.35	100%	66	47,207
1979	94	0.05	5.0	0.000	0.001	0.44	100%	94	59,761
1980	87	0.05	5.1	0.000	0.001	0.45	100%	87	61,143
1981	258	0.15	15	0.000	0.002	1.3	100%	258	180,361
1982	236	0.13	13	0.000	0.002	1.2	100%	236	156,209
1983	219	0.13	13	0.000	0.002	1.1	100%	219	151,257
1984	274	0.18	18	0.000	0.003	1.6	100%	274	214,575
1985	404	0.25	25	0.000	0.004	2.2	100%	404	301,188
1986	396	0.25	25	0.000	0.004	2.2	100%	396	301,092
1987	426	0.29	27	0.000	0.004	2.4	100%	426	324,223
1988	484	0.34	32	0.000	0.005	2.9	100%	484	387,591
1989	567	0.40	38	0.000	0.006	3.4	100%	567	454,438
1990	539	0.39	37	0.000	0.006	3.3	100%	539	446,862
1991	475	0.34	28	0.000	0.004	2.5	100%	475	335,098
1992	399	0.31	25	0.000	0.004	2.2	100%	399	301,877
1993	363	0.29	25	0.000	0.004	2.2	100%	363	295,585
1994	379	0.31	28	0.000	0.004	2.5	100%	379	330,512
1995	507	0.41	37	0.000	0.006	3.3	100%	507	443,837
1996	1,142	1.8	150	0.006	0.02	13	100%	1,142	1,800,897
1997	1,167	1.8	149	0.006	0.02	13	100%	1,167	1,790,241
1998	1,370	2.2	192	0.008	0.03	17	100%	1,370	2,305,455
1999	1,972	4.1	291	0.01	0.05	26	100%	1,972	3,484,066
2000	4,067	9.0	641	0.02	0.10	57	100%	4,067	7,683,603
2001	3,153	6.6	476	0.02	0.07	42	100%	3,153	5,706,180
2002	2,427	4.6	338	0.01	0.05	30	100%	2,427	4,046,083
2003	2,907	3.5	425	0.01	0.07	38	100%	2,907	5,088,912
2004	2,913	3.0	421	0.01	0.07	38	100%	2,913	5,047,803
2005	4,812	5.1	719	0.02	0.11	64	100%	4,812	8,613,212
2006	5,968	6.9	972	0.03	0.15	87	100%	5,968	11,650,876
2007	8,303	9.5	1,454	0.03	0.23	130	100%	8,303	17,419,576
2008	12,274	13	2,417	0.02	0.38	215	100%	12,274	28,960,284
2009	14,354	16	3,080	0.03	0.48	275	100%	14,354	36,913,677
2010	11,383	13	2,653	0.02	0.42	236	100%	11,383	31,795,323
2011	13,627	10	3,166	0.01	0.50	282	100%	13,627	37,940,166
2012	39,297	19	6,724	0.01	1.1	599	100%	39,297	80,581,115
2013	21,084	14	5,397	0.010	0.85	481	100%	21,084	64,680,893
2014	23,061	12	5,525	0.01	0.87	492	100%	23,061	66,207,976
2015	28,916	14	7,779	0.02	1.2	693	100%	28,916	93,222,050
2016	41,998	22	12,488	0.02	2.0	1,113	100%	41,998	149,658,452
2017	16,101	6.6	3,944	0.008	0.62	351	100%	16,101	47,265,405
2018	12,688	5.9	3,720	0.007	0.58	332	100%	12,688	44,579,225
2019	12,851	5.6	3,844	0.007	0.60	343	100%	12,851	46,069,473
2020	8,537	3.3	2,461	0.004	0.39	219	100%	8,537	29,496,897
2021	4,246	1.1	575	0.002	0.09	51	100%	4,246	6,891,960

Model Year	Federal Low NOx DSL			CA Cert. Low NOx DSL			Low NOx NG		
	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)
1976	0%	0	0	0%	0	0	0%	0	0
1977	0%	0	0	0%	0	0	0%	0	0
1978	0%	0	0	0%	0	0	0%	0	0
1979	0%	0	0	0%	0	0	0%	0	0
1980	0%	0	0	0%	0	0	0%	0	0
1981	0%	0	0	0%	0	0	0%	0	0
1982	0%	0	0	0%	0	0	0%	0	0
1983	0%	0	0	0%	0	0	0%	0	0
1984	0%	0	0	0%	0	0	0%	0	0
1985	0%	0	0	0%	0	0	0%	0	0
1986	0%	0	0	0%	0	0	0%	0	0
1987	0%	0	0	0%	0	0	0%	0	0
1988	0%	0	0	0%	0	0	0%	0	0
1989	0%	0	0	0%	0	0	0%	0	0
1990	0%	0	0	0%	0	0	0%	0	0
1991	0%	0	0	0%	0	0	0%	0	0
1992	0%	0	0	0%	0	0	0%	0	0
1993	0%	0	0	0%	0	0	0%	0	0
1994	0%	0	0	0%	0	0	0%	0	0
1995	0%	0	0	0%	0	0	0%	0	0
1996	0%	0	0	0%	0	0	0%	0	0
1997	0%	0	0	0%	0	0	0%	0	0
1998	0%	0	0	0%	0	0	0%	0	0
1999	0%	0	0	0%	0	0	0%	0	0
2000	0%	0	0	0%	0	0	0%	0	0
2001	0%	0	0	0%	0	0	0%	0	0
2002	0%	0	0	0%	0	0	0%	0	0
2003	0%	0	0	0%	0	0	0%	0	0
2004	0%	0	0	0%	0	0	0%	0	0
2005	0%	0	0	0%	0	0	0%	0	0
2006	0%	0	0	0%	0	0	0%	0	0
2007	0%	0	0	0%	0	0	0%	0	0
2008	0%	0	0	0%	0	0	0%	0	0
2009	0%	0	0	0%	0	0	0%	0	0
2010	0%	0	0	0%	0	0	0%	0	0
2011	0%	0	0	0%	0	0	0%	0	0
2012	0%	0	0	0%	0	0	0%	0	0
2013	0%	0	0	0%	0	0	0%	0	0
2014	0%	0	0	0%	0	0	0%	0	0
2015	0%	0	0	0%	0	0	0%	0	0
2016	0%	0	0	0%	0	0	0%	0	0
2017	0%	0	0	0%	0	0	0%	0	0
2018	0%	0	0	0%	0	0	0%	0	0
2019	0%	0	0	0%	0	0	0%	0	0
2020	0%	0	0	0%	0	0	0%	0	0
2021	0%	0	0	0%	0	0	0%	0	0

	BEV			Tailpipe Emission Estimates[5] (tons/day)			
Model Year	**Fleet Mix[2] (%)**	**Population[3]**	**Energy Consumption[4] (MJ/day)**	**NO_X**	**CO_2**	**CH_4**	**N_2O**
1976	0%	0	0	0.02	1.7	0.000	0.000
1977	0%	0	0	0.02	2.3	0.000	0.000
1978	0%	0	0	0.04	3.9	0.000	0.001
1979	0%	0	0	0.05	5.0	0.000	0.001
1980	0%	0	0	0.05	5.1	0.000	0.001
1981	0%	0	0	0.15	15	0.000	0.002
1982	0%	0	0	0.13	13	0.000	0.002
1983	0%	0	0	0.13	13	0.000	0.002
1984	0%	0	0	0.18	18	0.000	0.003
1985	0%	0	0	0.25	25	0.000	0.004
1986	0%	0	0	0.25	25	0.000	0.004
1987	0%	0	0	0.29	27	0.000	0.004
1988	0%	0	0	0.34	32	0.000	0.005
1989	0%	0	0	0.40	38	0.000	0.006
1990	0%	0	0	0.39	37	0.000	0.006
1991	0%	0	0	0.34	28	0.000	0.004
1992	0%	0	0	0.31	25	0.000	0.004
1993	0%	0	0	0.29	25	0.000	0.004
1994	0%	0	0	0.31	28	0.000	0.004
1995	0%	0	0	0.41	37	0.000	0.006
1996	0%	0	0	1.8	150	0.006	0.02
1997	0%	0	0	1.8	149	0.006	0.02
1998	0%	0	0	2.2	192	0.008	0.03
1999	0%	0	0	4.1	291	0.01	0.05
2000	0%	0	0	9.0	641	0.02	0.10
2001	0%	0	0	6.6	476	0.02	0.07
2002	0%	0	0	4.6	338	0.01	0.05
2003	0%	0	0	3.5	425	0.01	0.07
2004	0%	0	0	3.0	421	0.01	0.07
2005	0%	0	0	5.1	719	0.02	0.11
2006	0%	0	0	6.9	972	0.03	0.15
2007	0%	0	0	9.5	1,454	0.03	0.23
2008	0%	0	0	13	2,417	0.02	0.38
2009	0%	0	0	16	3,080	0.03	0.48
2010	0%	0	0	13	2,653	0.02	0.42
2011	0%	0	0	10	3,166	0.01	0.50
2012	0%	0	0	19	6,724	0.01	1.1
2013	0%	0	0	14	5,397	0.010	0.85
2014	0%	0	0	12	5,525	0.01	0.87
2015	0%	0	0	14	7,779	0.02	1.2
2016	0%	0	0	22	12,488	0.02	2.0
2017	0%	0	0	6.6	3,944	0.008	0.62
2018	0%	0	0	5.9	3,720	0.007	0.58
2019	0%	0	0	5.6	3,844	0.007	0.60
2020	0%	0	0	3.3	2,461	0.004	0.39
2021	0%	0	0	1.1	575	0.002	0.09

Notes:

[1] EMFAC data shown here are adjusted by subtracting data for T7 SWCVs from corresponding data for all HHDTs as described in Appendix A. Accelerated turnover adjustments are included in calendar years 2031, 2037, 2045, and 2050 as described in Appendix A.

[2] Fleet mix percentages for each alternative HHDT technology type are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[3] Population in each model year is calculated based on the fleet mix percentages for each HHDT type and the total population in the adjusted EMFAC data.

[4] Energy consumption is calculated based on adjusted EMFAC data, using the EER for each HHDT type shown in Table A-38.

[5] Emissions from vehicles in each model year are calculated based on the fleet mix composition and the reduction in tailpipe NOx emissions achieved by each HHDT type shown in Table 3-2. Total emissions in each calendar year are calculated as the sum of tailpipe emissions across all HHDT types and all model years in each calendar year.

[6] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CA Cert. - California certified
CH_4 - methane
CO_2 - carbon dioxide
DSL - diesel
EER - energy economy ratio
EMFAC2017 - Emission Factor Model
gal - gallon
HHDT - heavy heavy duty truck
MJ - megajoule
N_2O - nitrous oxide
NG - natural gas
NO_x - oxides of nitrogen
T7 SWCV - solid waste collection vehicles
TOTEX - total exhaust

Table A-21. NOx and GHG Tailpipe Emissions for Scenario 3 in Calendar Year 2023

	Adjusted EMFAC2017 Output[1]						Conventional DSL		
Model Year	Population	NOx_TOTEX (tons/day)	CO2_TOTEX (tons/day)	CH4_TOTEX (tons/day)	N2O_TOTEX (tons/day)	Fuel Consumption (1000 gal/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)
1979	53	0.03	2.9	0.000	0.000	0.26	100%	53	35,019
1980	64	0.04	3.7	0.000	0.001	0.33	100%	64	44,086
1981	209	0.12	12	0.000	0.002	1.1	100%	209	142,790
1982	208	0.11	11	0.000	0.002	1.0	100%	208	134,214
1983	196	0.11	11	0.000	0.002	1.0	100%	196	131,088
1984	241	0.15	15	0.000	0.002	1.3	100%	241	176,822
1985	357	0.21	21	0.000	0.003	1.9	100%	357	252,082
1986	331	0.20	20	0.000	0.003	1.8	100%	331	243,579
1987	345	0.22	21	0.000	0.003	1.9	100%	345	253,082
1988	370	0.26	24	0.000	0.004	2.2	100%	370	290,997
1989	420	0.29	28	0.000	0.004	2.5	100%	420	332,355
1990	382	0.28	27	0.000	0.004	2.4	100%	382	319,401
1991	331	0.24	20	0.000	0.003	1.8	100%	331	238,471
1992	279	0.22	18	0.000	0.003	1.6	100%	279	214,037
1993	235	0.20	17	0.000	0.003	1.5	100%	235	202,566
1994	257	0.21	19	0.000	0.003	1.7	100%	257	228,163
1995	341	0.29	26	0.000	0.004	2.3	100%	341	308,497
1996	354	0.29	26	0.000	0.004	2.3	100%	354	309,827
1997	358	0.27	24	0.000	0.004	2.2	100%	358	292,799
1998	350	0.29	27	0.000	0.004	2.4	100%	350	324,850
1999	484	0.48	38	0.000	0.006	3.4	100%	484	458,610
2000	570	0.55	44	0.000	0.007	3.9	100%	570	522,449
2001	630	0.52	42	0.000	0.007	3.7	100%	630	502,288
2002	683	0.50	41	0.000	0.006	3.7	100%	683	490,906
2003	607	0.31	41	0.000	0.006	3.7	100%	607	491,836
2004	588	0.27	39	0.000	0.006	3.4	100%	588	462,594
2005	722	0.33	48	0.000	0.008	4.3	100%	722	579,188
2006	789	0.37	53	0.000	0.008	4.7	100%	789	635,640
2007	1,010	0.43	69	0.000	0.01	6.1	100%	1,010	822,391
2008	958	0.24	51	0.000	0.008	4.5	100%	958	608,971
2009	1,054	0.24	57	0.000	0.009	5.1	100%	1,054	681,595
2010	516	0.11	28	0.000	0.004	2.5	100%	516	336,250
2011	601	0.08	32	0.000	0.005	2.8	100%	601	381,333
2012	36,456	15	5,160	0.010	0.81	460	100%	36,456	61,840,416
2013	23,385	13	4,715	0.009	0.74	420	100%	23,385	56,503,770
2014	25,954	12	4,907	0.01	0.77	437	100%	25,954	58,805,403
2015	43,313	18	8,476	0.02	1.3	755	100%	43,313	101,582,009
2016	51,092	25	12,180	0.03	1.9	1,086	100%	51,092	145,975,230
2017	45,093	20	10,301	0.02	1.6	918	100%	45,093	123,455,483
2018	15,699	7.6	3,880	0.008	0.61	346	100%	15,699	46,494,284
2019	15,755	7.5	4,119	0.008	0.65	367	100%	15,755	49,364,115
2020	14,758	7.0	4,076	0.008	0.64	363	100%	14,758	48,851,177
2021	13,866	6.3	3,442	0.008	0.54	307	100%	13,866	41,250,943
2022	13,999	6.1	3,590	0.008	0.56	320	100%	13,999	43,027,237
2023	9,671	3.7	2,395	0.005	0.38	213	100%	9,671	28,707,076
2024	4,843	1.3	599	0.003	0.09	53	0%	0	0

	Federal Low NOx DSL			CA Cert. Low NOx DSL			Low NOx NG		
Model Year	**Fleet Mix[2] (%)**	**Population[3]**	**Energy Consumption[4] (MJ/day)**	**Fleet Mix[2] (%)**	**Population[3]**	**Energy Consumption[4] (MJ/day)**	**Fleet Mix[2] (%)**	**Population[3]**	**Energy Consumption[4] (MJ/day)**
1979	0%	0	0	0%	0	0	0%	0	0
1980	0%	0	0	0%	0	0	0%	0	0
1981	0%	0	0	0%	0	0	0%	0	0
1982	0%	0	0	0%	0	0	0%	0	0
1983	0%	0	0	0%	0	0	0%	0	0
1984	0%	0	0	0%	0	0	0%	0	0
1985	0%	0	0	0%	0	0	0%	0	0
1986	0%	0	0	0%	0	0	0%	0	0
1987	0%	0	0	0%	0	0	0%	0	0
1988	0%	0	0	0%	0	0	0%	0	0
1989	0%	0	0	0%	0	0	0%	0	0
1990	0%	0	0	0%	0	0	0%	0	0
1991	0%	0	0	0%	0	0	0%	0	0
1992	0%	0	0	0%	0	0	0%	0	0
1993	0%	0	0	0%	0	0	0%	0	0
1994	0%	0	0	0%	0	0	0%	0	0
1995	0%	0	0	0%	0	0	0%	0	0
1996	0%	0	0	0%	0	0	0%	0	0
1997	0%	0	0	0%	0	0	0%	0	0
1998	0%	0	0	0%	0	0	0%	0	0
1999	0%	0	0	0%	0	0	0%	0	0
2000	0%	0	0	0%	0	0	0%	0	0
2001	0%	0	0	0%	0	0	0%	0	0
2002	0%	0	0	0%	0	0	0%	0	0
2003	0%	0	0	0%	0	0	0%	0	0
2004	0%	0	0	0%	0	0	0%	0	0
2005	0%	0	0	0%	0	0	0%	0	0
2006	0%	0	0	0%	0	0	0%	0	0
2007	0%	0	0	0%	0	0	0%	0	0
2008	0%	0	0	0%	0	0	0%	0	0
2009	0%	0	0	0%	0	0	0%	0	0
2010	0%	0	0	0%	0	0	0%	0	0
2011	0%	0	0	0%	0	0	0%	0	0
2012	0%	0	0	0%	0	0	0%	0	0
2013	0%	0	0	0%	0	0	0%	0	0
2014	0%	0	0	0%	0	0	0%	0	0
2015	0%	0	0	0%	0	0	0%	0	0
2016	0%	0	0	0%	0	0	0%	0	0
2017	0%	0	0	0%	0	0	0%	0	0
2018	0%	0	0	0%	0	0	0%	0	0
2019	0%	0	0	0%	0	0	0%	0	0
2020	0%	0	0	0%	0	0	0%	0	0
2021	0%	0	0	0%	0	0	0%	0	0
2022	0%	0	0	0%	0	0	0%	0	0
2023	0%	0	0	0%	0	0	0%	0	0
2024	10%	484	717,286	0%	0	0	90%	4,358	7,172,863

Table A-21. NOx and GHG Tailpipe Emissions for Scenario 3 in Calendar Year 2023

	BEV			Tailpipe Emission Estimates[5] (tons/day)			
Model Year	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	NO_X	CO_2	CH_4	N_2O
1979	0%	0	0	0.03	2.9	0.000	0.000
1980	0%	0	0	0.04	3.7	0.000	0.001
1981	0%	0	0	0.12	12	0.000	0.002
1982	0%	0	0	0.11	11	0.000	0.002
1983	0%	0	0	0.11	11	0.000	0.002
1984	0%	0	0	0.15	15	0.000	0.002
1985	0%	0	0	0.21	21	0.000	0.003
1986	0%	0	0	0.20	20	0.000	0.003
1987	0%	0	0	0.22	21	0.000	0.003
1988	0%	0	0	0.26	24	0.000	0.004
1989	0%	0	0	0.29	28	0.000	0.004
1990	0%	0	0	0.28	27	0.000	0.004
1991	0%	0	0	0.24	20	0.000	0.003
1992	0%	0	0	0.22	18	0.000	0.003
1993	0%	0	0	0.20	17	0.000	0.003
1994	0%	0	0	0.21	19	0.000	0.003
1995	0%	0	0	0.29	26	0.000	0.004
1996	0%	0	0	0.29	26	0.000	0.004
1997	0%	0	0	0.27	24	0.000	0.004
1998	0%	0	0	0.29	27	0.000	0.004
1999	0%	0	0	0.48	38	0.000	0.006
2000	0%	0	0	0.55	44	0.000	0.007
2001	0%	0	0	0.52	42	0.000	0.007
2002	0%	0	0	0.50	41	0.000	0.006
2003	0%	0	0	0.31	41	0.000	0.006
2004	0%	0	0	0.27	39	0.000	0.006
2005	0%	0	0	0.33	48	0.000	0.008
2006	0%	0	0	0.37	53	0.000	0.008
2007	0%	0	0	0.43	69	0.000	0.01
2008	0%	0	0	0.24	51	0.000	0.008
2009	0%	0	0	0.24	57	0.000	0.009
2010	0%	0	0	0.11	28	0.000	0.004
2011	0%	0	0	0.08	32	0.000	0.005
2012	0%	0	0	15	5,160	0.010	0.81
2013	0%	0	0	13	4,715	0.009	0.74
2014	0%	0	0	12	4,907	0.01	0.77
2015	0%	0	0	18	8,476	0.02	1.3
2016	0%	0	0	25	12,180	0.03	1.9
2017	0%	0	0	20	10,301	0.02	1.6
2018	0%	0	0	7.6	3,880	0.008	0.61
2019	0%	0	0	7.5	4,119	0.008	0.65
2020	0%	0	0	7.0	4,076	0.008	0.64
2021	0%	0	0	6.3	3,442	0.008	0.54
2022	0%	0	0	6.1	3,590	0.008	0.56
2023	0%	0	0	3.7	2,395	0.005	0.38
2024	0%	0	0	0.14	599	0.003	0.09

Notes:

[1] EMFAC data shown here are adjusted by subtracting data for T7 SWCVs from corresponding data for all HHDTs as described in Appendix A. Accelerated turnover adjustments are included in calendar years 2031, 2037, 2045, and 2050 as described in Appendix A.

[2] Fleet mix percentages for each alternative HHDT technology type are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[3] Population in each model year is calculated based on the fleet mix percentages for each HHDT type and the total population in the adjusted EMFAC data.

[4] Energy consumption is calculated based on adjusted EMFAC data, using the EER for each HHDT type shown in Table A-38.

[5] Emissions from vehicles in each model year are calculated based on the fleet mix composition and the reduction in tailpipe NOx emissions achieved by each HHDT type shown in Table 3-2. Total emissions in each calendar year are calculated as the sum of tailpipe emissions across all HHDT types and all model years in each calendar year.

[6] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CA Cert. - California certified
CH_4 - methane
CO_2 - carbon dioxide
DSL - diesel
EER - energy economy ratio
EMFAC2017 - Emission Factor Model
gal - gallon
HHDT - heavy heavy duty truck
MJ - megajoule
N_2O - nitrous oxide
NG - natural gas
NO_x - oxides of nitrogen
T7 SWCV - solid waste collection vehicles
TOTEX - total exhaust

Table A-22. NOx and GHG Tailpipe Emissions for Scenario 3 in Calendar Year 2031

	Adjusted EMFAC2017 Output[1]						Conventional DSL		
Model Year	Population	NOx_TOTEX (tons/day)	CO2_TOTEX (tons/day)	CH4_TOTEX (tons/day)	N2O_TOTEX (tons/day)	Fuel Consumption (1000 gal/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)
1987	166	0.09	8.9	0.000	0.001	0.79	100%	166	106,532
1988	223	0.13	12	0.000	0.002	1.1	100%	223	144,024
1989	279	0.16	15	0.000	0.002	1.3	100%	279	179,202
1990	256	0.15	14	0.000	0.002	1.3	100%	256	168,297
1991	221	0.14	11	0.000	0.002	1.0	100%	221	134,880
1992	173	0.11	9.2	0.000	0.001	0.82	100%	173	110,429
1993	132	0.09	7.5	0.000	0.001	0.67	100%	132	90,308
1994	131	0.08	7.6	0.000	0.001	0.68	100%	131	91,104
1995	161	0.11	10	0.000	0.002	0.87	100%	161	116,335
1996	159	0.11	10	0.000	0.002	0.85	100%	159	114,485
1997	155	0.10	9.1	0.000	0.001	0.81	100%	155	108,509
1998	145	0.10	10	0.000	0.001	0.85	100%	145	114,337
1999	197	0.17	13	0.000	0.002	1.2	100%	197	160,607
2000	233	0.20	16	0.000	0.002	1.4	100%	233	188,016
2001	267	0.20	16	0.000	0.003	1.4	100%	267	193,494
2002	300	0.21	17	0.000	0.003	1.5	100%	300	200,551
2003	272	0.13	17	0.000	0.003	1.5	100%	272	200,037
2004	276	0.12	17	0.000	0.003	1.5	100%	276	198,929
2005	353	0.15	22	0.000	0.003	1.9	100%	353	259,740
2006	403	0.18	25	0.000	0.004	2.3	100%	403	303,073
2007	543	0.22	35	0.000	0.006	3.1	100%	543	422,431
2008	564	0.14	29	0.000	0.005	2.6	100%	564	352,228
2009	654	0.15	34	0.000	0.005	3.1	100%	654	410,832
2010	337	0.07	18	0.000	0.003	1.6	100%	337	211,381
2011	419	0.05	21	0.000	0.003	1.9	100%	419	253,413
2012	18,775	6.3	2,125	0.004	0.33	189	100%	18,775	25,469,698
2013	10,866	5.2	1,931	0.003	0.30	172	100%	10,866	23,141,590
2014	12,373	4.9	1,993	0.004	0.31	178	100%	12,373	23,884,682
2015	22,601	8.0	3,471	0.007	0.55	309	100%	22,601	41,601,211
2016	25,559	9.1	3,866	0.010	0.61	345	100%	25,559	46,327,589
2017	29,560	9.2	4,023	0.009	0.63	359	100%	29,560	48,215,934
2018	10,153	3.8	1,588	0.004	0.25	142	100%	10,153	19,030,587
2019	11,512	4.5	1,861	0.004	0.29	166	100%	11,512	22,305,607
2020	13,043	5.4	2,255	0.005	0.35	201	100%	13,043	27,025,846
2021	14,295	6.2	2,272	0.006	0.36	203	100%	14,295	27,231,919
2022	16,417	7.5	2,835	0.007	0.45	253	100%	16,417	33,979,835
2023	22,059	12	4,261	0.010	0.67	380	100%	22,059	51,063,434
2024	21,715	11	3,988	0.01	0.63	355	0%	0	0
2025	22,619	12	4,524	0.01	0.71	403	0%	0	0
2026	22,104	12	4,758	0.01	0.75	424	0%	0	0
2027	21,594	11	4,671	0.01	0.73	416	0%	0	0
2028	19,744	10	4,452	0.01	0.70	397	0%	0	0
2029	18,560	9.0	4,281	0.01	0.67	382	0%	0	0
2030	17,915	8.2	4,205	0.01	0.66	375	0%	0	0
2031	11,497	4.6	2,590	0.006	0.41	231	0%	0	0
2032	5,864	1.6	694	0.003	0.11	62	0%	0	0

	Federal Low NOx DSL			**CA Cert. Low NOx DSL**			**Low NOx NG**		
Model Year	**Fleet Mix[2] (%)**	**Population[3]**	**Energy Consumption[4] (MJ/day)**	**Fleet Mix[2] (%)**	**Population[3]**	**Energy Consumption[4] (MJ/day)**	**Fleet Mix[2] (%)**	**Population[3]**	**Energy Consumption[4] (MJ/day)**
1987	0%	0	0	0%	0	0	0%	0	0
1988	0%	0	0	0%	0	0	0%	0	0
1989	0%	0	0	0%	0	0	0%	0	0
1990	0%	0	0	0%	0	0	0%	0	0
1991	0%	0	0	0%	0	0	0%	0	0
1992	0%	0	0	0%	0	0	0%	0	0
1993	0%	0	0	0%	0	0	0%	0	0
1994	0%	0	0	0%	0	0	0%	0	0
1995	0%	0	0	0%	0	0	0%	0	0
1996	0%	0	0	0%	0	0	0%	0	0
1997	0%	0	0	0%	0	0	0%	0	0
1998	0%	0	0	0%	0	0	0%	0	0
1999	0%	0	0	0%	0	0	0%	0	0
2000	0%	0	0	0%	0	0	0%	0	0
2001	0%	0	0	0%	0	0	0%	0	0
2002	0%	0	0	0%	0	0	0%	0	0
2003	0%	0	0	0%	0	0	0%	0	0
2004	0%	0	0	0%	0	0	0%	0	0
2005	0%	0	0	0%	0	0	0%	0	0
2006	0%	0	0	0%	0	0	0%	0	0
2007	0%	0	0	0%	0	0	0%	0	0
2008	0%	0	0	0%	0	0	0%	0	0
2009	0%	0	0	0%	0	0	0%	0	0
2010	0%	0	0	0%	0	0	0%	0	0
2011	0%	0	0	0%	0	0	0%	0	0
2012	0%	0	0	0%	0	0	0%	0	0
2013	0%	0	0	0%	0	0	0%	0	0
2014	0%	0	0	0%	0	0	0%	0	0
2015	0%	0	0	0%	0	0	0%	0	0
2016	0%	0	0	0%	0	0	0%	0	0
2017	0%	0	0	0%	0	0	0%	0	0
2018	0%	0	0	0%	0	0	0%	0	0
2019	0%	0	0	0%	0	0	0%	0	0
2020	0%	0	0	0%	0	0	0%	0	0
2021	0%	0	0	0%	0	0	0%	0	0
2022	0%	0	0	0%	0	0	0%	0	0
2023	0%	0	0	0%	0	0	0%	0	0
2024	10%	2,171	4,779,835	0%	0	0	90%	19,543	47,798,351
2025	10%	2,262	5,421,301	0%	0	0	90%	20,358	54,213,007
2026	10%	2,210	5,702,550	0%	0	0	90%	19,894	57,025,496
2027	15%	3,239	8,396,467	0%	0	0	85%	18,355	52,866,643
2028	15%	2,962	8,002,355	0%	0	0	85%	16,783	50,385,200
2029	20%	3,712	10,260,841	0%	0	0	80%	14,848	45,603,739
2030	20%	3,583	10,079,515	0%	0	0	80%	14,332	44,797,846
2031	20%	2,299	6,209,013	0%	0	0	80%	9,198	27,595,615
2032	10%	586	831,861	0%	0	0	90%	5,277	8,318,607

Table A-22. NOx and GHG Tailpipe Emissions for Scenario 3 in Calendar Year 2031

	BEV			Tailpipe Emission Estimates[5] (tons/day)			
Model Year	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	NO_X	CO_2	CH_4	N_2O
1987	0%	0	0	0.09	8.9	0.000	0.001
1988	0%	0	0	0.13	12	0.000	0.002
1989	0%	0	0	0.16	15	0.000	0.002
1990	0%	0	0	0.15	14	0.000	0.002
1991	0%	0	0	0.14	11	0.000	0.002
1992	0%	0	0	0.11	9.2	0.000	0.001
1993	0%	0	0	0.09	7.5	0.000	0.001
1994	0%	0	0	0.08	7.6	0.000	0.001
1995	0%	0	0	0.11	10	0.000	0.002
1996	0%	0	0	0.11	10	0.000	0.002
1997	0%	0	0	0.10	9.1	0.000	0.001
1998	0%	0	0	0.10	10	0.000	0.001
1999	0%	0	0	0.17	13	0.000	0.002
2000	0%	0	0	0.20	16	0.000	0.002
2001	0%	0	0	0.20	16	0.000	0.003
2002	0%	0	0	0.21	17	0.000	0.003
2003	0%	0	0	0.13	17	0.000	0.003
2004	0%	0	0	0.12	17	0.000	0.003
2005	0%	0	0	0.15	22	0.000	0.003
2006	0%	0	0	0.18	25	0.000	0.004
2007	0%	0	0	0.22	35	0.000	0.006
2008	0%	0	0	0.14	29	0.000	0.005
2009	0%	0	0	0.15	34	0.000	0.005
2010	0%	0	0	0.07	18	0.000	0.003
2011	0%	0	0	0.05	21	0.000	0.003
2012	0%	0	0	6.3	2,125	0.004	0.33
2013	0%	0	0	5.2	1,931	0.003	0.30
2014	0%	0	0	4.9	1,993	0.004	0.31
2015	0%	0	0	8.0	3,471	0.007	0.55
2016	0%	0	0	9.1	3,866	0.010	0.61
2017	0%	0	0	9.2	4,023	0.009	0.63
2018	0%	0	0	3.8	1,588	0.004	0.25
2019	0%	0	0	4.5	1,861	0.004	0.29
2020	0%	0	0	5.4	2,255	0.005	0.35
2021	0%	0	0	6.2	2,272	0.006	0.36
2022	0%	0	0	7.5	2,835	0.007	0.45
2023	0%	0	0	12	4,261	0.010	0.67
2024	0%	0	0	1.3	3,988	0.01	0.63
2025	0%	0	0	1.4	4,524	0.01	0.71
2026	0%	0	0	1.3	4,758	0.01	0.75
2027	0%	0	0	1.4	4,671	0.01	0.73
2028	0%	0	0	1.2	4,452	0.01	0.70
2029	0%	0	0	1.2	4,281	0.01	0.67
2030	0%	0	0	1.1	4,205	0.01	0.66
2031	0%	0	0	0.60	2,590	0.006	0.41
2032	0%	0	0	0.18	694	0.003	0.11

Notes:

[1] EMFAC data shown here are adjusted by subtracting data for T7 SWCVs from corresponding data for all HHDTs as described in Appendix A. Accelerated turnover adjustments are included in calendar years 2031, 2037, 2045, and 2050 as described in Appendix A.

[2] Fleet mix percentages for each alternative HHDT technology type are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[3] Population in each model year is calculated based on the fleet mix percentages for each HHDT type and the total population in the adjusted EMFAC data.

[4] Energy consumption is calculated based on adjusted EMFAC data, using the EER for each HHDT type shown in Table A-38.

[5] Emissions from vehicles in each model year are calculated based on the fleet mix composition and the reduction in tailpipe NOx emissions achieved by each HHDT type shown in Table 3-2. Total emissions in each calendar year are calculated as the sum of tailpipe emissions across all HHDT types and all model years in each calendar year.

[6] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CA Cert. - California certified
CH_4 - methane
CO_2 - carbon dioxide
DSL - diesel
EER - energy economy ratio
EMFAC2017 - Emission Factor Model
gal - gallon
HHDT - heavy heavy duty truck
MJ - megajoule
N_2O - nitrous oxide
NG - natural gas
NO_x - oxides of nitrogen
T7 SWCV - solid waste collection vehicles
TOTEX - total exhaust

Table A-23. NOx and GHG Tailpipe Emissions for Scenario 3 in Calendar Year 2037

Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

	Adjusted EMFAC2017 Output[1]						Conventional DSL		
Model Year	Population	NOx_TOTEX (tons/day)	CO2_TOTEX (tons/day)	CH4_TOTEX (tons/day)	N2O_TOTEX (tons/day)	Fuel Consumption (1000 gal/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)
1993	66	0.04	3.5	0.000	0.001	0.31	100%	66	42,043
1994	83	0.05	4.2	0.000	0.001	0.38	100%	83	50,721
1995	115	0.07	5.9	0.000	0.001	0.53	100%	115	70,970
1996	119	0.07	6.1	0.000	0.001	0.54	100%	119	72,842
1997	117	0.06	5.9	0.000	0.001	0.52	100%	117	70,488
1998	104	0.06	5.7	0.000	0.001	0.50	100%	104	67,898
1999	133	0.10	7.6	0.000	0.001	0.67	100%	133	90,610
2000	147	0.11	8.5	0.000	0.001	0.76	100%	147	101,850
2001	161	0.11	8.8	0.000	0.001	0.79	100%	161	105,603
2002	172	0.11	9.0	0.000	0.001	0.80	100%	172	107,968
2003	146	0.06	8.3	0.000	0.001	0.74	100%	146	99,226
2004	143	0.06	8.1	0.000	0.001	0.72	100%	143	96,731
2005	178	0.07	10	0.000	0.002	0.92	100%	178	123,640
2006	202	0.09	12	0.000	0.002	1.1	100%	202	143,033
2007	272	0.11	17	0.000	0.003	1.5	100%	272	200,277
2008	292	0.07	15	0.000	0.002	1.3	100%	292	179,211
2009	346	0.08	18	0.000	0.003	1.6	100%	346	213,122
2010	183	0.04	9.3	0.000	0.001	0.83	100%	183	111,727
2011	234	0.03	11	0.000	0.002	1.0	100%	234	136,809
2012	7,969	2.4	804	0.002	0.13	72	100%	7,969	9,641,296
2013	4,340	2.0	750	0.001	0.12	67	100%	4,340	8,984,556
2014	4,954	2.0	817	0.001	0.13	73	100%	4,954	9,795,650
2015	9,674	3.7	1,601	0.003	0.25	143	100%	9,674	19,190,427
2016	10,519	3.7	1,604	0.004	0.25	143	100%	10,519	19,227,562
2017	14,184	3.9	1,723	0.004	0.27	154	100%	14,184	20,654,585
2018	4,924	1.7	692	0.002	0.11	62	100%	4,924	8,290,062
2019	5,803	1.9	807	0.002	0.13	72	100%	5,803	9,667,889
2020	6,713	2.3	945	0.002	0.15	84	100%	6,713	11,329,480
2021	7,708	2.6	942	0.003	0.15	84	100%	7,708	11,285,971
2022	9,361	3.4	1,197	0.003	0.19	107	100%	9,361	14,344,235
2023	12,311	5.2	1,799	0.004	0.28	160	100%	12,311	21,557,339
2024	14,157	5.5	1,804	0.005	0.28	161	0%	0	0
2025	15,781	6.4	2,112	0.006	0.33	188	0%	0	0
2026	17,659	7.5	2,484	0.007	0.39	221	0%	0	0
2027	19,532	8.7	2,768	0.008	0.44	247	0%	0	0
2028	21,365	10	3,236	0.010	0.51	288	0%	0	0
2029	22,985	11	3,748	0.01	0.59	334	0%	0	0
2030	24,081	12	4,213	0.01	0.66	375	0%	0	0
2037	24,791	13	4,671	0.01	0.73	416	0%	0	0
2032	24,114	13	4,857	0.01	0.76	433	0%	0	0
2033	23,670	12	5,060	0.01	0.80	451	0%	0	0
2034	21,948	11	4,883	0.01	0.77	435	0%	0	0
2035	20,791	10	4,742	0.01	0.75	423	0%	0	0
2036	19,699	9.0	4,573	0.01	0.72	408	0%	0	0
2037	12,409	5.0	2,773	0.007	0.44	247	0%	0	0
2038	6,391	1.7	743	0.003	0.12	66	0%	0	0

Table A-23. NOx and GHG Tailpipe Emissions for Scenario 3 in Calendar Year 2037
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

	Federal Low NOx DSL			CA Cert. Low NOx DSL			Low NOx NG		
Model Year	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)
1993	0%	0	0	0%	0	0	0%	0	0
1994	0%	0	0	0%	0	0	0%	0	0
1995	0%	0	0	0%	0	0	0%	0	0
1996	0%	0	0	0%	0	0	0%	0	0
1997	0%	0	0	0%	0	0	0%	0	0
1998	0%	0	0	0%	0	0	0%	0	0
1999	0%	0	0	0%	0	0	0%	0	0
2000	0%	0	0	0%	0	0	0%	0	0
2001	0%	0	0	0%	0	0	0%	0	0
2002	0%	0	0	0%	0	0	0%	0	0
2003	0%	0	0	0%	0	0	0%	0	0
2004	0%	0	0	0%	0	0	0%	0	0
2005	0%	0	0	0%	0	0	0%	0	0
2006	0%	0	0	0%	0	0	0%	0	0
2007	0%	0	0	0%	0	0	0%	0	0
2008	0%	0	0	0%	0	0	0%	0	0
2009	0%	0	0	0%	0	0	0%	0	0
2010	0%	0	0	0%	0	0	0%	0	0
2011	0%	0	0	0%	0	0	0%	0	0
2012	0%	0	0	0%	0	0	0%	0	0
2013	0%	0	0	0%	0	0	0%	0	0
2014	0%	0	0	0%	0	0	0%	0	0
2015	0%	0	0	0%	0	0	0%	0	0
2016	0%	0	0	0%	0	0	0%	0	0
2017	0%	0	0	0%	0	0	0%	0	0
2018	0%	0	0	0%	0	0	0%	0	0
2019	0%	0	0	0%	0	0	0%	0	0
2020	0%	0	0	0%	0	0	0%	0	0
2021	0%	0	0	0%	0	0	0%	0	0
2022	0%	0	0	0%	0	0	0%	0	0
2023	0%	0	0	0%	0	0	0%	0	0
2024	10%	1,416	2,161,542	0%	0	0	90%	12,741	21,615,421
2025	10%	1,578	2,531,043	0%	0	0	90%	14,203	25,310,426
2026	10%	1,766	2,977,192	0%	0	0	90%	15,893	29,771,924
2027	15%	2,930	4,975,264	0%	0	0	85%	16,602	31,325,736
2028	15%	3,205	5,817,346	0%	0	0	85%	18,160	36,627,733
2029	20%	4,597	8,983,030	0%	0	0	80%	18,388	39,924,577
2030	20%	4,816	10,097,767	0%	0	0	80%	19,265	44,878,963
2037	12%	2,975	6,717,948	0%	0	0	88%	21,816	54,738,832
2032	10%	2,411	5,821,019	0%	0	0	90%	21,703	58,210,191
2033	10%	2,367	6,063,891	0%	0	0	90%	21,303	60,638,909
2034	10%	2,195	5,851,702	0%	0	0	90%	19,754	58,517,021
2035	12%	2,495	6,819,958	0%	0	0	88%	18,296	55,570,025
2036	12%	2,364	6,576,732	0%	0	0	88%	17,335	53,588,185
2037	12%	1,489	3,988,015	0%	0	0	88%	10,920	32,494,941
2038	12%	767	1,068,563	0%	0	0	88%	5,624	8,706,809

	BEV			Tailpipe Emission Estimates[5] (tons/day)			
Model Year	**Fleet Mix[2] (%)**	**Population[3]**	**Energy Consumption[4] (MJ/day)**	**NO_X**	**CO_2**	**CH_4**	**N_2O**
1993	0%	0	0	0.04	3.5	0.000	0.001
1994	0%	0	0	0.05	4.2	0.000	0.001
1995	0%	0	0	0.07	5.9	0.000	0.001
1996	0%	0	0	0.07	6.1	0.000	0.001
1997	0%	0	0	0.06	5.9	0.000	0.001
1998	0%	0	0	0.06	5.7	0.000	0.001
1999	0%	0	0	0.10	7.6	0.000	0.001
2000	0%	0	0	0.11	8.5	0.000	0.001
2001	0%	0	0	0.11	8.8	0.000	0.001
2002	0%	0	0	0.11	9.0	0.000	0.001
2003	0%	0	0	0.06	8.3	0.000	0.001
2004	0%	0	0	0.06	8.1	0.000	0.001
2005	0%	0	0	0.07	10	0.000	0.002
2006	0%	0	0	0.09	12	0.000	0.002
2007	0%	0	0	0.11	17	0.000	0.003
2008	0%	0	0	0.07	15	0.000	0.002
2009	0%	0	0	0.08	18	0.000	0.003
2010	0%	0	0	0.04	9.3	0.000	0.001
2011	0%	0	0	0.03	11	0.000	0.002
2012	0%	0	0	2.4	804	0.002	0.13
2013	0%	0	0	2.0	750	0.001	0.12
2014	0%	0	0	2.0	817	0.001	0.13
2015	0%	0	0	3.7	1,601	0.003	0.25
2016	0%	0	0	3.7	1,604	0.004	0.25
2017	0%	0	0	3.9	1,723	0.004	0.27
2018	0%	0	0	1.7	692	0.002	0.11
2019	0%	0	0	1.9	807	0.002	0.13
2020	0%	0	0	2.3	945	0.002	0.15
2021	0%	0	0	2.6	942	0.003	0.15
2022	0%	0	0	3.4	1,197	0.003	0.19
2023	0%	0	0	5.2	1,799	0.004	0.28
2024	0%	0	0	0.63	1,804	0.005	0.28
2025	0%	0	0	0.74	2,112	0.006	0.33
2026	0%	0	0	0.87	2,484	0.007	0.39
2027	0%	0	0	1.1	2,768	0.008	0.44
2028	0%	0	0	1.2	3,236	0.010	0.51
2029	0%	0	0	1.5	3,748	0.01	0.59
2030	0%	0	0	1.6	4,213	0.01	0.66
2037	0%	0	0	1.5	4,671	0.01	0.73
2032	0%	0	0	1.5	4,857	0.01	0.76
2033	0%	0	0	1.4	5,060	0.01	0.80
2034	0%	0	0	1.3	4,883	0.01	0.77
2035	0%	0	0	1.2	4,742	0.01	0.75
2036	0%	0	0	1.1	4,573	0.01	0.72
2037	0%	0	0	0.59	2,773	0.007	0.44
2038	0%	0	0	0.20	743	0.003	0.12

Notes:

[1] EMFAC data shown here are adjusted by subtracting data for T7 SWCVs from corresponding data for all HHDTs as described in Appendix A. Accelerated turnover adjustments are included in calendar years 2031, 2037, 2045, and 2050 as described in Appendix A.

[2] Fleet mix percentages for each alternative HHDT technology type are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[3] Population in each model year is calculated based on the fleet mix percentages for each HHDT type and the total population in the adjusted EMFAC data.

[4] Energy consumption is calculated based on adjusted EMFAC data, using the EER for each HHDT type shown in Table A-38.

[5] Emissions from vehicles in each model year are calculated based on the fleet mix composition and the reduction in tailpipe NOx emissions achieved by each HHDT type shown in Table 3-2. Total emissions in each calendar year are calculated as the sum of tailpipe emissions across all HHDT types and all model years in each calendar year.

[6] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CA Cert. - California certified
CH_4 - methane
CO_2 - carbon dioxide
DSL - diesel
EER - energy economy ratio
EMFAC2017 - Emission Factor Model
gal - gallon
HHDT - heavy heavy duty truck
MJ - megajoule
N_2O - nitrous oxide
NG - natural gas
NO_x - oxides of nitrogen
T7 SWCV - solid waste collection vehicles
TOTEX - total exhaust

Table A-24. NOx and GHG Tailpipe Emissions for Scenario 3 in Calendar Year 2045

Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

	Adjusted EMFAC2017 Output[1]						Conventional DSL		
Model Year	**Population**	**NOx_TOTEX (tons/day)**	**CO2_TOTEX (tons/day)**	**CH4_TOTEX (tons/day)**	**N2O_TOTEX (tons/day)**	**Fuel Consumption (1000 gal/day)**	**Fleet Mix[2] (%)**	**Population[3]**	**Energy Consumption[4] (MJ/day)**
2001	0	0	0	0	0	0	0%	0	0
2002	0	0	0	0	0	0	0%	0	0
2003	0	0	0	0	0	0	0%	0	0
2004	0	0	0	0	0	0	0%	0	0
2005	0	0	0	0	0	0	0%	0	0
2006	0	0	0	0	0	0	0%	0	0
2007	0	0	0	0	0	0	0%	0	0
2008	0	0	0	0	0	0	0%	0	0
2009	0	0	0	0	0	0	0%	0	0
2010	0	0	0	0	0	0	0%	0	0
2011	0	0	0	0	0	0	0%	0	0
2012	0	0	0	0	0	0	0%	0	0
2013	0	0	0	0	0	0	0%	0	0
2014	0	0	0	0	0	0	0%	0	0
2015	0	0	0	0	0	0	0%	0	0
2016	0	0	0	0	0	0	0%	0	0
2017	0	0	0	0	0	0	0%	0	0
2018	0	0	0	0	0	0	0%	0	0
2019	0	0	0	0	0	0	0%	0	0
2020	0	0	0	0	0	0	0%	0	0
2021	0	0	0	0	0	0	0%	0	0
2022	0	0	0	0	0	0	0%	0	0
2023	0	0	0	0	0	0	0%	0	0
2024	5,738	1.9	631	0.002	0.10	56	0%	0	0
2025	6,682	2.2	740	0.002	0.12	66	0%	0	0
2026	7,830	2.6	869	0.002	0.14	77	0%	0	0
2027	8,960	3.0	954	0.003	0.15	85	0%	0	0
2028	10,297	3.5	1,096	0.003	0.17	98	0%	0	0
2029	11,921	4.1	1,276	0.004	0.20	114	0%	0	0
2030	13,807	4.8	1,488	0.005	0.23	133	0%	0	0
2045	15,655	5.9	1,819	0.006	0.29	162	0%	0	0
2032	17,813	7.1	2,196	0.007	0.35	196	0%	0	0
2033	20,003	8.3	2,581	0.008	0.41	230	0%	0	0
2034	22,623	10	3,067	0.009	0.48	273	0%	0	0
2035	24,976	11	3,584	0.01	0.56	319	0%	0	0
2036	26,967	13	4,118	0.01	0.65	367	0%	0	0
2037	28,599	14	4,677	0.01	0.74	417	0%	0	0
2038	29,556	15	5,172	0.01	0.81	461	0%	0	0
2039	30,085	16	5,646	0.02	0.89	503	0%	0	0
2040	28,520	15	5,685	0.02	0.89	507	0%	0	0
2041	27,485	14	5,816	0.02	0.91	518	0%	0	0
2042	24,780	12	5,446	0.01	0.86	485	0%	0	0
2043	23,286	11	5,243	0.01	0.82	467	0%	0	0
2044	22,012	10	5,025	0.01	0.79	448	0%	0	0
2045	13,831	5.5	3,030	0.007	0.48	270	0%	0	0
2046	7,111	1.9	812	0.004	0.13	72	0%	0	0

Table A-24. NOx and GHG Tailpipe Emissions for Scenario 3 in Calendar Year 2045

Model Year	Federal Low NOx DSL			CA Cert. Low NOx DSL			Low NOx NG		
	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)
2001	0%	0	0	0%	0	0	0%	0	0
2002	0%	0	0	0%	0	0	0%	0	0
2003	0%	0	0	0%	0	0	0%	0	0
2004	0%	0	0	0%	0	0	0%	0	0
2005	0%	0	0	0%	0	0	0%	0	0
2006	0%	0	0	0%	0	0	0%	0	0
2007	0%	0	0	0%	0	0	0%	0	0
2008	0%	0	0	0%	0	0	0%	0	0
2009	0%	0	0	0%	0	0	0%	0	0
2010	0%	0	0	0%	0	0	0%	0	0
2011	0%	0	0	0%	0	0	0%	0	0
2012	0%	0	0	0%	0	0	0%	0	0
2013	0%	0	0	0%	0	0	0%	0	0
2014	0%	0	0	0%	0	0	0%	0	0
2015	0%	0	0	0%	0	0	0%	0	0
2016	0%	0	0	0%	0	0	0%	0	0
2017	0%	0	0	0%	0	0	0%	0	0
2018	0%	0	0	0%	0	0	0%	0	0
2019	0%	0	0	0%	0	0	0%	0	0
2020	0%	0	0	0%	0	0	0%	0	0
2021	0%	0	0	0%	0	0	0%	0	0
2022	0%	0	0	0%	0	0	0%	0	0
2023	0%	0	0	0%	0	0	0%	0	0
2024	10%	574	756,340	0%	0	0	90%	5,164	7,563,401
2025	10%	668	886,781	0%	0	0	90%	6,014	8,867,814
2026	10%	783	1,041,761	0%	0	0	90%	7,047	10,417,613
2027	15%	1,344	1,715,605	0%	0	0	85%	7,616	10,801,955
2028	15%	1,544	1,969,828	0%	0	0	85%	8,752	12,402,622
2029	20%	2,384	3,059,507	0%	0	0	80%	9,536	13,597,807
2030	20%	2,761	3,566,433	0%	0	0	80%	11,045	15,850,813
2045	12%	1,879	2,615,706	0%	0	0	88%	13,777	21,313,157
2032	10%	1,781	2,631,722	0%	0	0	90%	16,032	26,317,219
2033	10%	2,000	3,093,484	0%	0	0	90%	18,003	30,934,842
2034	10%	2,262	3,676,051	0%	0	0	90%	20,361	36,760,514
2035	12%	2,997	5,154,227	0%	0	0	88%	21,979	41,997,404
2036	12%	3,236	5,922,773	0%	0	0	88%	23,731	48,259,631
2037	12%	3,432	6,725,482	0%	0	0	88%	25,167	54,800,225
2038	12%	3,547	7,438,400	0%	0	0	88%	26,009	60,609,188
2039	12%	3,610	8,118,998	0%	0	0	88%	26,475	66,154,795
2040	12%	3,422	8,176,299	0%	0	0	88%	25,097	66,621,697
2041	12%	3,298	8,363,731	0%	0	0	88%	24,187	68,148,920
2042	12%	2,974	7,831,788	0%	0	0	88%	21,807	63,814,568
2043	12%	2,794	7,539,421	0%	0	0	88%	20,492	61,432,320
2044	12%	2,641	7,227,079	0%	0	0	88%	19,370	58,887,313
2045	12%	1,660	4,357,601	0%	0	0	88%	12,172	35,506,382
2046	12%	853	1,167,185	0%	0	0	88%	6,258	9,510,397

Table A-24. NOx and GHG Tailpipe Emissions for Scenario 3 in Calendar Year 2045

	BEV			**Tailpipe Emission Estimates[5] (tons/day)**			
Model Year	**Fleet Mix[2] (%)**	**Population[3]**	**Energy Consumption[4] (MJ/day)**	**NO_X**	**CO_2**	**CH_4**	**N_2O**
2001	0%	0	0	0	0	0	0
2002	0%	0	0	0	0	0	0
2003	0%	0	0	0	0	0	0
2004	0%	0	0	0	0	0	0
2005	0%	0	0	0	0	0	0
2006	0%	0	0	0	0	0	0
2007	0%	0	0	0	0	0	0
2008	0%	0	0	0	0	0	0
2009	0%	0	0	0	0	0	0
2010	0%	0	0	0	0	0	0
2011	0%	0	0	0	0	0	0
2012	0%	0	0	0	0	0	0
2013	0%	0	0	0	0	0	0
2014	0%	0	0	0	0	0	0
2015	0%	0	0	0	0	0	0
2016	0%	0	0	0	0	0	0
2017	0%	0	0	0	0	0	0
2018	0%	0	0	0	0	0	0
2019	0%	0	0	0	0	0	0
2020	0%	0	0	0	0	0	0
2021	0%	0	0	0	0	0	0
2022	0%	0	0	0	0	0	0
2023	0%	0	0	0	0	0	0
2024	0%	0	0	0.22	631	0.002	0.10
2025	0%	0	0	0.26	740	0.002	0.12
2026	0%	0	0	0.30	869	0.002	0.14
2027	0%	0	0	0.37	954	0.003	0.15
2028	0%	0	0	0.43	1,096	0.003	0.17
2029	0%	0	0	0.54	1,276	0.004	0.20
2030	0%	0	0	0.63	1,488	0.005	0.23
2045	0%	0	0	0.70	1,819	0.006	0.29
2032	0%	0	0	0.82	2,196	0.007	0.35
2033	0%	0	0	1.0	2,581	0.008	0.41
2034	0%	0	0	1.1	3,067	0.009	0.48
2035	0%	0	0	1.3	3,584	0.01	0.56
2036	0%	0	0	1.5	4,118	0.01	0.65
2037	0%	0	0	1.7	4,677	0.01	0.74
2038	0%	0	0	1.8	5,172	0.01	0.81
2039	0%	0	0	1.8	5,646	0.02	0.89
2040	0%	0	0	1.7	5,685	0.02	0.89
2041	0%	0	0	1.7	5,816	0.02	0.91
2042	0%	0	0	1.5	5,446	0.01	0.86
2043	0%	0	0	1.3	5,243	0.01	0.82
2044	0%	0	0	1.2	5,025	0.01	0.79
2045	0%	0	0	0.64	3,030	0.007	0.48
2046	0%	0	0	0.22	812	0.004	0.13

Notes:

[1] EMFAC data shown here are adjusted by subtracting data for T7 SWCVs from corresponding data for all HHDTs as described in Appendix A. Accelerated turnover adjustments are included in calendar years 2031, 2037, 2045, and 2050 as described in Appendix A.

[2] Fleet mix percentages for each alternative HHDT technology type are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[3] Population in each model year is calculated based on the fleet mix percentages for each HHDT type and the total population in the adjusted EMFAC data.

[4] Energy consumption is calculated based on adjusted EMFAC data, using the EER for each HHDT type shown in Table A-38.

[5] Emissions from vehicles in each model year are calculated based on the fleet mix composition and the reduction in tailpipe NOx emissions achieved by each HHDT type shown in Table 3-2. Total emissions in each calendar year are calculated as the sum of tailpipe emissions across all HHDT types and all model years in each calendar year.

[6] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CA Cert. - California certified
CH_4 - methane
CO_2 - carbon dioxide
DSL - diesel
EER - energy economy ratio
EMFAC2017 - Emission Factor Model
gal - gallon
HHDT - heavy heavy duty truck
MJ - megajoule
N_2O - nitrous oxide
NG - natural gas
NO_x - oxides of nitrogen
T7 SWCV - solid waste collection vehicles
TOTEX - total exhaust

Table A-25. NOx and GHG Tailpipe Emissions for Scenario 3 in Calendar Year 2050

	Adjusted EMFAC2017 Output[1]						Conventional DSL		
Model Year	**Population**	**NOx_TOTEX (tons/day)**	**CO2_TOTEX (tons/day)**	**CH4_TOTEX (tons/day)**	**N2O_TOTEX (tons/day)**	**Fuel Consumption (1000 gal/day)**	**Fleet Mix[2] (%)**	**Population[3]**	**Energy Consumption[4] (MJ/day)**
2006	0	0	0	0	0	0	0%	0	0
2007	0	0	0	0	0	0	0%	0	0
2008	0	0	0	0	0	0	0%	0	0
2009	0	0	0	0	0	0	0%	0	0
2010	0	0	0	0	0	0	0%	0	0
2011	0	0	0	0	0	0	0%	0	0
2012	0	0	0	0	0	0	0%	0	0
2013	0	0	0	0	0	0	0%	0	0
2014	0	0	0	0	0	0	0%	0	0
2015	0	0	0	0	0	0	0%	0	0
2016	0	0	0	0	0	0	0%	0	0
2017	0	0	0	0	0	0	0%	0	0
2018	0	0	0	0	0	0	0%	0	0
2019	0	0	0	0	0	0	0%	0	0
2020	0	0	0	0	0	0	0%	0	0
2021	0	0	0	0	0	0	0%	0	0
2022	0	0	0	0	0	0	0%	0	0
2023	0	0	0	0	0	0	0%	0	0
2024	2,595	0.86	281	0.001	0.04	25	0%	0	0
2025	3,028	1.0	330	0.001	0.05	29	0%	0	0
2026	3,626	1.2	393	0.001	0.06	35	0%	0	0
2027	4,257	1.4	439	0.001	0.07	39	0%	0	0
2028	5,060	1.7	526	0.001	0.08	47	0%	0	0
2029	6,031	2.0	632	0.002	0.10	56	0%	0	0
2030	7,066	2.4	743	0.002	0.12	66	0%	0	0
2050	8,217	2.8	872	0.003	0.14	78	0%	0	0
2032	9,494	3.2	1,017	0.003	0.16	91	0%	0	0
2033	11,004	3.8	1,176	0.004	0.18	105	0%	0	0
2034	12,911	4.5	1,386	0.004	0.22	124	0%	0	0
2035	14,935	5.3	1,619	0.005	0.25	144	0%	0	0
2036	16,783	6.4	1,962	0.006	0.31	175	0%	0	0
2037	18,732	7.5	2,328	0.007	0.37	208	0%	0	0
2038	20,725	8.7	2,699	0.008	0.42	241	0%	0	0
2039	22,925	10	3,137	0.009	0.49	280	0%	0	0
2040	25,074	11	3,619	0.01	0.57	323	0%	0	0
2041	27,099	13	4,155	0.01	0.65	370	0%	0	0
2042	28,740	14	4,704	0.01	0.74	419	0%	0	0
2043	29,658	15	5,184	0.01	0.81	462	0%	0	0
2044	30,119	16	5,634	0.02	0.89	502	0%	0	0
2045	28,407	15	5,643	0.02	0.89	503	0%	0	0
2046	27,387	14	5,770	0.02	0.91	514	0%	0	0
2047	24,660	12	5,397	0.01	0.85	481	0%	0	0
2048	23,198	11	5,206	0.01	0.82	464	0%	0	0
2049	21,872	10	4,978	0.01	0.78	444	0%	0	0
2050	13,695	5.4	2,992	0.007	0.47	267	0%	0	0
2051	7,053	1.8	1,226	0.004	0.19	109	0%	0	0

	Federal Low NOx DSL			CA Cert. Low NOx DSL			Low NOx NG		
Model Year	**Fleet Mix[2] (%)**	**Population[3]**	**Energy Consumption[4] (MJ/day)**	**Fleet Mix[2] (%)**	**Population[3]**	**Energy Consumption[4] (MJ/day)**	**Fleet Mix[2] (%)**	**Population[3]**	**Energy Consumption[4] (MJ/day)**
2006	0%	0	0	0%	0	0	0%	0	0
2007	0%	0	0	0%	0	0	0%	0	0
2008	0%	0	0	0%	0	0	0%	0	0
2009	0%	0	0	0%	0	0	0%	0	0
2010	0%	0	0	0%	0	0	0%	0	0
2011	0%	0	0	0%	0	0	0%	0	0
2012	0%	0	0	0%	0	0	0%	0	0
2013	0%	0	0	0%	0	0	0%	0	0
2014	0%	0	0	0%	0	0	0%	0	0
2015	0%	0	0	0%	0	0	0%	0	0
2016	0%	0	0	0%	0	0	0%	0	0
2017	0%	0	0	0%	0	0	0%	0	0
2018	0%	0	0	0%	0	0	0%	0	0
2019	0%	0	0	0%	0	0	0%	0	0
2020	0%	0	0	0%	0	0	0%	0	0
2021	0%	0	0	0%	0	0	0%	0	0
2022	0%	0	0	0%	0	0	0%	0	0
2023	0%	0	0	0%	0	0	0%	0	0
2024	10%	260	337,270	0%	0	0	90%	2,336	3,372,701
2025	10%	303	395,918	0%	0	0	90%	2,725	3,959,178
2026	10%	363	471,136	0%	0	0	90%	3,263	4,711,362
2027	15%	639	789,915	0%	0	0	85%	3,618	4,973,538
2028	15%	759	945,969	0%	0	0	85%	4,301	5,956,103
2029	20%	1,206	1,514,257	0%	0	0	80%	4,825	6,730,033
2030	20%	1,413	1,780,183	0%	0	0	80%	5,653	7,911,924
2050	12%	986	1,253,331	0%	0	0	88%	7,231	10,212,325
2032	10%	949	1,218,218	0%	0	0	90%	8,544	12,182,179
2033	10%	1,100	1,409,784	0%	0	0	90%	9,904	14,097,835
2034	10%	1,291	1,660,800	0%	0	0	90%	11,620	16,608,001
2035	12%	1,792	2,327,866	0%	0	0	88%	13,142	18,967,798
2036	12%	2,014	2,822,001	0%	0	0	88%	14,769	22,994,084
2037	12%	2,248	3,348,517	0%	0	0	88%	16,484	27,284,212
2038	12%	2,487	3,881,574	0%	0	0	88%	18,238	31,627,641
2039	12%	2,751	4,511,626	0%	0	0	88%	20,174	36,761,398
2040	12%	3,009	5,204,512	0%	0	0	88%	22,065	42,407,136
2041	12%	3,252	5,974,789	0%	0	0	88%	23,847	48,683,467
2042	12%	3,449	6,765,245	0%	0	0	88%	25,292	55,124,220
2043	12%	3,559	7,455,772	0%	0	0	88%	26,099	60,750,732
2044	12%	3,614	8,101,789	0%	0	0	88%	26,505	66,014,573
2045	12%	3,409	8,115,025	0%	0	0	88%	24,998	66,122,425
2046	12%	3,286	8,297,953	0%	0	0	88%	24,101	67,612,952
2047	12%	2,959	7,761,898	0%	0	0	88%	21,701	63,245,098
2048	12%	2,784	7,487,127	0%	0	0	88%	20,414	61,006,220
2049	12%	2,625	7,158,856	0%	0	0	88%	19,248	58,331,418
2050	12%	1,643	4,302,930	0%	0	0	88%	12,051	35,060,913
2051	12%	846	1,763,371	0%	0	0	88%	6,207	14,368,205

	BEV			Tailpipe Emission Estimates[5] (tons/day)			
Model Year	**Fleet Mix[2] (%)**	**Population[3]**	**Energy Consumption[4] (MJ/day)**	**NO_X**	**CO_2**	**CH_4**	**N_2O**
2006	0%	0	0	0	0	0	0
2007	0%	0	0	0	0	0	0
2008	0%	0	0	0	0	0	0
2009	0%	0	0	0	0	0	0
2010	0%	0	0	0	0	0	0
2011	0%	0	0	0	0	0	0
2012	0%	0	0	0	0	0	0
2013	0%	0	0	0	0	0	0
2014	0%	0	0	0	0	0	0
2015	0%	0	0	0	0	0	0
2016	0%	0	0	0	0	0	0
2017	0%	0	0	0	0	0	0
2018	0%	0	0	0	0	0	0
2019	0%	0	0	0	0	0	0
2020	0%	0	0	0	0	0	0
2021	0%	0	0	0	0	0	0
2022	0%	0	0	0	0	0	0
2023	0%	0	0	0	0	0	0
2024	0%	0	0	0.10	281	0.001	0.04
2025	0%	0	0	0.12	330	0.001	0.05
2026	0%	0	0	0.14	393	0.001	0.06
2027	0%	0	0	0.17	439	0.001	0.07
2028	0%	0	0	0.21	526	0.001	0.08
2029	0%	0	0	0.26	632	0.002	0.10
2030	0%	0	0	0.31	743	0.002	0.12
2050	0%	0	0	0.33	872	0.003	0.14
2032	0%	0	0	0.37	1,017	0.003	0.16
2033	0%	0	0	0.43	1,176	0.004	0.18
2034	0%	0	0	0.52	1,386	0.004	0.22
2035	0%	0	0	0.62	1,619	0.005	0.25
2036	0%	0	0	0.75	1,962	0.006	0.31
2037	0%	0	0	0.89	2,328	0.007	0.37
2038	0%	0	0	1.0	2,699	0.008	0.42
2039	0%	0	0	1.2	3,137	0.009	0.49
2040	0%	0	0	1.4	3,619	0.01	0.57
2041	0%	0	0	1.5	4,155	0.01	0.65
2042	0%	0	0	1.7	4,704	0.01	0.74
2043	0%	0	0	1.8	5,184	0.01	0.81
2044	0%	0	0	1.8	5,634	0.02	0.89
2045	0%	0	0	1.7	5,643	0.02	0.89
2046	0%	0	0	1.7	5,770	0.02	0.91
2047	0%	0	0	1.5	5,397	0.01	0.85
2048	0%	0	0	1.3	5,206	0.01	0.82
2049	0%	0	0	1.2	4,978	0.01	0.78
2050	0%	0	0	0.64	2,992	0.007	0.47
2051	0%	0	0	0.22	1,226	0.004	0.19

Notes:

[1] EMFAC data shown here are adjusted by subtracting data for T7 SWCVs from corresponding data for all HHDTs as described in Appendix A. Accelerated turnover adjustments are included in calendar years 2031, 2037, 2045, and 2050 as described in Appendix A.

[2] Fleet mix percentages for each alternative HHDT technology type are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[3] Population in each model year is calculated based on the fleet mix percentages for each HHDT type and the total population in the adjusted EMFAC data.

[4] Energy consumption is calculated based on adjusted EMFAC data, using the EER for each HHDT type shown in Table A-38.

[5] Emissions from vehicles in each model year are calculated based on the fleet mix composition and the reduction in tailpipe NOx emissions achieved by each HHDT type shown in Table 3-2. Total emissions in each calendar year are calculated as the sum of tailpipe emissions across all HHDT types and all model years in each calendar year.

[6] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CA Cert. - California certified
CH_4 - methane
CO_2 - carbon dioxide
DSL - diesel
EER - energy economy ratio
EMFAC2017 - Emission Factor Model
gal - gallon
HHDT - heavy heavy duty truck
MJ - megajoule
N_2O - nitrous oxide
NG - natural gas
NO_x - oxides of nitrogen
T7 SWCV - solid waste collection vehicles
TOTEX - total exhaust

Table A-26. NOx and GHG Emissions for Tailpipe Scenario 4 in Calendar Year 2020

	Adjusted EMFAC2017 Output[1]						Conventional DSL		
Model Year	**Population**	**NOx_TOTEX (tons/day)**	**CO2_TOTEX (tons/day)**	**CH4_TOTEX (tons/day)**	**N2O_TOTEX (tons/day)**	**Fuel Consumption (1000 gal/day)**	**Fleet Mix[2] (%)**	**Population[3]**	**Energy Consumption[4] (MJ/day)**
1976	29	0.02	1.7	0.000	0.000	0.15	100%	29	19,871
1977	34	0.02	2.3	0.000	0.000	0.20	100%	34	27,331
1978	66	0.04	3.9	0.000	0.001	0.35	100%	66	47,207
1979	94	0.05	5.0	0.000	0.001	0.44	100%	94	59,761
1980	87	0.05	5.1	0.000	0.001	0.45	100%	87	61,143
1981	258	0.15	15	0.000	0.002	1.3	100%	258	180,361
1982	236	0.13	13	0.000	0.002	1.2	100%	236	156,209
1983	219	0.13	13	0.000	0.002	1.1	100%	219	151,257
1984	274	0.18	18	0.000	0.003	1.6	100%	274	214,575
1985	404	0.25	25	0.000	0.004	2.2	100%	404	301,188
1986	396	0.25	25	0.000	0.004	2.2	100%	396	301,092
1987	426	0.29	27	0.000	0.004	2.4	100%	426	324,223
1988	484	0.34	32	0.000	0.005	2.9	100%	484	387,591
1989	567	0.40	38	0.000	0.006	3.4	100%	567	454,438
1990	539	0.39	37	0.000	0.006	3.3	100%	539	446,862
1991	475	0.34	28	0.000	0.004	2.5	100%	475	335,098
1992	399	0.31	25	0.000	0.004	2.2	100%	399	301,877
1993	363	0.29	25	0.000	0.004	2.2	100%	363	295,585
1994	379	0.31	28	0.000	0.004	2.5	100%	379	330,512
1995	507	0.41	37	0.000	0.006	3.3	100%	507	443,837
1996	1,142	1.8	150	0.006	0.02	13	100%	1,142	1,800,897
1997	1,167	1.8	149	0.006	0.02	13	100%	1,167	1,790,241
1998	1,370	2.2	192	0.008	0.03	17	100%	1,370	2,305,455
1999	1,972	4.1	291	0.01	0.05	26	100%	1,972	3,484,066
2000	4,067	9.0	641	0.02	0.10	57	100%	4,067	7,683,603
2001	3,153	6.6	476	0.02	0.07	42	100%	3,153	5,706,180
2002	2,427	4.6	338	0.01	0.05	30	100%	2,427	4,046,083
2003	2,907	3.5	425	0.01	0.07	38	100%	2,907	5,088,912
2004	2,913	3.0	421	0.01	0.07	38	100%	2,913	5,047,803
2005	4,812	5.1	719	0.02	0.11	64	100%	4,812	8,613,212
2006	5,968	6.9	972	0.03	0.15	87	100%	5,968	11,650,876
2007	8,303	9.5	1,454	0.03	0.23	130	100%	8,303	17,419,576
2008	12,274	13	2,417	0.02	0.38	215	100%	12,274	28,960,284
2009	14,354	16	3,080	0.03	0.48	275	100%	14,354	36,913,677
2010	11,383	13	2,653	0.02	0.42	236	100%	11,383	31,795,323
2011	13,627	10	3,166	0.01	0.50	282	100%	13,627	37,940,166
2012	39,297	19	6,724	0.01	1.1	599	100%	39,297	80,581,115
2013	21,084	14	5,397	0.010	0.85	481	100%	21,084	64,680,893
2014	23,061	12	5,525	0.01	0.87	492	100%	23,061	66,207,976
2015	28,916	14	7,779	0.02	1.2	693	100%	28,916	93,222,050
2016	41,998	22	12,488	0.02	2.0	1,113	100%	41,998	149,658,452
2017	16,101	6.6	3,944	0.008	0.62	351	100%	16,101	47,265,405
2018	12,688	5.9	3,720	0.007	0.58	332	25%	3,172	11,144,806
2019	12,851	5.6	3,844	0.007	0.60	343	10%	1,285	4,606,947
2020	8,537	3.3	2,461	0.004	0.39	219	0%	0	0
2021	4,246	1.1	575	0.002	0.09	51	0%	0	0

Table A-26. NOx and GHG Emissions for Tailpipe Scenario 4 in Calendar Year 2020
Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

	Federal Low NOx DSL			CA Cert. Low NOx DSL			Low NOx NG		
Model Year	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)
1976	0%	0	0	0%	0	0	0%	0	0
1977	0%	0	0	0%	0	0	0%	0	0
1978	0%	0	0	0%	0	0	0%	0	0
1979	0%	0	0	0%	0	0	0%	0	0
1980	0%	0	0	0%	0	0	0%	0	0
1981	0%	0	0	0%	0	0	0%	0	0
1982	0%	0	0	0%	0	0	0%	0	0
1983	0%	0	0	0%	0	0	0%	0	0
1984	0%	0	0	0%	0	0	0%	0	0
1985	0%	0	0	0%	0	0	0%	0	0
1986	0%	0	0	0%	0	0	0%	0	0
1987	0%	0	0	0%	0	0	0%	0	0
1988	0%	0	0	0%	0	0	0%	0	0
1989	0%	0	0	0%	0	0	0%	0	0
1990	0%	0	0	0%	0	0	0%	0	0
1991	0%	0	0	0%	0	0	0%	0	0
1992	0%	0	0	0%	0	0	0%	0	0
1993	0%	0	0	0%	0	0	0%	0	0
1994	0%	0	0	0%	0	0	0%	0	0
1995	0%	0	0	0%	0	0	0%	0	0
1996	0%	0	0	0%	0	0	0%	0	0
1997	0%	0	0	0%	0	0	0%	0	0
1998	0%	0	0	0%	0	0	0%	0	0
1999	0%	0	0	0%	0	0	0%	0	0
2000	0%	0	0	0%	0	0	0%	0	0
2001	0%	0	0	0%	0	0	0%	0	0
2002	0%	0	0	0%	0	0	0%	0	0
2003	0%	0	0	0%	0	0	0%	0	0
2004	0%	0	0	0%	0	0	0%	0	0
2005	0%	0	0	0%	0	0	0%	0	0
2006	0%	0	0	0%	0	0	0%	0	0
2007	0%	0	0	0%	0	0	0%	0	0
2008	0%	0	0	0%	0	0	0%	0	0
2009	0%	0	0	0%	0	0	0%	0	0
2010	0%	0	0	0%	0	0	0%	0	0
2011	0%	0	0	0%	0	0	0%	0	0
2012	0%	0	0	0%	0	0	0%	0	0
2013	0%	0	0	0%	0	0	0%	0	0
2014	0%	0	0	0%	0	0	0%	0	0
2015	0%	0	0	0%	0	0	0%	0	0
2016	0%	0	0	0%	0	0	0%	0	0
2017	0%	0	0	0%	0	0	0%	0	0
2018	0%	0	0	0%	0	0	75%	9,516	37,149,354
2019	0%	0	0	0%	0	0	90%	11,566	46,069,473
2020	0%	0	0	0%	0	0	100%	8,537	32,774,330
2021	0%	0	0	0%	0	0	100%	4,246	7,657,733

Table A-26. NOx and GHG Emissions for Tailpipe Scenario 4 in Calendar Year 2020

Model Year	BEV			Tailpipe Emission Estimates[5] (tons/day)			
	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	NO_X	CO_2	CH_4	N_2O
1976	0%	0	0	0.02	1.7	0.000	0.000
1977	0%	0	0	0.02	2.3	0.000	0.000
1978	0%	0	0	0.04	3.9	0.000	0.001
1979	0%	0	0	0.05	5.0	0.000	0.001
1980	0%	0	0	0.05	5.1	0.000	0.001
1981	0%	0	0	0.15	15	0.000	0.002
1982	0%	0	0	0.13	13	0.000	0.002
1983	0%	0	0	0.13	13	0.000	0.002
1984	0%	0	0	0.18	18	0.000	0.003
1985	0%	0	0	0.25	25	0.000	0.004
1986	0%	0	0	0.25	25	0.000	0.004
1987	0%	0	0	0.29	27	0.000	0.004
1988	0%	0	0	0.34	32	0.000	0.005
1989	0%	0	0	0.40	38	0.000	0.006
1990	0%	0	0	0.39	37	0.000	0.006
1991	0%	0	0	0.34	28	0.000	0.004
1992	0%	0	0	0.31	25	0.000	0.004
1993	0%	0	0	0.29	25	0.000	0.004
1994	0%	0	0	0.31	28	0.000	0.004
1995	0%	0	0	0.41	37	0.000	0.006
1996	0%	0	0	1.8	150	0.006	0.02
1997	0%	0	0	1.8	149	0.006	0.02
1998	0%	0	0	2.2	192	0.008	0.03
1999	0%	0	0	4.1	291	0.01	0.05
2000	0%	0	0	9.0	641	0.02	0.10
2001	0%	0	0	6.6	476	0.02	0.07
2002	0%	0	0	4.6	338	0.01	0.05
2003	0%	0	0	3.5	425	0.01	0.07
2004	0%	0	0	3.0	421	0.01	0.07
2005	0%	0	0	5.1	719	0.02	0.11
2006	0%	0	0	6.9	972	0.03	0.15
2007	0%	0	0	9.5	1,454	0.03	0.23
2008	0%	0	0	13	2,417	0.02	0.38
2009	0%	0	0	16	3,080	0.03	0.48
2010	0%	0	0	13	2,653	0.02	0.42
2011	0%	0	0	10	3,166	0.01	0.50
2012	0%	0	0	19	6,724	0.01	1.1
2013	0%	0	0	14	5,397	0.010	0.85
2014	0%	0	0	12	5,525	0.01	0.87
2015	0%	0	0	14	7,779	0.02	1.2
2016	0%	0	0	22	12,488	0.02	2.0
2017	0%	0	0	6.6	3,944	0.008	0.62
2018	0%	0	0	1.9	3,720	0.007	0.58
2019	0%	0	0	1.1	3,844	0.007	0.60
2020	0%	0	0	0.33	2,461	0.004	0.39
2021	0%	0	0	0.11	575	0.002	0.09

Notes:

[1] EMFAC data shown here are adjusted by subtracting data for T7 SWCVs from corresponding data for all HHDTs as described in Appendix A. Accelerated turnover adjustments are included in calendar years 2031, 2037, 2045, and 2050 as described in Appendix A.

[2] Fleet mix percentages for each alternative HHDT technology type are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[3] Population in each model year is calculated based on the fleet mix percentages for each HHDT type and the total population in the adjusted EMFAC data.

[4] Energy consumption is calculated based on adjusted EMFAC data, using the EER for each HHDT type shown in Table A-38.

[5] Emissions from vehicles in each model year are calculated based on the fleet mix composition and the reduction in tailpipe NOx emissions achieved by each HHDT type shown in Table 3-2. Total emissions in each calendar year are calculated as the sum of tailpipe emissions across all HHDT types and all model years in each calendar year.

[6] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CA Cert. - California certified
CH_4 - methane
CO_2 - carbon dioxide
DSL - diesel
EER - energy economy ratio
EMFAC2017 - Emission Factor Model
gal - gallon
HHDT - heavy heavy duty truck
MJ - megajoule
N_2O - nitrous oxide
NG - natural gas
NO_x - oxides of nitrogen
T7 SWCV - solid waste collection vehicles
TOTEX - total exhaust

Table A-27. NOx and GHG Tailpipe Emissions for Scenario 4 in Calendar Year 2023

	Adjusted EMFAC2017 Output[1]						Conventional DSL		
Model Year	Population	NOx_TOTEX (tons/day)	CO2_TOTEX (tons/day)	CH4_TOTEX (tons/day)	N2O_TOTEX (tons/day)	Fuel Consumption (1000 gal/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)
1979	53	0.03	2.9	0.000	0.000	0.26	100%	53	35,019
1980	64	0.04	3.7	0.000	0.001	0.33	100%	64	44,086
1981	209	0.12	12	0.000	0.002	1.1	100%	209	142,790
1982	208	0.11	11	0.000	0.002	1.0	100%	208	134,214
1983	196	0.11	11	0.000	0.002	1.0	100%	196	131,088
1984	241	0.15	15	0.000	0.002	1.3	100%	241	176,822
1985	357	0.21	21	0.000	0.003	1.9	100%	357	252,082
1986	331	0.20	20	0.000	0.003	1.8	100%	331	243,579
1987	345	0.22	21	0.000	0.003	1.9	100%	345	253,082
1988	370	0.26	24	0.000	0.004	2.2	100%	370	290,997
1989	420	0.29	28	0.000	0.004	2.5	100%	420	332,355
1990	382	0.28	27	0.000	0.004	2.4	100%	382	319,401
1991	331	0.24	20	0.000	0.003	1.8	100%	331	238,471
1992	279	0.22	18	0.000	0.003	1.6	100%	279	214,037
1993	235	0.20	17	0.000	0.003	1.5	100%	235	202,566
1994	257	0.21	19	0.000	0.003	1.7	100%	257	228,163
1995	341	0.29	26	0.000	0.004	2.3	100%	341	308,497
1996	354	0.29	26	0.000	0.004	2.3	100%	354	309,827
1997	358	0.27	24	0.000	0.004	2.2	100%	358	292,799
1998	350	0.29	27	0.000	0.004	2.4	100%	350	324,850
1999	484	0.48	38	0.000	0.006	3.4	100%	484	458,610
2000	570	0.55	44	0.000	0.007	3.9	100%	570	522,449
2001	630	0.52	42	0.000	0.007	3.7	100%	630	502,288
2002	683	0.50	41	0.000	0.006	3.7	100%	683	490,906
2003	607	0.31	41	0.000	0.006	3.7	100%	607	491,836
2004	588	0.27	39	0.000	0.006	3.4	100%	588	462,594
2005	722	0.33	48	0.000	0.008	4.3	100%	722	579,188
2006	789	0.37	53	0.000	0.008	4.7	100%	789	635,640
2007	1,010	0.43	69	0.000	0.01	6.1	100%	1,010	822,391
2008	958	0.24	51	0.000	0.008	4.5	100%	958	608,971
2009	1,054	0.24	57	0.000	0.009	5.1	100%	1,054	681,595
2010	516	0.11	28	0.000	0.004	2.5	100%	516	336,250
2011	601	0.08	32	0.000	0.005	2.8	100%	601	381,333
2012	36,456	15	5,160	0.010	0.81	460	100%	36,456	61,840,416
2013	23,385	13	4,715	0.009	0.74	420	100%	23,385	56,503,770
2014	25,954	12	4,907	0.01	0.77	437	100%	25,954	58,805,403
2015	43,313	18	8,476	0.02	1.3	755	100%	43,313	101,582,009
2016	51,092	25	12,180	0.03	1.9	1,086	100%	51,092	145,975,230
2017	45,093	20	10,301	0.02	1.6	918	100%	45,093	123,455,483
2018	15,699	7.6	3,880	0.008	0.61	346	25%	3,925	11,623,571
2019	15,755	7.5	4,119	0.008	0.65	367	10%	1,575	4,936,412
2020	14,758	7.0	4,076	0.008	0.64	363	0%	0	0
2021	13,866	6.3	3,442	0.008	0.54	307	0%	0	0
2022	13,999	6.1	3,590	0.008	0.56	320	0%	0	0
2023	9,671	3.7	2,395	0.005	0.38	213	0%	0	0
2024	4,843	1.3	599	0.003	0.09	53	0%	0	0

Table A-27. NOx and GHG Tailpipe Emissions for Scenario 4 in Calendar Year 2023

	Federal Low NOx DSL			CA Cert. Low NOx DSL			Low NOx NG		
Model Year	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)
1979	0%	0	0	0%	0	0	0%	0	0
1980	0%	0	0	0%	0	0	0%	0	0
1981	0%	0	0	0%	0	0	0%	0	0
1982	0%	0	0	0%	0	0	0%	0	0
1983	0%	0	0	0%	0	0	0%	0	0
1984	0%	0	0	0%	0	0	0%	0	0
1985	0%	0	0	0%	0	0	0%	0	0
1986	0%	0	0	0%	0	0	0%	0	0
1987	0%	0	0	0%	0	0	0%	0	0
1988	0%	0	0	0%	0	0	0%	0	0
1989	0%	0	0	0%	0	0	0%	0	0
1990	0%	0	0	0%	0	0	0%	0	0
1991	0%	0	0	0%	0	0	0%	0	0
1992	0%	0	0	0%	0	0	0%	0	0
1993	0%	0	0	0%	0	0	0%	0	0
1994	0%	0	0	0%	0	0	0%	0	0
1995	0%	0	0	0%	0	0	0%	0	0
1996	0%	0	0	0%	0	0	0%	0	0
1997	0%	0	0	0%	0	0	0%	0	0
1998	0%	0	0	0%	0	0	0%	0	0
1999	0%	0	0	0%	0	0	0%	0	0
2000	0%	0	0	0%	0	0	0%	0	0
2001	0%	0	0	0%	0	0	0%	0	0
2002	0%	0	0	0%	0	0	0%	0	0
2003	0%	0	0	0%	0	0	0%	0	0
2004	0%	0	0	0%	0	0	0%	0	0
2005	0%	0	0	0%	0	0	0%	0	0
2006	0%	0	0	0%	0	0	0%	0	0
2007	0%	0	0	0%	0	0	0%	0	0
2008	0%	0	0	0%	0	0	0%	0	0
2009	0%	0	0	0%	0	0	0%	0	0
2010	0%	0	0	0%	0	0	0%	0	0
2011	0%	0	0	0%	0	0	0%	0	0
2012	0%	0	0	0%	0	0	0%	0	0
2013	0%	0	0	0%	0	0	0%	0	0
2014	0%	0	0	0%	0	0	0%	0	0
2015	0%	0	0	0%	0	0	0%	0	0
2016	0%	0	0	0%	0	0	0%	0	0
2017	0%	0	0	0%	0	0	0%	0	0
2018	0%	0	0	0%	0	0	75%	11,774	38,745,237
2019	0%	0	0	0%	0	0	90%	14,179	49,364,115
2020	0%	0	0	0%	0	0	100%	14,758	54,279,085
2021	0%	0	0	0%	0	0	100%	13,866	45,834,381
2022	0%	0	0	0%	0	0	100%	13,999	47,808,041
2023	0%	0	0	0%	0	0	100%	9,671	31,896,751
2024	10%	484	717,286	0%	0	0	86%	4,141	6,814,220

Table A-27. NOx and GHG Tailpipe Emissions for Scenario 4 in Calendar Year 2023

Model Year	BEV			Tailpipe Emission Estimates[5] (tons/day)			
	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	NO_x	CO_2	CH_4	N_2O
1979	0%	0	0	0.03	2.9	0.000	0.000
1980	0%	0	0	0.04	3.7	0.000	0.001
1981	0%	0	0	0.12	12	0.000	0.002
1982	0%	0	0	0.11	11	0.000	0.002
1983	0%	0	0	0.11	11	0.000	0.002
1984	0%	0	0	0.15	15	0.000	0.002
1985	0%	0	0	0.21	21	0.000	0.003
1986	0%	0	0	0.20	20	0.000	0.003
1987	0%	0	0	0.22	21	0.000	0.003
1988	0%	0	0	0.26	24	0.000	0.004
1989	0%	0	0	0.29	28	0.000	0.004
1990	0%	0	0	0.28	27	0.000	0.004
1991	0%	0	0	0.24	20	0.000	0.003
1992	0%	0	0	0.22	18	0.000	0.003
1993	0%	0	0	0.20	17	0.000	0.003
1994	0%	0	0	0.21	19	0.000	0.003
1995	0%	0	0	0.29	26	0.000	0.004
1996	0%	0	0	0.29	26	0.000	0.004
1997	0%	0	0	0.27	24	0.000	0.004
1998	0%	0	0	0.29	27	0.000	0.004
1999	0%	0	0	0.48	38	0.000	0.006
2000	0%	0	0	0.55	44	0.000	0.007
2001	0%	0	0	0.52	42	0.000	0.007
2002	0%	0	0	0.50	41	0.000	0.006
2003	0%	0	0	0.31	41	0.000	0.006
2004	0%	0	0	0.27	39	0.000	0.006
2005	0%	0	0	0.33	48	0.000	0.008
2006	0%	0	0	0.37	53	0.000	0.008
2007	0%	0	0	0.43	69	0.000	0.01
2008	0%	0	0	0.24	51	0.000	0.008
2009	0%	0	0	0.24	57	0.000	0.009
2010	0%	0	0	0.11	28	0.000	0.004
2011	0%	0	0	0.08	32	0.000	0.005
2012	0%	0	0	15	5,160	0.010	0.81
2013	0%	0	0	13	4,715	0.009	0.74
2014	0%	0	0	12	4,907	0.01	0.77
2015	0%	0	0	18	8,476	0.02	1.3
2016	0%	0	0	25	12,180	0.03	1.9
2017	0%	0	0	20	10,301	0.02	1.6
2018	0%	0	0	2.5	3,880	0.008	0.61
2019	0%	0	0	1.4	4,119	0.008	0.65
2020	0%	0	0	0.70	4,076	0.008	0.64
2021	0%	0	0	0.63	3,442	0.008	0.54
2022	0%	0	0	0.61	3,590	0.008	0.56
2023	0%	0	0	0.37	2,395	0.005	0.38
2024	5%	218	106,580	0.14	572	0.002	0.09

Notes:

[1] EMFAC data shown here are adjusted by subtracting data for T7 SWCVs from corresponding data for all HHDTs as described in Appendix A. Accelerated turnover adjustments are included in calendar years 2031, 2037, 2045, and 2050 as described in Appendix A.

[2] Fleet mix percentages for each alternative HHDT technology type are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[3] Population in each model year is calculated based on the fleet mix percentages for each HHDT type and the total population in the adjusted EMFAC data.

[4] Energy consumption is calculated based on adjusted EMFAC data, using the EER for each HHDT type shown in Table A-38.

[5] Emissions from vehicles in each model year are calculated based on the fleet mix composition and the reduction in tailpipe NOx emissions achieved by each HHDT type shown in Table 3-2. Total emissions in each calendar year are calculated as the sum of tailpipe emissions across all HHDT types and all model years in each calendar year.

[6] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CA Cert. - California certified
CH_4 - methane
CO_2 - carbon dioxide
DSL - diesel
EER - energy economy ratio
EMFAC2017 - Emission Factor Model
gal - gallon
HHDT - heavy heavy duty truck
MJ - megajoule
N_2O - nitrous oxide
NG - natural gas
NO_x - oxides of nitrogen
T7 SWCV - solid waste collection vehicles
TOTEX - total exhaust

Table A-28. NOx and GHG Tailpipe Emissions for Scenario 4 in Calendar Year 2031

	Adjusted EMFAC2017 Output[1]						Conventional DSL		
Model Year	**Population**	**NOx_TOTEX (tons/day)**	**CO2_TOTEX (tons/day)**	**CH4_TOTEX (tons/day)**	**N2O_TOTEX (tons/day)**	**Fuel Consumption (1000 gal/day)**	**Fleet Mix[2] (%)**	**Population[3]**	**Energy Consumption[4] (MJ/day)**
1987	166	0.09	8.9	0.000	0.001	0.79	100%	166	106,532
1988	223	0.13	12	0.000	0.002	1.1	100%	223	144,024
1989	279	0.16	15	0.000	0.002	1.3	100%	279	179,202
1990	256	0.15	14	0.000	0.002	1.3	100%	256	168,297
1991	221	0.14	11	0.000	0.002	1.0	100%	221	134,880
1992	173	0.11	9.2	0.000	0.001	0.82	100%	173	110,429
1993	132	0.09	7.5	0.000	0.001	0.67	100%	132	90,308
1994	131	0.08	7.6	0.000	0.001	0.68	100%	131	91,104
1995	161	0.11	10	0.000	0.002	0.87	100%	161	116,335
1996	159	0.11	10	0.000	0.002	0.85	100%	159	114,485
1997	155	0.10	9.1	0.000	0.001	0.81	100%	155	108,509
1998	145	0.10	10	0.000	0.001	0.85	100%	145	114,337
1999	197	0.17	13	0.000	0.002	1.2	100%	197	160,607
2000	233	0.20	16	0.000	0.002	1.4	100%	233	188,016
2001	267	0.20	16	0.000	0.003	1.4	100%	267	193,494
2002	300	0.21	17	0.000	0.003	1.5	100%	300	200,551
2003	272	0.13	17	0.000	0.003	1.5	100%	272	200,037
2004	276	0.12	17	0.000	0.003	1.5	100%	276	198,929
2005	353	0.15	22	0.000	0.003	1.9	100%	353	259,740
2006	403	0.18	25	0.000	0.004	2.3	100%	403	303,073
2007	543	0.22	35	0.000	0.006	3.1	100%	543	422,431
2008	564	0.14	29	0.000	0.005	2.6	100%	564	352,228
2009	654	0.15	34	0.000	0.005	3.1	100%	654	410,832
2010	337	0.07	18	0.000	0.003	1.6	100%	337	211,381
2011	419	0.05	21	0.000	0.003	1.9	100%	419	253,413
2012	18,775	6.3	2,125	0.004	0.33	189	100%	18,775	25,469,698
2013	10,866	5.2	1,931	0.003	0.30	172	100%	10,866	23,141,590
2014	12,373	4.9	1,993	0.004	0.31	178	100%	12,373	23,884,682
2015	22,601	8.0	3,471	0.007	0.55	309	100%	22,601	41,601,211
2016	25,559	9.1	3,866	0.010	0.61	345	100%	25,559	46,327,589
2017	29,560	9.2	4,023	0.009	0.63	359	100%	29,560	48,215,934
2018	10,153	3.8	1,588	0.004	0.25	142	25%	2,538	4,757,647
2019	11,512	4.5	1,861	0.004	0.29	166	10%	1,151	2,230,561
2020	13,043	5.4	2,255	0.005	0.35	201	0%	0	0
2021	14,295	6.2	2,272	0.006	0.36	203	0%	0	0
2022	16,417	7.5	2,835	0.007	0.45	253	0%	0	0
2023	22,059	12	4,261	0.010	0.67	380	0%	0	0
2024	21,715	11	3,988	0.01	0.63	355	0%	0	0
2025	22,619	12	4,524	0.01	0.71	403	0%	0	0
2026	22,104	12	4,758	0.01	0.75	424	0%	0	0
2027	21,594	11	4,671	0.01	0.73	416	0%	0	0
2028	19,744	10	4,452	0.01	0.70	397	0%	0	0
2029	18,560	9.0	4,281	0.01	0.67	382	0%	0	0
2030	17,915	8.2	4,205	0.01	0.66	375	0%	0	0
2031	11,497	4.6	2,590	0.006	0.41	231	0%	0	0
2032	5,864	1.6	694	0.003	0.11	62	0%	0	0

Table A-28. NOx and GHG Tailpipe Emissions for Scenario 4 in Calendar Year 2031

Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

	Federal Low NOx DSL			**CA Cert. Low NOx DSL**			**Low NOx NG**		
Model Year	**Fleet Mix[2] (%)**	**Population[3]**	**Energy Consumption[4] (MJ/day)**	**Fleet Mix[2] (%)**	**Population[3]**	**Energy Consumption[4] (MJ/day)**	**Fleet Mix[2] (%)**	**Population[3]**	**Energy Consumption[4] (MJ/day)**
1987	0%	0	0	0%	0	0	0%	0	0
1988	0%	0	0	0%	0	0	0%	0	0
1989	0%	0	0	0%	0	0	0%	0	0
1990	0%	0	0	0%	0	0	0%	0	0
1991	0%	0	0	0%	0	0	0%	0	0
1992	0%	0	0	0%	0	0	0%	0	0
1993	0%	0	0	0%	0	0	0%	0	0
1994	0%	0	0	0%	0	0	0%	0	0
1995	0%	0	0	0%	0	0	0%	0	0
1996	0%	0	0	0%	0	0	0%	0	0
1997	0%	0	0	0%	0	0	0%	0	0
1998	0%	0	0	0%	0	0	0%	0	0
1999	0%	0	0	0%	0	0	0%	0	0
2000	0%	0	0	0%	0	0	0%	0	0
2001	0%	0	0	0%	0	0	0%	0	0
2002	0%	0	0	0%	0	0	0%	0	0
2003	0%	0	0	0%	0	0	0%	0	0
2004	0%	0	0	0%	0	0	0%	0	0
2005	0%	0	0	0%	0	0	0%	0	0
2006	0%	0	0	0%	0	0	0%	0	0
2007	0%	0	0	0%	0	0	0%	0	0
2008	0%	0	0	0%	0	0	0%	0	0
2009	0%	0	0	0%	0	0	0%	0	0
2010	0%	0	0	0%	0	0	0%	0	0
2011	0%	0	0	0%	0	0	0%	0	0
2012	0%	0	0	0%	0	0	0%	0	0
2013	0%	0	0	0%	0	0	0%	0	0
2014	0%	0	0	0%	0	0	0%	0	0
2015	0%	0	0	0%	0	0	0%	0	0
2016	0%	0	0	0%	0	0	0%	0	0
2017	0%	0	0	0%	0	0	0%	0	0
2018	0%	0	0	0%	0	0	75%	7,615	15,858,823
2019	0%	0	0	0%	0	0	90%	10,361	22,305,607
2020	0%	0	0	0%	0	0	100%	13,043	30,028,717
2021	0%	0	0	0%	0	0	100%	14,295	30,257,688
2022	0%	0	0	0%	0	0	100%	16,417	37,755,372
2023	0%	0	0	0%	0	0	100%	22,059	56,737,149
2024	10%	2,171	4,779,835	0%	0	0	86%	18,566	45,408,434
2025	10%	2,262	5,421,301	0%	0	0	84%	18,932	50,418,096
2026	10%	2,210	5,702,550	0%	0	0	81%	17,904	51,322,947
2027	15%	3,239	8,396,467	0%	0	0	72%	15,602	44,936,647
2028	15%	2,962	8,002,355	0%	0	0	68%	13,426	40,308,160
2029	20%	3,712	10,260,841	0%	0	0	60%	11,136	34,202,804
2030	20%	3,583	10,079,515	0%	0	0	56%	10,032	31,358,493
2031	20%	2,299	6,209,013	0%	0	0	52%	5,979	17,937,150
2032	10%	586	831,861	0%	0	0	54%	3,166	4,991,164

Table A-28. NOx and GHG Tailpipe Emissions for Scenario 4 in Calendar Year 2031

Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Model Year	BEV Fleet Mix[2] (%)	BEV Population[3]	BEV Energy Consumption[4] (MJ/day)	Tailpipe Emission Estimates[5] (tons/day) NO_X	CO_2	CH_4	N_2O
1987	0%	0	0	0.09	8.9	0.000	0.001
1988	0%	0	0	0.13	12	0.000	0.002
1989	0%	0	0	0.16	15	0.000	0.002
1990	0%	0	0	0.15	14	0.000	0.002
1991	0%	0	0	0.14	11	0.000	0.002
1992	0%	0	0	0.11	9.2	0.000	0.001
1993	0%	0	0	0.09	7.5	0.000	0.001
1994	0%	0	0	0.08	7.6	0.000	0.001
1995	0%	0	0	0.11	10	0.000	0.002
1996	0%	0	0	0.11	10	0.000	0.002
1997	0%	0	0	0.10	9.1	0.000	0.001
1998	0%	0	0	0.10	10	0.000	0.001
1999	0%	0	0	0.17	13	0.000	0.002
2000	0%	0	0	0.20	16	0.000	0.002
2001	0%	0	0	0.20	16	0.000	0.003
2002	0%	0	0	0.21	17	0.000	0.003
2003	0%	0	0	0.13	17	0.000	0.003
2004	0%	0	0	0.12	17	0.000	0.003
2005	0%	0	0	0.15	22	0.000	0.003
2006	0%	0	0	0.18	25	0.000	0.004
2007	0%	0	0	0.22	35	0.000	0.006
2008	0%	0	0	0.14	29	0.000	0.005
2009	0%	0	0	0.15	34	0.000	0.005
2010	0%	0	0	0.07	18	0.000	0.003
2011	0%	0	0	0.05	21	0.000	0.003
2012	0%	0	0	6.3	2,125	0.004	0.33
2013	0%	0	0	5.2	1,931	0.003	0.30
2014	0%	0	0	4.9	1,993	0.004	0.31
2015	0%	0	0	8.0	3,471	0.007	0.55
2016	0%	0	0	9.1	3,866	0.010	0.61
2017	0%	0	0	9.2	4,023	0.009	0.63
2018	0%	0	0	1.2	1,588	0.004	0.25
2019	0%	0	0	0.85	1,861	0.004	0.29
2020	0%	0	0	0.54	2,255	0.005	0.35
2021	0%	0	0	0.62	2,272	0.006	0.36
2022	0%	0	0	0.75	2,835	0.007	0.45
2023	0%	0	0	1.2	4,261	0.010	0.67
2024	5%	977	710,226	1.2	3,809	0.01	0.60
2025	6%	1,425	1,127,756	1.3	4,239	0.01	0.67
2026	9%	1,989	1,694,660	1.2	4,330	0.01	0.68
2027	13%	2,753	2,356,604	1.2	4,075	0.01	0.64
2028	17%	3,357	2,994,653	1.1	3,695	0.009	0.58
2029	20%	3,712	3,388,083	1.0	3,425	0.009	0.54
2030	24%	4,300	3,993,852	0.87	3,196	0.008	0.50
2031	28%	3,219	2,870,263	0.47	1,865	0.004	0.29
2032	36%	2,111	988,836	0.12	444	0.002	0.07

Notes:

[1] EMFAC data shown here are adjusted by subtracting data for T7 SWCVs from corresponding data for all HHDTs as described in Appendix A. Accelerated turnover adjustments are included in calendar years 2031, 2037, 2045, and 2050 as described in Appendix A.

[2] Fleet mix percentages for each alternative HHDT technology type are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[3] Population in each model year is calculated based on the fleet mix percentages for each HHDT type and the total population in the adjusted EMFAC data.

[4] Energy consumption is calculated based on adjusted EMFAC data, using the EER for each HHDT type shown in Table A-38.

[5] Emissions from vehicles in each model year are calculated based on the fleet mix composition and the reduction in tailpipe NOx emissions achieved by each HHDT type shown in Table 3-2. Total emissions in each calendar year are calculated as the sum of tailpipe emissions across all HHDT types and all model years in each calendar year.

[6] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CA Cert. - California certified
CH_4 - methane
CO_2 - carbon dioxide
DSL - diesel
EER - energy economy ratio
EMFAC2017 - Emission Factor Model
gal - gallon
HHDT - heavy heavy duty truck
MJ - megajoule
N_2O - nitrous oxide
NG - natural gas
NO_x - oxides of nitrogen
T7 SWCV - solid waste collection vehicles
TOTEX - total exhaust

Table A-29. NOx and GHG Emissions Tailpipe for Scenario 4 in Calendar Year 2037

	Adjusted EMFAC2017 Output[1]						Conventional DSL		
Model Year	**Population**	**NOx_TOTEX (tons/day)**	**CO2_TOTEX (tons/day)**	**CH4_TOTEX (tons/day)**	**N2O_TOTEX (tons/day)**	**Fuel Consumption (1000 gal/day)**	**Fleet Mix[2] (%)**	**Population[3]**	**Energy Consumption[4] (MJ/day)**
1993	66	0.04	3.5	0.000	0.001	0.31	100%	66	42,043
1994	83	0.05	4.2	0.000	0.001	0.38	100%	83	50,721
1995	115	0.07	5.9	0.000	0.001	0.53	100%	115	70,970
1996	119	0.07	6.1	0.000	0.001	0.54	100%	119	72,842
1997	117	0.06	5.9	0.000	0.001	0.52	100%	117	70,488
1998	104	0.06	5.7	0.000	0.001	0.50	100%	104	67,898
1999	133	0.10	7.6	0.000	0.001	0.67	100%	133	90,610
2000	147	0.11	8.5	0.000	0.001	0.76	100%	147	101,850
2001	161	0.11	8.8	0.000	0.001	0.79	100%	161	105,603
2002	172	0.11	9.0	0.000	0.001	0.80	100%	172	107,968
2003	146	0.06	8.3	0.000	0.001	0.74	100%	146	99,226
2004	143	0.06	8.1	0.000	0.001	0.72	100%	143	96,731
2005	178	0.07	10	0.000	0.002	0.92	100%	178	123,640
2006	202	0.09	12	0.000	0.002	1.1	100%	202	143,033
2007	272	0.11	17	0.000	0.003	1.5	100%	272	200,277
2008	292	0.07	15	0.000	0.002	1.3	100%	292	179,211
2009	346	0.08	18	0.000	0.003	1.6	100%	346	213,122
2010	183	0.04	9.3	0.000	0.001	0.83	100%	183	111,727
2011	234	0.03	11	0.000	0.002	1.0	100%	234	136,809
2012	7,969	2.4	804	0.002	0.13	72	100%	7,969	9,641,296
2013	4,340	2.0	750	0.001	0.12	67	100%	4,340	8,984,556
2014	4,954	2.0	817	0.001	0.13	73	100%	4,954	9,795,650
2015	9,674	3.7	1,601	0.003	0.25	143	100%	9,674	19,190,427
2016	10,519	3.7	1,604	0.004	0.25	143	100%	10,519	19,227,562
2017	14,184	3.9	1,723	0.004	0.27	154	100%	14,184	20,654,585
2018	4,924	1.7	692	0.002	0.11	62	25%	1,231	2,072,516
2019	5,803	1.9	807	0.002	0.13	72	10%	580	966,789
2020	6,713	2.3	945	0.002	0.15	84	0%	0	0
2021	7,708	2.6	942	0.003	0.15	84	0%	0	0
2022	9,361	3.4	1,197	0.003	0.19	107	0%	0	0
2023	12,311	5.2	1,799	0.004	0.28	160	0%	0	0
2024	14,157	5.5	1,804	0.005	0.28	161	0%	0	0
2025	15,781	6.4	2,112	0.006	0.33	188	0%	0	0
2026	17,659	7.5	2,484	0.007	0.39	221	0%	0	0
2027	19,532	8.7	2,768	0.008	0.44	247	0%	0	0
2028	21,365	10	3,236	0.010	0.51	288	0%	0	0
2029	22,985	11	3,748	0.01	0.59	334	0%	0	0
2030	24,081	12	4,213	0.01	0.66	375	0%	0	0
2037	24,791	13	4,671	0.01	0.73	416	0%	0	0
2032	24,114	13	4,857	0.01	0.76	433	0%	0	0
2033	23,670	12	5,060	0.01	0.80	451	0%	0	0
2034	21,948	11	4,883	0.01	0.77	435	0%	0	0
2035	20,791	10	4,742	0.01	0.75	423	0%	0	0
2036	19,699	9.0	4,573	0.01	0.72	408	0%	0	0
2037	12,409	5.0	2,773	0.007	0.44	247	0%	0	0
2038	6,391	1.7	743	0.003	0.12	66	0%	0	0

Table A-29. NOx and GHG Emissions Tailpipe for Scenario 4 in Calendar Year 2037

	Federal Low NOx DSL			CA Cert. Low NOx DSL			Low NOx NG		
Model Year	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)
1993	0%	0	0	0%	0	0	0%	0	0
1994	0%	0	0	0%	0	0	0%	0	0
1995	0%	0	0	0%	0	0	0%	0	0
1996	0%	0	0	0%	0	0	0%	0	0
1997	0%	0	0	0%	0	0	0%	0	0
1998	0%	0	0	0%	0	0	0%	0	0
1999	0%	0	0	0%	0	0	0%	0	0
2000	0%	0	0	0%	0	0	0%	0	0
2001	0%	0	0	0%	0	0	0%	0	0
2002	0%	0	0	0%	0	0	0%	0	0
2003	0%	0	0	0%	0	0	0%	0	0
2004	0%	0	0	0%	0	0	0%	0	0
2005	0%	0	0	0%	0	0	0%	0	0
2006	0%	0	0	0%	0	0	0%	0	0
2007	0%	0	0	0%	0	0	0%	0	0
2008	0%	0	0	0%	0	0	0%	0	0
2009	0%	0	0	0%	0	0	0%	0	0
2010	0%	0	0	0%	0	0	0%	0	0
2011	0%	0	0	0%	0	0	0%	0	0
2012	0%	0	0	0%	0	0	0%	0	0
2013	0%	0	0	0%	0	0	0%	0	0
2014	0%	0	0	0%	0	0	0%	0	0
2015	0%	0	0	0%	0	0	0%	0	0
2016	0%	0	0	0%	0	0	0%	0	0
2017	0%	0	0	0%	0	0	0%	0	0
2018	0%	0	0	0%	0	0	75%	3,693	6,908,385
2019	0%	0	0	0%	0	0	90%	5,223	9,667,889
2020	0%	0	0	0%	0	0	100%	6,713	12,588,312
2021	0%	0	0	0%	0	0	100%	7,708	12,539,967
2022	0%	0	0	0%	0	0	100%	9,361	15,938,038
2023	0%	0	0	0%	0	0	100%	12,311	23,952,598
2024	10%	1,416	2,161,542	0%	0	0	86%	12,104	20,534,650
2025	10%	1,578	2,531,043	0%	0	0	84%	13,209	23,538,696
2026	10%	1,766	2,977,192	0%	0	0	81%	14,304	26,794,732
2027	15%	2,930	4,975,264	0%	0	0	72%	14,112	26,626,876
2028	15%	3,205	5,817,346	0%	0	0	68%	14,528	29,302,186
2029	20%	4,597	8,983,030	0%	0	0	60%	13,791	29,943,433
2030	20%	4,816	10,097,767	0%	0	0	56%	13,485	31,415,274
2037	12%	2,975	6,717,948	0%	0	0	53%	13,090	32,843,299
2032	10%	2,411	5,821,019	0%	0	0	54%	13,022	34,926,115
2033	10%	2,367	6,063,891	0%	0	0	54%	12,782	36,383,345
2034	10%	2,195	5,851,702	0%	0	0	54%	11,852	35,110,212
2035	12%	2,495	6,819,958	0%	0	0	53%	10,978	33,342,015
2036	12%	2,364	6,576,732	0%	0	0	53%	10,401	32,152,911
2037	12%	1,489	3,988,015	0%	0	0	53%	6,552	19,496,964
2038	12%	767	1,068,563	0%	0	0	53%	3,375	5,224,086

Table A-29. NOx and GHG Emissions Tailpipe for Scenario 4 in Calendar Year 2037

Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

	BEV			**Tailpipe Emission Estimates[5] (tons/day)**			
Model Year	**Fleet Mix[2] (%)**	**Population[3]**	**Energy Consumption[4] (MJ/day)**	**NO_X**	**CO_2**	**CH_4**	**N_2O**
1993	0%	0	0	0.04	3.5	0.000	0.001
1994	0%	0	0	0.05	4.2	0.000	0.001
1995	0%	0	0	0.07	5.9	0.000	0.001
1996	0%	0	0	0.07	6.1	0.000	0.001
1997	0%	0	0	0.06	5.9	0.000	0.001
1998	0%	0	0	0.06	5.7	0.000	0.001
1999	0%	0	0	0.10	7.6	0.000	0.001
2000	0%	0	0	0.11	8.5	0.000	0.001
2001	0%	0	0	0.11	8.8	0.000	0.001
2002	0%	0	0	0.11	9.0	0.000	0.001
2003	0%	0	0	0.06	8.3	0.000	0.001
2004	0%	0	0	0.06	8.1	0.000	0.001
2005	0%	0	0	0.07	10	0.000	0.002
2006	0%	0	0	0.09	12	0.000	0.002
2007	0%	0	0	0.11	17	0.000	0.003
2008	0%	0	0	0.07	15	0.000	0.002
2009	0%	0	0	0.08	18	0.000	0.003
2010	0%	0	0	0.04	9.3	0.000	0.001
2011	0%	0	0	0.03	11	0.000	0.002
2012	0%	0	0	2.4	804	0.002	0.13
2013	0%	0	0	2.0	750	0.001	0.12
2014	0%	0	0	2.0	817	0.001	0.13
2015	0%	0	0	3.7	1,601	0.003	0.25
2016	0%	0	0	3.7	1,604	0.004	0.25
2017	0%	0	0	3.9	1,723	0.004	0.27
2018	0%	0	0	0.54	692	0.002	0.11
2019	0%	0	0	0.37	807	0.002	0.13
2020	0%	0	0	0.23	945	0.002	0.15
2021	0%	0	0	0.26	942	0.003	0.15
2022	0%	0	0	0.34	1,197	0.003	0.19
2023	0%	0	0	0.52	1,799	0.004	0.28
2024	5%	637	321,179	0.61	1,722	0.005	0.27
2025	6%	994	526,515	0.70	1,979	0.006	0.31
2026	9%	1,589	884,750	0.80	2,261	0.007	0.36
2027	13%	2,490	1,396,388	1.0	2,415	0.007	0.38
2028	17%	3,632	2,176,976	1.1	2,686	0.008	0.42
2029	20%	4,597	2,966,155	1.2	2,998	0.009	0.47
2030	24%	5,779	4,001,083	1.3	3,202	0.009	0.50
2037	35%	8,727	6,506,824	1.1	3,027	0.008	0.48
2032	36%	8,681	6,919,465	1.0	3,109	0.009	0.49
2033	36%	8,521	7,208,168	1.0	3,238	0.008	0.51
2034	36%	7,901	6,955,938	0.88	3,125	0.008	0.49
2035	35%	7,318	6,605,628	0.83	3,073	0.008	0.48
2036	35%	6,934	6,370,046	0.74	2,963	0.007	0.47
2037	35%	4,368	3,862,685	0.41	1,797	0.004	0.28
2038	35%	2,250	1,034,981	0.14	481	0.002	0.08

Notes:

[1] EMFAC data shown here are adjusted by subtracting data for T7 SWCVs from corresponding data for all HHDTs as described in Appendix A. Accelerated turnover adjustments are included in calendar years 2031, 2037, 2045, and 2050 as described in Appendix A.

[2] Fleet mix percentages for each alternative HHDT technology type are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[3] Population in each model year is calculated based on the fleet mix percentages for each HHDT type and the total population in the adjusted EMFAC data.

[4] Energy consumption is calculated based on adjusted EMFAC data, using the EER for each HHDT type shown in Table A-38.

[5] Emissions from vehicles in each model year are calculated based on the fleet mix composition and the reduction in tailpipe NOx emissions achieved by each HHDT type shown in Table 3-2. Total emissions in each calendar year are calculated as the sum of tailpipe emissions across all HHDT types and all model years in each calendar year.

[6] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle	EER - energy economy ratio	N_2O - nitrous oxide
CA Cert. - California certified	EMFAC2017 - Emission Factor Model	NG - natural gas
CH_4 - methane	gal - gallon	NO_x - oxides of nitrogen
CO_2 - carbon dioxide	HHDT - heavy heavy duty truck	T7 SWCV - solid waste collection vehicles
DSL - diesel	MJ - megajoule	TOTEX - total exhaust

Table A-30. NOx and GHG Tailpipe Emissions for Scenario 4 in Calendar Year 2045

Model Year	Adjusted EMFAC2017 Output[1]						Conventional DSL		
	Population	NOx_TOTEX (tons/day)	CO2_TOTEX (tons/day)	CH4_TOTEX (tons/day)	N2O_TOTEX (tons/day)	Fuel Consumption (1000 gal/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)
2001	0	0	0	0	0	0	0%	0	0
2002	0	0	0	0	0	0	0%	0	0
2003	0	0	0	0	0	0	0%	0	0
2004	0	0	0	0	0	0	0%	0	0
2005	0	0	0	0	0	0	0%	0	0
2006	0	0	0	0	0	0	0%	0	0
2007	0	0	0	0	0	0	0%	0	0
2008	0	0	0	0	0	0	0%	0	0
2009	0	0	0	0	0	0	0%	0	0
2010	0	0	0	0	0	0	0%	0	0
2011	0	0	0	0	0	0	0%	0	0
2012	0	0	0	0	0	0	0%	0	0
2013	0	0	0	0	0	0	0%	0	0
2014	0	0	0	0	0	0	0%	0	0
2015	0	0	0	0	0	0	0%	0	0
2016	0	0	0	0	0	0	0%	0	0
2017	0	0	0	0	0	0	0%	0	0
2018	0	0	0	0	0	0	0%	0	0
2019	0	0	0	0	0	0	0%	0	0
2020	0	0	0	0	0	0	0%	0	0
2021	0	0	0	0	0	0	0%	0	0
2022	0	0	0	0	0	0	0%	0	0
2023	0	0	0	0	0	0	0%	0	0
2024	5,738	1.9	631	0.002	0.10	56	0%	0	0
2025	6,682	2.2	740	0.002	0.12	66	0%	0	0
2026	7,830	2.6	869	0.002	0.14	77	0%	0	0
2027	8,960	3.0	954	0.003	0.15	85	0%	0	0
2028	10,297	3.5	1,096	0.003	0.17	98	0%	0	0
2029	11,921	4.1	1,276	0.004	0.20	114	0%	0	0
2030	13,807	4.8	1,488	0.005	0.23	133	0%	0	0
2045	15,655	5.9	1,819	0.006	0.29	162	0%	0	0
2032	17,813	7.1	2,196	0.007	0.35	196	0%	0	0
2033	20,003	8.3	2,581	0.008	0.41	230	0%	0	0
2034	22,623	10	3,067	0.009	0.48	273	0%	0	0
2035	24,976	11	3,584	0.01	0.56	319	0%	0	0
2036	26,967	13	4,118	0.01	0.65	367	0%	0	0
2037	28,599	14	4,677	0.01	0.74	417	0%	0	0
2038	29,556	15	5,172	0.01	0.81	461	0%	0	0
2039	30,085	16	5,646	0.02	0.89	503	0%	0	0
2040	28,520	15	5,685	0.02	0.89	507	0%	0	0
2041	27,485	14	5,816	0.02	0.91	518	0%	0	0
2042	24,780	12	5,446	0.01	0.86	485	0%	0	0
2043	23,286	11	5,243	0.01	0.82	467	0%	0	0
2044	22,012	10	5,025	0.01	0.79	448	0%	0	0
2045	13,831	5.5	3,030	0.007	0.48	270	0%	0	0
2046	7,111	1.9	812	0.004	0.13	72	0%	0	0

Table A-30. NOx and GHG Tailpipe Emissions for Scenario 4 in Calendar Year 2045

Model Year	Federal Low NOx DSL			CA Cert. Low NOx DSL			Low NOx NG		
	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)
2001	0%	0	0	0%	0	0	0%	0	0
2002	0%	0	0	0%	0	0	0%	0	0
2003	0%	0	0	0%	0	0	0%	0	0
2004	0%	0	0	0%	0	0	0%	0	0
2005	0%	0	0	0%	0	0	0%	0	0
2006	0%	0	0	0%	0	0	0%	0	0
2007	0%	0	0	0%	0	0	0%	0	0
2008	0%	0	0	0%	0	0	0%	0	0
2009	0%	0	0	0%	0	0	0%	0	0
2010	0%	0	0	0%	0	0	0%	0	0
2011	0%	0	0	0%	0	0	0%	0	0
2012	0%	0	0	0%	0	0	0%	0	0
2013	0%	0	0	0%	0	0	0%	0	0
2014	0%	0	0	0%	0	0	0%	0	0
2015	0%	0	0	0%	0	0	0%	0	0
2016	0%	0	0	0%	0	0	0%	0	0
2017	0%	0	0	0%	0	0	0%	0	0
2018	0%	0	0	0%	0	0	0%	0	0
2019	0%	0	0	0%	0	0	0%	0	0
2020	0%	0	0	0%	0	0	0%	0	0
2021	0%	0	0	0%	0	0	0%	0	0
2022	0%	0	0	0%	0	0	0%	0	0
2023	0%	0	0	0%	0	0	0%	0	0
2024	10%	574	756,340	0%	0	0	86%	4,906	7,185,231
2025	10%	668	886,781	0%	0	0	84%	5,593	8,247,067
2026	10%	783	1,041,761	0%	0	0	81%	6,343	9,375,851
2027	15%	1,344	1,715,605	0%	0	0	72%	6,474	9,181,662
2028	15%	1,544	1,969,828	0%	0	0	68%	7,002	9,922,098
2029	20%	2,384	3,059,507	0%	0	0	60%	7,152	10,198,356
2030	20%	2,761	3,566,433	0%	0	0	56%	7,732	11,095,569
2045	12%	1,879	2,615,706	0%	0	0	53%	8,266	12,787,894
2032	10%	1,781	2,631,722	0%	0	0	54%	9,619	15,790,332
2033	10%	2,000	3,093,484	0%	0	0	54%	10,802	18,560,905
2034	10%	2,262	3,676,051	0%	0	0	54%	12,217	22,056,309
2035	12%	2,997	5,154,227	0%	0	0	53%	13,188	25,198,442
2036	12%	3,236	5,922,773	0%	0	0	53%	14,239	28,955,778
2037	12%	3,432	6,725,482	0%	0	0	53%	15,100	32,880,135
2038	12%	3,547	7,438,400	0%	0	0	53%	15,606	36,365,513
2039	12%	3,610	8,118,998	0%	0	0	53%	15,885	39,692,877
2040	12%	3,422	8,176,299	0%	0	0	53%	15,058	39,973,018
2041	12%	3,298	8,363,731	0%	0	0	53%	14,512	40,889,352
2042	12%	2,974	7,831,788	0%	0	0	53%	13,084	38,288,741
2043	12%	2,794	7,539,421	0%	0	0	53%	12,295	36,859,392
2044	12%	2,641	7,227,079	0%	0	0	53%	11,622	35,332,388
2045	12%	1,660	4,357,601	0%	0	0	53%	7,303	21,303,829
2046	12%	853	1,167,185	0%	0	0	53%	3,755	5,706,238

Table A-30. NOx and GHG Tailpipe Emissions for Scenario 4 in Calendar Year 2045

Model Year	BEV			Tailpipe Emission Estimates[5] (tons/day)			
	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	NO_X	CO_2	CH_4	N_2O
2001	0%	0	0	0	0	0	0
2002	0%	0	0	0	0	0	0
2003	0%	0	0	0	0	0	0
2004	0%	0	0	0	0	0	0
2005	0%	0	0	0	0	0	0
2006	0%	0	0	0	0	0	0
2007	0%	0	0	0	0	0	0
2008	0%	0	0	0	0	0	0
2009	0%	0	0	0	0	0	0
2010	0%	0	0	0	0	0	0
2011	0%	0	0	0	0	0	0
2012	0%	0	0	0	0	0	0
2013	0%	0	0	0	0	0	0
2014	0%	0	0	0	0	0	0
2015	0%	0	0	0	0	0	0
2016	0%	0	0	0	0	0	0
2017	0%	0	0	0	0	0	0
2018	0%	0	0	0	0	0	0
2019	0%	0	0	0	0	0	0
2020	0%	0	0	0	0	0	0
2021	0%	0	0	0	0	0	0
2022	0%	0	0	0	0	0	0
2023	0%	0	0	0	0	0	0
2024	5%	258	112,383	0.21	603	0.002	0.09
2025	6%	421	184,471	0.24	693	0.002	0.11
2026	9%	705	309,586	0.28	791	0.002	0.12
2027	13%	1,142	481,512	0.33	833	0.002	0.13
2028	17%	1,750	737,152	0.37	909	0.003	0.14
2029	20%	2,384	1,010,235	0.45	1,021	0.003	0.16
2030	24%	3,314	1,413,144	0.51	1,131	0.003	0.18
2045	35%	5,511	2,533,502	0.49	1,179	0.004	0.19
2032	36%	6,413	3,128,337	0.56	1,405	0.004	0.22
2033	36%	7,201	3,677,235	0.66	1,652	0.005	0.26
2034	36%	8,144	4,369,735	0.78	1,963	0.006	0.31
2035	35%	8,792	4,992,246	0.94	2,322	0.007	0.37
2036	35%	9,493	5,736,639	1.1	2,669	0.008	0.42
2037	35%	10,067	6,514,121	1.2	3,030	0.009	0.48
2038	35%	10,404	7,204,635	1.2	3,352	0.009	0.53
2039	35%	10,590	7,863,843	1.3	3,658	0.01	0.58
2040	35%	10,039	7,919,344	1.2	3,684	0.01	0.58
2041	35%	9,675	8,100,885	1.2	3,769	0.010	0.59
2042	35%	8,723	7,585,660	1.0	3,529	0.009	0.55
2043	35%	8,197	7,302,481	0.92	3,397	0.008	0.53
2044	35%	7,748	6,999,955	0.82	3,256	0.008	0.51
2045	35%	4,869	4,220,656	0.45	1,963	0.005	0.31
2046	35%	2,503	1,130,504	0.15	526	0.002	0.08

Notes:

[1] EMFAC data shown here are adjusted by subtracting data for T7 SWCVs from corresponding data for all HHDTs as described in Appendix A. Accelerated turnover adjustments are included in calendar years 2031, 2037, 2045, and 2050 as described in Appendix A.

[2] Fleet mix percentages for each alternative HHDT technology type are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[3] Population in each model year is calculated based on the fleet mix percentages for each HHDT type and the total population in the adjusted EMFAC data.

[4] Energy consumption is calculated based on adjusted EMFAC data, using the EER for each HHDT type shown in Table A-38.

[5] Emissions from vehicles in each model year are calculated based on the fleet mix composition and the reduction in tailpipe NOx emissions achieved by each HHDT type shown in Table 3-2. Total emissions in each calendar year are calculated as the sum of tailpipe emissions across all HHDT types and all model years in each calendar year.

[6] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CA Cert. - California certified
CH_4 - methane
CO_2 - carbon dioxide
DSL - diesel
EER - energy economy ratio
EMFAC2017 - Emission Factor Model
gal - gallon
HHDT - heavy heavy duty truck
MJ - megajoule
N_2O - nitrous oxide
NG - natural gas
NO_x - oxides of nitrogen
T7 SWCV - solid waste collection vehicles
TOTEX - total exhaust

Table A-31. NOx and GHG Tailpipe Emissions for Scenario 4 in Calendar Year 2050

	Adjusted EMFAC2017 Output[1]						Conventional DSL		
Model Year	**Population**	**NOx_TOTEX (tons/day)**	**CO2_TOTEX (tons/day)**	**CH4_TOTEX (tons/day)**	**N2O_TOTEX (tons/day)**	**Fuel Consumption (1000 gal/day)**	**Fleet Mix[2] (%)**	**Population[3]**	**Energy Consumption[4] (MJ/day)**
2006	0	0	0	0	0	0	0%	0	0
2007	0	0	0	0	0	0	0%	0	0
2008	0	0	0	0	0	0	0%	0	0
2009	0	0	0	0	0	0	0%	0	0
2010	0	0	0	0	0	0	0%	0	0
2011	0	0	0	0	0	0	0%	0	0
2012	0	0	0	0	0	0	0%	0	0
2013	0	0	0	0	0	0	0%	0	0
2014	0	0	0	0	0	0	0%	0	0
2015	0	0	0	0	0	0	0%	0	0
2016	0	0	0	0	0	0	0%	0	0
2017	0	0	0	0	0	0	0%	0	0
2018	0	0	0	0	0	0	0%	0	0
2019	0	0	0	0	0	0	0%	0	0
2020	0	0	0	0	0	0	0%	0	0
2021	0	0	0	0	0	0	0%	0	0
2022	0	0	0	0	0	0	0%	0	0
2023	0	0	0	0	0	0	0%	0	0
2024	2,595	0.86	281	0.001	0.04	25	0%	0	0
2025	3,028	1.0	330	0.001	0.05	29	0%	0	0
2026	3,626	1.2	393	0.001	0.06	35	0%	0	0
2027	4,257	1.4	439	0.001	0.07	39	0%	0	0
2028	5,060	1.7	526	0.001	0.08	47	0%	0	0
2029	6,031	2.0	632	0.002	0.10	56	0%	0	0
2030	7,066	2.4	743	0.002	0.12	66	0%	0	0
2050	8,217	2.8	872	0.003	0.14	78	0%	0	0
2032	9,494	3.2	1,017	0.003	0.16	91	0%	0	0
2033	11,004	3.8	1,176	0.004	0.18	105	0%	0	0
2034	12,911	4.5	1,386	0.004	0.22	124	0%	0	0
2035	14,935	5.3	1,619	0.005	0.25	144	0%	0	0
2036	16,783	6.4	1,962	0.006	0.31	175	0%	0	0
2037	18,732	7.5	2,328	0.007	0.37	208	0%	0	0
2038	20,725	8.7	2,699	0.008	0.42	241	0%	0	0
2039	22,925	10	3,137	0.009	0.49	280	0%	0	0
2040	25,074	11	3,619	0.01	0.57	323	0%	0	0
2041	27,099	13	4,155	0.01	0.65	370	0%	0	0
2042	28,740	14	4,704	0.01	0.74	419	0%	0	0
2043	29,658	15	5,184	0.01	0.81	462	0%	0	0
2044	30,119	16	5,634	0.02	0.89	502	0%	0	0
2045	28,407	15	5,643	0.02	0.89	503	0%	0	0
2046	27,387	14	5,770	0.02	0.91	514	0%	0	0
2047	24,660	12	5,397	0.01	0.85	481	0%	0	0
2048	23,198	11	5,206	0.01	0.82	464	0%	0	0
2049	21,872	10	4,978	0.01	0.78	444	0%	0	0
2050	13,695	5.4	2,992	0.007	0.47	267	0%	0	0
2051	7,053	1.8	1,226	0.004	0.19	109	0%	0	0

Table A-31. NOx and GHG Tailpipe Emissions for Scenario 4 in Calendar Year 2050

Model Year	Federal Low NOx DSL			CA Cert. Low NOx DSL			Low NOx NG		
	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)
2006	0%	0	0	0%	0	0	0%	0	0
2007	0%	0	0	0%	0	0	0%	0	0
2008	0%	0	0	0%	0	0	0%	0	0
2009	0%	0	0	0%	0	0	0%	0	0
2010	0%	0	0	0%	0	0	0%	0	0
2011	0%	0	0	0%	0	0	0%	0	0
2012	0%	0	0	0%	0	0	0%	0	0
2013	0%	0	0	0%	0	0	0%	0	0
2014	0%	0	0	0%	0	0	0%	0	0
2015	0%	0	0	0%	0	0	0%	0	0
2016	0%	0	0	0%	0	0	0%	0	0
2017	0%	0	0	0%	0	0	0%	0	0
2018	0%	0	0	0%	0	0	0%	0	0
2019	0%	0	0	0%	0	0	0%	0	0
2020	0%	0	0	0%	0	0	0%	0	0
2021	0%	0	0	0%	0	0	0%	0	0
2022	0%	0	0	0%	0	0	0%	0	0
2023	0%	0	0	0%	0	0	0%	0	0
2024	10%	260	337,270	0%	0	0	86%	2,219	3,204,066
2025	10%	303	395,918	0%	0	0	84%	2,534	3,682,036
2026	10%	363	471,136	0%	0	0	81%	2,937	4,240,226
2027	15%	639	789,915	0%	0	0	72%	3,076	4,227,507
2028	15%	759	945,969	0%	0	0	68%	3,441	4,764,882
2029	20%	1,206	1,514,257	0%	0	0	60%	3,619	5,047,525
2030	20%	1,413	1,780,183	0%	0	0	56%	3,957	5,538,347
2050	12%	986	1,253,331	0%	0	0	53%	4,339	6,127,395
2032	10%	949	1,218,218	0%	0	0	54%	5,127	7,309,307
2033	10%	1,100	1,409,784	0%	0	0	54%	5,942	8,458,701
2034	10%	1,291	1,660,800	0%	0	0	54%	6,972	9,964,800
2035	12%	1,792	2,327,866	0%	0	0	53%	7,885	11,380,679
2036	12%	2,014	2,822,001	0%	0	0	53%	8,861	13,796,450
2037	12%	2,248	3,348,517	0%	0	0	53%	9,890	16,370,527
2038	12%	2,487	3,881,574	0%	0	0	53%	10,943	18,976,585
2039	12%	2,751	4,511,626	0%	0	0	53%	12,105	22,056,839
2040	12%	3,009	5,204,512	0%	0	0	53%	13,239	25,444,282
2041	12%	3,252	5,974,789	0%	0	0	53%	14,308	29,210,080
2042	12%	3,449	6,765,245	0%	0	0	53%	15,175	33,074,532
2043	12%	3,559	7,455,772	0%	0	0	53%	15,660	36,450,439
2044	12%	3,614	8,101,789	0%	0	0	53%	15,903	39,608,744
2045	12%	3,409	8,115,025	0%	0	0	53%	14,999	39,673,455
2046	12%	3,286	8,297,953	0%	0	0	53%	14,461	40,567,771
2047	12%	2,959	7,761,898	0%	0	0	53%	13,021	37,947,059
2048	12%	2,784	7,487,127	0%	0	0	53%	12,249	36,603,732
2049	12%	2,625	7,158,856	0%	0	0	53%	11,549	34,998,851
2050	12%	1,643	4,302,930	0%	0	0	53%	7,231	21,036,548
2051	12%	846	1,763,371	0%	0	0	53%	3,724	8,620,923

Table A-31. NOx and GHG Tailpipe Emissions for Scenario 4 in Calendar Year 2050

Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Model Year	BEV			Tailpipe Emission Estimates[5] (tons/day)			
	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	NO_X	CO_2	CH_4	N_2O
2006	0%	0	0	0	0	0	0
2007	0%	0	0	0	0	0	0
2008	0%	0	0	0	0	0	0
2009	0%	0	0	0	0	0	0
2010	0%	0	0	0	0	0	0
2011	0%	0	0	0	0	0	0
2012	0%	0	0	0	0	0	0
2013	0%	0	0	0	0	0	0
2014	0%	0	0	0	0	0	0
2015	0%	0	0	0	0	0	0
2016	0%	0	0	0	0	0	0
2017	0%	0	0	0	0	0	0
2018	0%	0	0	0	0	0	0
2019	0%	0	0	0	0	0	0
2020	0%	0	0	0	0	0	0
2021	0%	0	0	0	0	0	0
2022	0%	0	0	0	0	0	0
2023	0%	0	0	0	0	0	0
2024	5%	117	50,114	0.10	269	0.001	0.04
2025	6%	191	82,360	0.11	310	0.001	0.05
2026	9%	326	140,010	0.13	358	0.001	0.06
2027	13%	543	221,702	0.15	383	0.001	0.06
2028	17%	860	354,002	0.18	437	0.001	0.07
2029	20%	1,206	500,001	0.22	505	0.001	0.08
2030	24%	1,696	705,370	0.25	564	0.002	0.09
2050	35%	2,892	1,213,943	0.23	565	0.002	0.09
2032	36%	3,418	1,448,100	0.26	651	0.002	0.10
2033	36%	3,961	1,675,814	0.30	753	0.002	0.12
2034	36%	4,648	1,974,199	0.35	887	0.003	0.14
2035	35%	5,257	2,254,709	0.44	1,049	0.003	0.16
2036	35%	5,907	2,733,315	0.53	1,272	0.004	0.20
2037	35%	6,594	3,243,284	0.62	1,509	0.005	0.24
2038	35%	7,295	3,759,589	0.72	1,749	0.005	0.27
2039	35%	8,070	4,369,840	0.84	2,033	0.006	0.32
2040	35%	8,826	5,040,951	1.0	2,345	0.007	0.37
2041	35%	9,539	5,787,020	1.1	2,692	0.008	0.42
2042	35%	10,117	6,552,635	1.2	3,048	0.009	0.48
2043	35%	10,440	7,221,460	1.3	3,359	0.009	0.53
2044	35%	10,602	7,847,175	1.3	3,651	0.01	0.57
2045	35%	9,999	7,859,995	1.2	3,657	0.01	0.57
2046	35%	9,640	8,037,175	1.2	3,739	0.010	0.59
2047	35%	8,680	7,517,967	1.0	3,497	0.009	0.55
2048	35%	8,166	7,251,830	0.91	3,374	0.008	0.53
2049	35%	7,699	6,933,876	0.81	3,226	0.008	0.51
2050	35%	4,821	4,167,703	0.45	1,939	0.005	0.30
2051	35%	2,483	1,707,953	0.15	795	0.002	0.12

Notes:

[1] EMFAC data shown here are adjusted by subtracting data for T7 SWCVs from corresponding data for all HHDTs as described in Appendix A. Accelerated turnover adjustments are included in calendar years 2031, 2037, 2045, and 2050 as described in Appendix A.

[2] Fleet mix percentages for each alternative HHDT technology type are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[3] Population in each model year is calculated based on the fleet mix percentages for each HHDT type and the total population in the adjusted EMFAC data.

[4] Energy consumption is calculated based on adjusted EMFAC data, using the EER for each HHDT type shown in Table A-38.

[5] Emissions from vehicles in each model year are calculated based on the fleet mix composition and the reduction in tailpipe NOx emissions achieved by each HHDT type shown in Table 3-2. Total emissions in each calendar year are calculated as the sum of tailpipe emissions across all HHDT types and all model years in each calendar year.

[6] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CA Cert. - California certified
CH_4 - methane
CO_2 - carbon dioxide
DSL - diesel
EER - energy economy ratio
EMFAC2017 - Emission Factor Model
gal - gallon
HHDT - heavy heavy duty truck
MJ - megajoule
N_2O - nitrous oxide
NG - natural gas
NO_x - oxides of nitrogen
T7 SWCV - solid waste collection vehicles
TOTEX - total exhaust

Table A-32. NOx and GHG Tailpipe Emissions for Scenario 5 in Calendar Year 2020

Model Year	Adjusted EMFAC2017 Output[1]						Conventional DSL		
	Population	NOx_TOTEX (tons/day)	CO2_TOTEX (tons/day)	CH4_TOTEX (tons/day)	N2O_TOTEX (tons/day)	Fuel Consumption (1000 gal/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)
1976	29	0.02	1.7	0.000	0.000	0.15	100%	29	19,871
1977	34	0.02	2.3	0.000	0.000	0.20	100%	34	27,331
1978	66	0.04	3.9	0.000	0.001	0.35	100%	66	47,207
1979	94	0.05	5.0	0.000	0.001	0.44	100%	94	59,761
1980	87	0.05	5.1	0.000	0.001	0.45	100%	87	61,143
1981	258	0.15	15	0.000	0.002	1.3	100%	258	180,361
1982	236	0.13	13	0.000	0.002	1.2	100%	236	156,209
1983	219	0.13	13	0.000	0.002	1.1	100%	219	151,257
1984	274	0.18	18	0.000	0.003	1.6	100%	274	214,575
1985	404	0.25	25	0.000	0.004	2.2	100%	404	301,188
1986	396	0.25	25	0.000	0.004	2.2	100%	396	301,092
1987	426	0.29	27	0.000	0.004	2.4	100%	426	324,223
1988	484	0.34	32	0.000	0.005	2.9	100%	484	387,591
1989	567	0.40	38	0.000	0.006	3.4	100%	567	454,438
1990	539	0.39	37	0.000	0.006	3.3	100%	539	446,862
1991	475	0.34	28	0.000	0.004	2.5	100%	475	335,098
1992	399	0.31	25	0.000	0.004	2.2	100%	399	301,877
1993	363	0.29	25	0.000	0.004	2.2	100%	363	295,585
1994	379	0.31	28	0.000	0.004	2.5	100%	379	330,512
1995	507	0.41	37	0.000	0.006	3.3	100%	507	443,837
1996	1,142	1.8	150	0.006	0.02	13	100%	1,142	1,800,897
1997	1,167	1.8	149	0.006	0.02	13	100%	1,167	1,790,241
1998	1,370	2.2	192	0.008	0.03	17	100%	1,370	2,305,455
1999	1,972	4.1	291	0.01	0.05	26	100%	1,972	3,484,066
2000	4,067	9.0	641	0.02	0.10	57	100%	4,067	7,683,603
2001	3,153	6.6	476	0.02	0.07	42	100%	3,153	5,706,180
2002	2,427	4.6	338	0.01	0.05	30	100%	2,427	4,046,083
2003	2,907	3.5	425	0.01	0.07	38	100%	2,907	5,088,912
2004	2,913	3.0	421	0.01	0.07	38	100%	2,913	5,047,803
2005	4,812	5.1	719	0.02	0.11	64	100%	4,812	8,613,212
2006	5,968	6.9	972	0.03	0.15	87	100%	5,968	11,650,876
2007	8,303	9.5	1,454	0.03	0.23	130	100%	8,303	17,419,576
2008	12,274	13	2,417	0.02	0.38	215	100%	12,274	28,960,284
2009	14,354	16	3,080	0.03	0.48	275	100%	14,354	36,913,677
2010	11,383	13	2,653	0.02	0.42	236	100%	11,383	31,795,323
2011	13,627	10	3,166	0.01	0.50	282	100%	13,627	37,940,166
2012	39,297	19	6,724	0.01	1.1	599	100%	39,297	80,581,115
2013	21,084	14	5,397	0.010	0.85	481	100%	21,084	64,680,893
2014	23,061	12	5,525	0.01	0.87	492	100%	23,061	66,207,976
2015	28,916	14	7,779	0.02	1.2	693	100%	28,916	93,222,050
2016	41,998	22	12,488	0.02	2.0	1,113	100%	41,998	149,658,452
2017	16,101	6.6	3,944	0.008	0.62	351	100%	16,101	47,265,405
2018	12,688	5.9	3,720	0.007	0.58	332	100%	12,688	44,579,225
2019	12,851	5.6	3,844	0.007	0.60	343	100%	12,851	46,069,473
2020	8,537	3.3	2,461	0.004	0.39	219	100%	8,537	29,496,897
2021	4,246	1.1	575	0.002	0.09	51	100%	4,246	6,891,960

Table A-32. NOx and GHG Tailpipe Emissions for Scenario 5 in Calendar Year 2020

Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Model Year	Federal Low NOx DSL			CA Cert. Low NOx DSL			Low NOx NG		
	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)
1976	0%	0	0	0%	0	0	0%	0	0
1977	0%	0	0	0%	0	0	0%	0	0
1978	0%	0	0	0%	0	0	0%	0	0
1979	0%	0	0	0%	0	0	0%	0	0
1980	0%	0	0	0%	0	0	0%	0	0
1981	0%	0	0	0%	0	0	0%	0	0
1982	0%	0	0	0%	0	0	0%	0	0
1983	0%	0	0	0%	0	0	0%	0	0
1984	0%	0	0	0%	0	0	0%	0	0
1985	0%	0	0	0%	0	0	0%	0	0
1986	0%	0	0	0%	0	0	0%	0	0
1987	0%	0	0	0%	0	0	0%	0	0
1988	0%	0	0	0%	0	0	0%	0	0
1989	0%	0	0	0%	0	0	0%	0	0
1990	0%	0	0	0%	0	0	0%	0	0
1991	0%	0	0	0%	0	0	0%	0	0
1992	0%	0	0	0%	0	0	0%	0	0
1993	0%	0	0	0%	0	0	0%	0	0
1994	0%	0	0	0%	0	0	0%	0	0
1995	0%	0	0	0%	0	0	0%	0	0
1996	0%	0	0	0%	0	0	0%	0	0
1997	0%	0	0	0%	0	0	0%	0	0
1998	0%	0	0	0%	0	0	0%	0	0
1999	0%	0	0	0%	0	0	0%	0	0
2000	0%	0	0	0%	0	0	0%	0	0
2001	0%	0	0	0%	0	0	0%	0	0
2002	0%	0	0	0%	0	0	0%	0	0
2003	0%	0	0	0%	0	0	0%	0	0
2004	0%	0	0	0%	0	0	0%	0	0
2005	0%	0	0	0%	0	0	0%	0	0
2006	0%	0	0	0%	0	0	0%	0	0
2007	0%	0	0	0%	0	0	0%	0	0
2008	0%	0	0	0%	0	0	0%	0	0
2009	0%	0	0	0%	0	0	0%	0	0
2010	0%	0	0	0%	0	0	0%	0	0
2011	0%	0	0	0%	0	0	0%	0	0
2012	0%	0	0	0%	0	0	0%	0	0
2013	0%	0	0	0%	0	0	0%	0	0
2014	0%	0	0	0%	0	0	0%	0	0
2015	0%	0	0	0%	0	0	0%	0	0
2016	0%	0	0	0%	0	0	0%	0	0
2017	0%	0	0	0%	0	0	0%	0	0
2018	0%	0	0	0%	0	0	0%	0	0
2019	0%	0	0	0%	0	0	0%	0	0
2020	0%	0	0	0%	0	0	0%	0	0
2021	0%	0	0	0%	0	0	0%	0	0

Table A-32. NOx and GHG Tailpipe Emissions for Scenario 5 in Calendar Year 2020

	BEV			Tailpipe Emission Estimates[5] (tons/day)			
Model Year	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	NO_X	CO_2	CH_4	N_2O
1976	0%	0	0	0.02	1.7	0.000	0.000
1977	0%	0	0	0.02	2.3	0.000	0.000
1978	0%	0	0	0.04	3.9	0.000	0.001
1979	0%	0	0	0.05	5.0	0.000	0.001
1980	0%	0	0	0.05	5.1	0.000	0.001
1981	0%	0	0	0.15	15	0.000	0.002
1982	0%	0	0	0.13	13	0.000	0.002
1983	0%	0	0	0.13	13	0.000	0.002
1984	0%	0	0	0.18	18	0.000	0.003
1985	0%	0	0	0.25	25	0.000	0.004
1986	0%	0	0	0.25	25	0.000	0.004
1987	0%	0	0	0.29	27	0.000	0.004
1988	0%	0	0	0.34	32	0.000	0.005
1989	0%	0	0	0.40	38	0.000	0.006
1990	0%	0	0	0.39	37	0.000	0.006
1991	0%	0	0	0.34	28	0.000	0.004
1992	0%	0	0	0.31	25	0.000	0.004
1993	0%	0	0	0.29	25	0.000	0.004
1994	0%	0	0	0.31	28	0.000	0.004
1995	0%	0	0	0.41	37	0.000	0.006
1996	0%	0	0	1.8	150	0.006	0.02
1997	0%	0	0	1.8	149	0.006	0.02
1998	0%	0	0	2.2	192	0.008	0.03
1999	0%	0	0	4.1	291	0.01	0.05
2000	0%	0	0	9.0	641	0.02	0.10
2001	0%	0	0	6.6	476	0.02	0.07
2002	0%	0	0	4.6	338	0.01	0.05
2003	0%	0	0	3.5	425	0.01	0.07
2004	0%	0	0	3.0	421	0.01	0.07
2005	0%	0	0	5.1	719	0.02	0.11
2006	0%	0	0	6.9	972	0.03	0.15
2007	0%	0	0	9.5	1,454	0.03	0.23
2008	0%	0	0	13	2,417	0.02	0.38
2009	0%	0	0	16	3,080	0.03	0.48
2010	0%	0	0	13	2,653	0.02	0.42
2011	0%	0	0	10	3,166	0.01	0.50
2012	0%	0	0	19	6,724	0.01	1.1
2013	0%	0	0	14	5,397	0.010	0.85
2014	0%	0	0	12	5,525	0.01	0.87
2015	0%	0	0	14	7,779	0.02	1.2
2016	0%	0	0	22	12,488	0.02	2.0
2017	0%	0	0	6.6	3,944	0.008	0.62
2018	0%	0	0	5.9	3,720	0.007	0.58
2019	0%	0	0	5.6	3,844	0.007	0.60
2020	0%	0	0	3.3	2,461	0.004	0.39
2021	0%	0	0	1.1	575	0.002	0.09

Notes:

[1] EMFAC data shown here are adjusted by subtracting data for T7 SWCVs from corresponding data for all HHDTs as described in Appendix A. Accelerated turnover adjustments are included in calendar years 2031, 2037, 2045, and 2050 as described in Appendix A.

[2] Fleet mix percentages for each alternative HHDT technology type are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[3] Population in each model year is calculated based on the fleet mix percentages for each HHDT type and the total population in the adjusted EMFAC data.

[4] Energy consumption is calculated based on adjusted EMFAC data, using the EER for each HHDT type shown in Table A-38.

[5] Emissions from vehicles in each model year are calculated based on the fleet mix composition and the reduction in tailpipe NOx emissions achieved by each HHDT type shown in Table 3-2. Total emissions in each calendar year are calculated as the sum of tailpipe emissions across all HHDT types and all model years in each calendar year.

[6] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CA Cert. - California certified
CH_4 - methane
CO_2 - carbon dioxide
DSL - diesel
EER - energy economy ratio
EMFAC2017 - Emission Factor Model
gal - gallon
HHDT - heavy heavy duty truck
MJ - megajoule
N_2O - nitrous oxide
NG - natural gas
NO_x - oxides of nitrogen
T7 SWCV - solid waste collection vehicles
TOTEX - total exhaust

Table A-33. NOx and GHG Tailpipe Emissions for Scenario 5 in Calendar Year 2023

	Adjusted EMFAC2017 Output[1]						Conventional DSL		
Model Year	**Population**	**NOx_TOTEX (tons/day)**	**CO2_TOTEX (tons/day)**	**CH4_TOTEX (tons/day)**	**N2O_TOTEX (tons/day)**	**Fuel Consumption (1000 gal/day)**	**Fleet Mix[2] (%)**	**Population[3]**	**Energy Consumption[4] (MJ/day)**
1979	53	0.03	2.9	0.000	0.000	0.26	100%	53	35,019
1980	64	0.04	3.7	0.000	0.001	0.33	100%	64	44,086
1981	209	0.12	12	0.000	0.002	1.1	100%	209	142,790
1982	208	0.11	11	0.000	0.002	1.0	100%	208	134,214
1983	196	0.11	11	0.000	0.002	1.0	100%	196	131,088
1984	241	0.15	15	0.000	0.002	1.3	100%	241	176,822
1985	357	0.21	21	0.000	0.003	1.9	100%	357	252,082
1986	331	0.20	20	0.000	0.003	1.8	100%	331	243,579
1987	345	0.22	21	0.000	0.003	1.9	100%	345	253,082
1988	370	0.26	24	0.000	0.004	2.2	100%	370	290,997
1989	420	0.29	28	0.000	0.004	2.5	100%	420	332,355
1990	382	0.28	27	0.000	0.004	2.4	100%	382	319,401
1991	331	0.24	20	0.000	0.003	1.8	100%	331	238,471
1992	279	0.22	18	0.000	0.003	1.6	100%	279	214,037
1993	235	0.20	17	0.000	0.003	1.5	100%	235	202,566
1994	257	0.21	19	0.000	0.003	1.7	100%	257	228,163
1995	341	0.29	26	0.000	0.004	2.3	100%	341	308,497
1996	354	0.29	26	0.000	0.004	2.3	100%	354	309,827
1997	358	0.27	24	0.000	0.004	2.2	100%	358	292,799
1998	350	0.29	27	0.000	0.004	2.4	100%	350	324,850
1999	484	0.48	38	0.000	0.006	3.4	100%	484	458,610
2000	570	0.55	44	0.000	0.007	3.9	100%	570	522,449
2001	630	0.52	42	0.000	0.007	3.7	100%	630	502,288
2002	683	0.50	41	0.000	0.006	3.7	100%	683	490,906
2003	607	0.31	41	0.000	0.006	3.7	100%	607	491,836
2004	588	0.27	39	0.000	0.006	3.4	100%	588	462,594
2005	722	0.33	48	0.000	0.008	4.3	100%	722	579,188
2006	789	0.37	53	0.000	0.008	4.7	100%	789	635,640
2007	1,010	0.43	69	0.000	0.01	6.1	100%	1,010	822,391
2008	958	0.24	51	0.000	0.008	4.5	100%	958	608,971
2009	1,054	0.24	57	0.000	0.009	5.1	100%	1,054	681,595
2010	516	0.11	28	0.000	0.004	2.5	100%	516	336,250
2011	601	0.08	32	0.000	0.005	2.8	100%	601	381,333
2012	36,456	15	5,160	0.010	0.81	460	100%	36,456	61,840,416
2013	23,385	13	4,715	0.009	0.74	420	100%	23,385	56,503,770
2014	25,954	12	4,907	0.01	0.77	437	100%	25,954	58,805,403
2015	43,313	18	8,476	0.02	1.3	755	100%	43,313	101,582,009
2016	51,092	25	12,180	0.03	1.9	1,086	100%	51,092	145,975,230
2017	45,093	20	10,301	0.02	1.6	918	100%	45,093	123,455,483
2018	15,699	7.6	3,880	0.008	0.61	346	100%	15,699	46,494,284
2019	15,755	7.5	4,119	0.008	0.65	367	100%	15,755	49,364,115
2020	14,758	7.0	4,076	0.008	0.64	363	100%	14,758	48,851,177
2021	13,866	6.3	3,442	0.008	0.54	307	100%	13,866	41,250,943
2022	13,999	6.1	3,590	0.008	0.56	320	100%	13,999	43,027,237
2023	9,671	3.7	2,395	0.005	0.38	213	100%	9,671	28,707,076
2024	4,843	1.3	599	0.003	0.09	53	0%	0	0

Table A-33. NOx and GHG Tailpipe Emissions for Scenario 5 in Calendar Year 2023

	Federal Low NOx DSL			CA Cert. Low NOx DSL			Low NOx NG		
Model Year	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)
1979	0%	0	0	0%	0	0	0%	0	0
1980	0%	0	0	0%	0	0	0%	0	0
1981	0%	0	0	0%	0	0	0%	0	0
1982	0%	0	0	0%	0	0	0%	0	0
1983	0%	0	0	0%	0	0	0%	0	0
1984	0%	0	0	0%	0	0	0%	0	0
1985	0%	0	0	0%	0	0	0%	0	0
1986	0%	0	0	0%	0	0	0%	0	0
1987	0%	0	0	0%	0	0	0%	0	0
1988	0%	0	0	0%	0	0	0%	0	0
1989	0%	0	0	0%	0	0	0%	0	0
1990	0%	0	0	0%	0	0	0%	0	0
1991	0%	0	0	0%	0	0	0%	0	0
1992	0%	0	0	0%	0	0	0%	0	0
1993	0%	0	0	0%	0	0	0%	0	0
1994	0%	0	0	0%	0	0	0%	0	0
1995	0%	0	0	0%	0	0	0%	0	0
1996	0%	0	0	0%	0	0	0%	0	0
1997	0%	0	0	0%	0	0	0%	0	0
1998	0%	0	0	0%	0	0	0%	0	0
1999	0%	0	0	0%	0	0	0%	0	0
2000	0%	0	0	0%	0	0	0%	0	0
2001	0%	0	0	0%	0	0	0%	0	0
2002	0%	0	0	0%	0	0	0%	0	0
2003	0%	0	0	0%	0	0	0%	0	0
2004	0%	0	0	0%	0	0	0%	0	0
2005	0%	0	0	0%	0	0	0%	0	0
2006	0%	0	0	0%	0	0	0%	0	0
2007	0%	0	0	0%	0	0	0%	0	0
2008	0%	0	0	0%	0	0	0%	0	0
2009	0%	0	0	0%	0	0	0%	0	0
2010	0%	0	0	0%	0	0	0%	0	0
2011	0%	0	0	0%	0	0	0%	0	0
2012	0%	0	0	0%	0	0	0%	0	0
2013	0%	0	0	0%	0	0	0%	0	0
2014	0%	0	0	0%	0	0	0%	0	0
2015	0%	0	0	0%	0	0	0%	0	0
2016	0%	0	0	0%	0	0	0%	0	0
2017	0%	0	0	0%	0	0	0%	0	0
2018	0%	0	0	0%	0	0	0%	0	0
2019	0%	0	0	0%	0	0	0%	0	0
2020	0%	0	0	0%	0	0	0%	0	0
2021	0%	0	0	0%	0	0	0%	0	0
2022	0%	0	0	0%	0	0	0%	0	0
2023	0%	0	0	0%	0	0	0%	0	0
2024	10%	484	717,286	86%	4,141	6,132,798	0%	0	0

Table A-33. NOx and GHG Tailpipe Emissions for Scenario 5 in Calendar Year 2023

	BEV			Tailpipe Emission Estimates[5] (tons/day)			
Model Year	**Fleet Mix[2] (%)**	**Population[3]**	**Energy Consumption[4] (MJ/day)**	**NO_X**	**CO_2**	**CH_4**	**N_2O**
1979	0%	0	0	0.03	2.9	0.000	0.000
1980	0%	0	0	0.04	3.7	0.000	0.001
1981	0%	0	0	0.12	12	0.000	0.002
1982	0%	0	0	0.11	11	0.000	0.002
1983	0%	0	0	0.11	11	0.000	0.002
1984	0%	0	0	0.15	15	0.000	0.002
1985	0%	0	0	0.21	21	0.000	0.003
1986	0%	0	0	0.20	20	0.000	0.003
1987	0%	0	0	0.22	21	0.000	0.003
1988	0%	0	0	0.26	24	0.000	0.004
1989	0%	0	0	0.29	28	0.000	0.004
1990	0%	0	0	0.28	27	0.000	0.004
1991	0%	0	0	0.24	20	0.000	0.003
1992	0%	0	0	0.22	18	0.000	0.003
1993	0%	0	0	0.20	17	0.000	0.003
1994	0%	0	0	0.21	19	0.000	0.003
1995	0%	0	0	0.29	26	0.000	0.004
1996	0%	0	0	0.29	26	0.000	0.004
1997	0%	0	0	0.27	24	0.000	0.004
1998	0%	0	0	0.29	27	0.000	0.004
1999	0%	0	0	0.48	38	0.000	0.006
2000	0%	0	0	0.55	44	0.000	0.007
2001	0%	0	0	0.52	42	0.000	0.007
2002	0%	0	0	0.50	41	0.000	0.006
2003	0%	0	0	0.31	41	0.000	0.006
2004	0%	0	0	0.27	39	0.000	0.006
2005	0%	0	0	0.33	48	0.000	0.008
2006	0%	0	0	0.37	53	0.000	0.008
2007	0%	0	0	0.43	69	0.000	0.01
2008	0%	0	0	0.24	51	0.000	0.008
2009	0%	0	0	0.24	57	0.000	0.009
2010	0%	0	0	0.11	28	0.000	0.004
2011	0%	0	0	0.08	32	0.000	0.005
2012	0%	0	0	15	5,160	0.010	0.81
2013	0%	0	0	13	4,715	0.009	0.74
2014	0%	0	0	12	4,907	0.01	0.77
2015	0%	0	0	18	8,476	0.02	1.3
2016	0%	0	0	25	12,180	0.03	1.9
2017	0%	0	0	20	10,301	0.02	1.6
2018	0%	0	0	7.6	3,880	0.008	0.61
2019	0%	0	0	7.5	4,119	0.008	0.65
2020	0%	0	0	7.0	4,076	0.008	0.64
2021	0%	0	0	6.3	3,442	0.008	0.54
2022	0%	0	0	6.1	3,590	0.008	0.56
2023	0%	0	0	3.7	2,395	0.005	0.38
2024	5%	218	106,580	0.14	572	0.002	0.09

Notes:

[1] EMFAC data shown here are adjusted by subtracting data for T7 SWCVs from corresponding data for all HHDTs as described in Appendix A. Accelerated turnover adjustments are included in calendar years 2031, 2037, 2045, and 2050 as described in Appendix A.

[2] Fleet mix percentages for each alternative HHDT technology type are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[3] Population in each model year is calculated based on the fleet mix percentages for each HHDT type and the total population in the adjusted EMFAC data.

[4] Energy consumption is calculated based on adjusted EMFAC data, using the EER for each HHDT type shown in Table A-38.

[5] Emissions from vehicles in each model year are calculated based on the fleet mix composition and the reduction in tailpipe NOx emissions achieved by each HHDT type shown in Table 3-2. Total emissions in each calendar year are calculated as the sum of tailpipe emissions across all HHDT types and all model years in each calendar year.

[6] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CA Cert. - California certified
CH_4 - methane
CO_2 - carbon dioxide
DSL - diesel
EER - energy economy ratio
EMFAC2017 - Emission Factor Model
gal - gallon
HHDT - heavy heavy duty truck
MJ - megajoule
N_2O - nitrous oxide
NG - natural gas
NO_x - oxides of nitrogen
T7 SWCV - solid waste collection vehicles
TOTEX - total exhaust

Table A-34. NOx and GHG Tailpipe Emissions for Scenario 5 in Calendar Year 2031

Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Model Year	Adjusted EMFAC2017 Output[1]						Conventional DSL		
	Population	NOx_TOTEX (tons/day)	CO2_TOTEX (tons/day)	CH4_TOTEX (tons/day)	N2O_TOTEX (tons/day)	Fuel Consumption (1000 gal/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)
1987	166	0.09	8.9	0.000	0.001	0.79	100%	166	106,532
1988	223	0.13	12	0.000	0.002	1.1	100%	223	144,024
1989	279	0.16	15	0.000	0.002	1.3	100%	279	179,202
1990	256	0.15	14	0.000	0.002	1.3	100%	256	168,297
1991	221	0.14	11	0.000	0.002	1.0	100%	221	134,880
1992	173	0.11	9.2	0.000	0.001	0.82	100%	173	110,429
1993	132	0.09	7.5	0.000	0.001	0.67	100%	132	90,308
1994	131	0.08	7.6	0.000	0.001	0.68	100%	131	91,104
1995	161	0.11	10	0.000	0.002	0.87	100%	161	116,335
1996	159	0.11	10	0.000	0.002	0.85	100%	159	114,485
1997	155	0.10	9.1	0.000	0.001	0.81	100%	155	108,509
1998	145	0.10	10	0.000	0.001	0.85	100%	145	114,337
1999	197	0.17	13	0.000	0.002	1.2	100%	197	160,607
2000	233	0.20	16	0.000	0.002	1.4	100%	233	188,016
2001	267	0.20	16	0.000	0.003	1.4	100%	267	193,494
2002	300	0.21	17	0.000	0.003	1.5	100%	300	200,551
2003	272	0.13	17	0.000	0.003	1.5	100%	272	200,037
2004	276	0.12	17	0.000	0.003	1.5	100%	276	198,929
2005	353	0.15	22	0.000	0.003	1.9	100%	353	259,740
2006	403	0.18	25	0.000	0.004	2.3	100%	403	303,073
2007	543	0.22	35	0.000	0.006	3.1	100%	543	422,431
2008	564	0.14	29	0.000	0.005	2.6	100%	564	352,228
2009	654	0.15	34	0.000	0.005	3.1	100%	654	410,832
2010	337	0.07	18	0.000	0.003	1.6	100%	337	211,381
2011	419	0.05	21	0.000	0.003	1.9	100%	419	253,413
2012	18,775	6.3	2,125	0.004	0.33	189	100%	18,775	25,469,698
2013	10,866	5.2	1,931	0.003	0.30	172	100%	10,866	23,141,590
2014	12,373	4.9	1,993	0.004	0.31	178	100%	12,373	23,884,682
2015	22,601	8.0	3,471	0.007	0.55	309	100%	22,601	41,601,211
2016	25,559	9.1	3,866	0.010	0.61	345	100%	25,559	46,327,589
2017	29,560	9.2	4,023	0.009	0.63	359	100%	29,560	48,215,934
2018	10,153	3.8	1,588	0.004	0.25	142	100%	10,153	19,030,587
2019	11,512	4.5	1,861	0.004	0.29	166	100%	11,512	22,305,607
2020	13,043	5.4	2,255	0.005	0.35	201	100%	13,043	27,025,846
2021	14,295	6.2	2,272	0.006	0.36	203	100%	14,295	27,231,919
2022	16,417	7.5	2,835	0.007	0.45	253	100%	16,417	33,979,835
2023	22,059	12	4,261	0.010	0.67	380	100%	22,059	51,063,434
2024	21,715	11	3,988	0.01	0.63	355	0%	0	0
2025	22,619	12	4,524	0.01	0.71	403	0%	0	0
2026	22,104	12	4,758	0.01	0.75	424	0%	0	0
2027	21,594	11	4,671	0.01	0.73	416	0%	0	0
2028	19,744	10	4,452	0.01	0.70	397	0%	0	0
2029	18,560	9.0	4,281	0.01	0.67	382	0%	0	0
2030	17,915	8.2	4,205	0.01	0.66	375	0%	0	0
2031	11,497	4.6	2,590	0.006	0.41	231	0%	0	0
2032	5,864	1.6	694	0.003	0.11	62	0%	0	0

Table A-34. NOx and GHG Tailpipe Emissions for Scenario 5 in Calendar Year 2031

	Federal Low NOx DSL			CA Cert. Low NOx DSL			Low NOx NG		
Model Year	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)
1987	0%	0	0	0%	0	0	0%	0	0
1988	0%	0	0	0%	0	0	0%	0	0
1989	0%	0	0	0%	0	0	0%	0	0
1990	0%	0	0	0%	0	0	0%	0	0
1991	0%	0	0	0%	0	0	0%	0	0
1992	0%	0	0	0%	0	0	0%	0	0
1993	0%	0	0	0%	0	0	0%	0	0
1994	0%	0	0	0%	0	0	0%	0	0
1995	0%	0	0	0%	0	0	0%	0	0
1996	0%	0	0	0%	0	0	0%	0	0
1997	0%	0	0	0%	0	0	0%	0	0
1998	0%	0	0	0%	0	0	0%	0	0
1999	0%	0	0	0%	0	0	0%	0	0
2000	0%	0	0	0%	0	0	0%	0	0
2001	0%	0	0	0%	0	0	0%	0	0
2002	0%	0	0	0%	0	0	0%	0	0
2003	0%	0	0	0%	0	0	0%	0	0
2004	0%	0	0	0%	0	0	0%	0	0
2005	0%	0	0	0%	0	0	0%	0	0
2006	0%	0	0	0%	0	0	0%	0	0
2007	0%	0	0	0%	0	0	0%	0	0
2008	0%	0	0	0%	0	0	0%	0	0
2009	0%	0	0	0%	0	0	0%	0	0
2010	0%	0	0	0%	0	0	0%	0	0
2011	0%	0	0	0%	0	0	0%	0	0
2012	0%	0	0	0%	0	0	0%	0	0
2013	0%	0	0	0%	0	0	0%	0	0
2014	0%	0	0	0%	0	0	0%	0	0
2015	0%	0	0	0%	0	0	0%	0	0
2016	0%	0	0	0%	0	0	0%	0	0
2017	0%	0	0	0%	0	0	0%	0	0
2018	0%	0	0	0%	0	0	0%	0	0
2019	0%	0	0	0%	0	0	0%	0	0
2020	0%	0	0	0%	0	0	0%	0	0
2021	0%	0	0	0%	0	0	0%	0	0
2022	0%	0	0	0%	0	0	0%	0	0
2023	0%	0	0	0%	0	0	0%	0	0
2024	10%	2,171	4,779,835	86%	18,566	40,867,590	0%	0	0
2025	10%	2,262	5,421,301	84%	18,932	45,376,287	0%	0	0
2026	10%	2,210	5,702,550	81%	17,904	46,190,652	0%	0	0
2027	15%	3,239	8,396,467	72%	15,602	40,442,982	0%	0	0
2028	15%	2,962	8,002,355	68%	13,426	36,277,344	0%	0	0
2029	20%	3,712	10,260,841	60%	11,136	30,782,524	0%	0	0
2030	20%	3,583	10,079,515	56%	10,032	28,222,643	0%	0	0
2031	20%	2,299	6,209,013	52%	5,979	16,143,435	0%	0	0
2032	10%	586	831,861	54%	3,166	4,492,048	0%	0	0

Table A-34. NOx and GHG Tailpipe Emissions for Scenario 5 in Calendar Year 2031

Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Model Year	BEV			Tailpipe Emission Estimates[5] (tons/day)			
	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	NO_X	CO_2	CH_4	N_2O
1987	0%	0	0	0.09	8.9	0.000	0.001
1988	0%	0	0	0.13	12	0.000	0.002
1989	0%	0	0	0.16	15	0.000	0.002
1990	0%	0	0	0.15	14	0.000	0.002
1991	0%	0	0	0.14	11	0.000	0.002
1992	0%	0	0	0.11	9.2	0.000	0.001
1993	0%	0	0	0.09	7.5	0.000	0.001
1994	0%	0	0	0.08	7.6	0.000	0.001
1995	0%	0	0	0.11	10	0.000	0.002
1996	0%	0	0	0.11	10	0.000	0.002
1997	0%	0	0	0.10	9.1	0.000	0.001
1998	0%	0	0	0.10	10	0.000	0.001
1999	0%	0	0	0.17	13	0.000	0.002
2000	0%	0	0	0.20	16	0.000	0.002
2001	0%	0	0	0.20	16	0.000	0.003
2002	0%	0	0	0.21	17	0.000	0.003
2003	0%	0	0	0.13	17	0.000	0.003
2004	0%	0	0	0.12	17	0.000	0.003
2005	0%	0	0	0.15	22	0.000	0.003
2006	0%	0	0	0.18	25	0.000	0.004
2007	0%	0	0	0.22	35	0.000	0.006
2008	0%	0	0	0.14	29	0.000	0.005
2009	0%	0	0	0.15	34	0.000	0.005
2010	0%	0	0	0.07	18	0.000	0.003
2011	0%	0	0	0.05	21	0.000	0.003
2012	0%	0	0	6.3	2,125	0.004	0.33
2013	0%	0	0	5.2	1,931	0.003	0.30
2014	0%	0	0	4.9	1,993	0.004	0.31
2015	0%	0	0	8.0	3,471	0.007	0.55
2016	0%	0	0	9.1	3,866	0.010	0.61
2017	0%	0	0	9.2	4,023	0.009	0.63
2018	0%	0	0	3.8	1,588	0.004	0.25
2019	0%	0	0	4.5	1,861	0.004	0.29
2020	0%	0	0	5.4	2,255	0.005	0.35
2021	0%	0	0	6.2	2,272	0.006	0.36
2022	0%	0	0	7.5	2,835	0.007	0.45
2023	0%	0	0	12	4,261	0.010	0.67
2024	5%	977	710,226	1.2	3,809	0.01	0.60
2025	6%	1,425	1,127,756	1.3	4,239	0.01	0.67
2026	9%	1,989	1,694,660	1.2	4,330	0.01	0.68
2027	13%	2,753	2,356,604	1.2	4,075	0.01	0.64
2028	17%	3,357	2,994,653	1.1	3,695	0.009	0.58
2029	20%	3,712	3,388,083	1.0	3,425	0.009	0.54
2030	24%	4,300	3,993,852	0.87	3,196	0.008	0.50
2031	28%	3,219	2,870,263	0.47	1,865	0.004	0.29
2032	36%	2,111	988,836	0.12	444	0.002	0.07

Notes:

[1] EMFAC data shown here are adjusted by subtracting data for T7 SWCVs from corresponding data for all HHDTs as described in Appendix A. Accelerated turnover adjustments are included in calendar years 2031, 2037, 2045, and 2050 as described in Appendix A.

[2] Fleet mix percentages for each alternative HHDT technology type are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[3] Population in each model year is calculated based on the fleet mix percentages for each HHDT type and the total population in the adjusted EMFAC data.

[4] Energy consumption is calculated based on adjusted EMFAC data, using the EER for each HHDT type shown in Table A-38.

[5] Emissions from vehicles in each model year are calculated based on the fleet mix composition and the reduction in tailpipe NOx emissions achieved by each HHDT type shown in Table 3-2. Total emissions in each calendar year are calculated as the sum of tailpipe emissions across all HHDT types and all model years in each calendar year.

[6] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CA Cert. - California certified
CH_4 - methane
CO_2 - carbon dioxide
DSL - diesel
EER - energy economy ratio
EMFAC2017 - Emission Factor Model
gal - gallon
HHDT - heavy heavy duty truck
MJ - megajoule
N_2O - nitrous oxide
NG - natural gas
NO_x - oxides of nitrogen
T7 SWCV - solid waste collection vehicles
TOTEX - total exhaust

Model Year	Adjusted EMFAC2017 Output[1]						Conventional DSL		
	Population	NOx_TOTEX (tons/day)	CO2_TOTEX (tons/day)	CH4_TOTEX (tons/day)	N2O_TOTEX (tons/day)	Fuel Consumption (1000 gal/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)
1993	66	0.04	3.5	0.000	0.001	0.31	100%	66	42,043
1994	83	0.05	4.2	0.000	0.001	0.38	100%	83	50,721
1995	115	0.07	5.9	0.000	0.001	0.53	100%	115	70,970
1996	119	0.07	6.1	0.000	0.001	0.54	100%	119	72,842
1997	117	0.06	5.9	0.000	0.001	0.52	100%	117	70,488
1998	104	0.06	5.7	0.000	0.001	0.50	100%	104	67,898
1999	133	0.10	7.6	0.000	0.001	0.67	100%	133	90,610
2000	147	0.11	8.5	0.000	0.001	0.76	100%	147	101,850
2001	161	0.11	8.8	0.000	0.001	0.79	100%	161	105,603
2002	172	0.11	9.0	0.000	0.001	0.80	100%	172	107,968
2003	146	0.06	8.3	0.000	0.001	0.74	100%	146	99,226
2004	143	0.06	8.1	0.000	0.001	0.72	100%	143	96,731
2005	178	0.07	10	0.000	0.002	0.92	100%	178	123,640
2006	202	0.09	12	0.000	0.002	1.1	100%	202	143,033
2007	272	0.11	17	0.000	0.003	1.5	100%	272	200,277
2008	292	0.07	15	0.000	0.002	1.3	100%	292	179,211
2009	346	0.08	18	0.000	0.003	1.6	100%	346	213,122
2010	183	0.04	9.3	0.000	0.001	0.83	100%	183	111,727
2011	234	0.03	11	0.000	0.002	1.0	100%	234	136,809
2012	7,969	2.4	804	0.002	0.13	72	100%	7,969	9,641,296
2013	4,340	2.0	750	0.001	0.12	67	100%	4,340	8,984,556
2014	4,954	2.0	817	0.001	0.13	73	100%	4,954	9,795,650
2015	9,674	3.7	1,601	0.003	0.25	143	100%	9,674	19,190,427
2016	10,519	3.7	1,604	0.004	0.25	143	100%	10,519	19,227,562
2017	14,184	3.9	1,723	0.004	0.27	154	100%	14,184	20,654,585
2018	4,924	1.7	692	0.002	0.11	62	100%	4,924	8,290,062
2019	5,803	1.9	807	0.002	0.13	72	100%	5,803	9,667,889
2020	6,713	2.3	945	0.002	0.15	84	100%	6,713	11,329,480
2021	7,708	2.6	942	0.003	0.15	84	100%	7,708	11,285,971
2022	9,361	3.4	1,197	0.003	0.19	107	100%	9,361	14,344,235
2023	12,311	5.2	1,799	0.004	0.28	160	100%	12,311	21,557,339
2024	14,157	5.5	1,804	0.005	0.28	161	0%	0	0
2025	15,781	6.4	2,112	0.006	0.33	188	0%	0	0
2026	17,659	7.5	2,484	0.007	0.39	221	0%	0	0
2027	19,532	8.7	2,768	0.008	0.44	247	0%	0	0
2028	21,365	10	3,236	0.010	0.51	288	0%	0	0
2029	22,985	11	3,748	0.01	0.59	334	0%	0	0
2030	24,081	12	4,213	0.01	0.66	375	0%	0	0
2037	24,791	13	4,671	0.01	0.73	416	0%	0	0
2032	24,114	13	4,857	0.01	0.76	433	0%	0	0
2033	23,670	12	5,060	0.01	0.80	451	0%	0	0
2034	21,948	11	4,883	0.01	0.77	435	0%	0	0
2035	20,791	10	4,742	0.01	0.75	423	0%	0	0
2036	19,699	9.0	4,573	0.01	0.72	408	0%	0	0
2037	12,409	5.0	2,773	0.007	0.44	247	0%	0	0
2038	6,391	1.7	743	0.003	0.12	66	0%	0	0

Table A-35. NOx and GHG Tailpipe Emissions for Scenario 5 in Calendar Year 2037

	Federal Low NOx DSL			CA Cert. Low NOx DSL			Low NOx NG		
Model Year	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)
1993	0%	0	0	0%	0	0	0%	0	0
1994	0%	0	0	0%	0	0	0%	0	0
1995	0%	0	0	0%	0	0	0%	0	0
1996	0%	0	0	0%	0	0	0%	0	0
1997	0%	0	0	0%	0	0	0%	0	0
1998	0%	0	0	0%	0	0	0%	0	0
1999	0%	0	0	0%	0	0	0%	0	0
2000	0%	0	0	0%	0	0	0%	0	0
2001	0%	0	0	0%	0	0	0%	0	0
2002	0%	0	0	0%	0	0	0%	0	0
2003	0%	0	0	0%	0	0	0%	0	0
2004	0%	0	0	0%	0	0	0%	0	0
2005	0%	0	0	0%	0	0	0%	0	0
2006	0%	0	0	0%	0	0	0%	0	0
2007	0%	0	0	0%	0	0	0%	0	0
2008	0%	0	0	0%	0	0	0%	0	0
2009	0%	0	0	0%	0	0	0%	0	0
2010	0%	0	0	0%	0	0	0%	0	0
2011	0%	0	0	0%	0	0	0%	0	0
2012	0%	0	0	0%	0	0	0%	0	0
2013	0%	0	0	0%	0	0	0%	0	0
2014	0%	0	0	0%	0	0	0%	0	0
2015	0%	0	0	0%	0	0	0%	0	0
2016	0%	0	0	0%	0	0	0%	0	0
2017	0%	0	0	0%	0	0	0%	0	0
2018	0%	0	0	0%	0	0	0%	0	0
2019	0%	0	0	0%	0	0	0%	0	0
2020	0%	0	0	0%	0	0	0%	0	0
2021	0%	0	0	0%	0	0	0%	0	0
2022	0%	0	0	0%	0	0	0%	0	0
2023	0%	0	0	0%	0	0	0%	0	0
2024	10%	1,416	2,161,542	86%	12,104	18,481,185	0%	0	0
2025	10%	1,578	2,531,043	84%	13,209	21,184,827	0%	0	0
2026	10%	1,766	2,977,192	81%	14,304	24,115,258	0%	0	0
2027	15%	2,930	4,975,264	72%	14,112	23,964,188	0%	0	0
2028	15%	3,205	5,817,346	68%	14,528	26,371,967	0%	0	0
2029	20%	4,597	8,983,030	60%	13,791	26,949,090	0%	0	0
2030	20%	4,816	10,097,767	56%	13,485	28,273,746	0%	0	0
2037	12%	2,975	6,717,948	53%	13,090	29,558,969	0%	0	0
2032	10%	2,411	5,821,019	54%	13,022	31,433,503	0%	0	0
2033	10%	2,367	6,063,891	54%	12,782	32,745,011	0%	0	0
2034	10%	2,195	5,851,702	54%	11,852	31,599,191	0%	0	0
2035	12%	2,495	6,819,958	53%	10,978	30,007,813	0%	0	0
2036	12%	2,364	6,576,732	53%	10,401	28,937,620	0%	0	0
2037	12%	1,489	3,988,015	53%	6,552	17,547,268	0%	0	0
2038	12%	767	1,068,563	53%	3,375	4,701,677	0%	0	0

Table A-35. NOx and GHG Tailpipe Emissions for Scenario 5 in Calendar Year 2037

Model Year	BEV			Tailpipe Emission Estimates[5] (tons/day)			
	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	NO_X	CO_2	CH_4	N_2O
1993	0%	0	0	0.04	3.5	0.000	0.001
1994	0%	0	0	0.05	4.2	0.000	0.001
1995	0%	0	0	0.07	5.9	0.000	0.001
1996	0%	0	0	0.07	6.1	0.000	0.001
1997	0%	0	0	0.06	5.9	0.000	0.001
1998	0%	0	0	0.06	5.7	0.000	0.001
1999	0%	0	0	0.10	7.6	0.000	0.001
2000	0%	0	0	0.11	8.5	0.000	0.001
2001	0%	0	0	0.11	8.8	0.000	0.001
2002	0%	0	0	0.11	9.0	0.000	0.001
2003	0%	0	0	0.06	8.3	0.000	0.001
2004	0%	0	0	0.06	8.1	0.000	0.001
2005	0%	0	0	0.07	10	0.000	0.002
2006	0%	0	0	0.09	12	0.000	0.002
2007	0%	0	0	0.11	17	0.000	0.003
2008	0%	0	0	0.07	15	0.000	0.002
2009	0%	0	0	0.08	18	0.000	0.003
2010	0%	0	0	0.04	9.3	0.000	0.001
2011	0%	0	0	0.03	11	0.000	0.002
2012	0%	0	0	2.4	804	0.002	0.13
2013	0%	0	0	2.0	750	0.001	0.12
2014	0%	0	0	2.0	817	0.001	0.13
2015	0%	0	0	3.7	1,601	0.003	0.25
2016	0%	0	0	3.7	1,604	0.004	0.25
2017	0%	0	0	3.9	1,723	0.004	0.27
2018	0%	0	0	1.7	692	0.002	0.11
2019	0%	0	0	1.9	807	0.002	0.13
2020	0%	0	0	2.3	945	0.002	0.15
2021	0%	0	0	2.6	942	0.003	0.15
2022	0%	0	0	3.4	1,197	0.003	0.19
2023	0%	0	0	5.2	1,799	0.004	0.28
2024	5%	637	321,179	0.61	1,722	0.005	0.27
2025	6%	994	526,515	0.70	1,979	0.006	0.31
2026	9%	1,589	884,750	0.80	2,261	0.007	0.36
2027	13%	2,490	1,396,388	1.0	2,415	0.007	0.38
2028	17%	3,632	2,176,976	1.1	2,686	0.008	0.42
2029	20%	4,597	2,966,155	1.2	2,998	0.009	0.47
2030	24%	5,779	4,001,083	1.3	3,202	0.009	0.50
2037	35%	8,727	6,506,824	1.1	3,027	0.008	0.48
2032	36%	8,681	6,919,465	1.0	3,109	0.009	0.49
2033	36%	8,521	7,208,168	1.0	3,238	0.008	0.51
2034	36%	7,901	6,955,938	0.88	3,125	0.008	0.49
2035	35%	7,318	6,605,628	0.83	3,073	0.008	0.48
2036	35%	6,934	6,370,046	0.74	2,963	0.007	0.47
2037	35%	4,368	3,862,685	0.41	1,797	0.004	0.28
2038	35%	2,250	1,034,981	0.14	481	0.002	0.08

Notes:

[1] EMFAC data shown here are adjusted by subtracting data for T7 SWCVs from corresponding data for all HHDTs as described in Appendix A. Accelerated turnover adjustments are included in calendar years 2031, 2037, 2045, and 2050 as described in Appendix A.

[2] Fleet mix percentages for each alternative HHDT technology type are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[3] Population in each model year is calculated based on the fleet mix percentages for each HHDT type and the total population in the adjusted EMFAC data.

[4] Energy consumption is calculated based on adjusted EMFAC data, using the EER for each HHDT type shown in Table A-38.

[5] Emissions from vehicles in each model year are calculated based on the fleet mix composition and the reduction in tailpipe NOx emissions achieved by each HHDT type shown in Table 3-2. Total emissions in each calendar year are calculated as the sum of tailpipe emissions across all HHDT types and all model years in each calendar year.

[6] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CA Cert. - California certified
CH_4 - methane
CO_2 - carbon dioxide
DSL - diesel
EER - energy economy ratio
EMFAC2017 - Emission Factor Model
gal - gallon
HHDT - heavy heavy duty truck
MJ - megajoule
N_2O - nitrous oxide
NG - natural gas
NO_x - oxides of nitrogen
T7 SWCV - solid waste collection vehicles
TOTEX - total exhaust

Table A-36. NOx and GHG Tailpipe Emissions for Scenario 5 in Calendar Year 2045

Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

	Adjusted EMFAC2017 Output[1]						Conventional DSL		
Model Year	Population	NOx_TOTEX (tons/day)	CO2_TOTEX (tons/day)	CH4_TOTEX (tons/day)	N2O_TOTEX (tons/day)	Fuel Consumption (1000 gal/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)
2001	0	0	0	0	0	0	0%	0	0
2002	0	0	0	0	0	0	0%	0	0
2003	0	0	0	0	0	0	0%	0	0
2004	0	0	0	0	0	0	0%	0	0
2005	0	0	0	0	0	0	0%	0	0
2006	0	0	0	0	0	0	0%	0	0
2007	0	0	0	0	0	0	0%	0	0
2008	0	0	0	0	0	0	0%	0	0
2009	0	0	0	0	0	0	0%	0	0
2010	0	0	0	0	0	0	0%	0	0
2011	0	0	0	0	0	0	0%	0	0
2012	0	0	0	0	0	0	0%	0	0
2013	0	0	0	0	0	0	0%	0	0
2014	0	0	0	0	0	0	0%	0	0
2015	0	0	0	0	0	0	0%	0	0
2016	0	0	0	0	0	0	0%	0	0
2017	0	0	0	0	0	0	0%	0	0
2018	0	0	0	0	0	0	0%	0	0
2019	0	0	0	0	0	0	0%	0	0
2020	0	0	0	0	0	0	0%	0	0
2021	0	0	0	0	0	0	0%	0	0
2022	0	0	0	0	0	0	0%	0	0
2023	0	0	0	0	0	0	0%	0	0
2024	5,738	1.9	631	0.002	0.10	56	0%	0	0
2025	6,682	2.2	740	0.002	0.12	66	0%	0	0
2026	7,830	2.6	869	0.002	0.14	77	0%	0	0
2027	8,960	3.0	954	0.003	0.15	85	0%	0	0
2028	10,297	3.5	1,096	0.003	0.17	98	0%	0	0
2029	11,921	4.1	1,276	0.004	0.20	114	0%	0	0
2030	13,807	4.8	1,488	0.005	0.23	133	0%	0	0
2045	15,655	5.9	1,819	0.006	0.29	162	0%	0	0
2032	17,813	7.1	2,196	0.007	0.35	196	0%	0	0
2033	20,003	8.3	2,581	0.008	0.41	230	0%	0	0
2034	22,623	10	3,067	0.009	0.48	273	0%	0	0
2035	24,976	11	3,584	0.01	0.56	319	0%	0	0
2036	26,967	13	4,118	0.01	0.65	367	0%	0	0
2037	28,599	14	4,677	0.01	0.74	417	0%	0	0
2038	29,556	15	5,172	0.01	0.81	461	0%	0	0
2039	30,085	16	5,646	0.02	0.89	503	0%	0	0
2040	28,520	15	5,685	0.02	0.89	507	0%	0	0
2041	27,485	14	5,816	0.02	0.91	518	0%	0	0
2042	24,780	12	5,446	0.01	0.86	485	0%	0	0
2043	23,286	11	5,243	0.01	0.82	467	0%	0	0
2044	22,012	10	5,025	0.01	0.79	448	0%	0	0
2045	13,831	5.5	3,030	0.007	0.48	270	0%	0	0
2046	7,111	1.9	812	0.004	0.13	72	0%	0	0

Table A-36. NOx and GHG Tailpipe Emissions for Scenario 5 in Calendar Year 2045

Model Year	Federal Low NOx DSL			CA Cert. Low NOx DSL			Low NOx NG		
	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)
2001	0%	0	0	0%	0	0	0%	0	0
2002	0%	0	0	0%	0	0	0%	0	0
2003	0%	0	0	0%	0	0	0%	0	0
2004	0%	0	0	0%	0	0	0%	0	0
2005	0%	0	0	0%	0	0	0%	0	0
2006	0%	0	0	0%	0	0	0%	0	0
2007	0%	0	0	0%	0	0	0%	0	0
2008	0%	0	0	0%	0	0	0%	0	0
2009	0%	0	0	0%	0	0	0%	0	0
2010	0%	0	0	0%	0	0	0%	0	0
2011	0%	0	0	0%	0	0	0%	0	0
2012	0%	0	0	0%	0	0	0%	0	0
2013	0%	0	0	0%	0	0	0%	0	0
2014	0%	0	0	0%	0	0	0%	0	0
2015	0%	0	0	0%	0	0	0%	0	0
2016	0%	0	0	0%	0	0	0%	0	0
2017	0%	0	0	0%	0	0	0%	0	0
2018	0%	0	0	0%	0	0	0%	0	0
2019	0%	0	0	0%	0	0	0%	0	0
2020	0%	0	0	0%	0	0	0%	0	0
2021	0%	0	0	0%	0	0	0%	0	0
2022	0%	0	0	0%	0	0	0%	0	0
2023	0%	0	0	0%	0	0	0%	0	0
2024	10%	574	756,340	86%	4,906	6,466,708	0%	0	0
2025	10%	668	886,781	84%	5,593	7,422,360	0%	0	0
2026	10%	783	1,041,761	81%	6,343	8,438,266	0%	0	0
2027	15%	1,344	1,715,605	72%	6,474	8,263,496	0%	0	0
2028	15%	1,544	1,969,828	68%	7,002	8,929,888	0%	0	0
2029	20%	2,384	3,059,507	60%	7,152	9,178,520	0%	0	0
2030	20%	2,761	3,566,433	56%	7,732	9,986,012	0%	0	0
2045	12%	1,879	2,615,706	53%	8,266	11,509,105	0%	0	0
2032	10%	1,781	2,631,722	54%	9,619	14,211,299	0%	0	0
2033	10%	2,000	3,093,484	54%	10,802	16,704,815	0%	0	0
2034	10%	2,262	3,676,051	54%	12,217	19,850,678	0%	0	0
2035	12%	2,997	5,154,227	53%	13,188	22,678,598	0%	0	0
2036	12%	3,236	5,922,773	53%	14,239	26,060,201	0%	0	0
2037	12%	3,432	6,725,482	53%	15,100	29,592,121	0%	0	0
2038	12%	3,547	7,438,400	53%	15,606	32,728,962	0%	0	0
2039	12%	3,610	8,118,998	53%	15,885	35,723,589	0%	0	0
2040	12%	3,422	8,176,299	53%	15,058	35,975,717	0%	0	0
2041	12%	3,298	8,363,731	53%	14,512	36,800,417	0%	0	0
2042	12%	2,974	7,831,788	53%	13,084	34,459,867	0%	0	0
2043	12%	2,794	7,539,421	53%	12,295	33,173,453	0%	0	0
2044	12%	2,641	7,227,079	53%	11,622	31,799,149	0%	0	0
2045	12%	1,660	4,357,601	53%	7,303	19,173,446	0%	0	0
2046	12%	853	1,167,185	53%	3,755	5,135,614	0%	0	0

Table A-36. NOx and GHG Tailpipe Emissions for Scenario 5 in Calendar Year 2045

	BEV			**Tailpipe Emission Estimates[5] (tons/day)**			
Model Year	**Fleet Mix[2] (%)**	**Population[3]**	**Energy Consumption[4] (MJ/day)**	**NO_X**	**CO_2**	**CH_4**	**N_2O**
2001	0%	0	0	0	0	0	0
2002	0%	0	0	0	0	0	0
2003	0%	0	0	0	0	0	0
2004	0%	0	0	0	0	0	0
2005	0%	0	0	0	0	0	0
2006	0%	0	0	0	0	0	0
2007	0%	0	0	0	0	0	0
2008	0%	0	0	0	0	0	0
2009	0%	0	0	0	0	0	0
2010	0%	0	0	0	0	0	0
2011	0%	0	0	0	0	0	0
2012	0%	0	0	0	0	0	0
2013	0%	0	0	0	0	0	0
2014	0%	0	0	0	0	0	0
2015	0%	0	0	0	0	0	0
2016	0%	0	0	0	0	0	0
2017	0%	0	0	0	0	0	0
2018	0%	0	0	0	0	0	0
2019	0%	0	0	0	0	0	0
2020	0%	0	0	0	0	0	0
2021	0%	0	0	0	0	0	0
2022	0%	0	0	0	0	0	0
2023	0%	0	0	0	0	0	0
2024	5%	258	112,383	0.21	603	0.002	0.09
2025	6%	421	184,471	0.24	693	0.002	0.11
2026	9%	705	309,586	0.28	791	0.002	0.12
2027	13%	1,142	481,512	0.33	833	0.002	0.13
2028	17%	1,750	737,152	0.37	909	0.003	0.14
2029	20%	2,384	1,010,235	0.45	1,021	0.003	0.16
2030	24%	3,314	1,413,144	0.51	1,131	0.003	0.18
2045	35%	5,511	2,533,502	0.49	1,179	0.004	0.19
2032	36%	6,413	3,128,337	0.56	1,405	0.004	0.22
2033	36%	7,201	3,677,235	0.66	1,652	0.005	0.26
2034	36%	8,144	4,369,735	0.78	1,963	0.006	0.31
2035	35%	8,792	4,992,246	0.94	2,322	0.007	0.37
2036	35%	9,493	5,736,639	1.1	2,669	0.008	0.42
2037	35%	10,067	6,514,121	1.2	3,030	0.009	0.48
2038	35%	10,404	7,204,635	1.2	3,352	0.009	0.53
2039	35%	10,590	7,863,843	1.3	3,658	0.01	0.58
2040	35%	10,039	7,919,344	1.2	3,684	0.01	0.58
2041	35%	9,675	8,100,885	1.2	3,769	0.010	0.59
2042	35%	8,723	7,585,660	1.0	3,529	0.009	0.55
2043	35%	8,197	7,302,481	0.92	3,397	0.008	0.53
2044	35%	7,748	6,999,955	0.82	3,256	0.008	0.51
2045	35%	4,869	4,220,656	0.45	1,963	0.005	0.31
2046	35%	2,503	1,130,504	0.15	526	0.002	0.08

Notes:

[1] EMFAC data shown here are adjusted by subtracting data for T7 SWCVs from corresponding data for all HHDTs as described in Appendix A. Accelerated turnover adjustments are included in calendar years 2031, 2037, 2045, and 2050 as described in Appendix A.

[2] Fleet mix percentages for each alternative HHDT technology type are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[3] Population in each model year is calculated based on the fleet mix percentages for each HHDT type and the total population in the adjusted EMFAC data.

[4] Energy consumption is calculated based on adjusted EMFAC data, using the EER for each HHDT type shown in Table A-38.

[5] Emissions from vehicles in each model year are calculated based on the fleet mix composition and the reduction in tailpipe NOx emissions achieved by each HHDT type shown in Table 3-2. Total emissions in each calendar year are calculated as the sum of tailpipe emissions across all HHDT types and all model years in each calendar year.

[6] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CA Cert. - California certified
CH_4 - methane
CO_2 - carbon dioxide
DSL - diesel
EER - energy economy ratio
EMFAC2017 - Emission Factor Model
gal - gallon
HHDT - heavy heavy duty truck
MJ - megajoule
N_2O - nitrous oxide
NG - natural gas
NO_x - oxides of nitrogen
T7 SWCV - solid waste collection vehicles
TOTEX - total exhaust

Table A-37. NOx and GHG Tailpipe Emissions for Scenario 5 in Calendar Year 2050

	Adjusted EMFAC2017 Output[1]						Conventional DSL		
Model Year	Population	NOx_TOTEX (tons/day)	CO2_TOTEX (tons/day)	CH4_TOTEX (tons/day)	N2O_TOTEX (tons/day)	Fuel Consumption (1000 gal/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)
2006	0	0	0	0	0	0	0%	0	0
2007	0	0	0	0	0	0	0%	0	0
2008	0	0	0	0	0	0	0%	0	0
2009	0	0	0	0	0	0	0%	0	0
2010	0	0	0	0	0	0	0%	0	0
2011	0	0	0	0	0	0	0%	0	0
2012	0	0	0	0	0	0	0%	0	0
2013	0	0	0	0	0	0	0%	0	0
2014	0	0	0	0	0	0	0%	0	0
2015	0	0	0	0	0	0	0%	0	0
2016	0	0	0	0	0	0	0%	0	0
2017	0	0	0	0	0	0	0%	0	0
2018	0	0	0	0	0	0	0%	0	0
2019	0	0	0	0	0	0	0%	0	0
2020	0	0	0	0	0	0	0%	0	0
2021	0	0	0	0	0	0	0%	0	0
2022	0	0	0	0	0	0	0%	0	0
2023	0	0	0	0	0	0	0%	0	0
2024	2,595	0.86	281	0.001	0.04	25	0%	0	0
2025	3,028	1.0	330	0.001	0.05	29	0%	0	0
2026	3,626	1.2	393	0.001	0.06	35	0%	0	0
2027	4,257	1.4	439	0.001	0.07	39	0%	0	0
2028	5,060	1.7	526	0.001	0.08	47	0%	0	0
2029	6,031	2.0	632	0.002	0.10	56	0%	0	0
2030	7,066	2.4	743	0.002	0.12	66	0%	0	0
2050	8,217	2.8	872	0.003	0.14	78	0%	0	0
2032	9,494	3.2	1,017	0.003	0.16	91	0%	0	0
2033	11,004	3.8	1,176	0.004	0.18	105	0%	0	0
2034	12,911	4.5	1,386	0.004	0.22	124	0%	0	0
2035	14,935	5.3	1,619	0.005	0.25	144	0%	0	0
2036	16,783	6.4	1,962	0.006	0.31	175	0%	0	0
2037	18,732	7.5	2,328	0.007	0.37	208	0%	0	0
2038	20,725	8.7	2,699	0.008	0.42	241	0%	0	0
2039	22,925	10	3,137	0.009	0.49	280	0%	0	0
2040	25,074	11	3,619	0.01	0.57	323	0%	0	0
2041	27,099	13	4,155	0.01	0.65	370	0%	0	0
2042	28,740	14	4,704	0.01	0.74	419	0%	0	0
2043	29,658	15	5,184	0.01	0.81	462	0%	0	0
2044	30,119	16	5,634	0.02	0.89	502	0%	0	0
2045	28,407	15	5,643	0.02	0.89	503	0%	0	0
2046	27,387	14	5,770	0.02	0.91	514	0%	0	0
2047	24,660	12	5,397	0.01	0.85	481	0%	0	0
2048	23,198	11	5,206	0.01	0.82	464	0%	0	0
2049	21,872	10	4,978	0.01	0.78	444	0%	0	0
2050	13,695	5.4	2,992	0.007	0.47	267	0%	0	0
2051	7,053	1.8	1,226	0.004	0.19	109	0%	0	0

Model Year	Federal Low NOx DSL Fleet Mix[2] (%)	Federal Low NOx DSL Population[3]	Federal Low NOx DSL Energy Consumption[4] (MJ/day)	CA Cert. Low NOx DSL Fleet Mix[2] (%)	CA Cert. Low NOx DSL Population[3]	CA Cert. Low NOx DSL Energy Consumption[4] (MJ/day)	Low NOx NG Fleet Mix[2] (%)	Low NOx NG Population[3]	Low NOx NG Energy Consumption[4] (MJ/day)
2006	0%	0	0	0%	0	0	0%	0	0
2007	0%	0	0	0%	0	0	0%	0	0
2008	0%	0	0	0%	0	0	0%	0	0
2009	0%	0	0	0%	0	0	0%	0	0
2010	0%	0	0	0%	0	0	0%	0	0
2011	0%	0	0	0%	0	0	0%	0	0
2012	0%	0	0	0%	0	0	0%	0	0
2013	0%	0	0	0%	0	0	0%	0	0
2014	0%	0	0	0%	0	0	0%	0	0
2015	0%	0	0	0%	0	0	0%	0	0
2016	0%	0	0	0%	0	0	0%	0	0
2017	0%	0	0	0%	0	0	0%	0	0
2018	0%	0	0	0%	0	0	0%	0	0
2019	0%	0	0	0%	0	0	0%	0	0
2020	0%	0	0	0%	0	0	0%	0	0
2021	0%	0	0	0%	0	0	0%	0	0
2022	0%	0	0	0%	0	0	0%	0	0
2023	0%	0	0	0%	0	0	0%	0	0
2024	10%	260	337,270	86%	2,219	2,883,660	0%	0	0
2025	10%	303	395,918	84%	2,534	3,313,832	0%	0	0
2026	10%	363	471,136	81%	2,937	3,816,203	0%	0	0
2027	15%	639	789,915	72%	3,076	3,804,757	0%	0	0
2028	15%	759	945,969	68%	3,441	4,288,394	0%	0	0
2029	20%	1,206	1,514,257	60%	3,619	4,542,772	0%	0	0
2030	20%	1,413	1,780,183	56%	3,957	4,984,512	0%	0	0
2050	12%	986	1,253,331	53%	4,339	5,514,655	0%	0	0
2032	10%	949	1,218,218	54%	5,127	6,578,377	0%	0	0
2033	10%	1,100	1,409,784	54%	5,942	7,612,831	0%	0	0
2034	10%	1,291	1,660,800	54%	6,972	8,968,320	0%	0	0
2035	12%	1,792	2,327,866	53%	7,885	10,242,611	0%	0	0
2036	12%	2,014	2,822,001	53%	8,861	12,416,805	0%	0	0
2037	12%	2,248	3,348,517	53%	9,890	14,733,474	0%	0	0
2038	12%	2,487	3,881,574	53%	10,943	17,078,926	0%	0	0
2039	12%	2,751	4,511,626	53%	12,105	19,851,155	0%	0	0
2040	12%	3,009	5,204,512	53%	13,239	22,899,854	0%	0	0
2041	12%	3,252	5,974,789	53%	14,308	26,289,072	0%	0	0
2042	12%	3,449	6,765,245	53%	15,175	29,767,079	0%	0	0
2043	12%	3,559	7,455,772	53%	15,660	32,805,395	0%	0	0
2044	12%	3,614	8,101,789	53%	15,903	35,647,870	0%	0	0
2045	12%	3,409	8,115,025	53%	14,999	35,706,110	0%	0	0
2046	12%	3,286	8,297,953	53%	14,461	36,510,994	0%	0	0
2047	12%	2,959	7,761,898	53%	13,021	34,152,353	0%	0	0
2048	12%	2,784	7,487,127	53%	12,249	32,943,359	0%	0	0
2049	12%	2,625	7,158,856	53%	11,549	31,498,966	0%	0	0
2050	12%	1,643	4,302,930	53%	7,231	18,932,893	0%	0	0
2051	12%	846	1,763,371	53%	3,724	7,758,831	0%	0	0

Table A-37. NOx and GHG Tailpipe Emissions for Scenario 5 in Calendar Year 2050

	BEV			Tailpipe Emission Estimates[5] (tons/day)			
Model Year	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	NO_X	CO_2	CH_4	N_2O
2006	0%	0	0	0	0	0	0
2007	0%	0	0	0	0	0	0
2008	0%	0	0	0	0	0	0
2009	0%	0	0	0	0	0	0
2010	0%	0	0	0	0	0	0
2011	0%	0	0	0	0	0	0
2012	0%	0	0	0	0	0	0
2013	0%	0	0	0	0	0	0
2014	0%	0	0	0	0	0	0
2015	0%	0	0	0	0	0	0
2016	0%	0	0	0	0	0	0
2017	0%	0	0	0	0	0	0
2018	0%	0	0	0	0	0	0
2019	0%	0	0	0	0	0	0
2020	0%	0	0	0	0	0	0
2021	0%	0	0	0	0	0	0
2022	0%	0	0	0	0	0	0
2023	0%	0	0	0	0	0	0
2024	5%	117	50,114	0.10	269	0.001	0.04
2025	6%	191	82,360	0.11	310	0.001	0.05
2026	9%	326	140,010	0.13	358	0.001	0.06
2027	13%	543	221,702	0.15	383	0.001	0.06
2028	17%	860	354,002	0.18	437	0.001	0.07
2029	20%	1,206	500,001	0.22	505	0.001	0.08
2030	24%	1,696	705,370	0.25	564	0.002	0.09
2050	35%	2,892	1,213,943	0.23	565	0.002	0.09
2032	36%	3,418	1,448,100	0.26	651	0.002	0.10
2033	36%	3,961	1,675,814	0.30	753	0.002	0.12
2034	36%	4,648	1,974,199	0.35	887	0.003	0.14
2035	35%	5,257	2,254,709	0.44	1,049	0.003	0.16
2036	35%	5,907	2,733,315	0.53	1,272	0.004	0.20
2037	35%	6,594	3,243,284	0.62	1,509	0.005	0.24
2038	35%	7,295	3,759,589	0.72	1,749	0.005	0.27
2039	35%	8,070	4,369,840	0.84	2,033	0.006	0.32
2040	35%	8,826	5,040,951	1.0	2,345	0.007	0.37
2041	35%	9,539	5,787,020	1.1	2,692	0.008	0.42
2042	35%	10,117	6,552,635	1.2	3,048	0.009	0.48
2043	35%	10,440	7,221,460	1.3	3,359	0.009	0.53
2044	35%	10,602	7,847,175	1.3	3,651	0.01	0.57
2045	35%	9,999	7,859,995	1.2	3,657	0.01	0.57
2046	35%	9,640	8,037,175	1.2	3,739	0.010	0.59
2047	35%	8,680	7,517,967	1.0	3,497	0.009	0.55
2048	35%	8,166	7,251,830	0.91	3,374	0.008	0.53
2049	35%	7,699	6,933,876	0.81	3,226	0.008	0.51
2050	35%	4,821	4,167,703	0.45	1,939	0.005	0.30
2051	35%	2,483	1,707,953	0.15	795	0.002	0.12

Notes:

[1] EMFAC data shown here are adjusted by subtracting data for T7 SWCVs from corresponding data for all HHDTs as described in Appendix A. Accelerated turnover adjustments are included in calendar years 2031, 2037, 2045, and 2050 as described in Appendix A.

[2] Fleet mix percentages for each alternative HHDT technology type are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[3] Population in each model year is calculated based on the fleet mix percentages for each HHDT type and the total population in the adjusted EMFAC data.

[4] Energy consumption is calculated based on adjusted EMFAC data, using the EER for each HHDT type shown in Table A-38.

[5] Emissions from vehicles in each model year are calculated based on the fleet mix composition and the reduction in tailpipe NOx emissions achieved by each HHDT type shown in Table 3-2. Total emissions in each calendar year are calculated as the sum of tailpipe emissions across all HHDT types and all model years in each calendar year.

[6] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CA Cert. - California certified
CH_4 - methane
CO_2 - carbon dioxide
DSL - diesel
EER - energy economy ratio
EMFAC2017 - Emission Factor Model
gal - gallon
HHDT - heavy heavy duty truck
MJ - megajoule
N_2O - nitrous oxide
NG - natural gas
NO_x - oxides of nitrogen
T7 SWCV - solid waste collection vehicles
TOTEX - total exhaust

Table A-38. NOx and GHG Tailpipe Emissions for Scenario 6 in Calendar Year 2020

	Adjusted EMFAC2017 Output[1]						Conventional DSL		
Model Year	**Population**	**NOx_TOTEX (tons/day)**	**CO2_TOTEX (tons/day)**	**CH4_TOTEX (tons/day)**	**N2O_TOTEX (tons/day)**	**Fuel Consumption (1000 gal/day)**	**Fleet Mix[2] (%)**	**Population[3]**	**Energy Consumption[4] (MJ/day)**
1976	29	0.02	1.7	0.000	0.000	0.15	100%	29	19,871
1977	34	0.02	2.3	0.000	0.000	0.20	100%	34	27,331
1978	66	0.04	3.9	0.000	0.001	0.35	100%	66	47,207
1979	94	0.05	5.0	0.000	0.001	0.44	100%	94	59,761
1980	87	0.05	5.1	0.000	0.001	0.45	100%	87	61,143
1981	258	0.15	15	0.000	0.002	1.3	100%	258	180,361
1982	236	0.13	13	0.000	0.002	1.2	100%	236	156,209
1983	219	0.13	13	0.000	0.002	1.1	100%	219	151,257
1984	274	0.18	18	0.000	0.003	1.6	100%	274	214,575
1985	404	0.25	25	0.000	0.004	2.2	100%	404	301,188
1986	396	0.25	25	0.000	0.004	2.2	100%	396	301,092
1987	426	0.29	27	0.000	0.004	2.4	100%	426	324,223
1988	484	0.34	32	0.000	0.005	2.9	100%	484	387,591
1989	567	0.40	38	0.000	0.006	3.4	100%	567	454,438
1990	539	0.39	37	0.000	0.006	3.3	100%	539	446,862
1991	475	0.34	28	0.000	0.004	2.5	100%	475	335,098
1992	399	0.31	25	0.000	0.004	2.2	100%	399	301,877
1993	363	0.29	25	0.000	0.004	2.2	100%	363	295,585
1994	379	0.31	28	0.000	0.004	2.5	100%	379	330,512
1995	507	0.41	37	0.000	0.006	3.3	100%	507	443,837
1996	1,142	1.8	150	0.006	0.02	13	100%	1,142	1,800,897
1997	1,167	1.8	149	0.006	0.02	13	100%	1,167	1,790,241
1998	1,370	2.2	192	0.008	0.03	17	100%	1,370	2,305,455
1999	1,972	4.1	291	0.01	0.05	26	100%	1,972	3,484,066
2000	4,067	9.0	641	0.02	0.10	57	100%	4,067	7,683,603
2001	3,153	6.6	476	0.02	0.07	42	100%	3,153	5,706,180
2002	2,427	4.6	338	0.01	0.05	30	100%	2,427	4,046,083
2003	2,907	3.5	425	0.01	0.07	38	100%	2,907	5,088,912
2004	2,913	3.0	421	0.01	0.07	38	100%	2,913	5,047,803
2005	4,812	5.1	719	0.02	0.11	64	100%	4,812	8,613,212
2006	5,968	6.9	972	0.03	0.15	87	100%	5,968	11,650,876
2007	8,303	9.5	1,454	0.03	0.23	130	100%	8,303	17,419,576
2008	12,274	13	2,417	0.02	0.38	215	100%	12,274	28,960,284
2009	14,354	16	3,080	0.03	0.48	275	100%	14,354	36,913,677
2010	11,383	13	2,653	0.02	0.42	236	100%	11,383	31,795,323
2011	13,627	10	3,166	0.01	0.50	282	100%	13,627	37,940,166
2012	39,297	19	6,724	0.01	1.1	599	100%	39,297	80,581,115
2013	21,084	14	5,397	0.010	0.85	481	100%	21,084	64,680,893
2014	23,061	12	5,525	0.01	0.87	492	100%	23,061	66,207,976
2015	28,916	14	7,779	0.02	1.2	693	100%	28,916	93,222,050
2016	41,998	22	12,488	0.02	2.0	1,113	100%	41,998	149,658,452
2017	16,101	6.6	3,944	0.008	0.62	351	100%	16,101	47,265,405
2018	12,688	5.9	3,720	0.007	0.58	332	100%	12,688	44,579,225
2019	12,851	5.6	3,844	0.007	0.60	343	100%	12,851	46,069,473
2020	8,537	3.3	2,461	0.004	0.39	219	100%	8,537	29,496,897
2021	4,246	1.1	575	0.002	0.09	51	100%	4,246	6,891,960

	Federal Low NOx DSL			**CA Cert. Low NOx DSL**			**Low NOx NG**		
Model Year	**Fleet Mix[2] (%)**	**Population[3]**	**Energy Consumption[4] (MJ/day)**	**Fleet Mix[2] (%)**	**Population[3]**	**Energy Consumption[4] (MJ/day)**	**Fleet Mix[2] (%)**	**Population[3]**	**Energy Consumption[4] (MJ/day)**
1976	0%	0	0	0%	0	0	0%	0	0
1977	0%	0	0	0%	0	0	0%	0	0
1978	0%	0	0	0%	0	0	0%	0	0
1979	0%	0	0	0%	0	0	0%	0	0
1980	0%	0	0	0%	0	0	0%	0	0
1981	0%	0	0	0%	0	0	0%	0	0
1982	0%	0	0	0%	0	0	0%	0	0
1983	0%	0	0	0%	0	0	0%	0	0
1984	0%	0	0	0%	0	0	0%	0	0
1985	0%	0	0	0%	0	0	0%	0	0
1986	0%	0	0	0%	0	0	0%	0	0
1987	0%	0	0	0%	0	0	0%	0	0
1988	0%	0	0	0%	0	0	0%	0	0
1989	0%	0	0	0%	0	0	0%	0	0
1990	0%	0	0	0%	0	0	0%	0	0
1991	0%	0	0	0%	0	0	0%	0	0
1992	0%	0	0	0%	0	0	0%	0	0
1993	0%	0	0	0%	0	0	0%	0	0
1994	0%	0	0	0%	0	0	0%	0	0
1995	0%	0	0	0%	0	0	0%	0	0
1996	0%	0	0	0%	0	0	0%	0	0
1997	0%	0	0	0%	0	0	0%	0	0
1998	0%	0	0	0%	0	0	0%	0	0
1999	0%	0	0	0%	0	0	0%	0	0
2000	0%	0	0	0%	0	0	0%	0	0
2001	0%	0	0	0%	0	0	0%	0	0
2002	0%	0	0	0%	0	0	0%	0	0
2003	0%	0	0	0%	0	0	0%	0	0
2004	0%	0	0	0%	0	0	0%	0	0
2005	0%	0	0	0%	0	0	0%	0	0
2006	0%	0	0	0%	0	0	0%	0	0
2007	0%	0	0	0%	0	0	0%	0	0
2008	0%	0	0	0%	0	0	0%	0	0
2009	0%	0	0	0%	0	0	0%	0	0
2010	0%	0	0	0%	0	0	0%	0	0
2011	0%	0	0	0%	0	0	0%	0	0
2012	0%	0	0	0%	0	0	0%	0	0
2013	0%	0	0	0%	0	0	0%	0	0
2014	0%	0	0	0%	0	0	0%	0	0
2015	0%	0	0	0%	0	0	0%	0	0
2016	0%	0	0	0%	0	0	0%	0	0
2017	0%	0	0	0%	0	0	0%	0	0
2018	0%	0	0	0%	0	0	0%	0	0
2019	0%	0	0	0%	0	0	0%	0	0
2020	0%	0	0	0%	0	0	0%	0	0
2021	0%	0	0	0%	0	0	0%	0	0

Table A-38. NOx and GHG Tailpipe Emissions for Scenario 6 in Calendar Year 2020

	BEV			Tailpipe Emission Estimates[5] (tons/day)			
Model Year	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	NO_X	CO_2	CH_4	N_2O
1976	0%	0	0	0.02	1.7	0.000	0.000
1977	0%	0	0	0.02	2.3	0.000	0.000
1978	0%	0	0	0.04	3.9	0.000	0.001
1979	0%	0	0	0.05	5.0	0.000	0.001
1980	0%	0	0	0.05	5.1	0.000	0.001
1981	0%	0	0	0.15	15	0.000	0.002
1982	0%	0	0	0.13	13	0.000	0.002
1983	0%	0	0	0.13	13	0.000	0.002
1984	0%	0	0	0.18	18	0.000	0.003
1985	0%	0	0	0.25	25	0.000	0.004
1986	0%	0	0	0.25	25	0.000	0.004
1987	0%	0	0	0.29	27	0.000	0.004
1988	0%	0	0	0.34	32	0.000	0.005
1989	0%	0	0	0.40	38	0.000	0.006
1990	0%	0	0	0.39	37	0.000	0.006
1991	0%	0	0	0.34	28	0.000	0.004
1992	0%	0	0	0.31	25	0.000	0.004
1993	0%	0	0	0.29	25	0.000	0.004
1994	0%	0	0	0.31	28	0.000	0.004
1995	0%	0	0	0.41	37	0.000	0.006
1996	0%	0	0	1.8	150	0.006	0.02
1997	0%	0	0	1.8	149	0.006	0.02
1998	0%	0	0	2.2	192	0.008	0.03
1999	0%	0	0	4.1	291	0.01	0.05
2000	0%	0	0	9.0	641	0.02	0.10
2001	0%	0	0	6.6	476	0.02	0.07
2002	0%	0	0	4.6	338	0.01	0.05
2003	0%	0	0	3.5	425	0.01	0.07
2004	0%	0	0	3.0	421	0.01	0.07
2005	0%	0	0	5.1	719	0.02	0.11
2006	0%	0	0	6.9	972	0.03	0.15
2007	0%	0	0	9.5	1,454	0.03	0.23
2008	0%	0	0	13	2,417	0.02	0.38
2009	0%	0	0	16	3,080	0.03	0.48
2010	0%	0	0	13	2,653	0.02	0.42
2011	0%	0	0	10	3,166	0.01	0.50
2012	0%	0	0	19	6,724	0.01	1.1
2013	0%	0	0	14	5,397	0.010	0.85
2014	0%	0	0	12	5,525	0.01	0.87
2015	0%	0	0	14	7,779	0.02	1.2
2016	0%	0	0	22	12,488	0.02	2.0
2017	0%	0	0	6.6	3,944	0.008	0.62
2018	0%	0	0	5.9	3,720	0.007	0.58
2019	0%	0	0	5.6	3,844	0.007	0.60
2020	0%	0	0	3.3	2,461	0.004	0.39
2021	0%	0	0	1.1	575	0.002	0.09

Notes:

[1] EMFAC data shown here are adjusted by subtracting data for T7 SWCVs from corresponding data for all HHDTs as described in Appendix A. Accelerated turnover adjustments are included in calendar years 2031, 2037, 2045, and 2050 as described in Appendix A.

[2] Fleet mix percentages for each alternative HHDT technology type are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[3] Population in each model year is calculated based on the fleet mix percentages for each HHDT type and the total population in the adjusted EMFAC data.

[4] Energy consumption is calculated based on adjusted EMFAC data, using the EER for each HHDT type shown in Table A-38.

[5] Emissions from vehicles in each model year are calculated based on the fleet mix composition and the reduction in tailpipe NOx emissions achieved by each HHDT type shown in Table 3-2. Total emissions in each calendar year are calculated as the sum of tailpipe emissions across all HHDT types and all model years in each calendar year.

[6] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CA Cert. - California certified
CH_4 - methane
CO_2 - carbon dioxide
DSL - diesel
EER - energy economy ratio
EMFAC2017 - Emission Factor Model
gal - gallon
HHDT - heavy heavy duty truck
MJ - megajoule
N_2O - nitrous oxide
NG - natural gas
NO_x - oxides of nitrogen
T7 SWCV - solid waste collection vehicles
TOTEX - total exhaust

Table A-39. NOx and GHG Tailpipe Emissions for Scenario 6 in Calendar Year 2023

	Adjusted EMFAC2017 Output[1]						Conventional DSL		
Model Year	Population	NOx_TOTEX (tons/day)	CO2_TOTEX (tons/day)	CH4_TOTEX (tons/day)	N2O_TOTEX (tons/day)	Fuel Consumption (1000 gal/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)
1979	53	0.03	2.9	0.000	0.000	0.26	100%	53	35,019
1980	64	0.04	3.7	0.000	0.001	0.33	100%	64	44,086
1981	209	0.12	12	0.000	0.002	1.1	100%	209	142,790
1982	208	0.11	11	0.000	0.002	1.0	100%	208	134,214
1983	196	0.11	11	0.000	0.002	1.0	100%	196	131,088
1984	241	0.15	15	0.000	0.002	1.3	100%	241	176,822
1985	357	0.21	21	0.000	0.003	1.9	100%	357	252,082
1986	331	0.20	20	0.000	0.003	1.8	100%	331	243,579
1987	345	0.22	21	0.000	0.003	1.9	100%	345	253,082
1988	370	0.26	24	0.000	0.004	2.2	100%	370	290,997
1989	420	0.29	28	0.000	0.004	2.5	100%	420	332,355
1990	382	0.28	27	0.000	0.004	2.4	100%	382	319,401
1991	331	0.24	20	0.000	0.003	1.8	100%	331	238,471
1992	279	0.22	18	0.000	0.003	1.6	100%	279	214,037
1993	235	0.20	17	0.000	0.003	1.5	100%	235	202,566
1994	257	0.21	19	0.000	0.003	1.7	100%	257	228,163
1995	341	0.29	26	0.000	0.004	2.3	100%	341	308,497
1996	354	0.29	26	0.000	0.004	2.3	100%	354	309,827
1997	358	0.27	24	0.000	0.004	2.2	100%	358	292,799
1998	350	0.29	27	0.000	0.004	2.4	100%	350	324,850
1999	484	0.48	38	0.000	0.006	3.4	100%	484	458,610
2000	570	0.55	44	0.000	0.007	3.9	100%	570	522,449
2001	630	0.52	42	0.000	0.007	3.7	100%	630	502,288
2002	683	0.50	41	0.000	0.006	3.7	100%	683	490,906
2003	607	0.31	41	0.000	0.006	3.7	100%	607	491,836
2004	588	0.27	39	0.000	0.006	3.4	100%	588	462,594
2005	722	0.33	48	0.000	0.008	4.3	100%	722	579,188
2006	789	0.37	53	0.000	0.008	4.7	100%	789	635,640
2007	1,010	0.43	69	0.000	0.01	6.1	100%	1,010	822,391
2008	958	0.24	51	0.000	0.008	4.5	100%	958	608,971
2009	1,054	0.24	57	0.000	0.009	5.1	100%	1,054	681,595
2010	516	0.11	28	0.000	0.004	2.5	100%	516	336,250
2011	601	0.08	32	0.000	0.005	2.8	100%	601	381,333
2012	36,456	15	5,160	0.010	0.81	460	100%	36,456	61,840,416
2013	23,385	13	4,715	0.009	0.74	420	100%	23,385	56,503,770
2014	25,954	12	4,907	0.01	0.77	437	100%	25,954	58,805,403
2015	43,313	18	8,476	0.02	1.3	755	100%	43,313	101,582,009
2016	51,092	25	12,180	0.03	1.9	1,086	100%	51,092	145,975,230
2017	45,093	20	10,301	0.02	1.6	918	100%	45,093	123,455,483
2018	15,699	7.6	3,880	0.008	0.61	346	100%	15,699	46,494,284
2019	15,755	7.5	4,119	0.008	0.65	367	100%	15,755	49,364,115
2020	14,758	7.0	4,076	0.008	0.64	363	100%	14,758	48,851,177
2021	13,866	6.3	3,442	0.008	0.54	307	100%	13,866	41,250,943
2022	13,999	6.1	3,590	0.008	0.56	320	100%	13,999	43,027,237
2023	9,671	3.7	2,395	0.005	0.38	213	100%	9,671	28,707,076
2024	4,843	1.3	599	0.003	0.09	53	0%	0	0

Model Year	Federal Low NOx DSL Fleet Mix[2] (%)	Federal Low NOx DSL Population[3]	Federal Low NOx DSL Energy Consumption[4] (MJ/day)	CA Cert. Low NOx DSL Fleet Mix[2] (%)	CA Cert. Low NOx DSL Population[3]	CA Cert. Low NOx DSL Energy Consumption[4] (MJ/day)	Low NOx NG Fleet Mix[2] (%)	Low NOx NG Population[3]	Low NOx NG Energy Consumption[4] (MJ/day)
1979	0%	0	0	0%	0	0	0%	0	0
1980	0%	0	0	0%	0	0	0%	0	0
1981	0%	0	0	0%	0	0	0%	0	0
1982	0%	0	0	0%	0	0	0%	0	0
1983	0%	0	0	0%	0	0	0%	0	0
1984	0%	0	0	0%	0	0	0%	0	0
1985	0%	0	0	0%	0	0	0%	0	0
1986	0%	0	0	0%	0	0	0%	0	0
1987	0%	0	0	0%	0	0	0%	0	0
1988	0%	0	0	0%	0	0	0%	0	0
1989	0%	0	0	0%	0	0	0%	0	0
1990	0%	0	0	0%	0	0	0%	0	0
1991	0%	0	0	0%	0	0	0%	0	0
1992	0%	0	0	0%	0	0	0%	0	0
1993	0%	0	0	0%	0	0	0%	0	0
1994	0%	0	0	0%	0	0	0%	0	0
1995	0%	0	0	0%	0	0	0%	0	0
1996	0%	0	0	0%	0	0	0%	0	0
1997	0%	0	0	0%	0	0	0%	0	0
1998	0%	0	0	0%	0	0	0%	0	0
1999	0%	0	0	0%	0	0	0%	0	0
2000	0%	0	0	0%	0	0	0%	0	0
2001	0%	0	0	0%	0	0	0%	0	0
2002	0%	0	0	0%	0	0	0%	0	0
2003	0%	0	0	0%	0	0	0%	0	0
2004	0%	0	0	0%	0	0	0%	0	0
2005	0%	0	0	0%	0	0	0%	0	0
2006	0%	0	0	0%	0	0	0%	0	0
2007	0%	0	0	0%	0	0	0%	0	0
2008	0%	0	0	0%	0	0	0%	0	0
2009	0%	0	0	0%	0	0	0%	0	0
2010	0%	0	0	0%	0	0	0%	0	0
2011	0%	0	0	0%	0	0	0%	0	0
2012	0%	0	0	0%	0	0	0%	0	0
2013	0%	0	0	0%	0	0	0%	0	0
2014	0%	0	0	0%	0	0	0%	0	0
2015	0%	0	0	0%	0	0	0%	0	0
2016	0%	0	0	0%	0	0	0%	0	0
2017	0%	0	0	0%	0	0	0%	0	0
2018	0%	0	0	0%	0	0	0%	0	0
2019	0%	0	0	0%	0	0	0%	0	0
2020	0%	0	0	0%	0	0	0%	0	0
2021	0%	0	0	0%	0	0	0%	0	0
2022	0%	0	0	0%	0	0	0%	0	0
2023	0%	0	0	0%	0	0	0%	0	0
2024	10%	484	717,286	90%	4,358	6,455,577	0%	0	0

Table A-39. NOx and GHG Tailpipe Emissions for Scenario 6 in Calendar Year 2023

	BEV			Tailpipe Emission Estimates[5] (tons/day)			
Model Year	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	NO_X	CO_2	CH_4	N_2O
1979	0%	0	0	0.03	2.9	0.000	0.000
1980	0%	0	0	0.04	3.7	0.000	0.001
1981	0%	0	0	0.12	12	0.000	0.002
1982	0%	0	0	0.11	11	0.000	0.002
1983	0%	0	0	0.11	11	0.000	0.002
1984	0%	0	0	0.15	15	0.000	0.002
1985	0%	0	0	0.21	21	0.000	0.003
1986	0%	0	0	0.20	20	0.000	0.003
1987	0%	0	0	0.22	21	0.000	0.003
1988	0%	0	0	0.26	24	0.000	0.004
1989	0%	0	0	0.29	28	0.000	0.004
1990	0%	0	0	0.28	27	0.000	0.004
1991	0%	0	0	0.24	20	0.000	0.003
1992	0%	0	0	0.22	18	0.000	0.003
1993	0%	0	0	0.20	17	0.000	0.003
1994	0%	0	0	0.21	19	0.000	0.003
1995	0%	0	0	0.29	26	0.000	0.004
1996	0%	0	0	0.29	26	0.000	0.004
1997	0%	0	0	0.27	24	0.000	0.004
1998	0%	0	0	0.29	27	0.000	0.004
1999	0%	0	0	0.48	38	0.000	0.006
2000	0%	0	0	0.55	44	0.000	0.007
2001	0%	0	0	0.52	42	0.000	0.007
2002	0%	0	0	0.50	41	0.000	0.006
2003	0%	0	0	0.31	41	0.000	0.006
2004	0%	0	0	0.27	39	0.000	0.006
2005	0%	0	0	0.33	48	0.000	0.008
2006	0%	0	0	0.37	53	0.000	0.008
2007	0%	0	0	0.43	69	0.000	0.01
2008	0%	0	0	0.24	51	0.000	0.008
2009	0%	0	0	0.24	57	0.000	0.009
2010	0%	0	0	0.11	28	0.000	0.004
2011	0%	0	0	0.08	32	0.000	0.005
2012	0%	0	0	15	5,160	0.010	0.81
2013	0%	0	0	13	4,715	0.009	0.74
2014	0%	0	0	12	4,907	0.01	0.77
2015	0%	0	0	18	8,476	0.02	1.3
2016	0%	0	0	25	12,180	0.03	1.9
2017	0%	0	0	20	10,301	0.02	1.6
2018	0%	0	0	7.6	3,880	0.008	0.61
2019	0%	0	0	7.5	4,119	0.008	0.65
2020	0%	0	0	7.0	4,076	0.008	0.64
2021	0%	0	0	6.3	3,442	0.008	0.54
2022	0%	0	0	6.1	3,590	0.008	0.56
2023	0%	0	0	3.7	2,395	0.005	0.38
2024	0%	0	0	0.14	599	0.003	0.09

Notes:

[1] EMFAC data shown here are adjusted by subtracting data for T7 SWCVs from corresponding data for all HHDTs as described in Appendix A. Accelerated turnover adjustments are included in calendar years 2031, 2037, 2045, and 2050 as described in Appendix A.

[2] Fleet mix percentages for each alternative HHDT technology type are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[3] Population in each model year is calculated based on the fleet mix percentages for each HHDT type and the total population in the adjusted EMFAC data.

[4] Energy consumption is calculated based on adjusted EMFAC data, using the EER for each HHDT type shown in Table A-38.

[5] Emissions from vehicles in each model year are calculated based on the fleet mix composition and the reduction in tailpipe NOx emissions achieved by each HHDT type shown in Table 3-2. Total emissions in each calendar year are calculated as the sum of tailpipe emissions across all HHDT types and all model years in each calendar year.

[6] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CA Cert. - California certified
CH_4 - methane
CO_2 - carbon dioxide
DSL - diesel
EER - energy economy ratio
EMFAC2017 - Emission Factor Model
gal - gallon
HHDT - heavy heavy duty truck
MJ - megajoule
N_2O - nitrous oxide
NG - natural gas
NO_x - oxides of nitrogen
T7 SWCV - solid waste collection vehicles
TOTEX - total exhaust

Table A-40. NOx and GHG Tailpipe Emissions for Scenario 6 in Calendar Year 2031

	Adjusted EMFAC2017 Output[1]						Conventional DSL		
Model Year	Population	NOx_TOTEX (tons/day)	CO2_TOTEX (tons/day)	CH4_TOTEX (tons/day)	N2O_TOTEX (tons/day)	Fuel Consumption (1000 gal/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)
1987	166	0.09	8.9	0.000	0.001	0.79	100%	166	106,532
1988	223	0.13	12	0.000	0.002	1.1	100%	223	144,024
1989	279	0.16	15	0.000	0.002	1.3	100%	279	179,202
1990	256	0.15	14	0.000	0.002	1.3	100%	256	168,297
1991	221	0.14	11	0.000	0.002	1.0	100%	221	134,880
1992	173	0.11	9.2	0.000	0.001	0.82	100%	173	110,429
1993	132	0.09	7.5	0.000	0.001	0.67	100%	132	90,308
1994	131	0.08	7.6	0.000	0.001	0.68	100%	131	91,104
1995	161	0.11	10	0.000	0.002	0.87	100%	161	116,335
1996	159	0.11	10	0.000	0.002	0.85	100%	159	114,485
1997	155	0.10	9.1	0.000	0.001	0.81	100%	155	108,509
1998	145	0.10	10	0.000	0.001	0.85	100%	145	114,337
1999	197	0.17	13	0.000	0.002	1.2	100%	197	160,607
2000	233	0.20	16	0.000	0.002	1.4	100%	233	188,016
2001	267	0.20	16	0.000	0.003	1.4	100%	267	193,494
2002	300	0.21	17	0.000	0.003	1.5	100%	300	200,551
2003	272	0.13	17	0.000	0.003	1.5	100%	272	200,037
2004	276	0.12	17	0.000	0.003	1.5	100%	276	198,929
2005	353	0.15	22	0.000	0.003	1.9	100%	353	259,740
2006	403	0.18	25	0.000	0.004	2.3	100%	403	303,073
2007	543	0.22	35	0.000	0.006	3.1	100%	543	422,431
2008	564	0.14	29	0.000	0.005	2.6	100%	564	352,228
2009	654	0.15	34	0.000	0.005	3.1	100%	654	410,832
2010	337	0.07	18	0.000	0.003	1.6	100%	337	211,381
2011	419	0.05	21	0.000	0.003	1.9	100%	419	253,413
2012	18,775	6.3	2,125	0.004	0.33	189	100%	18,775	25,469,698
2013	10,866	5.2	1,931	0.003	0.30	172	100%	10,866	23,141,590
2014	12,373	4.9	1,993	0.004	0.31	178	100%	12,373	23,884,682
2015	22,601	8.0	3,471	0.007	0.55	309	100%	22,601	41,601,211
2016	25,559	9.1	3,866	0.010	0.61	345	100%	25,559	46,327,589
2017	29,560	9.2	4,023	0.009	0.63	359	100%	29,560	48,215,934
2018	10,153	3.8	1,588	0.004	0.25	142	100%	10,153	19,030,587
2019	11,512	4.5	1,861	0.004	0.29	166	100%	11,512	22,305,607
2020	13,043	5.4	2,255	0.005	0.35	201	100%	13,043	27,025,846
2021	14,295	6.2	2,272	0.006	0.36	203	100%	14,295	27,231,919
2022	16,417	7.5	2,835	0.007	0.45	253	100%	16,417	33,979,835
2023	22,059	12	4,261	0.010	0.67	380	100%	22,059	51,063,434
2024	21,715	11	3,988	0.01	0.63	355	0%	0	0
2025	22,619	12	4,524	0.01	0.71	403	0%	0	0
2026	22,104	12	4,758	0.01	0.75	424	0%	0	0
2027	21,594	11	4,671	0.01	0.73	416	0%	0	0
2028	19,744	10	4,452	0.01	0.70	397	0%	0	0
2029	18,560	9.0	4,281	0.01	0.67	382	0%	0	0
2030	17,915	8.2	4,205	0.01	0.66	375	0%	0	0
2031	11,497	4.6	2,590	0.006	0.41	231	0%	0	0
2032	5,864	1.6	694	0.003	0.11	62	0%	0	0

Table A-40. NOx and GHG Tailpipe Emissions for Scenario 6 in Calendar Year 2031

Model Year	Federal Low NOx DSL			CA Cert. Low NOx DSL			Low NOx NG		
	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)
1987	0%	0	0	0%	0	0	0%	0	0
1988	0%	0	0	0%	0	0	0%	0	0
1989	0%	0	0	0%	0	0	0%	0	0
1990	0%	0	0	0%	0	0	0%	0	0
1991	0%	0	0	0%	0	0	0%	0	0
1992	0%	0	0	0%	0	0	0%	0	0
1993	0%	0	0	0%	0	0	0%	0	0
1994	0%	0	0	0%	0	0	0%	0	0
1995	0%	0	0	0%	0	0	0%	0	0
1996	0%	0	0	0%	0	0	0%	0	0
1997	0%	0	0	0%	0	0	0%	0	0
1998	0%	0	0	0%	0	0	0%	0	0
1999	0%	0	0	0%	0	0	0%	0	0
2000	0%	0	0	0%	0	0	0%	0	0
2001	0%	0	0	0%	0	0	0%	0	0
2002	0%	0	0	0%	0	0	0%	0	0
2003	0%	0	0	0%	0	0	0%	0	0
2004	0%	0	0	0%	0	0	0%	0	0
2005	0%	0	0	0%	0	0	0%	0	0
2006	0%	0	0	0%	0	0	0%	0	0
2007	0%	0	0	0%	0	0	0%	0	0
2008	0%	0	0	0%	0	0	0%	0	0
2009	0%	0	0	0%	0	0	0%	0	0
2010	0%	0	0	0%	0	0	0%	0	0
2011	0%	0	0	0%	0	0	0%	0	0
2012	0%	0	0	0%	0	0	0%	0	0
2013	0%	0	0	0%	0	0	0%	0	0
2014	0%	0	0	0%	0	0	0%	0	0
2015	0%	0	0	0%	0	0	0%	0	0
2016	0%	0	0	0%	0	0	0%	0	0
2017	0%	0	0	0%	0	0	0%	0	0
2018	0%	0	0	0%	0	0	0%	0	0
2019	0%	0	0	0%	0	0	0%	0	0
2020	0%	0	0	0%	0	0	0%	0	0
2021	0%	0	0	0%	0	0	0%	0	0
2022	0%	0	0	0%	0	0	0%	0	0
2023	0%	0	0	0%	0	0	0%	0	0
2024	10%	2,171	4,779,835	90%	19,543	43,018,516	0%	0	0
2025	10%	2,262	5,421,301	90%	20,358	48,791,706	0%	0	0
2026	10%	2,210	5,702,550	90%	19,894	51,322,947	0%	0	0
2027	15%	3,239	8,396,467	85%	18,355	47,579,979	0%	0	0
2028	15%	2,962	8,002,355	85%	16,783	45,346,680	0%	0	0
2029	20%	3,712	10,260,841	80%	14,848	41,043,365	0%	0	0
2030	20%	3,583	10,079,515	80%	14,332	40,318,062	0%	0	0
2031	20%	2,299	6,209,013	80%	9,198	24,836,053	0%	0	0
2032	10%	586	831,861	90%	5,277	7,486,747	0%	0	0

Table A-40. NOx and GHG Tailpipe Emissions for Scenario 6 in Calendar Year 2031

	BEV			Tailpipe Emission Estimates[5] (tons/day)			
Model Year	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	NO_X	CO_2	CH_4	N_2O
1987	0%	0	0	0.09	8.9	0.000	0.001
1988	0%	0	0	0.13	12	0.000	0.002
1989	0%	0	0	0.16	15	0.000	0.002
1990	0%	0	0	0.15	14	0.000	0.002
1991	0%	0	0	0.14	11	0.000	0.002
1992	0%	0	0	0.11	9.2	0.000	0.001
1993	0%	0	0	0.09	7.5	0.000	0.001
1994	0%	0	0	0.08	7.6	0.000	0.001
1995	0%	0	0	0.11	10	0.000	0.002
1996	0%	0	0	0.11	10	0.000	0.002
1997	0%	0	0	0.10	9.1	0.000	0.001
1998	0%	0	0	0.10	10	0.000	0.001
1999	0%	0	0	0.17	13	0.000	0.002
2000	0%	0	0	0.20	16	0.000	0.002
2001	0%	0	0	0.20	16	0.000	0.003
2002	0%	0	0	0.21	17	0.000	0.003
2003	0%	0	0	0.13	17	0.000	0.003
2004	0%	0	0	0.12	17	0.000	0.003
2005	0%	0	0	0.15	22	0.000	0.003
2006	0%	0	0	0.18	25	0.000	0.004
2007	0%	0	0	0.22	35	0.000	0.006
2008	0%	0	0	0.14	29	0.000	0.005
2009	0%	0	0	0.15	34	0.000	0.005
2010	0%	0	0	0.07	18	0.000	0.003
2011	0%	0	0	0.05	21	0.000	0.003
2012	0%	0	0	6.3	2,125	0.004	0.33
2013	0%	0	0	5.2	1,931	0.003	0.30
2014	0%	0	0	4.9	1,993	0.004	0.31
2015	0%	0	0	8.0	3,471	0.007	0.55
2016	0%	0	0	9.1	3,866	0.010	0.61
2017	0%	0	0	9.2	4,023	0.009	0.63
2018	0%	0	0	3.8	1,588	0.004	0.25
2019	0%	0	0	4.5	1,861	0.004	0.29
2020	0%	0	0	5.4	2,255	0.005	0.35
2021	0%	0	0	6.2	2,272	0.006	0.36
2022	0%	0	0	7.5	2,835	0.007	0.45
2023	0%	0	0	12	4,261	0.010	0.67
2024	0%	0	0	1.3	3,988	0.01	0.63
2025	0%	0	0	1.4	4,524	0.01	0.71
2026	0%	0	0	1.3	4,758	0.01	0.75
2027	0%	0	0	1.4	4,671	0.01	0.73
2028	0%	0	0	1.2	4,452	0.01	0.70
2029	0%	0	0	1.2	4,281	0.01	0.67
2030	0%	0	0	1.1	4,205	0.01	0.66
2031	0%	0	0	0.60	2,590	0.006	0.41
2032	0%	0	0	0.18	694	0.003	0.11

Notes:

[1] EMFAC data shown here are adjusted by subtracting data for T7 SWCVs from corresponding data for all HHDTs as described in Appendix A. Accelerated turnover adjustments are included in calendar years 2031, 2037, 2045, and 2050 as described in Appendix A.

[2] Fleet mix percentages for each alternative HHDT technology type are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[3] Population in each model year is calculated based on the fleet mix percentages for each HHDT type and the total population in the adjusted EMFAC data.

[4] Energy consumption is calculated based on adjusted EMFAC data, using the EER for each HHDT type shown in Table A-38.

[5] Emissions from vehicles in each model year are calculated based on the fleet mix composition and the reduction in tailpipe NOx emissions achieved by each HHDT type shown in Table 3-2. Total emissions in each calendar year are calculated as the sum of tailpipe emissions across all HHDT types and all model years in each calendar year.

[6] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CA Cert. - California certified
CH_4 - methane
CO_2 - carbon dioxide
DSL - diesel
EER - energy economy ratio
EMFAC2017 - Emission Factor Model
gal - gallon
HHDT - heavy heavy duty truck
MJ - megajoule
N_2O - nitrous oxide
NG - natural gas
NO_x - oxides of nitrogen
T7 SWCV - solid waste collection vehicles
TOTEX - total exhaust

Table A-41. NOx and GHG Tailpipe Emissions for Scenario 6 in Calendar Year 2037

	Adjusted EMFAC2017 Output[1]						Conventional DSL		
Model Year	**Population**	**NOx_TOTEX (tons/day)**	**CO2_TOTEX (tons/day)**	**CH4_TOTEX (tons/day)**	**N2O_TOTEX (tons/day)**	**Fuel Consumption (1000 gal/day)**	**Fleet Mix[2] (%)**	**Population[3]**	**Energy Consumption[4] (MJ/day)**
1993	66	0.04	3.5	0.000	0.001	0.31	100%	66	42,043
1994	83	0.05	4.2	0.000	0.001	0.38	100%	83	50,721
1995	115	0.07	5.9	0.000	0.001	0.53	100%	115	70,970
1996	119	0.07	6.1	0.000	0.001	0.54	100%	119	72,842
1997	117	0.06	5.9	0.000	0.001	0.52	100%	117	70,488
1998	104	0.06	5.7	0.000	0.001	0.50	100%	104	67,898
1999	133	0.10	7.6	0.000	0.001	0.67	100%	133	90,610
2000	147	0.11	8.5	0.000	0.001	0.76	100%	147	101,850
2001	161	0.11	8.8	0.000	0.001	0.79	100%	161	105,603
2002	172	0.11	9.0	0.000	0.001	0.80	100%	172	107,968
2003	146	0.06	8.3	0.000	0.001	0.74	100%	146	99,226
2004	143	0.06	8.1	0.000	0.001	0.72	100%	143	96,731
2005	178	0.07	10	0.000	0.002	0.92	100%	178	123,640
2006	202	0.09	12	0.000	0.002	1.1	100%	202	143,033
2007	272	0.11	17	0.000	0.003	1.5	100%	272	200,277
2008	292	0.07	15	0.000	0.002	1.3	100%	292	179,211
2009	346	0.08	18	0.000	0.003	1.6	100%	346	213,122
2010	183	0.04	9.3	0.000	0.001	0.83	100%	183	111,727
2011	234	0.03	11	0.000	0.002	1.0	100%	234	136,809
2012	7,969	2.4	804	0.002	0.13	72	100%	7,969	9,641,296
2013	4,340	2.0	750	0.001	0.12	67	100%	4,340	8,984,556
2014	4,954	2.0	817	0.001	0.13	73	100%	4,954	9,795,650
2015	9,674	3.7	1,601	0.003	0.25	143	100%	9,674	19,190,427
2016	10,519	3.7	1,604	0.004	0.25	143	100%	10,519	19,227,562
2017	14,184	3.9	1,723	0.004	0.27	154	100%	14,184	20,654,585
2018	4,924	1.7	692	0.002	0.11	62	100%	4,924	8,290,062
2019	5,803	1.9	807	0.002	0.13	72	100%	5,803	9,667,889
2020	6,713	2.3	945	0.002	0.15	84	100%	6,713	11,329,480
2021	7,708	2.6	942	0.003	0.15	84	100%	7,708	11,285,971
2022	9,361	3.4	1,197	0.003	0.19	107	100%	9,361	14,344,235
2023	12,311	5.2	1,799	0.004	0.28	160	100%	12,311	21,557,339
2024	14,157	5.5	1,804	0.005	0.28	161	0%	0	0
2025	15,781	6.4	2,112	0.006	0.33	188	0%	0	0
2026	17,659	7.5	2,484	0.007	0.39	221	0%	0	0
2027	19,532	8.7	2,768	0.008	0.44	247	0%	0	0
2028	21,365	10	3,236	0.010	0.51	288	0%	0	0
2029	22,985	11	3,748	0.01	0.59	334	0%	0	0
2030	24,081	12	4,213	0.01	0.66	375	0%	0	0
2037	24,791	13	4,671	0.01	0.73	416	0%	0	0
2032	24,114	13	4,857	0.01	0.76	433	0%	0	0
2033	23,670	12	5,060	0.01	0.80	451	0%	0	0
2034	21,948	11	4,883	0.01	0.77	435	0%	0	0
2035	20,791	10	4,742	0.01	0.75	423	0%	0	0
2036	19,699	9.0	4,573	0.01	0.72	408	0%	0	0
2037	12,409	5.0	2,773	0.007	0.44	247	0%	0	0
2038	6,391	1.7	743	0.003	0.12	66	0%	0	0

Table A-41. NOx and GHG Tailpipe Emissions for Scenario 6 in Calendar Year 2037

	Federal Low NOx DSL			CA Cert. Low NOx DSL			Low NOx NG		
Model Year	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)
1993	0%	0	0	0%	0	0	0%	0	0
1994	0%	0	0	0%	0	0	0%	0	0
1995	0%	0	0	0%	0	0	0%	0	0
1996	0%	0	0	0%	0	0	0%	0	0
1997	0%	0	0	0%	0	0	0%	0	0
1998	0%	0	0	0%	0	0	0%	0	0
1999	0%	0	0	0%	0	0	0%	0	0
2000	0%	0	0	0%	0	0	0%	0	0
2001	0%	0	0	0%	0	0	0%	0	0
2002	0%	0	0	0%	0	0	0%	0	0
2003	0%	0	0	0%	0	0	0%	0	0
2004	0%	0	0	0%	0	0	0%	0	0
2005	0%	0	0	0%	0	0	0%	0	0
2006	0%	0	0	0%	0	0	0%	0	0
2007	0%	0	0	0%	0	0	0%	0	0
2008	0%	0	0	0%	0	0	0%	0	0
2009	0%	0	0	0%	0	0	0%	0	0
2010	0%	0	0	0%	0	0	0%	0	0
2011	0%	0	0	0%	0	0	0%	0	0
2012	0%	0	0	0%	0	0	0%	0	0
2013	0%	0	0	0%	0	0	0%	0	0
2014	0%	0	0	0%	0	0	0%	0	0
2015	0%	0	0	0%	0	0	0%	0	0
2016	0%	0	0	0%	0	0	0%	0	0
2017	0%	0	0	0%	0	0	0%	0	0
2018	0%	0	0	0%	0	0	0%	0	0
2019	0%	0	0	0%	0	0	0%	0	0
2020	0%	0	0	0%	0	0	0%	0	0
2021	0%	0	0	0%	0	0	0%	0	0
2022	0%	0	0	0%	0	0	0%	0	0
2023	0%	0	0	0%	0	0	0%	0	0
2024	10%	1,416	2,161,542	90%	12,741	19,453,879	0%	0	0
2025	10%	1,578	2,531,043	90%	14,203	22,779,383	0%	0	0
2026	10%	1,766	2,977,192	90%	15,893	26,794,732	0%	0	0
2027	15%	2,930	4,975,264	85%	16,602	28,193,162	0%	0	0
2028	15%	3,205	5,817,346	85%	18,160	32,964,959	0%	0	0
2029	20%	4,597	8,983,030	80%	18,388	35,932,119	0%	0	0
2030	20%	4,816	10,097,767	80%	19,265	40,391,066	0%	0	0
2037	12%	2,975	6,717,948	88%	21,816	49,264,949	0%	0	0
2032	10%	2,411	5,821,019	90%	21,703	52,389,172	0%	0	0
2033	10%	2,367	6,063,891	90%	21,303	54,575,018	0%	0	0
2034	10%	2,195	5,851,702	90%	19,754	52,665,319	0%	0	0
2035	12%	2,495	6,819,958	88%	18,296	50,013,022	0%	0	0
2036	12%	2,364	6,576,732	88%	17,335	48,229,366	0%	0	0
2037	12%	1,489	3,988,015	88%	10,920	29,245,447	0%	0	0
2038	12%	767	1,068,563	88%	5,624	7,836,129	0%	0	0

Table A-41. NOx and GHG Tailpipe Emissions for Scenario 6 in Calendar Year 2037

Model Year	BEV			Tailpipe Emission Estimates[5] (tons/day)			
	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	NO_X	CO_2	CH_4	N_2O
1993	0%	0	0	0.04	3.5	0.000	0.001
1994	0%	0	0	0.05	4.2	0.000	0.001
1995	0%	0	0	0.07	5.9	0.000	0.001
1996	0%	0	0	0.07	6.1	0.000	0.001
1997	0%	0	0	0.06	5.9	0.000	0.001
1998	0%	0	0	0.06	5.7	0.000	0.001
1999	0%	0	0	0.10	7.6	0.000	0.001
2000	0%	0	0	0.11	8.5	0.000	0.001
2001	0%	0	0	0.11	8.8	0.000	0.001
2002	0%	0	0	0.11	9.0	0.000	0.001
2003	0%	0	0	0.06	8.3	0.000	0.001
2004	0%	0	0	0.06	8.1	0.000	0.001
2005	0%	0	0	0.07	10	0.000	0.002
2006	0%	0	0	0.09	12	0.000	0.002
2007	0%	0	0	0.11	17	0.000	0.003
2008	0%	0	0	0.07	15	0.000	0.002
2009	0%	0	0	0.08	18	0.000	0.003
2010	0%	0	0	0.04	9.3	0.000	0.001
2011	0%	0	0	0.03	11	0.000	0.002
2012	0%	0	0	2.4	804	0.002	0.13
2013	0%	0	0	2.0	750	0.001	0.12
2014	0%	0	0	2.0	817	0.001	0.13
2015	0%	0	0	3.7	1,601	0.003	0.25
2016	0%	0	0	3.7	1,604	0.004	0.25
2017	0%	0	0	3.9	1,723	0.004	0.27
2018	0%	0	0	1.7	692	0.002	0.11
2019	0%	0	0	1.9	807	0.002	0.13
2020	0%	0	0	2.3	945	0.002	0.15
2021	0%	0	0	2.6	942	0.003	0.15
2022	0%	0	0	3.4	1,197	0.003	0.19
2023	0%	0	0	5.2	1,799	0.004	0.28
2024	0%	0	0	0.63	1,804	0.005	0.28
2025	0%	0	0	0.74	2,112	0.006	0.33
2026	0%	0	0	0.87	2,484	0.007	0.39
2027	0%	0	0	1.1	2,768	0.008	0.44
2028	0%	0	0	1.2	3,236	0.010	0.51
2029	0%	0	0	1.5	3,748	0.01	0.59
2030	0%	0	0	1.6	4,213	0.01	0.66
2037	0%	0	0	1.5	4,671	0.01	0.73
2032	0%	0	0	1.5	4,857	0.01	0.76
2033	0%	0	0	1.4	5,060	0.01	0.80
2034	0%	0	0	1.3	4,883	0.01	0.77
2035	0%	0	0	1.2	4,742	0.01	0.75
2036	0%	0	0	1.1	4,573	0.01	0.72
2037	0%	0	0	0.59	2,773	0.007	0.44
2038	0%	0	0	0.20	743	0.003	0.12

Notes:

[1] EMFAC data shown here are adjusted by subtracting data for T7 SWCVs from corresponding data for all HHDTs as described in Appendix A. Accelerated turnover adjustments are included in calendar years 2031, 2037, 2045, and 2050 as described in Appendix A.

[2] Fleet mix percentages for each alternative HHDT technology type are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[3] Population in each model year is calculated based on the fleet mix percentages for each HHDT type and the total population in the adjusted EMFAC data.

[4] Energy consumption is calculated based on adjusted EMFAC data, using the EER for each HHDT type shown in Table A-38.

[5] Emissions from vehicles in each model year are calculated based on the fleet mix composition and the reduction in tailpipe NOx emissions achieved by each HHDT type shown in Table 3-2. Total emissions in each calendar year are calculated as the sum of tailpipe emissions across all HHDT types and all model years in each calendar year.

[6] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CA Cert. - California certified
CH_4 - methane
CO_2 - carbon dioxide
DSL - diesel
EER - energy economy ratio
EMFAC2017 - Emission Factor Model
gal - gallon
HHDT - heavy heavy duty truck
MJ - megajoule
N_2O - nitrous oxide
NG - natural gas
NO_x - oxides of nitrogen
T7 SWCV - solid waste collection vehicles
TOTEX - total exhaust

Table A-42. NOx and GHG Tailpipe Emissions for Scenario 6 in Calendar Year 2045

	Adjusted EMFAC2017 Output[1]						**Conventional DSL**		
Model Year	**Population**	**NOx_TOTEX (tons/day)**	**CO2_TOTEX (tons/day)**	**CH4_TOTEX (tons/day)**	**N2O_TOTEX (tons/day)**	**Fuel Consumption (1000 gal/day)**	**Fleet Mix[2] (%)**	**Population[3]**	**Energy Consumption[4] (MJ/day)**
2001	0	0	0	0	0	0	0%	0	0
2002	0	0	0	0	0	0	0%	0	0
2003	0	0	0	0	0	0	0%	0	0
2004	0	0	0	0	0	0	0%	0	0
2005	0	0	0	0	0	0	0%	0	0
2006	0	0	0	0	0	0	0%	0	0
2007	0	0	0	0	0	0	0%	0	0
2008	0	0	0	0	0	0	0%	0	0
2009	0	0	0	0	0	0	0%	0	0
2010	0	0	0	0	0	0	0%	0	0
2011	0	0	0	0	0	0	0%	0	0
2012	0	0	0	0	0	0	0%	0	0
2013	0	0	0	0	0	0	0%	0	0
2014	0	0	0	0	0	0	0%	0	0
2015	0	0	0	0	0	0	0%	0	0
2016	0	0	0	0	0	0	0%	0	0
2017	0	0	0	0	0	0	0%	0	0
2018	0	0	0	0	0	0	0%	0	0
2019	0	0	0	0	0	0	0%	0	0
2020	0	0	0	0	0	0	0%	0	0
2021	0	0	0	0	0	0	0%	0	0
2022	0	0	0	0	0	0	0%	0	0
2023	0	0	0	0	0	0	0%	0	0
2024	5,738	1.9	631	0.002	0.10	56	0%	0	0
2025	6,682	2.2	740	0.002	0.12	66	0%	0	0
2026	7,830	2.6	869	0.002	0.14	77	0%	0	0
2027	8,960	3.0	954	0.003	0.15	85	0%	0	0
2028	10,297	3.5	1,096	0.003	0.17	98	0%	0	0
2029	11,921	4.1	1,276	0.004	0.20	114	0%	0	0
2030	13,807	4.8	1,488	0.005	0.23	133	0%	0	0
2045	15,655	5.9	1,819	0.006	0.29	162	0%	0	0
2032	17,813	7.1	2,196	0.007	0.35	196	0%	0	0
2033	20,003	8.3	2,581	0.008	0.41	230	0%	0	0
2034	22,623	10	3,067	0.009	0.48	273	0%	0	0
2035	24,976	11	3,584	0.01	0.56	319	0%	0	0
2036	26,967	13	4,118	0.01	0.65	367	0%	0	0
2037	28,599	14	4,677	0.01	0.74	417	0%	0	0
2038	29,556	15	5,172	0.01	0.81	461	0%	0	0
2039	30,085	16	5,646	0.02	0.89	503	0%	0	0
2040	28,520	15	5,685	0.02	0.89	507	0%	0	0
2041	27,485	14	5,816	0.02	0.91	518	0%	0	0
2042	24,780	12	5,446	0.01	0.86	485	0%	0	0
2043	23,286	11	5,243	0.01	0.82	467	0%	0	0
2044	22,012	10	5,025	0.01	0.79	448	0%	0	0
2045	13,831	5.5	3,030	0.007	0.48	270	0%	0	0
2046	7,111	1.9	812	0.004	0.13	72	0%	0	0

Table A-42. NOx and GHG Tailpipe Emissions for Scenario 6 in Calendar Year 2045

Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

	Federal Low NOx DSL			CA Cert. Low NOx DSL			Low NOx NG		
Model Year	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)
2001	0%	0	0	0%	0	0	0%	0	0
2002	0%	0	0	0%	0	0	0%	0	0
2003	0%	0	0	0%	0	0	0%	0	0
2004	0%	0	0	0%	0	0	0%	0	0
2005	0%	0	0	0%	0	0	0%	0	0
2006	0%	0	0	0%	0	0	0%	0	0
2007	0%	0	0	0%	0	0	0%	0	0
2008	0%	0	0	0%	0	0	0%	0	0
2009	0%	0	0	0%	0	0	0%	0	0
2010	0%	0	0	0%	0	0	0%	0	0
2011	0%	0	0	0%	0	0	0%	0	0
2012	0%	0	0	0%	0	0	0%	0	0
2013	0%	0	0	0%	0	0	0%	0	0
2014	0%	0	0	0%	0	0	0%	0	0
2015	0%	0	0	0%	0	0	0%	0	0
2016	0%	0	0	0%	0	0	0%	0	0
2017	0%	0	0	0%	0	0	0%	0	0
2018	0%	0	0	0%	0	0	0%	0	0
2019	0%	0	0	0%	0	0	0%	0	0
2020	0%	0	0	0%	0	0	0%	0	0
2021	0%	0	0	0%	0	0	0%	0	0
2022	0%	0	0	0%	0	0	0%	0	0
2023	0%	0	0	0%	0	0	0%	0	0
2024	10%	574	756,340	90%	5,164	6,807,061	0%	0	0
2025	10%	668	886,781	90%	6,014	7,981,032	0%	0	0
2026	10%	783	1,041,761	90%	7,047	9,375,851	0%	0	0
2027	15%	1,344	1,715,605	85%	7,616	9,721,760	0%	0	0
2028	15%	1,544	1,969,828	85%	8,752	11,162,360	0%	0	0
2029	20%	2,384	3,059,507	80%	9,536	12,238,027	0%	0	0
2030	20%	2,761	3,566,433	80%	11,045	14,265,732	0%	0	0
2045	12%	1,879	2,615,706	88%	13,777	19,181,841	0%	0	0
2032	10%	1,781	2,631,722	90%	16,032	23,685,498	0%	0	0
2033	10%	2,000	3,093,484	90%	18,003	27,841,358	0%	0	0
2034	10%	2,262	3,676,051	90%	20,361	33,084,463	0%	0	0
2035	12%	2,997	5,154,227	88%	21,979	37,797,664	0%	0	0
2036	12%	3,236	5,922,773	88%	23,731	43,433,668	0%	0	0
2037	12%	3,432	6,725,482	88%	25,167	49,320,202	0%	0	0
2038	12%	3,547	7,438,400	88%	26,009	54,548,270	0%	0	0
2039	12%	3,610	8,118,998	88%	26,475	59,539,315	0%	0	0
2040	12%	3,422	8,176,299	88%	25,097	59,959,528	0%	0	0
2041	12%	3,298	8,363,731	88%	24,187	61,334,028	0%	0	0
2042	12%	2,974	7,831,788	88%	21,807	57,433,112	0%	0	0
2043	12%	2,794	7,539,421	88%	20,492	55,289,088	0%	0	0
2044	12%	2,641	7,227,079	88%	19,370	52,998,582	0%	0	0
2045	12%	1,660	4,357,601	88%	12,172	31,955,744	0%	0	0
2046	12%	853	1,167,185	88%	6,258	8,559,357	0%	0	0

Table A-42. NOx and GHG Tailpipe Emissions for Scenario 6 in Calendar Year 2045

Model Year	BEV			Tailpipe Emission Estimates[5] (tons/day)			
	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	NO_X	CO_2	CH_4	N_2O
2001	0%	0	0	0	0	0	0
2002	0%	0	0	0	0	0	0
2003	0%	0	0	0	0	0	0
2004	0%	0	0	0	0	0	0
2005	0%	0	0	0	0	0	0
2006	0%	0	0	0	0	0	0
2007	0%	0	0	0	0	0	0
2008	0%	0	0	0	0	0	0
2009	0%	0	0	0	0	0	0
2010	0%	0	0	0	0	0	0
2011	0%	0	0	0	0	0	0
2012	0%	0	0	0	0	0	0
2013	0%	0	0	0	0	0	0
2014	0%	0	0	0	0	0	0
2015	0%	0	0	0	0	0	0
2016	0%	0	0	0	0	0	0
2017	0%	0	0	0	0	0	0
2018	0%	0	0	0	0	0	0
2019	0%	0	0	0	0	0	0
2020	0%	0	0	0	0	0	0
2021	0%	0	0	0	0	0	0
2022	0%	0	0	0	0	0	0
2023	0%	0	0	0	0	0	0
2024	0%	0	0	0.22	631	0.002	0.10
2025	0%	0	0	0.26	740	0.002	0.12
2026	0%	0	0	0.30	869	0.002	0.14
2027	0%	0	0	0.37	954	0.003	0.15
2028	0%	0	0	0.43	1,096	0.003	0.17
2029	0%	0	0	0.54	1,276	0.004	0.20
2030	0%	0	0	0.63	1,488	0.005	0.23
2045	0%	0	0	0.70	1,819	0.006	0.29
2032	0%	0	0	0.82	2,196	0.007	0.35
2033	0%	0	0	1.0	2,581	0.008	0.41
2034	0%	0	0	1.1	3,067	0.009	0.48
2035	0%	0	0	1.3	3,584	0.01	0.56
2036	0%	0	0	1.5	4,118	0.01	0.65
2037	0%	0	0	1.7	4,677	0.01	0.74
2038	0%	0	0	1.8	5,172	0.01	0.81
2039	0%	0	0	1.8	5,646	0.02	0.89
2040	0%	0	0	1.7	5,685	0.02	0.89
2041	0%	0	0	1.7	5,816	0.02	0.91
2042	0%	0	0	1.5	5,446	0.01	0.86
2043	0%	0	0	1.3	5,243	0.01	0.82
2044	0%	0	0	1.2	5,025	0.01	0.79
2045	0%	0	0	0.64	3,030	0.007	0.48
2046	0%	0	0	0.22	812	0.004	0.13

Notes:

[1] EMFAC data shown here are adjusted by subtracting data for T7 SWCVs from corresponding data for all HHDTs as described in Appendix A. Accelerated turnover adjustments are included in calendar years 2031, 2037, 2045, and 2050 as described in Appendix A.

[2] Fleet mix percentages for each alternative HHDT technology type are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[3] Population in each model year is calculated based on the fleet mix percentages for each HHDT type and the total population in the adjusted EMFAC data.

[4] Energy consumption is calculated based on adjusted EMFAC data, using the EER for each HHDT type shown in Table A-38.

[5] Emissions from vehicles in each model year are calculated based on the fleet mix composition and the reduction in tailpipe NOx emissions achieved by each HHDT type shown in Table 3-2. Total emissions in each calendar year are calculated as the sum of tailpipe emissions across all HHDT types and all model years in each calendar year.

[6] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CA Cert. - California certified
CH_4 - methane
CO_2 - carbon dioxide
DSL - diesel
EER - energy economy ratio
EMFAC2017 - Emission Factor Model
gal - gallon
HHDT - heavy heavy duty truck
MJ - megajoule
N_2O - nitrous oxide
NG - natural gas
NO_x - oxides of nitrogen
T7 SWCV - solid waste collection vehicles
TOTEX - total exhaust

Table A-43. NOx and GHG Tailpipe Emissions for Scenario 6 in Calendar Year 2050

Model Year	Adjusted EMFAC2017 Output[1]						Conventional DSL		
	Population	NOx_TOTEX (tons/day)	CO2_TOTEX (tons/day)	CH4_TOTEX (tons/day)	N2O_TOTEX (tons/day)	Fuel Consumption (1000 gal/day)	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)
2006	0	0	0	0	0	0	0%	0	0
2007	0	0	0	0	0	0	0%	0	0
2008	0	0	0	0	0	0	0%	0	0
2009	0	0	0	0	0	0	0%	0	0
2010	0	0	0	0	0	0	0%	0	0
2011	0	0	0	0	0	0	0%	0	0
2012	0	0	0	0	0	0	0%	0	0
2013	0	0	0	0	0	0	0%	0	0
2014	0	0	0	0	0	0	0%	0	0
2015	0	0	0	0	0	0	0%	0	0
2016	0	0	0	0	0	0	0%	0	0
2017	0	0	0	0	0	0	0%	0	0
2018	0	0	0	0	0	0	0%	0	0
2019	0	0	0	0	0	0	0%	0	0
2020	0	0	0	0	0	0	0%	0	0
2021	0	0	0	0	0	0	0%	0	0
2022	0	0	0	0	0	0	0%	0	0
2023	0	0	0	0	0	0	0%	0	0
2024	2,595	0.86	281	0.001	0.04	25	0%	0	0
2025	3,028	1.0	330	0.001	0.05	29	0%	0	0
2026	3,626	1.2	393	0.001	0.06	35	0%	0	0
2027	4,257	1.4	439	0.001	0.07	39	0%	0	0
2028	5,060	1.7	526	0.001	0.08	47	0%	0	0
2029	6,031	2.0	632	0.002	0.10	56	0%	0	0
2030	7,066	2.4	743	0.002	0.12	66	0%	0	0
2050	8,217	2.8	872	0.003	0.14	78	0%	0	0
2032	9,494	3.2	1,017	0.003	0.16	91	0%	0	0
2033	11,004	3.8	1,176	0.004	0.18	105	0%	0	0
2034	12,911	4.5	1,386	0.004	0.22	124	0%	0	0
2035	14,935	5.3	1,619	0.005	0.25	144	0%	0	0
2036	16,783	6.4	1,962	0.006	0.31	175	0%	0	0
2037	18,732	7.5	2,328	0.007	0.37	208	0%	0	0
2038	20,725	8.7	2,699	0.008	0.42	241	0%	0	0
2039	22,925	10	3,137	0.009	0.49	280	0%	0	0
2040	25,074	11	3,619	0.01	0.57	323	0%	0	0
2041	27,099	13	4,155	0.01	0.65	370	0%	0	0
2042	28,740	14	4,704	0.01	0.74	419	0%	0	0
2043	29,658	15	5,184	0.01	0.81	462	0%	0	0
2044	30,119	16	5,634	0.02	0.89	502	0%	0	0
2045	28,407	15	5,643	0.02	0.89	503	0%	0	0
2046	27,387	14	5,770	0.02	0.91	514	0%	0	0
2047	24,660	12	5,397	0.01	0.85	481	0%	0	0
2048	23,198	11	5,206	0.01	0.82	464	0%	0	0
2049	21,872	10	4,978	0.01	0.78	444	0%	0	0
2050	13,695	5.4	2,992	0.007	0.47	267	0%	0	0
2051	7,053	1.8	1,226	0.004	0.19	109	0%	0	0

Table A-43. NOx and GHG Tailpipe Emissions for Scenario 6 in Calendar Year 2050

Model Year	**Federal Low NOx DSL**			**CA Cert. Low NOx DSL**			**Low NOx NG**		
	Fleet Mix^{2} (%)	**Population^{3}**	**Energy Consumption^{4} (MJ/day)**	**Fleet Mix^{2} (%)**	**Population^{3}**	**Energy Consumption^{4} (MJ/day)**	**Fleet Mix^{2} (%)**	**Population^{3}**	**Energy Consumption^{4} (MJ/day)**
2006	0%	0	0	0%	0	0	0%	0	0
2007	0%	0	0	0%	0	0	0%	0	0
2008	0%	0	0	0%	0	0	0%	0	0
2009	0%	0	0	0%	0	0	0%	0	0
2010	0%	0	0	0%	0	0	0%	0	0
2011	0%	0	0	0%	0	0	0%	0	0
2012	0%	0	0	0%	0	0	0%	0	0
2013	0%	0	0	0%	0	0	0%	0	0
2014	0%	0	0	0%	0	0	0%	0	0
2015	0%	0	0	0%	0	0	0%	0	0
2016	0%	0	0	0%	0	0	0%	0	0
2017	0%	0	0	0%	0	0	0%	0	0
2018	0%	0	0	0%	0	0	0%	0	0
2019	0%	0	0	0%	0	0	0%	0	0
2020	0%	0	0	0%	0	0	0%	0	0
2021	0%	0	0	0%	0	0	0%	0	0
2022	0%	0	0	0%	0	0	0%	0	0
2023	0%	0	0	0%	0	0	0%	0	0
2024	10%	260	337,270	90%	2,336	3,035,431	0%	0	0
2025	10%	303	395,918	90%	2,725	3,563,261	0%	0	0
2026	10%	363	471,136	90%	3,263	4,240,226	0%	0	0
2027	15%	639	789,915	85%	3,618	4,476,184	0%	0	0
2028	15%	759	945,969	85%	4,301	5,360,493	0%	0	0
2029	20%	1,206	1,514,257	80%	4,825	6,057,030	0%	0	0
2030	20%	1,413	1,780,183	80%	5,653	7,120,732	0%	0	0
2050	12%	986	1,253,331	88%	7,231	9,191,092	0%	0	0
2032	10%	949	1,218,218	90%	8,544	10,963,961	0%	0	0
2033	10%	1,100	1,409,784	90%	9,904	12,688,052	0%	0	0
2034	10%	1,291	1,660,800	90%	11,620	14,947,200	0%	0	0
2035	12%	1,792	2,327,866	88%	13,142	17,071,018	0%	0	0
2036	12%	2,014	2,822,001	88%	14,769	20,694,676	0%	0	0
2037	12%	2,248	3,348,517	88%	16,484	24,555,791	0%	0	0
2038	12%	2,487	3,881,574	88%	18,238	28,464,877	0%	0	0
2039	12%	2,751	4,511,626	88%	20,174	33,085,259	0%	0	0
2040	12%	3,009	5,204,512	88%	22,065	38,166,423	0%	0	0
2041	12%	3,252	5,974,789	88%	23,847	43,815,120	0%	0	0
2042	12%	3,449	6,765,245	88%	25,292	49,611,798	0%	0	0
2043	12%	3,559	7,455,772	88%	26,099	54,675,659	0%	0	0
2044	12%	3,614	8,101,789	88%	26,505	59,413,116	0%	0	0
2045	12%	3,409	8,115,025	88%	24,998	59,510,183	0%	0	0
2046	12%	3,286	8,297,953	88%	24,101	60,851,657	0%	0	0
2047	12%	2,959	7,761,898	88%	21,701	56,920,588	0%	0	0
2048	12%	2,784	7,487,127	88%	20,414	54,905,598	0%	0	0
2049	12%	2,625	7,158,856	88%	19,248	52,498,276	0%	0	0
2050	12%	1,643	4,302,930	88%	12,051	31,554,822	0%	0	0
2051	12%	846	1,763,371	88%	6,207	12,931,384	0%	0	0

Table A-43. NOx and GHG Tailpipe Emissions for Scenario 6 in Calendar Year 2050

	BEV			Tailpipe Emission Estimates[5] (tons/day)			
Model Year	Fleet Mix[2] (%)	Population[3]	Energy Consumption[4] (MJ/day)	NO_X	CO_2	CH_4	N_2O
2006	0%	0	0	0	0	0	0
2007	0%	0	0	0	0	0	0
2008	0%	0	0	0	0	0	0
2009	0%	0	0	0	0	0	0
2010	0%	0	0	0	0	0	0
2011	0%	0	0	0	0	0	0
2012	0%	0	0	0	0	0	0
2013	0%	0	0	0	0	0	0
2014	0%	0	0	0	0	0	0
2015	0%	0	0	0	0	0	0
2016	0%	0	0	0	0	0	0
2017	0%	0	0	0	0	0	0
2018	0%	0	0	0	0	0	0
2019	0%	0	0	0	0	0	0
2020	0%	0	0	0	0	0	0
2021	0%	0	0	0	0	0	0
2022	0%	0	0	0	0	0	0
2023	0%	0	0	0	0	0	0
2024	0%	0	0	0.10	281	0.001	0.04
2025	0%	0	0	0.12	330	0.001	0.05
2026	0%	0	0	0.14	393	0.001	0.06
2027	0%	0	0	0.17	439	0.001	0.07
2028	0%	0	0	0.21	526	0.001	0.08
2029	0%	0	0	0.26	632	0.002	0.10
2030	0%	0	0	0.31	743	0.002	0.12
2050	0%	0	0	0.33	872	0.003	0.14
2032	0%	0	0	0.37	1,017	0.003	0.16
2033	0%	0	0	0.43	1,176	0.004	0.18
2034	0%	0	0	0.52	1,386	0.004	0.22
2035	0%	0	0	0.62	1,619	0.005	0.25
2036	0%	0	0	0.75	1,962	0.006	0.31
2037	0%	0	0	0.89	2,328	0.007	0.37
2038	0%	0	0	1.0	2,699	0.008	0.42
2039	0%	0	0	1.2	3,137	0.009	0.49
2040	0%	0	0	1.4	3,619	0.01	0.57
2041	0%	0	0	1.5	4,155	0.01	0.65
2042	0%	0	0	1.7	4,704	0.01	0.74
2043	0%	0	0	1.8	5,184	0.01	0.81
2044	0%	0	0	1.8	5,634	0.02	0.89
2045	0%	0	0	1.7	5,643	0.02	0.89
2046	0%	0	0	1.7	5,770	0.02	0.91
2047	0%	0	0	1.5	5,397	0.01	0.85
2048	0%	0	0	1.3	5,206	0.01	0.82
2049	0%	0	0	1.2	4,978	0.01	0.78
2050	0%	0	0	0.64	2,992	0.007	0.47
2051	0%	0	0	0.22	1,226	0.004	0.19

Notes:

[1] EMFAC data shown here are adjusted by subtracting data for T7 SWCVs from corresponding data for all HHDTs as described in Appendix A. Accelerated turnover adjustments are included in calendar years 2031, 2037, 2045, and 2050 as described in Appendix A.

[2] Fleet mix percentages for each alternative HHDT technology type are determined based on the specific fleet mix assumptions in each scenario, as described in Section 2 of the report.

[3] Population in each model year is calculated based on the fleet mix percentages for each HHDT type and the total population in the adjusted EMFAC data.

[4] Energy consumption is calculated based on adjusted EMFAC data, using the EER for each HHDT type shown in Table A-38.

[5] Emissions from vehicles in each model year are calculated based on the fleet mix composition and the reduction in tailpipe NOx emissions achieved by each HHDT type shown in Table 3-2. Total emissions in each calendar year are calculated as the sum of tailpipe emissions across all HHDT types and all model years in each calendar year.

[6] Values in shaded cells are zero. Numbers may not add due to rounding.

Abbreviations:

BEV - battery electric vehicle
CA Cert. - California certified
CH_4 - methane
CO_2 - carbon dioxide
DSL - diesel
EER - energy economy ratio
EMFAC2017 - Emission Factor Model
gal - gallon
HHDT - heavy heavy duty truck
MJ - megajoule
N_2O - nitrous oxide
NG - natural gas
NO_x - oxides of nitrogen
T7 SWCV - solid waste collection vehicles
TOTEX - total exhaust

Table A-44. Upstream Emission Factors

Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Upstream Emission Factors by Fuel Type (g/MJ)

Calendar Year	Diesel		CNG		Electricity	
	NO_x	CO_2e	NO_x	CO_2e	NO_x	CO_2e
2023	0.015	25.3	0.047	17.6	0.084	75.3
2024	0.015	25.2	0.047	17.4	0.080	71.7
2025	0.015	25.2	0.047	17.3	0.076	68.2
2026	0.015	25.2	0.047	17.2	0.071	64.6
2027	0.015	25.1	0.047	17.1	0.067	61.0
2028	0.015	25.1	0.047	17.0	0.063	57.4
2029	0.015	25.1	0.047	16.9	0.059	53.8
2030	0.015	25.0	0.047	16.8	0.055	50.2
2031	0.015	25.0	0.046	16.6	0.051	46.6
2032	0.015	25.0	0.046	16.6	0.047	44.2
2033	0.015	25.0	0.046	16.5	0.042	41.8
2034	0.015	25.0	0.046	16.4	0.038	39.4
2035	0.015	24.9	0.046	16.3	0.033	36.9
2036	0.015	24.9	0.046	16.3	0.029	34.5
2037	0.014	24.9	0.046	16.2	0.024	32.1
2038	0.014	24.9	0.046	16.1	0.023	30.2
2039	0.014	24.9	0.046	16.1	0.021	28.2
2040	0.014	24.8	0.046	16.0	0.020	26.3
2041	0.014	24.8	0.046	15.9	0.018	24.4
2042	0.014	24.8	0.046	15.9	0.016	22.5
2043	0.014	24.8	0.046	15.8	0.015	20.6
2044	0.014	24.8	0.046	15.8	0.013	18.6
2045	0.014	24.8	0.046	15.7	0.012	16.7
2046	0.014	24.8	0.045	15.7	0.011	15.6
2047	0.014	24.7	0.045	15.6	0.010	14.5
2048	0.014	24.7	0.045	15.6	0.009	13.4
2049	0.014	24.7	0.045	15.6	0.008	12.2
2050	0.014	24.7	0.045	15.5	0.007	11.1

Notes:

[1] Upstream emission factors for years 2023, 2031, 2037, 2045 and 2050 were derived from CA-GREET3.0 model. These values were used to interpolate emission factors for all other years. Details regarding model inputs and assumptions are provided in Appendix A.

Abbreviations:

CA-GREET - California Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation Model
CNG - compressed natural gas
CO_2e - carbon dioxide equivalent
g - gram
MJ - megajoule
NOx - nitrogen oxides

Table A-45. Electricity Grid Mix Assumptions

Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Year[1,2]	Residual Oil	Natural Gas	Coal	Nuclear	Biomass	Hydro-electric	Geo-thermal	Wind	Solar
2020	0.16%	45.45%	3.30%	9.05%	2.35%	12.29%	4.54%	11.46%	11.40%
2023	0.00%	47.20%	0.00%	2.32%	3.03%	9.11%	6.97%	10.03%	21.35%
2031	0.00%	28.27%	0.00%	0.32%	1.96%	9.41%	9.85%	12.29%	37.91%
2037	0.00%	19.22%	0.00%	0.03%	0.12%	7.57%	8.98%	21.34%	42.74%
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] California electricity grid mix assumptions for year 2020 were taken from the most recently available CEC electricity mix data for 2018. Available at: https://www.energy.ca.gov/data-reports/energy-almanac/california-electricity-data/2019-total-system-electric-generation/2018. Accessed December 2020.

[2] 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 November 2020.

Abbreviations:

CEC - California Energy Commission

Table A-46. Renewable Fuel GREET 3.0 Transportation Assumptions

Parameter	Ramboll Assumptions	Source
RNG Pipeline Distance (mi)	1,000	CARB CA- GREET3.0 NG Pipeline Distance[1]
Tallow Transport Distance (mi)	HD Truck - 100	ANL Tallow-based Pathway in GREET[2], EDF Biodiesel in CA[3]
Renewable Diesel Transport Distance (mi)	HD Truck - 100	EDF Biodiesel in CA[3]

Notes:

[1] 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: August 2020.

[2] ANL Tallow-Based Diesel Pathway in GREET. Available at: https://greet.es.anl.gov/publication-tallow-13. Accessed: August 2020.

[3] EDF Biodiesel in California. Available at: https://www.edf.org/sites/default/files/sites/default/files/content/Biodiesel%20Value%20Chain%20-%20August%202013.pdf. Accessed: January 2020.

Abbreviations:

ANL - Argonne National Laboratory
CARB - California Air Resources Board
CA - California
EDF - Environmental Defense Fund
GREET - Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation Model
HD - heavy-duty
mi - miles
NG - natural gas
RNG - Renewable Natural Gas

Table A-47. Energy Economy Ratios and Fuel Economy

Appendix A Tables - Scenario Analysis Assumptions and Detailed Methodology

Truck Technology	EER value[1]	Fuel Economy (mi/DGE)	Source	Description
Conventional Diesel HHDT	1	7.03	CARB ACT ISOR, Appendix H[1]	Fuel Economy of a MY2024 Diesel HHDT.
Low NOx Diesel HHDT	1	7.03	CARB LCFS Regulation[2]	Diesel HHDT EER value from CARB LCFS regulation was used to calculate the fuel economy for a Low-NOx Diesel HHDT.
Low NOx NG HHDT	0.9	6.33	CARB LCFS Regulation[2]	Spark Ignition CNG EER value from CARB LCFS regulation was used to calculate a Low NOx NG HHDT fuel economy.
BEV HHDT	3.029	21.3	CARB ACT Cost Calculator[3]	Fuel Economy of a MY2024 BEV HHDT.

Notes:

[1] EER values are relative to conventional diesel

[1] CARB ACT ISOR Appendix H. Available at: https://ww3.arb.ca.gov/regact/2019/act2019/apph.pdf. Accessed November 2020

[2] LCFS Regulation, 2019. Table 5. Available at: https://ww2.arb.ca.gov/sites/default/files/2020-07/2020_lcfs_fro_oal-approved_unofficial_06302020.pdf. Accessed November 2020.

[3] CARB ACT Cost Calculator. Available at: https://ww2.arb.ca.gov/sites/default/files/2019-05/190508tcocalc_2.xlsx. Accessed November 2020.

Abbreviations:

ACT - Advanced Clean Truck
BEV - battery electric vehicle
CARB - California Air Resources Board
CNG - compressed natural gas
DGE - diesel gallon equivalent
EER - Energy Economy Ratio
HHDT - heavy-heavy-duty truck
ISOR - Initial Statement of Reason
LDV - light duty vehicle
LCFS - Low Carbon Fuel Standard
mi - miles
MY - model year
NG - Natural Gas
NOx - nitrogen oxides

APPENDIX B TABLES
COST ANALYSIS ASSUMPTIONS AND METHODOLOGY

APPENDIX B TABLES

B-1 Vehicle Purchase Cost Assumptions
B-2 Charging Infrastructure Cost Assumptions
B-3 Useful Truck Life Assumptions
B-4 Vehicle Maintenance Cost Assumptions
B-5 Midlife Overhaul Costs Assumptions
B-6 Fuel Economy Assumptions
B-7 Vehicle Registration Fees
B-8 Vehicle License Fees
B-19 Vehicle Insurance Fees
B-10 Vehicle Tailpipe Emission Assumptions
B-11 Vehicle Tailpipe Emissions Calculations
B-12 Upstream Emission Factors
B-13 Fuel Consumption
B-14 Upstream Emissions Calculations
B-15 Total Cost of Ownership 10-year Analysis Summary
B-16 Total Cost of Ownership 15-year Analysis Summary
B-17 LCFS Revenue Estimation

Table B-1. Vehicle Purchase Cost Assumptions

Technology	Purchase Cost (with tax[1])	Source	Description
Conventional Diesel Truck	$172,921	CARB ACT ISOR, Appendix H[2]	Cost of a MY2024 Class 8 Day Cab, assuming compliance with GHG Phase 2 Standards.
Federal Low-NO_x Diesel Truck	$178,623	NREL Low-NOx Diesel Cost Study[3]	The NREL Low-NOx Study, commissioned by CARB, provides a range of incremental engine and aftertreatment costs for a 12-13L Truck. For a Federal Low-NOx diesel truck, the study assumes: - 0.02 g/bhp-hr Federal NOx Regulation begins MY 2023 - 10-year useful truck life (435,000 miles) - US wide implementation Ramboll Cost Analysis adds the average of high and low incremental cost values reported in the NREL Study to the baseline cost of a conventional diesel truck as reported by the CARB ACT Cost Calculator.
CA Low-NO_x Diesel Truck	$210,876	NREL Low-NO_x Diesel Cost Study[3,4]	The NREL Low-NOx Study, commissioned by CARB, provides a range of incremental engine and aftertreatment costs for a 12-13L Truck. For a CA Low-NOx diesel truck, the study assumes: - 0.02 g/bhp hr CA NOx regulation beginning MY 2027 - extended useful truck life (15 years) - extended warranty (800,000 miles) - CA only implementation Ramboll Cost Analysis adds the average of high and low incremental cost values reported in the NREL Study to the baseline cost of a conventional diesel truck as reported by the CARB ACT Cost Calculator.
Low-NO_x NG Truck	$192,719	Port Feasibility Study[5]	Cost of a MY2018 Class 8 Drayage Truck.
2018 BEV	$569,916	CARB ACT ISOR, Appendix H[2]	Cost of a MY2018 Class 8 Truck with 510kWh battery size.
2024 BEV	$384,448	CARB ACT ISOR, Appendix H[2]	Cost of a MY2024 Class 8 Truck with 510kWh battery size. Cost projection of powertrain based on ICCT Projections[6]. Cost Projection of batteries based on Bloomberg battery projections[7] for LDVs with a five-year delay.

Notes:

[1] These purchase costs are inclusive of sales tax (8%) and Federal Excise Tax (12%).

[2] CARB ACT ISOR Appendix H. Available at: https://ww3.arb.ca.gov/regact/2019/act2019/apph.pdf. Accessed: January 2021.

[3] NREL 2020 Low-NOx Diesel Cost Study. Available at: https://www.nrel.gov/docs/fy20osti/76571.pdf. Accessed: January 2021.

[4] While the NREL Low-NOx Diesel Cost Study provides incremental engine and aftertreatment costs assuming a 0.02 g/bhp-hr Federal NOx regulation, the Ramboll total cost of ownership analysis assumes a 0.05 g/bhp-hr emission rate to calculate the total lifetime emissions of a Federal Low-NOx Truck. Please see Table B-10-1 Tailpipe Assumptions for more details.

[5] 2018 Feasibility Assessment for Drayage Trucks for San Pedro Bay Ports Clean Air Action Plan, 2019. Available at: https://cleanairactionplan.org/documents/final-drayage-truck-feasibility-assessment.pdf/. Accessed: January 2021.

[6] 2017 ICCT ZEV Report. Available at: https://theicct.org/sites/default/files/publications/Zero-emission-freight-trucks_ICCT-white-paper_26092017_vF.pdf. Accessed: January 2021.

[7] Bloomberg 2019 Better Batteries Report. Available at: https://www.bloomberg.com/quicktake/batteries. Accessed: January 2021.

Abbreviations:

ACT - Advanced Clean Truck
BEV - battery electric vehicle
CA - California
CARB - California Air Resources Board
g/bhp-hr - gram per brakewear horsepower hour
GHG - greenhouse gas
ICCT - International Council on Clean Transportation
ISOR - Initial Statement of Reason
kWh - kilowatt-hour
L - liter
LDV - light duty vehicle
MY - model year
NOx - nitrogen oxides
NREL - National Renewable Energy Laboratory
ZEV - zero emission vehicle

Table B-2. Charging Infrastructure Cost Assumptions

Infrastructure Item	Cost	Unit	Source	Description
Infrastructure Purchase Cost	$50,000	$/Charger	CARB ACT ISOR, Appendix H[1]	Cost for a 100kW DC Fast charger.
Infrastructure Installation and Upgrade	$55,000	$/Charger	CARB ACT ISOR, Appendix H[1] CARB ICT ISOR[2]	Infrastructure installation and upgrade estimates include the cost of trenching, cables, and transformers. These costs are not inclusive of the costs for new and/or enhanced transmission infrastructure or generation.
Infrastructure Maintenance	$415	$/year	Port Feasibility Study[3]	Annualized maintenance cost over a 10-year truck lifetime. Cost estimate includes annual inspection costs and charger replacement every 10 years.

Notes:

[1] CARB ACT ISOR Appendix H. Available at: https://ww3.arb.ca.gov/regact/2019/act2019/apph.pdf. Accessed: November 2020.

[2] CARB ICT ISOR. Available at: https://ww3.arb.ca.gov/regact/2018/ict2018/isor.pdf. Accessed: January 2021.

[3] 2018 Feasibility Assessment for Drayage Trucks for San Pedro Bay Ports Clean Air Action Plan, 2019. Available at: https://cleanairactionplan.org/documents/final-drayage-truck-feasibility-assessment.pdf/. Accessed: January 2021.

Abbreviations:

ACT - Advanced Clean Truck
CARB - California Air Resources Board
DC - direct current
ICT - Innovative Clean Transit
ISOR - Initial Statement of Reason
kW - kilowatt

Table B-3. Useful Truck Life Assumptions

Useful Truck Life[1]	Unit	Source	Description
10	years	EPA CFR Title 40 Chapter 1 Subchapter C Part 86 A5[2]	Existing EPA adopted useful truck life values for heavy heavy-duty (Class 8) engines.
435,000	miles/lifetime		
15	years	EPA Cleaner Trucks Initiative Proposed Rulemaking[3]	EPA proposed useful truck life update for heavy heavy-duty (Class 8) engines.
909,900	miles/lifetime		

Notes:

[1] Ramboll Cost Analysis conducts a total cost of ownership analysis for both a 10- and 15-year useful truck life.

[2] EPA CFR Title 40 Chapter 1 Subchapter C Part 86 A. Available at: https://www.ecfr.gov/cgi-bin/text-idx?SID=0245958e1b9e7cd2a95602f83bd51858&mc=true&node=se40.21.86_1004_62&rgn=div8. Accessed: July 2020.

[3] EPA Cleaner Trucks Initiative. Available at: https://www.govinfo.gov/content/pkg/FR-2020-01-21/pdf/2020-00542.pdf. Accessed: January 2021.

Abbreviations:

CFR - Code of Federal Regulations
EPA - United States Environmental Protection Agency

Table B-4. Vehicle Maintenance Cost Assumptions

Vehicle Type	Maintenance Cost[1] ($/mile)	Source	Description
Diesel HHDT	$0.19	CARB ACT ISOR, Appendix H[2]	Ramboll Cost Analysis assumes that Low-NOx diesel and NG HHDT trucks have the same maintenace costs as a diesel HHDT.
Low NOx Diesel HHDT	$0.19	CARB ACT ISOR, Appendix H[2]	
Low NOx NG HHDT	$0.19	CARB ACT ISOR, Appendix H[2]	
HHDT BEV	$0.14	CARB ACT ISOR, Appendix H[2]	CARB ACT ISOR assumes that HHDT BEV maintenance costs are 25% lower than diesel HHDT maintenance costs.

<u>Notes:</u>

[1] Maintenace costs in this table are for a Regional Class 8 tractor. These values reflects the cost of labor and parts for routine maintenance, preventative maintenance, and repairing broken components.

[2] CARB ACT ISOR Appendix H. Available at: https://ww3.arb.ca.gov/regact/2019/act2019/apph.pdf. Accessed: January 2021.

<u>Abbreviations:</u>

ACT - Advanced Clean Truck
BEV - battery electric vehicle
CARB - California Air Resources Board
HHDT - heavy-heavy duty truck
ISOR - Initial Statement of Reason
NG - natural gas
NOx - nitrogen oxides

Table B-5. Midlife Overhaul Costs Assumptions

Vehicle Type	Battery Replacement Cost	Source	Description
MY 2018 BEV	**$32,432**	CARB ACT ISOR Appendix H[1]	CARB ACT ISOR assumes that a class 8 day cab will require battery replacement in year 8 of operation. CARB uses assumptions from Bloomberg's LDV battery projections with a 5-year delay to arrive at a $/kWh battery replacement cost. CARB ACT cost calculator assumes a replacement battery size of 227kWh regardless of original vehicle battery size (510kWh). Costs reported in this table are for a 227kWh battery replacement. This assumption may underestimate the overhaul cost for BEV HHDTs.
MY 2024 BEV	**$21,773**	CARB ACT Cost Calculator[2]	

Notes:

[1] CARB ACT ISOR Appendix H. Available at: https://ww3.arb.ca.gov/regact/2019/act2019/apph.pdf. Accessed: January 2021.

[2] CARB ACT Cost Calculator. Available at: https://ww2.arb.ca.gov/sites/default/files/2019-05/190508tcocalc_2.xlsx. Accessed: Accessed: January 2021.

Abbreviations:

ACT - Advanced Clean Truck
BEV - battery electric vehicle
CARB - California Air Resources Board
HHDT - heavy-heavy duty truck
ISOR - Initial Statement of Reason
kWh - kilowatt-hour
LDV - light duty vehicle
MY - model year

Table B-6. Fuel Economy Assumptions

Truck Technology	EER value[1]	Fuel Economy (mi/DGE)	Source	Description
Conventional Diesel HHDT	1	7.03	CARB ACT ISOR, Appendix H[1]	Fuel Economy of a MY2024 Diesel HHDT.
Low NOx Diesel HHDT	1	7.03	CARB LCFS Regulation[2]	Diesel HHDT EER value from CARB LCFS regulation was used to calculate the fuel economy for a Low-NOx Diesel HHDT.
Low NOx NG HHDT	0.9	6.33	CARB LCFS Regulation[2]	Spark Ignition CNG EER value from CARB LCFS regulation was used to calculate a Low NOx NG HHDT fuel economy.
BEV HHDT	3.029	21.3	CARB ACT Cost Calculator[3]	Fuel Economy of a MY2024 BEV HHDT.

Notes:

[1] EER values are relative to conventional diesel

[1] CARB ACT ISOR Appendix H. Available at: https://ww3.arb.ca.gov/regact/2019/act2019/apph.pdf. Accessed: January 2021.

[2] LCFS Regulation, 2019. Table 5. Available at: https://ww2.arb.ca.gov/sites/default/files/2020-07/2020_lcfs_fro_oal-approved_unofficial_06302020.pdf. Accessed: January 2021.

[3] CARB ACT Cost Calculator. Available at: https://ww2.arb.ca.gov/sites/default/files/2019-05/190508tcocalc_2.xlsx. Accessed: January 2021.

Abbreviations:

ACT - Advanced Clean Truck
BEV - battery electric vehicle
CARB - California Air Resources Board
CNG - compressed natural gas
DGE - diesel gallon equivalent
EER - Energy Economy Ratio
HHDT - heavy-heavy duty truck
ISOR - Initial Statement of Reason
LDV - light duty vehicle
LCFS - Low Carbon Fuel Standard
mi - miles
MY - model year
NG - Natural Gas
NO_X - nitrogen oxides

Table B-7. Vehicle Registration Fees

Annual Registration Fees[1] ($/year)	Conventional Diesel HHDT	Federal Low-NOx Diesel HHDT	CA Low-NOx Diesel HHDT	Low-NOx NG HHDT	HHDT BEV-MY2018	HHDT BEV-MY2024
Fixed Fees[2]	$247	$247	$247	$247	$95	$95
Weight Fee[3]	$2,064	$2,064	$2,064	$2,064	$358	$358
Transportation Improvement Fee[4]	$175	$175	$175	$175	$175	$175

Notes:

[1] CARB ACT ISOR Appendix H. Available at: https://ww3.arb.ca.gov/regact/2019/act2019/apph.pdf. Accessed: January 2021.

[2] Fixed registration fees are the sum of all fees that stay constant across all vehicles. These fees vary slightly from county to county; the ones shown here are specifically for Sacramento County. Low-NOx vehicles are assumed to have the same registration fees as conventional diesel trucks.

[3] Weight fees are based on the registered weight of the vehicle. This analysis assumes at all trucks are at or above 80,000 pounds. Diesel and zero-emission trucks pay different weight fees. The annual weight fee for electric vehicles greater than 10,000 pounds is $358. Low-NOx vehicles are assumed to pay the same weight fees as conventional diesel trucks.

[4] The Transportation Improvement Fee is based on vehicle purchase cost and is the same for both diesel and zero-emission vehicles. For vehicles with a price above $60,000, the fee is $175 annually. Low-NOx vehicles are assumed to pay the same Transportation Improvement Fees.

Abbreviations:

ACT - Advanced Clean Truck
BEV - battery electric vehicle
CARB - California Air Resources Board
HHDT - heavy-heavy duty truck
ISOR - Initial Statement of Reason
MY - model year
NG - Natural Gas
NO_X - nitrogen oxides

Table B-8. Vehicle License Fees

Truck Age	Market Value[1,2]	Vehicle License Fees[3,4]					
		Conventional Diesel HHDT	Federal Low-NOx Diesel HHDT	CA Low-NOx Diesel HHDT	Low NOx NG HHDT	HHDT BEV-MY2018	HHDT BEV-MY2024
1	100%	$1,124	$1,161	$1,371	$1,253	$3,704	$1,811
2	90%	$1,012	$1,045	$1,234	$1,127	$3,334	$1,630
3	80%	$899	$929	$1,097	$1,002	$2,964	$1,449
4	70%	$787	$813	$959	$877	$2,593	$1,268
5	60%	$674	$697	$822	$752	$2,223	$1,086
6	50%	$562	$581	$685	$626	$1,852	$905
7	40%	$450	$464	$548	$501	$1,482	$724
8	30%	$337	$348	$411	$376	$1,111	$543
9	25%	$281	$290	$343	$313	$926	$453
10	20%	$225	$232	$274	$251	$741	$362
11	15%	$169	$174	$206	$188	$556	$272
12	15%	$169	$174	$206	$188	$556	$272
13	15%	$169	$174	$206	$188	$556	$272
14	15%	$169	$174	$206	$188	$556	$272
15	15%	$169	$174	$206	$188	$556	$272
16	15%	$169	$174	$206	$188	$556	$272
17	15%	$169	$174	$206	$188	$556	$272
18	15%	$169	$174	$206	$188	$556	$272
19	15%	$169	$174	$206	$188	$556	$272
20	15%	$169	$174	$206	$188	$556	$272

Notes:

[1] 2018 Feasibility Assessment for Drayage Trucks for San Pedro Bay Ports Clean Air Action Plan, 2019. Available at: https://cleanairactionplan.org/documents/final-drayage-truck-feasibility-assessment.pdf/. Accessed: January 2021.

[2] Market value is assumed to stay constant after the 11th truck year age.

[3] CARB ACT ISOR Appendix H. Available at: https://ww3.arb.ca.gov/regact/2019/act2019/apph.pdf. Accessed: January 2021.

The Vehicle License fee is calculated by multiplying the market value of the vehicle by 0.65%. Vehicle Purchase costs are reported in Table B-1

[5] Insurance cost is calculated by multiplying the market value of the vehicle by 3%. Vehicle Purchase costs are reported in Table B-1.

Abbreviations:

ACT - Advanced Clean Truck
BEV - battery electric vehicle
CARB - California Air Resources Board
HHDT - heavy-heavy duty truck
ISOR - Initial Statement of Reason
MY - model year
NG - Natural Gas
NO_X - nitrogen oxides

Table B-9. Vehicle Insurance Fees

Truck Age	Market Value[1,2]	Insurance Costs[1,3]					
		Conventional Diesel HHDT	Federal Low-NOx Diesel HHDT	CA Low-NOx Diesel HHDT	Low NOx NG HHDT	HHDT BEV-MY2018	HHDT BEV-MY2024
1	100%	$5,188	$5,359	$6,326	$5,782	$17,097	$8,358
2	90%	$4,669	$4,823	$5,694	$5,203	$15,388	$7,522
3	80%	$4,150	$4,287	$5,061	$4,625	$13,678	$6,686
4	70%	$3,631	$3,751	$4,428	$4,047	$11,968	$5,850
5	60%	$3,113	$3,215	$3,796	$3,469	$10,258	$5,015
6	50%	$2,594	$2,679	$3,163	$2,891	$8,549	$4,179
7	40%	$2,075	$2,143	$2,531	$2,313	$6,839	$3,343
8	30%	$1,556	$1,608	$1,898	$1,734	$5,129	$2,507
9	25%	$1,297	$1,340	$1,582	$1,445	$4,274	$2,089
10	20%	$1,038	$1,072	$1,265	$1,156	$3,419	$1,672
11	15%	$778	$804	$949	$867	$2,565	$1,254
12	15%	$778	$804	$949	$867	$2,565	$1,254
13	15%	$778	$804	$949	$867	$2,565	$1,254
14	15%	$778	$804	$949	$867	$2,565	$1,254
15	15%	$778	$804	$949	$867	$2,565	$1,254
16	15%	$778	$804	$949	$867	$2,565	$1,254
17	15%	$778	$804	$949	$867	$2,565	$1,254
18	15%	$778	$804	$949	$867	$2,565	$1,254
19	15%	$778	$804	$949	$867	$2,565	$1,254
20	15%	$778	$804	$949	$867	$2,565	$1,254

Notes:

[1] 2018 Feasibility Assessment for Drayage Trucks for San Pedro Bay Ports Clean Air Action Plan, 2019. Available at: https://cleanairactionplan.org/documents/final-drayage-truck-feasibility-assessment.pdf/. Accessed: January 2021.

[2] Market value is assumed to stay constant after the 11th truck year age.

[3] Insurance cost is calculated by multiplying the market value of the vehicle by 3%. Vehicle Purchase costs are reported in Table B-1.

Abbreviations:

ACT - Advanced Clean Truck
BEV - battery electric vehicle
CARB - California Air Resources Board
HHDT - heavy-heavy duty truck
ISOR - Initial Statement of Reason
MY - model year
NG - Natural Gas
NO_X - nitrogen oxides

Table B-10. Vehicle Tailpipe Emission Assumptions

Vehicle Type	Tailpipe Emission Assumptions	
	Tailpipe NO_x	Tailpipe GHG
Conventional Diesel HHDT	Default EMFAC Output	Default EMFAC Output
Federal Low-NOx Diesel HHDT	**75% NO_X** reduction from existing conventional diesel vehicle based on 0.05 g/bhp-hr NOx certification[1]	Default EMFAC Output
California Certified Low-NOx Diesel HHDT	**90% NO_X** reduction from conventional diesel vehicle based on 0.02 g/bhp-hr NOx certification[2]	Default EMFAC Output
Low-NOx Natural Gas HHDT	**90% NO_X** reduction from conventional diesel vehicle based on 0.02 g/bhp-hr NOx certification[3]	Default EMFAC Output
Battery Electric HHDT	Zero NO_x tailpipe emissions	Zero GHG tailpipe emissions

Notes:

[1] EPA is currently developing regulations to establish a Low-NOx emission standard for HHDTs through the Cleaner Trucks Initiative. As no standards have been proposed, this analysis assumes a 0.05 g/bhp-hr standard for Federal Low-NOx Diesel HHDT. Available at: https://ww3.arb.ca.gov/board/books/2020/082720/20-8-2pres.pdf. Accessed: January 2021.

[2] CARB Low NOx Omnibus has implemented a 0.05 g/bhp-hr NOx standard for MY2024-2026 Diesel HHDT. For MY2027-2030 Diesel HHDT, the regulation implements a 0.02 g/bhp-hr NOx standard. Available at: https://ww3.arb.ca.gov/regact/2020/hdomnibuslownox/isor.pdf. Accessed: January 2021.

[3] A number of NG HHDT engines are currently certified to the CARB optional 0.02 g/bhp-hr NOx standard. Available at: https://ww2.arb.ca.gov/our-work/programs/heavy-duty-low-nox/about. Accessed: January 2021.

Abbreviations:

CARB - California Air Resources Board
EMFAC - Emission Estimator model
EPA - United States Environmental Protection Agency
g/bhp-hr - gram per brake horsepower hour
GHG - greenhouse gas
HHDT - heavy-heavy duty truck
MY - model year
NG - natural gas
NO_X - nitrogen oxides

Table B-11. Vehicle Tailpipe Emissions Calculations

Calendar Year	Truck Age	Tailpipe Emission Factors[1,2] (g/mile)		Tailpipe Emissions (ton/year)							
				Conventional Diesel HHDT		Federal Low-NOx HHDT		CA Low-NOx Diesel HHDT		Low NOx NG HHDT	
		NO_x	CO_2e	NO_x	CO_2e	NO_x	CO_2e	NO_x	CO_2e	NO_x	CO_2e
Tailpipe Emissions for a 10-year (435,00 miles) Useful Truck life											
2024	1	1.818	1122	0.087	53.820	0.022	53.820	0.009	53.820	0.009	53.820
2025	2	1.983	1121	0.095	53.748	0.024	53.748	0.010	53.748	0.010	53.748
2026	3	2.142	1120	0.103	53.721	0.026	53.721	0.010	53.721	0.010	53.721
2027	4	2.296	1118	0.110	53.630	0.028	53.630	0.011	53.630	0.011	53.630
2028	5	2.456	1119	0.118	53.678	0.029	53.678	0.012	53.678	0.012	53.678
2029	6	2.631	1123	0.126	53.871	0.032	53.871	0.013	53.871	0.013	53.871
2030	7	2.817	1133	0.135	54.346	0.034	54.346	0.014	54.346	0.014	54.346
2031	8	2.985	1142	0.143	54.760	0.036	54.760	0.014	54.760	0.014	54.760
2032	9	3.138	1151	0.150	55.169	0.038	55.169	0.015	55.169	0.015	55.169
2033	10	3.231	1159	0.155	55.566	0.039	55.566	0.015	55.566	0.015	55.566
Tailpipe Emissions for a 15-year (909,900 miles) Useful Truck life											
2024	1	1.818	1122	0.122	75.051	0.030	75.051	0.012	75.051	0.012	75.051
2025	2	1.983	1121	0.133	74.951	0.033	74.951	0.013	74.951	0.013	74.951
2026	3	2.142	1120	0.143	74.913	0.036	74.913	0.014	74.913	0.014	74.913
2027	4	2.296	1118	0.154	74.786	0.038	74.786	0.015	74.786	0.015	74.786
2028	5	2.456	1119	0.164	74.853	0.041	74.853	0.016	74.853	0.016	74.853
2029	6	2.631	1123	0.176	75.123	0.044	75.123	0.018	75.123	0.018	75.123
2030	7	2.817	1133	0.188	75.785	0.047	75.785	0.019	75.785	0.019	75.785
2031	8	2.985	1142	0.200	76.361	0.050	76.361	0.020	76.361	0.020	76.361
2032	9	3.138	1151	0.210	76.933	0.052	76.933	0.021	76.933	0.021	76.933
2033	10	3.231	1159	0.216	77.486	0.054	77.486	0.022	77.486	0.022	77.486
2034	11	3.323	1167	0.222	78.053	0.056	78.053	0.022	78.053	0.022	78.053
2035	12	3.401	1175	0.227	78.569	0.057	78.569	0.023	78.569	0.023	78.569
2036	13	3.434	1181	0.230	78.990	0.057	78.990	0.023	78.990	0.023	78.990
2037	14	3.455	1187	0.231	79.342	0.058	79.342	0.023	79.342	0.023	79.342
2038	15	3.484	1192	0.233	79.679	0.058	79.679	0.023	79.679	0.023	79.679

Notes:

[1] Tailpipe emission factors are estimated from EMFAC2017 output and adjusted using tailpipe emission assumptiosn provided in Table B-11.

[2] Global warming potential (GWP) of 25 and 298 for CH_4 and N_2O respectively were obtained from the IPCC Fifth Assessment Report, 2014 (AR5). Available at: https://www.ghgprotocol.org/sites/default/files/ghgp/Global-Warming-Potential-Values%20%28Feb%2016%202016%29_1.pdf. Accessed: January 2021.

Abbreviations:

CH_4 - methane	g - gram
CO_2e - carbon dioxide equivalent	NG - natural gas
EMFAC - Emission Estimator model	NO_X - nitrogen oxides
HHDT - heavy-heavy duty truck	N_2O - nitrous oxide

Table B-12. Upstream Emission Factors

Upstream Emission Factors by Fuel Type (g/MJ)						
Calendar Year	Diesel		CNG		Electricity	
	NO_x	CO_2e	NO_x	CO_2e	NO_x	CO_2e
2023	0.015	25.3	0.047	17.6	0.084	75.3
2024	0.015	25.2	0.047	17.4	0.080	71.7
2025	0.015	25.2	0.047	17.3	0.076	68.2
2026	0.015	25.2	0.047	17.2	0.071	64.6
2027	0.015	25.1	0.047	17.1	0.067	61.0
2028	0.015	25.1	0.047	17.0	0.063	57.4
2029	0.015	25.1	0.047	16.9	0.059	53.8
2030	0.015	25.0	0.047	16.8	0.055	50.2
2031	0.015	25.0	0.046	16.6	0.051	46.6
2032	0.015	25.0	0.046	16.6	0.047	44.2
2033	0.015	25.0	0.046	16.5	0.042	41.8
2034	0.015	25.0	0.046	16.4	0.038	39.4
2035	0.015	24.9	0.046	16.3	0.033	36.9
2036	0.015	24.9	0.046	16.3	0.029	34.5
2037	0.014	24.9	0.046	16.2	0.024	32.1
2038	0.014	24.9	0.046	16.1	0.023	30.2
2039	0.014	24.9	0.046	16.1	0.021	28.2
2040	0.014	24.8	0.046	16.0	0.020	26.3
2041	0.014	24.8	0.046	15.9	0.018	24.4
2042	0.014	24.8	0.046	15.9	0.016	22.5
2043	0.014	24.8	0.046	15.8	0.015	20.6
2044	0.014	24.8	0.046	15.8	0.013	18.6
2045	0.014	24.8	0.046	15.7	0.012	16.7
2046	0.014	24.8	0.045	15.7	0.011	15.6
2047	0.014	24.7	0.045	15.6	0.010	14.5
2048	0.014	24.7	0.045	15.6	0.009	13.4
2049	0.014	24.7	0.045	15.6	0.008	12.2
2050	0.014	24.7	0.045	15.5	0.007	11.1

Notes:

[1] Upstream emission factors for years 2023, 2031, 2037, 2045 and 2050 were derived from CA-GREET3.0 model. Emission factors for all other years were estimated by interpolating the emission factors for these years. Details regarding model inputs and assumptions are provided in Appendix A.

Abbreviations:

CA-GREET - California Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation Model
CNG - compressed natural gas
CO_2e - carbon dioxide equivalent
g - gram
MJ - megajoule
NOx - nitrogen oxides

Table B-13. Fuel Consumption

	Conventional Diesel HHDT	Low NOx Diesel HHDT	Low NOx NG HHDT	BEV HHDT
Fuel Economy (mpDGe)	7.03	7.03	6.33	21.29
10-year (435,00 miles) Useful Truck life				
Annual Mileage[1] (mi/yr)	43,500			
Fuel Usage (DGe/yr)	6,188	6,188	6,875	2,043
Energy Consumption (MJ/yr)	832,069	832,069	924,521	274,745
15-year (909,900 miles) Useful Truck life				
Annual Mileage[1] (mi/yr)	60,660			
Fuel Usage (DGe/yr)	8,629	8,629	9,587	2,849
Energy Consumption (MJ/yr)	1,160,306	1,160,306	1,289,229	383,128

Conversion Factor:

Diesel Energy Content[2]	134	MJ/gal

Notes:

[1] Annual Mileage is calculated by dividing useful truck life mileage by the useful truck life age.

[2] LCFS Regulation, Table 4. Available at: https://ww2.arb.ca.gov/sites/default/files/2020-07/2020_lcfs_fro_oal-approved_unofficial_06302020.pdf. Accessed: January 2021.

Abbreviations:

BEV - battery electric vehicle
HHDT - heavy-heavy duty truck
mi - mile
MJ - megajoule
mpDGe - miles per diesel gallon equivalent
NG - natural gas
yr - year

Table B-14. Upstream Emissions Calculations

Year	Truck Age	Upstream Emissions[1] (ton/year)							
		Conventional Diesel HHDT		Low-NOx Diesel HHDT		Low-NOx CNG HHDT		BEV HHDT	
		Diesel		Diesel		CNG		Electricity	
		NO_x	CO_2e	NO_x	CO_2e	NO_x	CO_2e	NO_x	CO_2e
Upstream Emissions for a 10-year (435,00 miles) Useful Truck life									
2024	1	0.014	23	0.014	23	0.048	18	0.024	22
2025	2	0.014	23	0.014	23	0.048	18	0.023	21
2026	3	0.014	23	0.014	23	0.048	18	0.022	20
2027	4	0.014	23	0.014	23	0.048	17	0.020	18
2028	5	0.014	23	0.014	23	0.048	17	0.019	17
2029	6	0.014	23	0.014	23	0.048	17	0.018	16
2030	7	0.013	23	0.013	23	0.047	17	0.017	15
2031	8	0.013	23	0.013	23	0.047	17	0.015	14
2032	9	0.013	23	0.013	23	0.047	17	0.014	13
2033	10	0.013	23	0.013	23	0.047	17	0.013	13
Upstream Emissions for a 15-year (909,900 miles) Useful Truck life									
2024	1	0.019	32	0.019	32	0.067	25	0.034	30
2025	2	0.019	32	0.019	32	0.067	25	0.032	29
2026	3	0.019	32	0.019	32	0.067	24	0.030	27
2027	4	0.019	32	0.019	32	0.067	24	0.028	26
2028	5	0.019	32	0.019	32	0.066	24	0.027	24
2029	6	0.019	32	0.019	32	0.066	24	0.025	23
2030	7	0.019	32	0.019	32	0.066	24	0.023	21
2031	8	0.019	32	0.019	32	0.066	24	0.022	20
2032	9	0.019	32	0.019	32	0.066	24	0.020	19
2033	10	0.019	32	0.019	32	0.066	23	0.018	18
2034	11	0.019	32	0.019	32	0.066	23	0.016	17
2035	12	0.019	32	0.019	32	0.066	23	0.014	16
2036	13	0.019	32	0.019	32	0.065	23	0.012	15
2037	14	0.019	32	0.019	32	0.065	23	0.010	14
2038	15	0.019	32	0.019	32	0.065	23	0.010	13

Notes:

[1] Upstream emissions are calculated using upstream emission factors from Table B-13 and fuel consumption values in Table B-14.

Abbreviations:

BEV - battery electric vehicle
CNG - compressed natural gas
CO_2e - carbon dioxide equivalent
HHDT - heavy-heavy duty truck
NO_X - nitrogen oxides

Table B-15. Total Cost of Ownership 10-year Analysis Summary

Description	Units[1]	Conventional Diesel HHDT	Federal Low-NO_x Diesel HHDT	CA Low-NO_x Diesel HHDT	Low-NO_x NG HHDT	BEV- 2018[2]	BEV-2024[2]
Capital Costs[3]							
Purchase Cost	dollars	$172,921	$178,623	$210,876	$192,719	$569,916	$384,448
Charging Infrastructure	dollar/charger	--	--	--	--	$105,000	$105,000
Total Capital Cost	***dollars***	***$172,921***	***$178,623***	***$210,876***	***$192,719***	***$674,916***	***$489,448***
Operational Costs[4]							
Useful Truck Life	years	10					
Annual Mileage	miles/year	43,500					
Fuel Economy	mpDGe	7.03	7.03	7.03	6.3	21.3	21.3
Lifetime Fuel Cost	dollars	$246,057	$246,057	$246,057	$140,604	$132,820	$132,820
Maintenance Cost	dollars/mile	$0.19	$0.19	$0.19	$0.19	$0.14	$0.14
Lifetime Maintenance Cost	dollars	$82,650	$82,650	$82,650	$82,650	$61,988	$61,988
Lifetime Registration Fees	dollars	$31,211	$31,420	$32,604	$31,938	$27,210	$20,399
Lifetime Insurance Fees	dollars	$29,310	$30,277	$35,744	$32,666	$96,601	$65,164
Lifetime EV Charging Infrastructure Maintenance Cost	dollars	--	--	--	--	$4,150	$4,150
8-year Battery Overhaul Cost	dollars	--	--	--	--	$32,432	$49,442
Total Lifetime Operational Costs	***dollars***	***$389,228***	***$390,404***	***$397,055***	***$287,857***	***$355,201***	***$333,962***
Total Cost							
Total Cost of Ownership	***dollars***	***$562,149***	***$569,027***	***$607,932***	***$480,576***	***$1,030,117***	***$823,411***
Incremental Cost of Ownership	***dollars***	***Baseline***	***$6,877***	***$45,782***	***-$81,573***	***$467,967***	***$261,262***
Emissions[5]							
Total Lifetime Tailpipe Emissions							
NO_x	tons	1.2	0.31	0.12	0.12	0	0
CO_2e	tons	542	542	542	542	0	0
Total Lifetime Upstream Emissions							
NO_x	tons	0.14	0.14	0.14	0.48	0.19	0.19
CO_2e	tons	230	230	230	173	169	169
Total Lifetime Emissions Well-to-Wheels[6]							
NO_x	tons	1.4	0.44	0.26	0.60	0.19	0.19
CO_2e	metric tons	701	701	701	649	154	154
Cost Effectiveness[7]							
Cost Effectiveness (Total Lifetime Tailpipe)							
NO_x	dollar/ton	Baseline	$7,501	$41,610	-$74,139	$382,791	$213,709
CO_2e	dollar/MT	Baseline	N/A	N/A	N/A	$60	$91
Cost Effectiveness (Total Lifetime Well-to-Wheels[6])							
NO_x	dollar/ton	Baseline	$7,501	$41,610	-$107,460	$399,145	$222,839
CO_2e	dollar/MT	Baseline	N/A	N/A	-$1,561	$855	$478

Notes:

[1] All Costs are in 2018 dollars.

[2] BEV-2018 refers to a MY2018 HHDT. All other HHDTs assessed are MY2024 vehicles. For more details please see Table B-1.

[3] Refer to Table B-1 and Table B-2 for details on capital cost assumptions.

[4] Refer to Tables B-4 through Table B-10 for details on operational cost assumptions.

[5] Refer to Tables B-11 through B-15 for details on emission calculations and assumptions.

[6] Well-to-Wheels emissions represent the sum of vehicle tailpipe emissions and upstream emissions.

[7] Cost effectiveness is calculated by dividing the incremental TCO of a vehicle (compared to a conventional diesel HHDT) by the total lifetime emissions reductions (compared to that of a conventional diesel HHDT). A negative cost effectiveness occurs when the cost of the vehicle is less than that of a baseline conventional diesel HHDT or when lifetime emissions of the vehicle is more than the baseline conventional diesel HHDT.

Abbreviations:

ACT - Advanced Clean Truck
BEV - battery electric vehicle
CA - California
CARB - California Air Resources Board
CO_2e - carbon dioxide equivalent
HHDT - heavy-heavy duty truck
ISOR - Initial Statement of Reason
kWh - kilowatt hour
LCFS - Low Carbon Fuel Standard
mpDGe - miles per diesel gallon equivalent
MT - Metric Ton
MY - model year
NG - natural gas
NOx - nitrogen oxides
TCO - total cost of ownership

Table B-16. Total Cost of Ownership 15-year Analysis Summary

Description	Units[1]	Conventional Diesel HHDT	Federal Low-NO_x Diesel HHDT	CA Low-NO_x Diesel HHDT	Low-NO_x NG HHDT	BEV- 2018[2]	BEV-2024[2]
Capital Costs[3]							
Purchase Cost	dollars	$172,921	$178,623	$210,876	$192,719	$569,916	$384,448
Charging Infrastructure	dollar/Charger	--	--	--	--	$105,000	$105,000
Total Capital Cost	***dollars***	***$172,921***	***$178,623***	***$210,876***	***$192,719***	***$674,916***	***$489,448***
Operational Costs[4]							
Useful Truck Life	years	15					
Annual Mileage	miles/year	60,660					
Fuel Economy	mpDGe	7.03	7.03	7.03	6.3	21.3	21.3
Lifetime Fuel Cost	dollars	$534,549	$534,549	$534,549	$301,837	$280,943	$280,943
Maintenance Cost	dollars/mile	$0.19	$0.19	$0.19	$0.19	$0.14	$0.14
Lifetime Maintenance Cost	dollars	$172,881	$172,881	$172,881	$172,881	$129,661	$129,661
Lifetime Registration Fees	dollars	$44,484	$44,721	$46,062	$45,307	$33,129	$25,413
Lifetime Insurance Fees	dollars	$33,201	$34,296	$40,488	$37,002	$109,424	$73,814
Lifetime EV Charging Infrastructure Maintenance Cost	dollars	--	--	--	--	$6,225	$6,225
8-year Battery Overhaul Cost	dollars	--	--	--	--	$32,432	$49,442
Total Lifetime Operational Costs	***dollars***	***$785,114***	***$786,446***	***$793,980***	***$557,028***	***$591,813***	***$565,498***
Total Cost							
Total Cost of Ownership	***dollars***	***$958,035***	***$965,069***	***$1,004,857***	***$749,747***	***$1,266,729***	***$1,054,946***
Incremental Cost of Ownership	***dollars***	***Baseline***	***$7,033***	***$46,821***	***-$208,289***	***$308,694***	***$96,911***
Emissions[5]							
Total Lifetime Tailpipe Emissions							
NO_x	tons	2.8	0.71	0.28	0.28	0	0
CO_2e	tons	1151	1151	1151	1151	0	0
Total Lifetime Upstream Emissions							
NO_x	tons	0.28	0.28	0.28	0.99	0.32	0.32
CO_2e	tons	480	480	480	356	309	309
Total Lifetime Emissions Well-to-Wheels[6]							
NO_x	tons	3.1	0.99	0.57	1.28	0.32	0.32
CO_2e	metric tons	1480	1480	1480	1367	281	281
Cost Effectiveness[7]							
Cost Effectiveness (Total Lifetime Tailpipe)							
NO_x	dollar/ton	Baseline	$3,293	$18,267	-$81,264	$108,394	$34,029
CO_2e	dollar/MT	Baseline	N/A	N/A	N/A	$514	$43
Cost Effectiveness (Total Lifetime Well-to-Wheels)[6]							
NO_x	dollar/ton	Baseline	$3,293	$18,267	-$112,410	$109,901	$34,502
CO_2e	dollar/MT	Baseline	N/A	N/A	-$1,850	$257	$81

Notes:

[1] All Costs are in 2018 dollars.

[2] BEV-2018 refers to a MY2018 HHDT. All other HHDTs assessed are MY2024 vehicles. For more details please see Table B-1.

[3] Refer to Table B-1 and Table B-2 for details on capital cost assumptions.

[4] Refer to Tables B-4 through Table B-10 for details on operational cost assumptions.

[5] Refer to Tables B-11 through B-15 for details on emission calculations and assumptions.

[6] Well-to-Wheels emissions represent the sum of vehicle tailpipe emissions and upstream emissions.

[7] Cost effectiveness is calculated by dividing the incremental TCO of a vehicle (compared to a conventional diesel HHDT) by the total lifetime emissions reductions (compared to that of a conventional diesel HHDT). A negative cost effectiveness occurs when the cost of the vehicle is less than that of a baseline conventional diesel HHDT or when lifetime emissions of the vehicle is more than the baseline conventional diesel HHDT.

Abbreviations:

ACT - Advanced Clean Truck
BEV - battery electric vehicle
CA - California
CARB - California Air Resources Board
CO_2e - carbon dioxide equivalent
HHDT - heavy-heavy duty truck
ISOR - Initial Statement of Reason
kWh - kilowatt hour
LCFS - Low Carbon Fuel Standard
mpDGe - miles per diesel gallon equivalent
MT - Metric Ton
MY - model year
NG - natural gas
NOx - nitrogen oxides
TCO - total cost of ownership

Table B-17. LCFS Revenue Estimation

CARB LCFS Credit Projections[1]	Units	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
Electricity	$/kWh	$0.12	$0.12	$0.12	$0.12	$0.12	$0.11	$0.11	$0.11	$0.11	$0.11	$0.11	$0.11	$0.11	$0.11	$0.11
	$/DGE	$4.65	$4.56	$4.48	$4.39	$4.31	$4.22	$4.14	$4.14	$4.14	$4.14	$4.14	$4.14	$4.14	$4.14	$4.14

Potential Truck Lifetime LCFS Revenue[2] ($/HHDT)	
BEV HHDT- 10-year Useful Life	$88,210
BEV HHDT- 15-year Useful Life	$181,986

Notes:

[1] CARB ACT Cost Calculator. Available at: https://ww2.arb.ca.gov/sites/default/files/2019-05/190508tcocalc_2.xlsx. Accessed: January 2021.

[2] Ramboll has calculated the potential LCFS revenue for BEVs across the truck lifetime using credit price projections from the ACT Cost Calculator and electricity usage assumptions detailed in Table B-13. This calculation is for illustrative purposes and assumes that the BEV HHDT owner and the BEV charging infrastructure owner are the same entity. This entity would generate credits from the LCFS program through charging of the BEV HHDT. Ramboll has not included LCFS revenue in the TCO analysis given uncertainties in future market conditions and availability of credit deficits in the LCFS program in future years.

Abbreviations:

ACT - Advanced Clean Truck
BEV - battery electric vehicle
CARB - California Air Resources Board
DGe - diesel gallon equivalent
HHDT - heavy-heavy duty truck
kWh - kilowatt hour
LCFS - Low Carbon Fuel Standard
TCO - total cost of ownership

Attachment 5:

Brief for *Amicus Curiae* American Petroleum Institute in Support of Petitioners, *Diamond Alternative Energy, LLC v. EPA*, No. 24-7 at 19-22

No. 24-7

In the
Supreme Court of the United States

DIAMOND ALTERNATIVE ENERGY, LLC, et al.,
Petitioners,
v.
ENVIRONMENTAL PROTECTION AGENCY, et al.,
Respondents.

On Petition for Writ of Certiorari to the United States Court of Appeals for the District of Columbia Circuit

BRIEF FOR *AMICUS CURIAE* AMERICAN PETROLEUM INSTITUTE IN SUPPORT OF PETITIONERS

PAUL D. CLEMENT
Counsel of Record
C. HARKER RHODES IV
NICHOLAS A. AQUART*
CLEMENT & MURPHY, PLLC
706 Duke Street
Alexandria, VA 22314
(202) 742-8900
paul.clement@clementmurphy.com

*Supervised by principals of the firm who are members of the Virginia bar

Counsel for Amicus Curiae

August 7, 2024

TABLE OF CONTENTS

TABLE OF AUTHORITIES ii

STATEMENT OF INTEREST 1

SUMMARY OF THE ARGUMENT 1

ARGUMENT 4

I. This Court Should Grant Review And Reverse The D.C. Circuit's Standing Decision 4

  A. The D.C. Circuit Erred in Holding That Petitioners Lacked Standing 5

  B. The D.C. Circuit's Standing Decision Will Create Confusion and Unnecessary Litigation Burdens 13

II. The Court Should Also Grant Review On The Merits And Vacate EPA's Erroneous Waiver Decision 16

CONCLUSION 22

TABLE OF AUTHORITIES

Cases

Am. Petroleum Inst. v. EPA,
No. 24-1196 (D.C. Cir. docketed June 13, 2024) 15

Am. Petroleum Inst. v. EPA,
No. 24-1208 (D.C. Cir. docketed June 18, 2024) 15

Bennett v. Spear,
520 U.S. 154 (1997) 6, 9, 10

Clapper v. Amnesty Int'l USA,
568 U.S. 398 (2013) 11

Corner Post, Inc.
v. Bd. of Governors of the Fed. Rsrv. Sys.,
144 S.Ct. 2440 (2024) 5, 6, 11, 12, 13, 15

Davis v. FEC,
554 U.S. 724 (2008) 12

Dep't of Com. v. New York,
588 U.S. 752 (2019) 6, 7, 10, 11

Energy Future Coal. v. EPA,
793 F.3d 141 (D.C. Cir. 2015) 6, 7

Ford Motor Co. v. EPA,
606 F.2d 1293 (D.C. Cir. 1979) 18

In re Nat'l Highway Traffic Safety Admin.,
No. 24-7001 (6th Cir. docketed July 18, 2024) 15

Larson v. Valente,
456 U.S. 228 (1982) 6, 13

Lujan v. Defenders of Wildlife,
504 U.S. 555 (1992) 5, 6, 7, 8, 10

Massachusetts v. EPA,
549 U.S. 497 (2007) 6, 11, 13

Motor Vehicle Mfrs. Ass'n v. N.Y. State Dep't of Env't Conservation,
17 F.3d 521 (2d Cir. 1994)................................ 18

Nat. Res. Def. Council v. NHTSA,
No. 22-1080 (D.C. Cir. argued Sept. 14, 2023)... 16

Texas v. EPA,
No. 22-1031 (D.C. Cir. argued Sept. 14, 2023)... 15

Uzuegbunam v. Preczewski,
141 S.Ct. 792 (2021) 7

Statute

42 U.S.C. §7543 .... 17, 18, 20, 21

Regulations

84 Fed. Reg. 51,310 (Sept. 27, 2019)........................ 19

87 Fed. Reg. 14,332 (Mar. 14, 2022) 7, 20

89 Fed. Reg. 27,842 (Apr. 18, 2024)................... 15, 16

Other Authorities

H.R. Rep. No. 90-728 (1967)..................................... 18

State of California, *Advanced Clean Cars Waiver Request* 7-9 (May 2012),
https://tinyurl.com/3ca8mf7s............................... 7

STATEMENT OF INTEREST[1]

The American Petroleum Institute ("API") is the national trade association for America's oil and natural gas industry. API has hundreds of members involved in all segments of the industry, including companies that produce, process, and distribute oil and natural gas products, as well as companies that support the oil and natural gas sector. With over 30 active chapters, API harnesses its members' experience to research and advocate for sound approaches to the production and supply of energy resources. API submits this brief to underscore the flaws in the D.C. Circuit's standing decision below, which departs from settled law, threatens to create unnecessary hurdles for a wide array of regulatory challenges, and warrants this Court's review. API also urges this Court to grant review on the merits as well and to vacate EPA's waiver of preemption, as EPA's decision to grant that waiver defies the plain language of the governing statute.

SUMMARY OF THE ARGUMENT

The net result of the decision below is that the D.C. Circuit deflected industry's challenge to EPA's decision to reverse course and green-light California's unprecedented efforts to regulate global climate

---

[1] Pursuant to Supreme Court Rule 37.6, *amicus curiae* states that no counsel for any party authored this brief in whole or in part and that no entity or person, aside from *amicus curiae*, its members, and its counsel, made any monetary contribution toward the preparation or submission of this brief. Pursuant to Supreme Court Rule 37.2, *amicus curiae* affirms that counsel of record for all parties received timely notice of the intent to file this brief.

change without even reaching the merits of the industry challenge. That decision is plainly wrong and plainly consequential. Article III's standing requirements are straightforward, and petitioners satisfy each element here—which is why the federal government did not even challenge petitioners' standing below. EPA's decision to waive federal preemption of California's heightened vehicle emissions standards causes straightforward and obvious harm to petitioners in the fuel industry, even though the standards are formally directed to automakers rather than the fuel industry itself. By forcing automakers to produce more electric vehicles, the standards necessarily reduce sales of fuel and the raw materials used to make that fuel. Indeed, that effect on fuel consumption and the fuel industry is the whole point of the rule. And both basic economics and the government's own administrative findings show that vacating EPA's waiver would be a setback for EPA and California and provide at least some redress for the fuel industry.

The decision below nevertheless concluded that petitioners had not shown redressability, because they had not submitted evidence showing precisely what effect vacating the waiver would have on automakers' manufacturing and pricing decisions. That decision overcomplicates the obvious and contravenes settled law. When a government regulation is imposed with a stated intent to reduce consumption of a particular industry's products, it does not take expert evidence or declarations from the directly regulated parties to show that vacating the regulation will be a setback for the regulators and a boon to the targeted industry—which is why other courts have routinely found Article

III satisfied without demanding that plaintiffs produce the kind of explicit evidence that the panel below considered necessary here. Put simply, the fact that a regulation has been designed to produce a particular effect should normally be sufficient to show that the likely result of vacating that regulation will be to reduce that effect, which is all that redressability requires. It is a fair assumption that a government regulation will at least advance its intended effect, and an equally fair assumption that vacating the rule will frustrate the government's efforts and be a boon to those seeking to avoid or minimize the government's intended effect. By demanding more, the decision below conflicts both with this Court's precedent and with decisions from other circuits.

That error should not escape this Court's review. Leaving the decision below in place threatens to create unnecessary hazards for future challenges to agency action. At best, it will drive parties to hire redressability experts whose testimony should be unnecessary, and encourage burdensome litigation of threshold redressability issues that should be straightforward. And at worst, the decision below may even in some cases entirely prevent judicial review of regulations that by their terms apply only to certain parties but whose effects fall heavily on others. Regulatory challenges are routinely brought by parties that are substantially affected by agency action even though they are not themselves formally regulated by that action, and redressability in those challenges should normally speak for itself. But if the decision below goes unreviewed, it will create perverse incentives for proponents of regulatory actions to contest redressability even where redressability is just the flip side of what the government purports to accomplish with its regulation—which will in turn encourage litigants to file unnecessary affidavits, and increase the cost and burden of litigation for all involved. Those adverse effects on future regulatory challenges, especially in the D.C. Circuit, warrant further review.

This Court should also review the merits, rather than invite the court below to substitute a mootness ruling for its misguided standing ruling. Given that the challenged California standards are in effect only through model year 2025, granting review of the merits now may be the only way to ensure that any court reaches the substance of petitioners' challenge before the waiver expires. And that challenge deserves this Court's attention, as EPA's waiver decision rests on interpretations of the governing statute that cannot be squared with its plain text. The Clean Air Act authorizes EPA to waive preemption only if California "needs" its own standards to address a "compelling and extraordinary" problem in California. But California's stated problem—global climate change—is hardly limited to or "extraordinary" as to California, and California cannot "need" standards that do not meaningfully address a global problem in any event. This Court should grant certiorari and reverse.

ARGUMENT

I. This Court Should Grant Review And Reverse The D.C. Circuit's Standing Decision.

The standing decision below flouts both common sense and well-settled law. If left in place, it threatens at a minimum to create unnecessary confusion and additional litigation burdens for countless "unregulated but adversely affected parties who traditionally have brought, and regularly still bring," challenges to agency rules that may have a significant and concrete impact on their interests even if those rules do not formally regulate their conduct. *Corner Post, Inc. v. Bd. of Governors of the Fed. Rsrv. Sys.*, 144 S.Ct. 2440, 2461 (2024) (Kavanaugh, J., concurring). Further review is accordingly warranted to ensure that the erroneous decision below will not imperil future challenges to agency rules that achieve their objectives by regulating third parties.

A. The D.C. Circuit Erred in Holding That Petitioners Lacked Standing.

1. To establish Article III standing, a party invoking federal jurisdiction must show an "injury in fact," a "causal connection between the injury and the conduct complained of," and that "the injury will be redressed by a favorable decision." *Lujan v. Defenders of Wildlife*, 504 U.S. 555, 560-61 (1992). The third element, redressability, does not usually present much ground for dispute in regulatory challenges. If the regulation is to have any effect vis-à-vis the petitioner, then vacating the rule will provide the petitioner some relief. It is generally that simple. When a plaintiff is itself regulated by a challenged agency action, "there is ordinarily little question" that a decision preventing or vacating that action will redress the plaintiff's injury. *Id.* at 561-62.

And as then-Judge Kavanaugh has observed, that is equally true when an agency action formally regulates a third party, but eliminating it "would remove a regulatory hurdle" to the challenger's business. *Energy Future Coal. v. EPA*, 793 F.3d 141, 144 (D.C. Cir. 2015). That was the precise scenario presented in *Energy Future Coalition*, where (as here) fuel producers challenged an EPA regulation that was "technically directed at vehicle manufacturers" but whose effect was to "prohibit[] or impede[]" the use of one of the challengers' products. *Id.* In that scenario, the challengers were "an object of the action (or forgone action) at issue," and so there was "'little question'" that they had injuries that would be redressed by vacating the regulation. *Id.* (quoting *Lujan*, 504 U.S. at 561-62); *see Bennett v. Spear*, 520 U.S. 154, 169 (1997) (recognizing that standing can arise from an "injury produced by [the] determinative or coercive effect" of the challenged regulation "upon the action of someone else"); *cf. Corner Post*, 144 S.Ct. at 2460 (Kavanaugh, J., concurring) (recognizing that a "typical APA suit" will "often" involve a plaintiff challenging "an allegedly unlawful agency rule that regulates others but also has adverse downstream effects on the plaintiff"). More generally, in establishing redressability, a petitioner can rest on "the predictable effect of Government action on the decisions of third parties," without having to make any specific evidentiary showing to substantiate those predictable effects. *Dep't of Com. v. New York*, 588 U.S. 752, 768 (2019).

A plaintiff likewise need not show that "a favorable decision will relieve his *every* injury." *Larson v. Valente*, 456 U.S. 228, 243 n.15 (1982). Instead, it is enough if prevailing will "*slow* or *reduce*" the relevant harm, *Massachusetts v. EPA*, 549 U.S. 497, 525 (2007), even if by as little as "one dollar," *Uzuegbunam v. Preczewski*, 141 S.Ct. 792, 802 (2021). As long as some degree of redress is "'likely' as opposed to merely 'speculative'" from a favorable judgment, Article III redressability is satisfied. *Lujan*, 504 U.S. at 561.

2. Under that settled precedent, the standing inquiry in this case should have been straightforward. The challenged EPA waiver empowers California to impose standards that require automakers to produce and deliver for sale vehicle fleets that consume less liquid fuel. The "predictable effect" of that regulation—and indeed, its explicitly intended effect—is to reduce the demand for petitioners' products. *Dep't of Com.*, 588 U.S. at 768. By the same token, vacating the waiver "would remove a regulatory hurdle" to petitioners' future sales, making clear that petitioners' injury "is redressable" even though they are not the direct object of the challenged agency action. *Energy Future Coal.*, 793 F.3d at 144-45; *see Lujan*, 504 U.S. at 561-62.

That conclusion is confirmed by California's own statements. After all, California had already determined that its standards would lead to "reductions in fuel production," 87 Fed. Reg. 14,332, 14,364 (Mar. 14, 2022) (quoting California's 2012 Waiver Request, EPA-HQ-OAR-2012-0562-0004, at 15-16), and acknowledged that the "oil and gas industry" would be among those "most adversely affected" by the new standards and their resulting "substantial reductions in demand for gasoline," C.A.App.801; *see also* State of California, *Advanced Clean Cars Waiver Request* 7-9 (May 2012), https://tinyurl.com/3ca8mf7s (noting that electric vehicles can "dramatically reduce petroleum consumption"). The California Air Resources Board's declarant below likewise recognized that without the standards, "it is reasonable to expect that there would be … additional gasoline-fueled vehicles produced and sold during these model years to meet the market's demand for vehicles," C.A.States.Interv.Mot.Add.11, with an attendant increase in demand for liquid fuel. California's own representations thus demonstrate that the state's standards were designed to reduce the consumption of the fuel products that petitioners produce and sell, and that petitioners would benefit from increased sales absent those standards. Nothing more is required to establish redressability.

3. The D.C. Circuit's contrary decision defies this Court's precedent and common sense. The panel acknowledged that petitioners' injuries would be redressed "if automobile manufacturers responded to vacatur of the waiver by producing [or] selling fewer non-conventional [i.e., electric] vehicles or by altering the prices of their vehicles such that fewer non-conventional vehicles—and more conventional vehicles—were sold." Pet.App.22a. But instead of recognizing the obvious—that it is at least "likely," *Lujan*, 504 U.S. at 561, that a waiver designed to mandate automakers to produce more electric vehicles would in fact operate as intended, and that vacating that mandate would at least retard that intended result—the panel insisted on "record evidence" that "manufacturers would, in fact, change course with respect to the relevant model years if this Court were to vacate the waiver." Pet.App.23a. Likewise, despite admitting that manufacturers "could change their prices" in response to vacatur of the waiver, "which

may redress Petitioners' injuries because pricing could affect the mix of conventional and electric vehicles purchased," the panel refused to credit that theory either because (it believed) petitioners had not submitted explicit "evidence that manufacturers would change their prices." Pet.App.24a.

That demand for specific "record evidence" to prove that eliminating coercive regulations is likely to lead regulated parties to change their behavior, Pet.App.23a, cannot be squared with this Court's precedent. In *Bennett*, for example, this Court considered a challenge by a group of ranchers and irrigation districts to a Biological Opinion issued by the U.S. Fish and Wildlife Service under the Endangered Species Act. 520 U.S. at 158-59. That Biological Opinion concluded that unless the Bureau of Reclamation made changes to the operation of the Klamath Project, a series of lakes, rivers, dams, and irrigation canals in northern California and southern Oregon from which the petitioners received water, it would jeopardize the continued existence of two endangered species of fish. *Id.* The government challenged the petitioners' Article III standing, asserting that vacating the Biological Opinion would not necessarily redress the petitioners' injury because the Bureau of Reclamation "retain[ed] ultimate responsibility for determining" how to operate the Klamath Project, and could decide to allocate less water to petitioners even absent the Biological Opinion. *Id.* at 168.

In a unanimous opinion by Justice Scalia, this Court rejected the government's argument. As the Court explained, while redressability may be lacking if a plaintiff's injury "is 'the result of the *independent* action of some third party not before the court,'" that "does not exclude injury produced by determinative or coercive effect upon the action of someone else." *Id.* at 169 (brackets omitted) (quoting *Lujan*, 504 U.S. at 560-61). Thus, it did not matter that the Bureau of Reclamation had the power to impose the same water restrictions independent of the Biological Opinion. What mattered was that the Biological Opinion "has a powerful coercive effect" on the Bureau, such that vacating it meant that petitioners' injury "will 'likely' be redressed—i.e., the Bureau will not impose [the same] water level restrictions—if the Biological Opinion" is set aside. *Id.* at 169, 171. The same logic applies here: Given the "powerful coercive effect" of the California standards, and their express intent of reducing liquid fuel consumption, it is "not difficult to conclude" that vacating the waiver is "likely" to affect the behavior of the regulated automakers and redress petitioners' injury. *Id.* at 169, 170-71. Petitioners here were not required to submit additional explicit evidence to prove that straightforward point, any more than the *Bennett* petitioners would have been required at summary judgment to submit an affidavit from the Bureau of Reclamation declaring that it would in fact change its water level restrictions if the Biological Opinion were vacated. *See id.* at 170-71.

This Court's decision in *Department of Commerce* confirms the point. The plaintiffs there—a variety of government and non-government organizations—challenged the government's decision to include a question about citizenship on the decennial census. 588 U.S. at 763-64. That decision did not regulate the plaintiffs directly, but they contended that they were injured because including that question would predictably lead noncitizen households to respond to the census at lower rates than other groups. *Id.* at 766-67. This Court—again unanimously—found that theory sufficient to support Article III standing, rejecting the government's argument that any harm to the plaintiffs depended on "speculation about the decisions of independent actors." *Id.* at 768 (quoting *Clapper v. Amnesty Int'l USA*, 568 U.S. 398, 414 (2013)). Again, the Court concluded that the "predictable effect of Government action on the decisions of third parties" was sufficient to show standing, without requiring explicit statements from those third parties themselves describing precisely how they would respond to a favorable judicial decision. *Id.* The D.C. Circuit's decision to require more here cannot be reconciled with either *Bennett* or *Department of Commerce*.

In short, it has been "long understood" that agency action can be challenged "in suits by unregulated plaintiffs who are adversely affected by an agency's regulation of others," *Corner Post*, 144 S.Ct. at 2460 (Kavanaugh, J., concurring)—and yet this Court has never required those adversely affected plaintiffs to submit explicit testimony from the directly regulated third parties detailing their likely response to a favorable judgment in order to establish redressability. That is for good reason. After all, if those third parties were going to do what the agency regulation required whether or not that regulation existed, the agency "would presumably not bother" promulgating the regulation at all. *Massachusetts*, 549 U.S. at 526.

More to the point, there is a reason why "entire classes of administrative litigation … have traditionally been brought by unregulated parties," *Corner Post*, 144 S.Ct. at 2464 (Kavanaugh, J., concurring): The directly regulated parties in those cases typically have their own reasons for not bringing the litigation themselves—ranging from a clear-eyed recognition that the real costs of the regulation fall elsewhere to agency capture or fear of retaliation after getting crosswise with their regulator. The same considerations that caused them to forgo bringing their own challenge will make them reluctant to cooperate with the unregulated parties even when it comes to something as simple as confirming that vacating a rule designed to increase the production and delivery for sale of electric vehicles will likely result in the production of fewer electric vehicles.

4. The panel below believed this case was special because (in its view) the "relatively short duration" of the waiver at issue, which applies only through model year 2025, suggested that the directly regulated parties might already be locked into their production decisions. Pet.App.22a. But that is at most a (misplaced) mootness concern, not a redressability deficiency. The standing inquiry "focuse[s] on whether the party invoking jurisdiction had the requisite stake in the outcome *when the suit was filed*," not when the court eventually renders its decision. *Davis v. FEC*, 554 U.S. 724, 734 (2008) (emphasis added); *see* Pet.App.25a. And at the time petitioners filed their challenge—within 60 days of EPA's March 2022 order, *see* Pet.App.14a-15a—the waiver still had some four years left to run, which was ample time for

automakers to revise their production and/or pricing plans if the waiver were vacated.

Again, the agency's own actions prove the point: If manufacturers' plans for the next four years were already firmly locked in place in March 2022, there would have been no point in issuing the waiver at all. While manufacturers may take "years of lead time" to plan their entire future model fleets or "re-optimize" their product plans in response to regulatory shifts, Pet.App.23a-24a, it hardly follows that vacating the waiver would lead to *no change at all* in automakers' production mixes for the next four years—and any change at all would suffice, as even partial relief is enough to establish redressability. *Massachusetts*, 549 U.S. at 525; *Larson*, 456 U.S. at 243 n.15. Moreover, even the panel below conceded that manufacturers "could change their prices" within the period that the waiver covers, "which may redress Petitioners' injuries." Pet.App.24a. Article III did not require petitioners to also submit explicit "evidence" that automobile pricing would respond to the laws of supply and demand if the artificial constraints imposed by the waiver were removed.

B. The D.C. Circuit's Standing Decision Will Create Confusion and Unnecessary Litigation Burdens.

The decision below is not only wrong, but threatens to cause substantial confusion and unwarranted litigation burdens for the wide swath of "unregulated but adversely affected parties who traditionally have brought, and regularly still bring, APA suits challenging agency rules." *Corner Post*, 144 S.Ct. at 2461 (Kavanaugh, J., concurring). As petitioners explain, the decision below conflicts with decisions from at least four other circuits that have correctly followed this Court's precedent and held that non-regulated parties can show standing based on a regulation's predictable effect on regulated third parties, without requiring those non-regulated parties to submit evidence explicitly spelling out that predictable effect in precise detail. Pet.21-23. That conflict over the basic question of what is required to establish Article III standing is of obvious importance and warrants this Court's attention.

That is all the more true because the decision below comes from the D.C. Circuit, which has long been a primary venue for regulatory challenges (and which Congress has made the exclusive venue for many challenges). By suggesting that adversely affected parties may need "additional affidavits or other evidence" to establish redressability even when the predictable effects of vacating the challenged regulation should be clear, Pet.App.24a-25a, the decision below threatens to encourage litigants in countless future regulatory challenges to spend significant resources filling the record with third-party declarations or expert evidence that should be unnecessary, just to explicitly state what common sense already makes obvious.

Those baleful consequences will not be limited to a handful of unlucky litigants. On the contrary, "entire classes of historically common and vitally important litigation against federal agencies" are routinely brought (and in some cases are only likely to be brought) by plaintiffs who are adversely affected but not directly regulated by the challenged agency action. *Corner Post*, 144 S.Ct. at 2464, 2469 (Kavanaugh, J., concurring). API itself provides a perfect example, as it is currently challenging two more recent (and even more extreme) EPA rules and a National Highway Traffic Safety Administration ("NHTSA") rule that together represent the latest front in the same whole-of-government regulatory effort to mandate electrification of the Nation's vehicle fleets. *See Am. Petroleum Inst. v. EPA*, No. 24-1196 (D.C. Cir. docketed June 13, 2024); *Am. Petroleum Inst. v. EPA*, No. 24-1208 (D.C. Cir. docketed June 18, 2024); *In re Nat'l Highway Traffic Safety Admin.*, No. 24-7001 (6th Cir. docketed July 18, 2024). API's members are not the direct object of those rules, but they are unquestionably adversely affected by those rules, which seek to dramatically reduce the number of liquid-fueled vehicles on the Nation's roads by 2032. *See, e.g.*, 89 Fed. Reg. 27,842, 27,858, 28,092, 28,129 (Apr. 18, 2024) (projecting that EPA's new emissions standards will "lower demand for liquid fuel," "reduc[e] … U.S. gasoline consumption by 780 billion gallons," and adversely affect "the petroleum refining industry [and] fuel distributors").

Given the obvious and severe impact of the rules at issue in those cases on API's members, and the equally obvious fact that vacating those rules would at least mitigate that impact, the standing inquiry should be straightforward—which is presumably why the government has not disputed fuel producers' Article III standing in the ongoing litigation over the previous round of analogous EPA and NHTSA standards. *See Texas v. EPA*, No. 22-1031 (D.C. Cir. argued Sept. 14, 2023); *Nat. Res. Def. Council v. NHTSA*, No. 22-1080 (D.C. Cir. argued Sept. 14, 2023). Indeed, API's standing to challenge this latest round of rules is even clearer given that the new standards reach eight years or more into the future. Given the agencies' own projections that their standards will cause automakers to change their behavior (and reduce gasoline consumption by hundreds of billions of gallons), *see, e.g.*, 89 Fed. Reg. at 28,092, there should be no question that vacating those behavior-modifying standards will redress the injuries of API members. But despite the blindingly obvious standing of API and its members, the decision below would require devoting additional resources to an effort to substantiate the obvious. All of that not only wastes resources, but distracts attention from the merits. The latter reality is dramatically illustrated by the decision below, which completely sidestepped petitioners' challenge to a waiver determination that repurposed a provision designed to address California-specific problems into a tool to address the decidedly global issues surrounding global climate change. As explained next, this Court should repudiate this effort to sidestep the merits by not only correcting the D.C. Circuit's flawed standing analysis, but by addressing the merits. At a bare minimum, however, this Court should review and reverse a decision that converts straightforward redressability inquiries into a satellite litigation that needlessly consumes resources and distracts from the merits.

II. The Court Should Also Grant Review On The Merits And Vacate EPA's Erroneous Waiver Decision.

The Court should also review the merits and decide whether EPA has statutory authority to waive preemption for California-specific standards directed at curbing global climate change. Despite repeated challenges, that important issue has now evaded judicial scrutiny for over a decade—and absent this Court's review, it may well evade judicial scrutiny here once again given that its application does not extend beyond the 2025 model year. That is no small matter, as EPA's strained interpretation of the statute cannot be squared with its plain text, and has allowed California to extend its unusual claim to regulatory authority over the Nation's automobile industry far beyond the careful limits that Congress set. This Court should take advantage of this opportunity to correct that seriously problematic state of affairs.

The waiver authority here was designed to allow California to continue to address extraordinary California-specific problems, not to empower California to supplant the federal government in addressing global issues. Under Section 209(b), EPA can waive preemption for California emissions standards only if it concludes that California "need[s] such State standards to meet compelling and extraordinary conditions." 42 U.S.C. §7543(b)(1)(B). The standards at issue here cannot meet that statutory test. They target global climate change, not "compelling and extraordinary" local conditions in California. *Id.* They cannot be "need[ed] … to meet" the conditions they target, *id.*, because (as EPA itself recognizes) they will have limited impact on climate change either in California or at the global level. And EPA's attempt to escape those problems by asserting that Section 209(b) allows it to waive preemption whenever California needs *any* part of its emissions program to address compelling local conditions—

whether or not it needs the particular "State standards" for which it seeks a waiver, *id.*—flatly contravenes the statutory text and would eviscerate the limits that Congress put on the unique regulatory power that it has permitted California to exercise.

1. Allowing California to rely on global climate change as a "compelling and extraordinary" condition that should allow California to set its own emissions standards contravenes the text, structure, and history of Section 209(b). *See* Pet.28-30. Global climate change is not "extraordinary" *to California.* And that is all that matters, as Section 209(b) is designed to allow California to address its own state-specific issues, not to second-guess federal regulation of national (let alone global) issues. *See, e.g.*, *Ford Motor Co. v. EPA*, 606 F.2d 1293, 1303 (D.C. Cir. 1979) (recognizing that the waiver provision "focus[es] on local air quality problems—problems that may differ substantially from those in other parts of the nation"); H.R. Rep. No. 90-728, at 22 (1967) (noting California's "unique problems" and particular "climate and topography"); *see also Motor Vehicle Mfrs. Ass'n v. N.Y. State Dep't of Env't Conservation*, 17 F.3d 521, 526 (2d Cir. 1994) (noting that the waiver provision applies to California "because its unique Los Angeles smog problem caused it to begin regulating auto emissions" before any other state). Nothing in the statutory text or structure remotely suggests that Congress intended to authorize California—and California alone—to set emissions standards targeted at nationwide issues, let alone global ones like global climate change.

2. Even if California were authorized to promulgate emissions standards targeting global

climate conditions, it does not “need” the standards at issue here to “meet” those conditions. By its plain and ordinary language, the statutory requirement that California must “need” its standards to “meet” the relevant conditions means that the standards must be essential to respond to those conditions. *See* Pet.31. That requirement cannot be met by standards that will have no meaningful impact on the conditions they are designed to address—as EPA itself has already concluded with respect to the standards at issue here. *See* 84 Fed. Reg. 51,310, 51,341 (Sept. 27, 2019) (“[T]he waiver would result in an indistinguishable change in global temperatures and … likely no change in temperatures or physical impacts resulting from anthropogenic climate change in California.”); *id.* at 51,349 (California standards “will not meaningfully address global air pollution problems of the sort associated with [greenhouse gas] emissions”).

And even if the standards at issue here were to produce some appreciable effect on greenhouse gas emissions, California cannot “need” those standards if there are other measures that would achieve the same reduction at a lower cost. Absent a showing that other regulatory options—from the wide swath of possible approaches to reducing greenhouse gas emissions that California has at its disposal—could not produce comparable outcomes at a lower cost, it cannot be said that California “needs” these particular emissions standards to meet its global climate change objectives. Section 209(b) therefore does not authorize waiving preemption for these standards.

3. Apparently recognizing those glaring problems, EPA attempts to evade them by arguing

that it can grant a waiver as long as California needs *any part* of its entire vehicle emissions program to respond to compelling and extraordinary local conditions—regardless of whether the particular standards for which California seeks a waiver respond to those local conditions. *See, e.g.*, 87 Fed. Reg. at 14,335. That whole-program approach fails to follow the statutory text. Section 209(b) permits EPA to waive preemption for particular California standards only when California "need[s] *such State standards* to meet compelling and extraordinary conditions," 42 U.S.C. §7543(b)(1)(B) (emphasis added), not whenever California may need some *other* part of its emissions program to address its local air pollution problems.

Congress understood when it enacted Section 209(b) that California's motor vehicle emissions control program would be an evolving program, and that California would have to apply for a new preemption waiver whenever it sought to impose new motor vehicle emissions standards based on changing circumstances. In that context, the decision to allow EPA to waive preemption only when "such State standards" are needed to address compelling local conditions, *id.*, cannot be read to give California free rein to issue any vehicle emissions standards it wants as long as some *other* part of its program is needed to address local air pollution. There is no plausible reason to believe that when Congress afforded California the unique power to set vehicle emissions standards to address its unusual local conditions, it also simultaneously handed California a blank check to tack on any other emissions regulations that California wants, especially when those tacked-on regulations target nationwide (or worldwide) conditions.

To the extent it seeks any textual basis for its interpretation at all, EPA relies on the first sentence of Section 209(b)(1), which provides that EPA can provide a waiver only if California "determines that the State standards will be, in the aggregate, at least as protective of public health and welfare as applicable Federal standards." *Id.* §7543(b)(1). But that "in the aggregate" requirement goes to the overall health and environmental protectiveness of California's program, allowing California to have standards that are different from EPA's but no less protective of public health or welfare. That threshold requirement has nothing to do with the separate requirement in Section 209(b)(1)(B) that the standards for which California seeks a waiver must be needed to meet compelling and extraordinary local conditions. Indeed, Congress' use of the "in the aggregate" language in setting the threshold condition for California's standards demonstrates that Congress knows how to focus on the overall effect of California's regulatory program when it wants to. By omitting that "in the aggregate" language in §209(b)(1)(B), Congress clearly wanted the focus to be on the particular standards for which California seeks a waiver.

The whole-program approach thus cannot be reconciled with the text or structure of Section 209(b)(1)(B). Indeed, it effectively eliminates the statutory requirement that California "need such State standards to meet compelling and extraordinary conditions" entirely, *id.*, and instead allows California to expand its emissions program to include any standards California considers desirable to address national or global air pollution problems—eviscerating the strict limits that Congress set on Section 209(b)'s unusual one-state-only grant of regulatory power. This Court should not allow EPA to continue to rely on that flawed interpretation of the statute to issue waivers authorizing California to regulate far more than Congress authorized.

CONCLUSION

For the foregoing reasons and those stated in the petition, this Court should grant certiorari.

Respectfully submitted,

PAUL D. CLEMENT
Counsel of Record
C. HARKER RHODES IV
NICHOLAS A. AQUART*
CLEMENT & MURPHY, PLLC
706 Duke Street
Alexandria, VA 22314
(202) 742-8900
paul.clement@clementmurphy.com

*Supervised by principals of the firm who are members of the Virginia bar

Counsel for Amicus Curiae

August 7, 2024