Western States Petroleum Association

Tiffany Roberts
Vice President, Regulatory Affairs

September 7, 2021

Ms. Rajinder Sahota
California Air Resources Board
1001 I Street
Sacramento, California 95814

Re: WSPA Comments on Aug 17th Scoping Plan Workshop

Dear Ms. Sahota,

Western States Petroleum Association (WSPA) is a trade association that represents energy companies that explore for, produce, refine, transport and market petroleum products, natural gas, and other energy supplies in California and four other western states. Currently 152,000 men and women have careers in the oil and gas industry in California and 366,000 people have careers whose jobs depend on the industry. The industry in California contributes $152 billion every year in economic activity and directly contributes $21.6 billion in in local, state, and federal tax revenue to support schools, roads, public safety and other vital services.

The way the world produces and consumes energy is evolving. And the members of WSPA are on the cutting edge of those changes, investing in and developing the diverse energy sources and technologies of the future. We believe that, working together, we can rise to the challenge of a changing climate.

We appreciate the opportunity to provide the below input on the August 17th Scoping Plan workshop. The first section of our letter provides key reflections which are applicable to the modeling work and broader development of the Scoping Plan that would incorporate more reasonable assumptions to expand the range of model parameters. The second section addresses questions which were posed during the workshop, with our discussion referencing specific presentation slides and recommendations on various proposed scenarios.

Key Take-aways and Overarching Reflections

CARB Needs to Expand the Range of Modeling Options – WSPA believes that there are a number of different pathways to achieve carbon neutrality in California and that the Scoping Plan process should be a comprehensive evaluation of those pathways. We appreciate that in CARB's past Scoping Plan updates, the state has put different scenarios side by side to compare the modeling findings. We are encouraged that this type of comparison will happen during the 2022 Scoping Plan update because it will be vital to evaluate which scenarios will be most feasible, provide the most flexibility, cost effective to the consumer in order to achieve the goal. That said, based on the material presented in the workshop, CARB has significantly constrained the options for decarbonization in a number of key sectors. With these constraints, many pathways to achieve carbon neutrality have already been taken off the table and will not even be considered during the Scoping Plan process. WSPA believes that this is not only a significant missed opportunity but is not consistent with what is required under the California Environmental Quality Act (CEQA). We therefore recommend that CARB expand the range of options and alternatives being considered for modeling decarbonization in multiple different sectors. Our specific recommendations on those start on page 5 of this letter.

CARB Needs the Right Tool for the Job - As with any job, having the right tool is essential for an optimal outcome. The modeling work that CARB is undertaking is no different. At a minimum, the type of model CARB should be using should enable the state to identify and optimize the pathways to achieve carbon neutrality based on different priorities such as cost, date certainty, feasibility of implementation, equity, and lifecycle impacts. Unfortunately, the PATHWAYS model (even when combined with the Rhodium Group and UC Irvine models) does not do that as E3 has described the PATHWAYS model as not being an optimization tool, meaning that it effectively presumes certain future endpoints and policy goals and works backwards.

Since the pace of technology deployment and the technology mix is intended to be "picked" by the model user in PATHWAYS - as opposed to endogenously being determined by the model - the scenarios will already be sub-optimal from the outset.

It is unclear how the state will find the "best" scenario using such a limited approach, evaluating only a limited number of user-defined scenarios, unless by sheer coincidence and lucky guess work, the scenario happens to reflect optimal sectoral emission reductions.

Alternatively, adequately modeling economy-wide deep decarbonization scenarios would require a model that has the following features:

- Represent all sectors of the economy and accounts for feedback between the sectors so that it is able to assess the cumulative impact of policies on the different sectors.
- Represent limitation or scarcity of economic and natural resources, e.g. capital, labor, and land. The California economy, as with any other economy, does not have unlimited resources. The combination of measures that defines the PATHWAYS scenarios will have resulted in forced investment that otherwise would not have been made leading to a crowding out of capital and an increase in costs of production through higher costs of capital. This can be one of the most important drivers of the macroeconomic impacts of a distortionary regulation, and simulating it requires a model that represents the supply and demand for scarce resources, including capital, labor, and natural resources. Thus, the model would need to have the ability to capture macroeconomic impacts from crowding out of capital and losses in long-term economic productivity from forced investments.
- Determine the response of supply/demand of goods and services to price changes.

- Determine least-cost technology choices based on cost trade-offs.

An example of a better modeling construct is Electric Power Research Institute's (EPRI) US Regional Economy, Greenhouse Gas, and Energy Model (US-REGEN) which combines a detailed dispatch and capacity expansion model of the United States electric sector with a high-level dynamic computable general equilibrium (CGE) model of the United States economy, including sectoral detail in electric power production, energy demand, and transportation. While this model is sector-specific, the important feature is that the two model components solve **iteratively to convergence**, allowing analysis of policy impacts on the electric sector while taking into account economy level responses. Other strong model examples include Pacific Northwest National Laboratory's GCAM model[1] and MIT's U.S. Regional Energy Policy (USREP) combined with NREL's Renewable Energy Development System (ReEDS) model.[2] Stanford University's Precourt Institute is also incorporating such an approach in conducting their study on climate change programs and technological solutions to reach carbon neutrality in a realistic manner.

The construct of CARB's approach to modeling deserves even more careful reconsideration in light of the number of goals that CARB is responsible for and the complexity of the underlying systems.

Recommendation: CARB should consult with more academic centers of excellence, national labs, and others to identify a stronger modeling construct. In particular, the model should be capable of evaluating the effects of a price on carbon to allow markets to determine the solutions rather than employing arbitrarily mandated targets and handpicked solutions.

CARB Needs the Right Process for the Job - In addition to having the right tool, we also believe CARB should use the right process for the job. Transparency is vital. Given the enormous economic implications and impacts to consumers the state is undertaking in meeting GHG goals, CARB should establish a robust public process for developing the assumptions that go into the model as well as an ability to check the veracity of the data and assumptions underpinning the model.

We request that prior to undertaking any modeling effort, CARB release all the assumptions that will be used in the model for public review. The scope should include information by technology such as greenhouse gas reduction potential and uncertainty, cost (including cost effectiveness), and technology development over time including implementation feasibility. We also request CARB hold at least two workshops on those assumptions and provide ample time for review and public comment.

Considering what is on the line for this Scoping Plan, the state would be well-served to have a peer review of the modeling performed by multiple individuals, including those from academic and non-academic communities as well as those representing different subject-matter disciplines. Independent researchers or research entities could provide valuable input and review of this research process. Including a peer review in the modeling and Scoping Plan process would also help increase transparency and demonstrate independence. Such a peer review could take many forms, including recommendations and guidance at

[1] https://unece.org/fileadmin/DAM/energy/se/pp/CSE/PATHWAYS/2019/ws_Pathways_14-15.May.2019/GCAM_results.pdf
[2] https://globalchange.mit.edu/publication/17596

various stages of the research process, feedback on preliminary findings (that can then be incorporated into the final analysis), and independent assessment of the final findings. A peer review could address many concerns related to the reliability of the data, assumptions and methods used, the validity of the results, and the robustness of interpretations and conclusions drawn from those results.

Lastly, in order to avoid unintended consequences, the Scoping Plan and modeling work that informs it should strive to maintain optionality and flexibility for unknown/unpredictable future events. The analysis should provide insight that will help the state avoid foreclosing on potential pathways and future technological advancements. Further, this optionality should favor consumer choice over mandates, due to these uncertainties. The Scoping Plan and scenarios should be based on actual information and data for where there is technology/cost certainty (e.g. Renewable diesel, Blue H2/CCS) vs. uncertainty (LEV/ZEV consumer adoption, precious metal suppy). That said, scenarios should be broad enough to acknowledge these uncertainties. CARB should broaden the range of assumed economic and technology assumptions. CARB's proposed options in some cases are so narrow that they will absolutely skew the outcome and not even contemplate a potentially real-world different outcome. For example, the vehicle fleet electrification scenarios all assume 100% sales of ZEVs, just varying by year. As another example, the VMT scenarios all assume at least a 15% VMT per capita improvement. In both cases, CARB is likely NOT bracketing its scenarios properly around a real-world potential midpoint. This will be especially important given the fact that the Scoping Plan is looking out decades into the future, and there is significant uncertainty.

Recommendation: CARB should (1) include a peer review in the modeling process; (2) broaden the range of assumed economic and technology assumptions.

Market Mechanisms Should Play a Key Role in Future Scoping Plan – Based on the August 17th presentation, it is unclear what CARB's assumptions are for a post-2030 cap-and-trade or LCFS and what role a price on carbon will play. We believe the price on carbon will drive solutions and that should be reflected in the modeling work. As presented however, we do not see CARB envisioning a role for market mechanisms and a price on carbon post-2030.

Market driven approaches can achieve greenhouse gas reductions across the board at a lower cost to society. WSPA believes that a market-based approach will be critical to reaching carbon neutrality in the most cost-effective manner. California has been a leader in supporting market-based programs like cap-and-trade and LCFS, and other jurisdictions have used the California programs as templates for their own. During the design phase of these programs, consideration should be given for how implementable they would be at the national and international level. Because California is part of a global economy, boutique programs that only exist in California (e.g. bans and mandates) are more likely to fail in achieving real net results. We encourage CARB and the state's policymakers not to lose this leadership and avoid falling into the mandate trap.

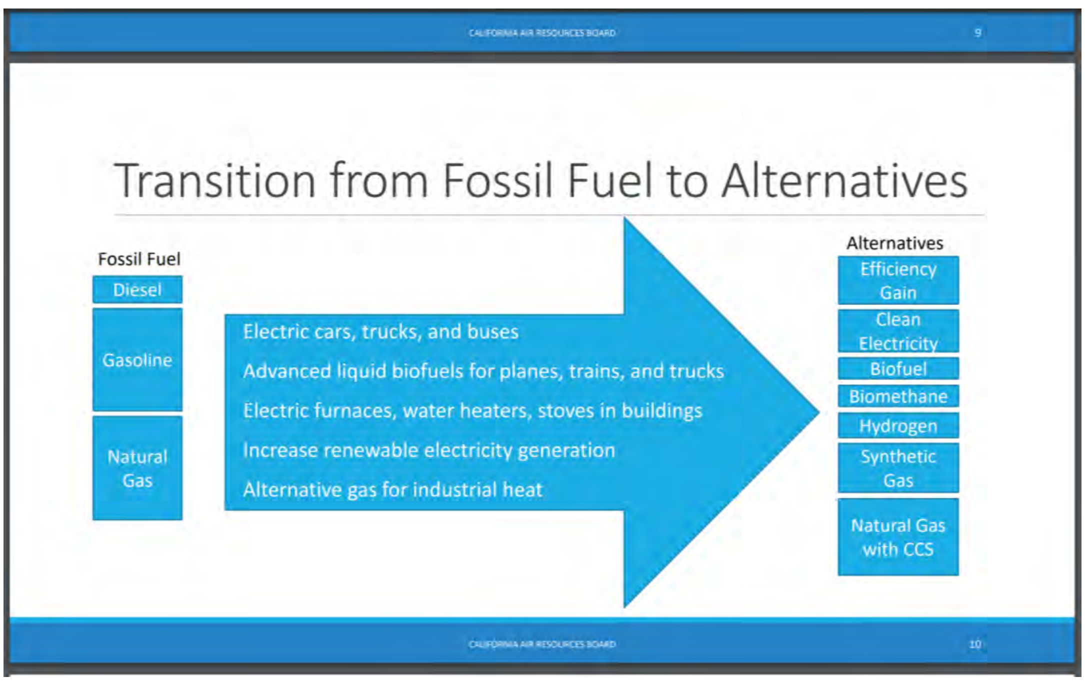
Recommendation: CARB should evaluate the potential role (and additional benefit) that market mechanisms and a price on carbon could contribute (in place of bans and mandates) to pursuing carbon neutrality. This type of evaluation would require the appropriate modeling tool as described above.

Responses to August 17th Questions Posed by CARB and Recommendations on Options

Transition from Fossil Fuels to Alternatives (Slide 10)

The Scoping Plan will need to not only acknowledge but also take very seriously the fact that there will be a significant need for petroleum fuels well beyond 2045. In addition, while CARB does not regulate marine and aviation fuels due to jurisdictional issues, it is important for CARB to contemplate what technological developments and breakthroughs the state might forgo in some sectors such as marine and aviation by prematurely accelerating elimination of fuels in other sectors.

Recommendation: To reflect the need for the state to maintain optionality, CARB should make some additions to the concepts illustrated in slide 10. In addition to items already listed, CARB should add elements to the arrow diagram and "Alternatives" list such as low carbon petroleum fuels, low carbon petroleum fuels with CCS, and low carbon gasoline for the light-duty sector.



Carbon Neutrality Timeline (Slides 11-12)

The workshop discussed the scenario concepts for modeling a future carbon neutral economy. However, little has been discussed in Scoping Plan workshops to date regarding the SB 32 goal of reducing GHG emissions by 40% below 1990 levels by 2030. California has just commenced the post-2020 increased rate of decline of the statewide emissions cap, and the impact on the carbon market price has already produced a significant rate of increase over the pre-2021 rate. Without waiting to see the effect of this increased carbon price on obligated entities' emissions, some stakeholders appear to be taking the 4-year-early achievement of the 2020 goal for granted and advocating to move the goalpost. This raises an important question: how much of the 2022 Scoping Plan will discuss the 2030 goal? At a minimum, we recommend that the Scoping Plan include a detailed summary of the assumptions and forecasts related to achieving the 2030 goal. This is effectively the 2030 "baseline" for the scenario modeling to future years. We believe that a strong public understanding of the implications of meeting the 2030 target will facilitate better public understanding and discussion. From the beginning, program designers have discussed the intent to have the program slowly increase in stringency over time as a means to protect California consumers from escalating costs and test the viability of new technologies. As a reminder, the program is doing exactly what it was designed to do regarding incentivizing innovation.

From a scientific perspective, a carbon budget that considers cumulative emissions over many years is more important than reaching a specific volume of emissions in a single target year (e.g. 2030 or 2045). A cumulative look at all emissions from now until 2045 is the appropriate approach as opposed to narrowly focusing on a single year. For example, a million-ton reduction that starts in 2025, would be, ceteris paribus, equal to 20 million tons in 2045. Therefore in the past CARB has encouraged and supported early actions to reduce emissions, and we believe CARB should continue to support this approach. This underscores the importance of allowing existing strategies (e.g. CCUS, efficiency, biofuels) to start bearing fruit today rather than rely on the promise of unlikely strategies. Doing so will avoid stifling innovation in technologies that can deliver large quantities of real reductions.

From a business planning perspective, the state needs to demonstrate that they will not change the rules of engagement midstream because doing so disrupts business planning processes, etc. The state has already laid out the path to 2030 and changing this path now will undermine the significant work that businesses have undertaken to prepare to operate under that pathway. This is critical because the current pathway relies on market-based approaches like cap-and-trade and the LCFS which depend on the confidence of investors and financial institutions to maintain the viability and stability of the program and are thus key factors in making investment decisions.

For evaluation purposes, WSPA believes that the carbon neutrality 2045 timeline should be bracketed with more and less aggressive cases that would include carbon neutrality by 2035 and carbon neutrality by mid-century (i.e., 2050) in line with IPCC recommendations. CARB's proposal to model only more aggressive cases (Options A and B on slide 12) in addition to the 2045 case does not effectively bracket the "mid" case.

Recommendations: (1) The Scoping Plan should include a detailed summary of the assumptions and forecasts related to achieving the 2030 goal. (2) CARB should continue to support the science of a cumulative emissions approach to planning. (3) We welcome CARB evaluating, as directed by Governor Newsom in 2021, an accelerated goal of achieving carbon net-neutrality by 2035, so long as that evaluation transparently identifies the technological and economic hurdles to full implementation and fairly recognizes that it will be exponentially more difficult to achieve that goal. CARB should also model options on the other end of the spectrum.

Role of Engineered Carbon Removal (Slides 13-14)

Our last comment letter included a robust list of emerging research that demonstrates and underscores the consensus in the scientific community about the need to deploy CCUS and other forms of negative emissions technologies if the world hopes to meet the goal of the Paris Accord. Decarbonization of transportation fuels, including difficult-to-decarbonize heavy transport, aviation and marine, can accelerate with deployment of CCUS. CCUS associated with fuel life cycle provides tangible, cost effective (given existing LCFS and federal programs) and technologically available carbon reductions in the near term as compared to other methodologies.

CCUS is one of the most promising technologies to decarbonize liquid fuels and as CARB has recognized that liquid fuels will be part of future long beyond 2045, CCUS is critical to reducing greenhouse gas emissions from those fuels. Additionally, when CCS is combined with biofuels there is the real potential for negative emissions on a lifecycle basis which other solutions simply cannot offer. Considering the vast application of CCUS in a number of different industries and solutions, there is also an economy of scale which can be captured with large scale adoption of CCUS using hubs, CO2 pipelines, and shared sequestration.

Recommendations: (1) More specificity is needed regarding levels of engineered carbon removal to be evaluated. Specifically, WSPA recommends that CARB include a scenario that uses at least 60 MMT/yr from industrial sources identified in the Stanford Report entitled "An Action Plan for Carbon Capture and Storage in California"[3] and at least 100 MMT/year of technological negative emissions identified in the LLNL Report entitled "Getting to Neutral: Options for Negative Carbon Emissions in California"[4]. WSPA also recommends that CARB include a scenario which has more than 100 MMT/year of negative emissions. We note that LLNL only included in their analysis projects adding up to 125 MMT/year of negative emissions that the lab identified would be needed to achieve carbon neutrality in 2045 taking into account the 80% reduction by 2050 goal. Due to this, LLNL only noted in their report projects with a cost up to ~$200/MT. If CARB is considering any scenario with emission reduction options that are more expensive than $200/MT CO2e, this option could significantly reduce the overall cost of achieving carbon neutrality. Additionally, it is very possible that the $200 MT CO2e could drop over time making this scenario even more attractive for reaching carbon neutrality. (2) CARB should not only model deployment of engineered carbon removal as part of its scenarios, but it should also evaluate the trade-offs of not deploying significant negative emissions technologies as part of its modeling exercise. We believe evaluation of these trade-offs should include a look at cost-effectiveness as well as an evaluation of the impact to employment and labor income.

Carbon Free Electricity Grid (Slides 15-16)

Attached to this letter is analysis completed by the engineering firm Ramboll Environ which evaluates the potential costs associated with necessary upgrades to California's electricity infrastructure in order to transition a significant amount of the state's energy reliance to the electricity grid. In this meta-study,

---

[3] CCS in CA: Full Report | Stanford Center for Carbon Storage

[4] https://www-gs.llnl.gov/content/assets/docs/energy/Getting_to_Neutral.pdf

Ramboll reviewed existing published literature in order to estimate the costs associated with purchase and installation of electric vehicle charging infrastructure as well as upgrades to California's electric grid that would be needed to meet the zero-emission vehicle (ZEV) targets laid forth in recent California Governor Executive Orders. Based on Ramboll's review and analysis of these studies, the cumulative infrastructure costs (generation, transmission, distribution, maintenance and electric vehicle chargers) from 2020 to 2050 to support a statewide on-road ZEV fleet are projected to be at least $2.1 to $3.3 Trillion. We would welcome the opportunity to discuss the analysis to understand how this information could inform scenario development.

In addition, there are key programmatic questions to consider while developing scenarios. Is CARB considering the different ranges for power generation capacity (volume) in its scenarios? For example, in a high EV case there is higher power demand and resulting electricity generation emissions. Are there power generation/emission considerations if the state were to continue to be a power importer, move to be balanced, or potentially grow to be a power exporter to help U.S regions that have less renewable (solar/wind/hydro) resources?

Ultimately, the scenario analysis should take into account what a transition to relying strictly on the grid to provide for the bulk of society's energy needs might mean, especially in terms of reliability and the impact that potential disruptions and the specter of disruptions could have to industry and consumers. The state should identify and adopt the most cost-effective approach to meeting the goal. One way to do this would be by using all available technologies including natural gas, RNG, biomass combustion and CCS as part of the RPS.

Recommendation: (1) CARB should ensure that modeling scenarios include potential increasing electricity generation and increasing electricity consumption. (2) WSPA strongly supports the inclusion of Scenarios C and D which use the widest possible range of technologies to meet the SB-100 goals. Of note, WSPA strongly believes that natural gas power plants equipped with CCS can play a large role in meeting our SB-100 goals while ensuring grid reliability. This should be included in the modeling.

Vehicle Miles Traveled - VMT (Slides 17-18)

CARB has discussed both in Scoping Plan settings as well as Mobile Source Strategy related activities such as Advanced Clean Cars 2 workshops that even after banning the purchase of internal combustion engine vehicles, the state **<u>would not</u>** achieve the goal of eliminating the use of liquid fuels. Thus, the administration is proposing that the state resort to adopting more draconian policies that limit travel. We do not believe a proposal of this nature is in line with the type of policies most Californians would support.

WSPA believes that this is a strong incentive for CARB to consider a wider range of options for the transportation sector and that bans/mandates are not effective tools. CARB should be open to considering policies that are less impactful to people's lives. With such aggressive proposals for VMT reductions, we believe CARB should develop a metric for the public to understand what the implications of these policies would mean to people's daily lives.

In addition to limiting and curtailing travel altogether, this could also mean more time focused on simply figuring out and planning for logistics of daily travel. Those vehicles traveling the most miles will also be the oldest and least efficient when it comes to emissions, further reducing the mandates efficacy. CARB should be considering better options that are less intrusive such as CCUS and carbon dioxide removal because those technologies would allow for emissions reductions while helping to reduce the disruption to people's lives.

The A/B/C options all assume a 15-20% VMT per capita reduction. Is this supportable by historic data of travel patterns and past attempts at reducing VMT? How does this mandate comport with the USEPA's recently proposed GHG auto emissions standard (based on the CARB-brokered California Automotive Framework) which does not project such a reduction in VMT? We do not believe this truly brackets the range of possible outcomes.

Recommendation: CARB should evaluate a wider range of scenarios including a flat (0%) VMT per capita change over time as well as a middle value of 10%. If the assumptions for VMT are too optimistic and not achieved in practice, the state will fall short of achieving its goals.

Vehicle Fleet Electrification (Slides 19-20)

CARB's draft modeling options all assume 100% ZEV sales, with variations by mandate date between 2025 and 2040. We are concerned that a singular focus on vehicle electrification is not realistic and does not represent the range of options available. Specifically, we believe CARB is not being expansive enough in its choice of scenarios for this sector because it fails to test the value of an ongoing long-term role for low-CI petroleum fuels, natural gas fuels and biofuels particularly given the ongoing technological advances that are enabling fuel manufacturers to continue to reduce the carbon intensity of liquid fuels.

While such an outcome may not be preferred by the Administration, it could be a more realistic consumer preference and market outcome. CARB should therefore include sensitivity analysis in its modeling work in order to adequately account for the long-term potential that the state will miss its ZEV targets. Furthermore, we recommend modeling scenarios where a broader range of technology options are considered to reach lower greenhouse gas and air quality emissions in the transportation sector.

It appears CARB is assuming that the barrier to the state achieving its ZEV goals can be remedied with blanket bans and mandates. However, rare earth mineral supply availability (both current and expected), the cost for incremental production of those materials, and the likelihood those materials will come to market are also major issues that may prove intractable. CARB should conduct a robust analysis to better understand the implications that these market forces will have. This should be similar to the approach taken with the biofuels scenario used in the 2017 Scoping plan. The constraints considered as part of that analysis included feedstock supply, impact due to other market forces, other states requiring the use of renewable fuels, and capital required for various facilities to produce incremental fuel. These barriers led CARB to certain conclusions on the supply of fuels into the state, informing the 2017 scoping plan. CARB should develop a similar ZEV supply model which includes a similar analysis for the explicit purpose of informing the Scoping Plan process.

CARB should also take into account the fact that leap frogging available technology today leaves significant air quality emission reductions on the table for almost two decades. This has been raised as a major concern by a broad number of stakeholders including the South Coast AQMD in the state's Mobile Source Strategy proceedings and associated transportation measures rulemakings. This air quality issue has been demonstrated by analysis conducted by Ramboll (attached as appendix to this comment letter) and furthermore cited by the South Coast AQMD as a significant impediment to reaching SIP requirements. CARB should not move forward with approaches that ignore short-term air quality targets in favor of longer-term climate goals; both are important, and neither should be ignored.

Recommendation on Scenarios: (1) CARB should include one or more scenario that account for and evaluates different EV adoption rates, including slower adoption than those shown in workshop slides. (2) CARB should also model at least one scenario where renewable and low-carbon fuels are used in combination with higher efficiency vehicles to compete with ZEVs on a lifecycle emissions AND cost basis. This should include an aggressive biofuels scenario that actually achieves early emission reductions as compared with ZEVs, and higher hydrogen FCEV adoption for both LDV and HDV.

Recommendation on ZEV Evaluation: (3) CARB should assess the full range of emissions, impacts, and costs generated outside of California for electric vehicles (e.g. from mining, battery production, recycling, etc.) and incorporate those into the model for the transportation system. If CARB continues to push forward with an approach that leads to significant EV adoptions, then CARB cannot and should not ignore full lifecycle greenhouse gas emissions and environmental and societal impacts resulting from the production of those EVs inside and outside of California. Doing so simply outsources and ignores negative societal impacts to those areas who do not have the same level of environmental protections as California. If CARB achieves carbon neutrality inside the state but increases emissions outside of the state, nothing would truly be gained and that leakage would need to be addressed per AB32. (4) CARB should develop a ZEV supply chain analysis and incorporate those findings into the Scoping Plan modeling. This analysis should evaluate market issues such as rare earth mineral supply availability (both current and expected), the cost for incremental production of those materials, and the likelihood those materials will come to market.

Petroleum Fuels (Slides 21-22)

CARB seems to be approaching this sector from a production standpoint instead of an emissions standpoint. Material in the workshop on August 17th seems to convey that CARB believes the only way to reduce emissions from the oil and gas sector is through reductions in refineries and upstream production. We strongly disagree with this assertion and ask that CARB instead approach this sector from an emissions standpoint as there are many opportunities to reduce emissions (efficiency, fuel switching, CCS, use of renewable power and feedstocks, etc.) that are not directly related to a decrease in production. **We believe that cost and feasibility should be the driving factors that determine what the reductions in this sector are.** Of note, CARB's proposed approach could also lead to significant leakage. We believe it is critical that CARB calculate the leakage associated with any scenarios they propose and properly mitigate that leakage, per AB32.

As referenced earlier, producing renewable fuels at in-state refineries from biomass (waste or other) offers the potential for negative emissions when combined with CCS. CA should not ignore this opportunity and should be embracing and encouraging all forms of negative emissions versus taking options off the table.

Climate programs in California provide an opportunity for in-state refining and oil and gas production to provide lower carbon fuels as compared to other parts of the world that are not as far along in their decarbonization journey. In fact, CARB already has programs in place that incentivize reductions in emissions from both upstream and refinery operations. Striving to shut these operations down would prevent those facilities from participating in the global market and contributing to greenhouse gas emission reductions. With a singular focus on eliminating this sector, CARB is missing a huge opportunity to allow the state oil and gas sector to contribute to greenhouse gas emissions reductions outside of the state while supporting jobs and the economy though continued in state production and refining.

Neither the state nor any other government entity should consider phasing out extraction operations. Beyond the legal questions, phasing out extraction is the equivalent of pushing on a string. It would create an artificial constraint on the market which would result in major environmental and economic leakage because demand would be filled from out of state/country. If CARB evaluates any scenarios that place a ban on production or refining, it should also acknowledge and quantify the leakage as well as conduct necessary sensitivity analysis per AB32.

Recommendation: CARB should include multiple scenarios that allow market forces and a price on carbon to drive the emission reductions from this sector as there are many opportunities to reduce emissions (efficiency, fuel switching, CCS, use of renewable power and feedstocks, etc.) that are not directly related to a decrease in production. We believe that cost and feasibility should be the driving factors that determine what the reductions in this sector are over time.

SLCP Methane and Woody and Solid Biomass Waste (Slides 23-26)

Biomass of SLCP methane should be allowed to be in the fuel mix to support low emission vehicles, and its use should not be restricted. Multiple pathways (fuels, residential, electricity, hydrogen, etc.) should be allowed to deal with these waste streams based on which is the most cost-efficient and effective. Ramboll's analysis of the heavy-heavy duty sector demonstrates that this is one of the most cost-effective ways to reduce NOX in the short term and still provide progress on GHG emissions aligned with CARB's goals.

Additionally, cutting off access to incentives and LCFS credits will only serve to prevent people from purchasing and investing in these vehicles which are critical for the NOx goals of SCAQMD and SJVAPCD. CARB should not ignore the potential for achieving short term air quality goals. If CARB cuts off a pathway which happens to be one of the most cost-effective ways to reduce GHG and NOx emissions, then it would increase the overall cost of achieving carbon neutrality.

Recommendation: WSPA supports CARB's modeling scenarios and appreciates that many allow all SLCP methane/woody/solid biomass waste to include fuels derived from those sources.

Residential and Commercial Building Decarbonization (Slides 27-28)

Similar to our comments in the Vehicle Electrification Section, CARB is taking the wrong approach to this sector. CARB seems to be viewing the elimination of natural gas as the only option to reduce emissions which is patently not the case as there is significant potential for emissions reduction from renewable fuel sources like renewable natural gas from landfills and dairies, lower carbon natural gas, hydrogen, energy efficiency, etc. Bans and mandates do not provide the most cost-effective solutions; appropriate modeling could help identify better, more cost-effective solutions for this sector as a whole Critically, natural gas in buildings is here for the foreseeable future, and we need to find ways to decarbonize the existing building stock using natural gas alongside efforts to reduce emissions from new building stock. As stated earlier, CARB should use an optimization model to determine the best, most cost-effective path forward that allows for consumer choice.

Recommendation: CARB should model scenarios where renewable and low-carbon fuels and energy efficiency improvements exist alongside electrification options.

Industry – Manufacturing, Construction, and Agriculture (Slide 29-30)

Options that require shutting down sectors of the economy should be a non-starter. AB32 requires the state to minimize leakage. Not only are their feasibility concerns, shutting down sectors of the economy would bring extraordinary burdens to families who depend on employment in those sectors. CARB should instead be focused on how to decarbonize the economy in the least disruptive way possible including evaluating additional flexibility like international investments to reduce emissions (similar to Sweden's approach).

Recommendation: CARB should revise Option A as any scenario which forces facilities or sectors to shut down is very likely to lead to leakage from that sector which is exactly the type of impact AB32 was written to avoid. Additionally, WSPA is concerned that the option to use CCS for the industrial sector is not specifically listed in the other options. WSPA strongly believes that CCS offers a significant opportunity for the state to decarbonize the industrial sector and believes it should be specifically called out in the options.

Conclusion

CARB's modeling work should ultimately be constructed with an eye towards supporting and fostering technological innovation. Doing so could create a foundational framework that would attract more investment into the market which would help the state achieve its long-term climate goals. WSPA is prepared to work collaboratively with CARB to help ensure the range of modeled scenarios is expanded given the full vetting and transparency that is necessary.

Thank you for consideration of our comments. We would welcome the opportunity to discuss these ideas in more detail with you. We look forward to working with you on these important issue areas.

Sincerely,

Tiffany K. Roberts,

Vice President, Regulatory Affairs
Western States Petroleum Association

Prepared for
Western States Petroleum Association

Prepared by
Ramboll US Consulting, Inc.
Los Angeles, California

Project Number
1690021217

Date
August 20, 2021

TRANSPORTATION ELECTRIFICATION INFRASTRUCTURE COSTS IN CALIFORNIA:

A META-STUDY OF PUBLISHED LITERATURE

Ramboll US Consulting, Inc.
350 S. Grand Avenue
Suite 2800
Los Angeles, California 90071

CONTENTS

		Page
EXECUTIVE SUMMARY		**1**
1.	**INTRODUCTION**	**3**
1.1	California's Electrification Targets	3
1.2	Purpose of this Study	4
2.	**ZERO-EMISSION LIGHT-DUTY VEHICLE PROJECTIONS IN CALIFORNIA**	**5**
3.	**CHARGING INFRASTRUCTURE SCENARIOS AND COST**	**7**
3.1	Electric Vehicle Charging Infrastructure	7
3.2	Electric Vehicle Charger Cost Estimates	10
4.	**GRID INFRASTRUCTURE COSTS**	**13**
5.	**CONCLUSION**	**16**

TABLES

Table 1-1:	California State ZEV and Charging Infrastructure Targets	3
Table 3-1:	Cumulative Costs for Purchase and Installation of EV Chargers	11
Table 3-2:	Electric Vehicle Charger Purchase and Installation Costs	12
Table 4-1:	EC CEC Study and Princeton NZA Report Scenario Descriptions	14

FIGURES

Figure 2-1:	Light-Duty Zero Emission Vehicle Population Projections	5
Figure 3-1:	CEC AB2127 Data on Installed and Projected Electric Light-Duty Vehicle Chargers Compared with Charging Needs for 1.5 million ZEVs in 2025 and 5 million ZEVs in 2030	7
Figure 3-2:	CEC AB2127 Projected 2030 Charger Counts to Support 5 Million and 8 Million LDV ZEVs	8
Figure 3-3:	Projected Statewide MD/HD and LD EV Chargers	9
Figure 3-4:	Cumulative Costs ($ Billions) for Purchase and Installation of EV Chargers	10
Figure 4-1:	E3 CEC Study's Cumulative Grid Infrastructure Upgrade Cost Estimates from 2020 to Target Year	13

ACRONYMS AND ABBREVIATIONS

AB:	Assembly Bill
BAU:	business-as-usual
BEV:	battery electric vehicle
CARB:	California Air Resources Board
CEC:	California Energy Commission
DC:	direct current
EMFAC2017:	Emission Factor Model
EO:	Executive Order
EV:	electric vehicle
FCEV:	fuel cell electric vehicle
GDP:	Gross Domestic Product
GHG:	greenhouse gas
HD:	heavy-duty
IEPR:	Integrated Energy Policy Report
LD:	light duty
MD:	medium-duty
MSS:	Mobile Source Strategy
NZA:	Net Zero America
RPS:	Renewable Portfolio Standard
SB:	Senate Bill
SCAQMD:	South Coast Air Quality Management District
ZEV:	zero emission vehicle

EXECUTIVE SUMMARY

The large-scale conversion of the statewide on-road vehicle fleet to a zero-emission fleet, as proposed by the California Governor's Executive Orders (EO) B-16-2012,[1] B-48-18,[2] and N-79-20,[3] would require a major shift in the transportation energy sector from fossil fuels to electricity and/or renewable hydrogen. In this meta-study, Ramboll estimates the costs associated with purchase and installation of electric vehicle charging infrastructure as well as upgrades to California's electric grid that would be needed to meet the zero-emission vehicle (ZEV) targets laid forth in these EOs based on published literature. This included studies published by the California Energy Commission (CEC),[4,5,6] Princeton's Net Zero America Report,[7] California Air Resources Board (CARB) Draft Mobile Source Strategy,[8] and South Coast Air Quality Management District (SCAQMD).[9] Refer to **Sections 3 and 4** of this report for further details on these reports.

Based on our analysis of these third-party studies, ***the cumulative transportation infrastructure costs*** (generation, transmission, distribution, maintenance and electric vehicle chargers) ***from 2020 to 2050 to achieve a statewide on-road ZEV fleet are projected to be <u>at least $2.1 to $3.3 Trillion.</u>***[10] This is equivalent to 12%-18% the 2019 gross domestic product (GDP) of United States of America.[11] It is also roughly equivalent to the entire 2019 GDP of the United Kingdom or, alternatively, France.[12]

This estimate included purchase and installation costs for electric vehicle charging infrastructure to achieve a 93% statewide on-road light duty ZEV fleet and a 100% medium-/heavy-duty ZEV fleet by 2050, in line with State projections for fleet electrification and the Governor's EO mandates. It also included estimated grid infrastructure investments (i.e., generation, transmission, distribution) required to support increased grid loads and renewable energy targets, noting that such estimates are underestimated since they only

1 Available at: https://www.ca.gov/archive/gov39/2012/03/23/news17472/index.html. Accessed: March 2021.

2 Available at: https://www.ca.gov/archive/gov39/2018/01/26/governor-brown-takes-action-to-increase-zero-emission-vehicles-fund-new-climate-investments/index.html. Accessed: March 2021.

3 Available at: https://www.gov.ca.gov/wp-content/uploads/2020/09/9.23.20-EO-N-79-20-text.pdf. Accessed: March 2021.

4 E3 2018 Deep Decarbonization PATHWAYS Report. Available at: https://www.ethree.com/projects/deep-decarbonization-california-cec/. Accessed April 2021.

5 CEC AB 2127 EV Charging Assessment. Available at: https://efiling.energy.ca.gov/getdocument.aspx?tn=236237. Accessed April 2021.

6 CEC 2020 Integrated Energy Policy Report (IEPR) Update Volume III. Available at: https://efiling.energy.ca.gov/getdocument.aspx?tn=237269. Accessed April 2021.

7 Princeton Net Zero America. Available at: https://acee.princeton.edu/rapidswitch/projects/net-zero-america-project/. Accessed April 2021.

8 CARB 2020 MSS META tool. Available at: https://ww2.arb.ca.gov/resources/documents/2020-mobile-source-strategy. Accessed April 2021.

9 Low- and High- range charger purchase and installation costs from AQMD WAIRE, Table 18. Available at: http://www.aqmd.gov/docs/default-source/planning/fbmsm-docs/pr2305_draft-staff-report_03032021.pdf?sfvrsn=8. Accessed April 2021.

10 Ramboll arrived at this estimate by summing the purchase and installation costs for LD and MD/HD EV chargers provided in Figure 3-4 with the grid infrastructure costs presented in Figure 4-1.

11 GDP of United States of America was 18.3 in calendar year 2019. Available at: https://data.worldbank.org/indicator/NY.GDP.MKTP.KD?locations=US-GB-FR. Accessed: April 2021.

12 GDP of United Kingdom and France 3.0, and 2.9 trillion respectively in calendar year 2019. Available at: https://data.worldbank.org/indicator/NY.GDP.MKTP.KD?locations=US-GB-FR. Accessed: April 2021.

accounted for infrastructure to electrify 18% of the in-state medium-duty/heavy-duty (MD/HD) fleet to BEV (short of the State's 100% zero emission target) and did not include grid infrastructure costs to support electrification of the remaining 6.1 million in-state medium- and heavy-duty vehicles. Other cost components for which estimates were unavailable, but which could contribute additional costs include:

- Infrastructure upgrade costs for generation, transmission, and supply of renewable hydrogen that is needed for operating fuel cell electric vehicles;
- Additional costs associated with upgrades to the electric grid to address grid reliability issues that could arise from increased use of renewables, public safety power shutoffs (PSPS) to avoid wildfires, and/or aging infrastructure;
- Changes in energy prices for conversion to a ZEV fleet (replacing conventional fossil fuels with electricity and/or renewable hydrogen); and
- Potential stranded asset costs, if any, arising from policies implemented to achieve a statewide on-road ZEV fleet and zero-carbon electricity supply in 2050.

1. INTRODUCTION

1.1 California's Electrification Targets

California EO B-30-15[13] requires that the State reduce its greenhouse gas (GHG) emissions to 40% below 1990 levels by 2030 and 80% below 1990 levels by 2050. In order to do this, California is pursuing aggressive vehicle electrification pathways. Since 2012, California Governors have passed several Executive Orders (EOs) that set forth ambitious goals to convert the statewide on-road vehicle fleet to a zero-emission (ZE) fleet. The ZE vehicle and infrastructure goals set forth in EO B-16-2012,[14] EO B-48-18,[15] and EO N-79-20[16] are summarized in **Table 1-1**.

Table 1-1. California State ZEV and Charging Infrastructure Targets

Target Year	Executive Order	ZEV Population Target	Charging Infrastructure Target
2020	EO B-16-2012	--	Infrastructure to support one million ZEVs
2025	EO B-16-2012, AB 2127	1.5 million light-duty (LD) ZEVs on the road	
	EO B-48-18	--	250,000 public and shared EV chargers, including 10,000 DC fast chargers
2030	EO B-48-18	5 million LD ZEVs on the road	--
2035	EO N-79-20	100% of LD vehicle sales to be ZEVs	--
	EO N-79-20	100% in-state zero emission drayage truck fleet	
	EO N-79-20	100% zero emission off-road vehicles and equipment operations	
2045	EO N-79-20	100% zero emission in-state medium-duty and heavy-duty truck fleet	--

[13] Available at: https://www.ca.gov/archive/gov39/2015/04/29/news18938/index.html. Accessed April 2021.

[14] Available at: https://www.ca.gov/archive/gov39/2012/03/23/news17472/index.html. Accessed: March 2021.

[15] Available at: https://www.ca.gov/archive/gov39/2018/01/26/governor-brown-takes-action-to-increase-zero-emission-vehicles-fund-new-climate-investments/index.html. Accessed: March 2021.

[16] Available at: https://www.gov.ca.gov/wp-content/uploads/2020/09/9.23.20-EO-N-79-20-text.pdf. Accessed: March 2021.

In addition to these transportation electrification targets, California has also passed building electrification mandates including Assembly Bill (AB) 3232,[17] which requires the CEC to assess the potential for the state to reduce GHG emissions from residential and commercial buildings by at least 40% below 1990 levels by 2030. Preliminary CEC studies indicate appliance electrification could be an effective strategy towards achieving this goal; the final CEC report is set to be released in early 2021.[18] Furthermore, process electrification is viewed as a potential mechanism to aid in decarbonization of California's industrial sector.[19]

In conjunction with pursing aggressive electrification targets, the State's decarbonization strategy depends on achieving zero-carbon electricity. The State has set renewable energy targets required to be met by electric utilities. Under the Renewables Portfolio Standard (RPS) and Senate Bill (SB) 100, 60% of retail electricity sales must be served by renewable resources by 2030, and 100% of the State's electricity must be sourced from carbon free resources by 2045.[20]

1.2 Purpose of this Study

The large-scale conversion of the statewide on-road vehicle fleet to a zero-emission fleet, as required by the executive orders detailed in **Section 1.1**, would require structural changes in the transportation energy sector away from fossil fuels and towards transportation powered by electricity and/or renewable hydrogen. As of this writing, the State has not performed a techno-economic assessment of the feasibility of achieving the Governor's mandates and milestones set forth in EO N-79-20. Thus, the purpose of this meta-study is two-fold:

- to summarize the current state and future projections of California's ZE vehicle fleet relative to the State targets defined in **Section 1.1**, and
- to estimate the cumulative costs for installing vehicle charging infrastructure to support such an increase in ZEV deployment including costs to upgrade the State's electric grid to meet the associated increase in electricity demand.

To do this, Ramboll reviewed numerous studies, reports and planning documents to understand the status of California's progress towards its ZE vehicle and infrastructure targets and identify gaps in the State's current planning efforts for the deployment and adoption of ZE vehicles. Ramboll also reviewed recent reports on pathways to decarbonization to identify future investments which may be needed to meet the ZE vehicle and infrastructure goals set forth by the Governors' EOs. A summary of our findings is presented in the following sections. The work reflects published reports and resources that were available as of April 2021.

---

[17] Available at: https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201720180AB3232. Accessed April 2021.

[18] Available at: https://www.energy.ca.gov/data-reports/reports/building-decarbonization-assessment. Accessed April 2021.

[19] Available at: https://ww2.arb.ca.gov/sites/default/files/classic//cc/scopingplan/meetings/022020/carb_cn_industry_feb2020.pdf. Accessed: April 2021.

[20] Available at: https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201720180SB100. Accessed April 2021.

2. ZERO-EMISSION LIGHT-DUTY VEHICLE PROJECTIONS IN CALIFORNIA

Ramboll reviewed LD ZEV fleet scenarios from the California Energy Commission (CEC) 2020 Integrated Energy Policy Report (IEPR),[21] the California Air Resources Board (CARB) 2020 Draft Mobile Source Strategy (MSS),[22] and the Princeton Net Zero America (NZA) Report[23] to understand the range of future projections for LD ZEV populations in California as compared to the State's LD ZEV targets noted in **Table 1-1**. These studies suggest that ***California is likely to meet its 2025 LD ZEV population target of 1.5 million but may fall short of the 2030 target of 5 million LD ZEVs.***

Figure 2-1 presents the range of statewide LD ZEV populations projected by the studies noted above for target years of 2025 and 2030. The black line represents existing State targets, i.e., 1.5 million LD ZEVs by 2025 and 5 million LD ZEVs by 2030. The CEC 2020 IEPR, CARB 2020 Draft MSS, and the Princeton NZE Report developed scenarios ranging from a reference policy case to aspirational goals. As such, the bars represent the range of LD ZEV population estimates projected by each these studies. Additional information on the data from each study is provided below.

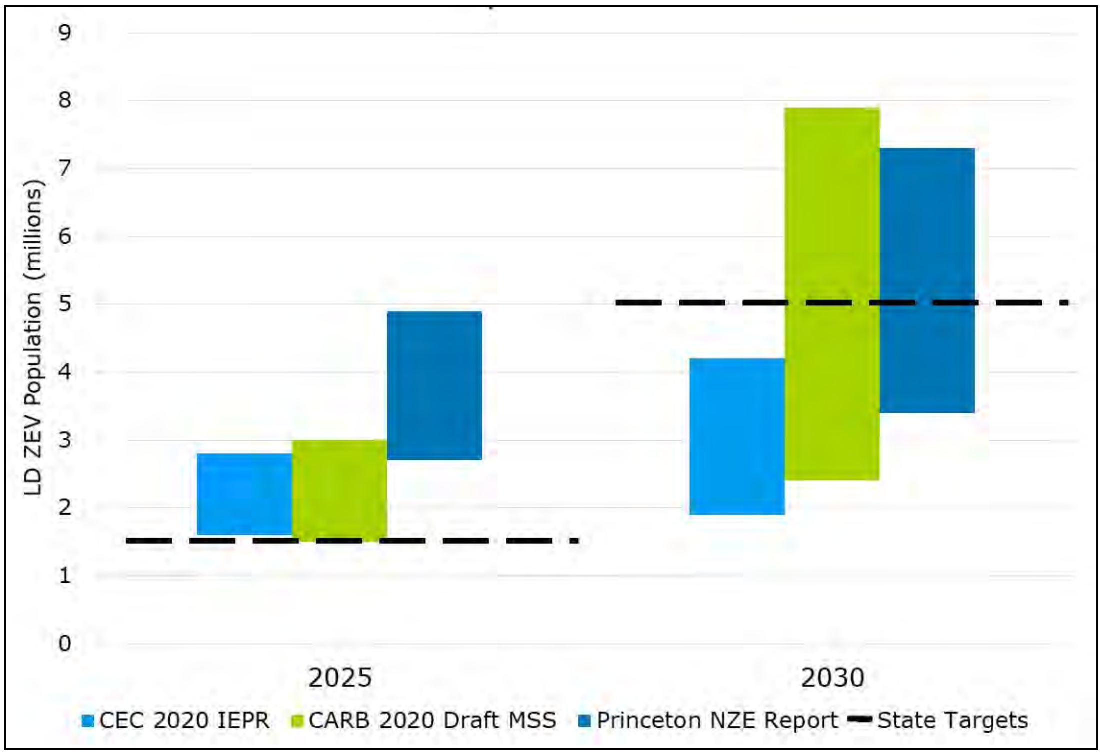


Figure 2-1. Light-Duty Zero Emission Vehicle Population Projections

---

[21] California Energy Commission (CEC) 2020 Integrated Energy Policy Report (IEPR) Update Volume III. Available at: https://efiling.energy.ca.gov/getdocument.aspx?tn=237269. Accessed April 2021

[22] CARB 2020 Draft MSS. Available at: https://ww2.arb.ca.gov/resources/documents/2020-mobile-source-strategy. Accessed April 2021.

[23] Princeton Net Zero America. Available at: https://acee.princeton.edu/rapidswitch/projects/net-zero-america-project/. Accessed April 2021.

The CEC 2020 IEPR's LD ZEV population estimates[24] were developed for low, mid, and high electrification demand scenarios, each of which assume a different rate of vehicle electrification based on projected fuel price and vehicle technology developments. As shown in **Figure 2-1**, the CEC 2020 IEPR's LD ZEV population projections for 2025 range from 1.6 million to 2.8 million, which are all above the 2025 State target of 1.5 million. However, the LD ZEV population projections of 1.9 million to 4.2 million for 2030 are below the State target of 5 million. Hence, CEC projects that while the State would meet the 2025 LD ZEV target, it is unlikely to meet the 2030 LD ZEV target even under a high electrification demand scenario. Further, the CEC 2020 IEPR estimates that only 15–20% of new LD vehicle sales will be ZEVs in 2030 and concludes that additional market interventions will be necessary to meet EO N-79-20's goal of 100% LDV ZEV new vehicle sales by 2035.

The CARB 2020 Draft MSS includes ZEV population projections[25] in its Mobile Emissions Toolkit for Analysis (META) tool.[26] The low end of the CARB 2020 Draft MSS LD ZEV population estimate, shown in **Figure 2-1**, is based on a business-as-usual (BAU) or reference policy case. Under the business-as-usual (BAU) scenario, California will have a LD ZEV population of 1.5 million in 2025 (equal to the 2025 State target) and 2.4 million in 2030 (less than half of the 2030 State target). The high end of LD ZEV population projection in the CARB Draft 2020 MSS is based on CARB's proposed MSS scenario that meets California's goal of 80% GHG emission reduction by 2050 from 1990 levels. This MSS scenario projects a LD ZEV population of 3 million by 2025 and 8 million by 2030, both of which exceed the State's ZEV targets noted in **Table 1-1**. Therefore, the CARB 2020 Draft MSS also projects that the State will meet the 2025 LD ZEV population target but may not meet the 2030 LD ZEV population target unless additional market interventions are made.

Finally, the Princeton NZA Report[27] modeled a range of scenarios that lay out potential pathways to a carbon neutral America by 2050. Ramboll examined the California part of this study. The Princeton NZA Report's E+ scenario assumes aggressive end-use electrification projected to result in the highest LD ZEV population in California; 4.9 and 7.3 million LD ZEVs in 2025 and 2030, respectively. Princeton NZA Report's E- scenario assumes less aggressive end-use electrification, resulting in lowest projected LD ZEV population in California of 2.7 and 3.4 million LD ZEVs in 2025 and 2030, respectively. As shown in **Figure 2-1**, the LD ZEV population projections for these aspirational scenarios (E+ and E-) would exceed the California's target of 1.5 million LD ZEVs by 2025. However, in 2030 the E-scenario falls short of the State's target of 5 million LD ZEVs and the E+ scenario exceeds this target.

---

[24] The LD ZEV population estimates from the CEC 2020 IEPR include plug-in battery electric and plug-in hybrid electric vehicles.

[25] The LD ZEV population estimated in the CARB 2020 Draft MSS include plug-in battery electric vehicles, plug-in hybrid electric vehicles, and hydrogen fuel cell electric vehicles.

[26] CARB META tool. Available at: https://ww3.arb.ca.gov/planning/sip/2020mss/draft_META.zip. Accessed April 2021.

[27] The LD ZEV population count from the Princeton NZA Report includes only plug-in battery electric vehicles.

3. CHARGING INFRASTRUCTURE SCENARIOS AND COST

3.1 Electric Vehicle Charging Infrastructure

Ramboll reviewed the CEC AB2127 Report published in January 2021,[28] which was performed in collaboration with the National Renewable Energy Laboratory (NREL) and includes data on the current status and projected gap in the number of electric vehicle chargers needed to support the State's 2025 and 2030 vehicle electrification targets. The CEC AB2127 Report concludes that ***California is expected to fall short of its 2025 charging infrastructure targets, a shortfall which will increase significantly by 2030 unless the rate of charger deployment is increased.***

As shown in **Figure 3-1**, based on allocated funding through 2025, the CEC expects California to have 188,000 light-duty electric vehicle chargers installed by 2025. That level would represent a net gap of 62,000 chargers as compared to EO B-48-18's charging infrastructure target of 250,000 chargers by 2025. Note, this 2025 target also includes 10,000 direct current (DC) fast chargers. CEC does not expect that many DC fast chargers will be installed by 2025.[29]

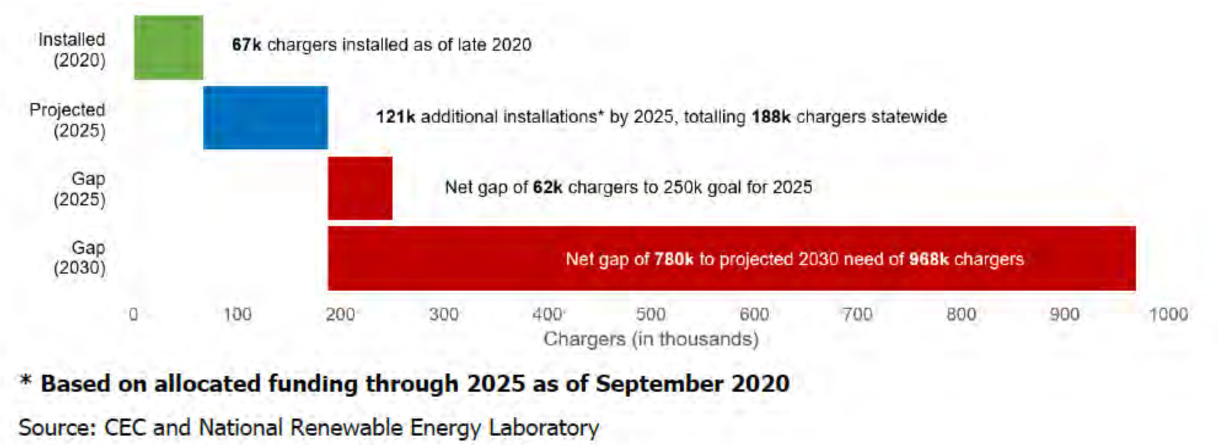


Figure 3-1. CEC AB2127 Data on Installed and Projected Electric Light-Duty Vehicle Chargers Compared with Charging Needs for 1.5 million ZEVs in 2025 and 5 million ZEVs in 2030[30]

As noted in **Figure 3-2**, CEC has estimated that a total of 968,000 chargers (including 35,000 DC fast chargers) will have to be installed by 2030 to support the State's target of deploying 5 million LD ZEVs. Based on its current projections, CEC anticipates that there will be a net gap of 780,000 chargers as compared to this 2030 target (**Figure 3-1**).

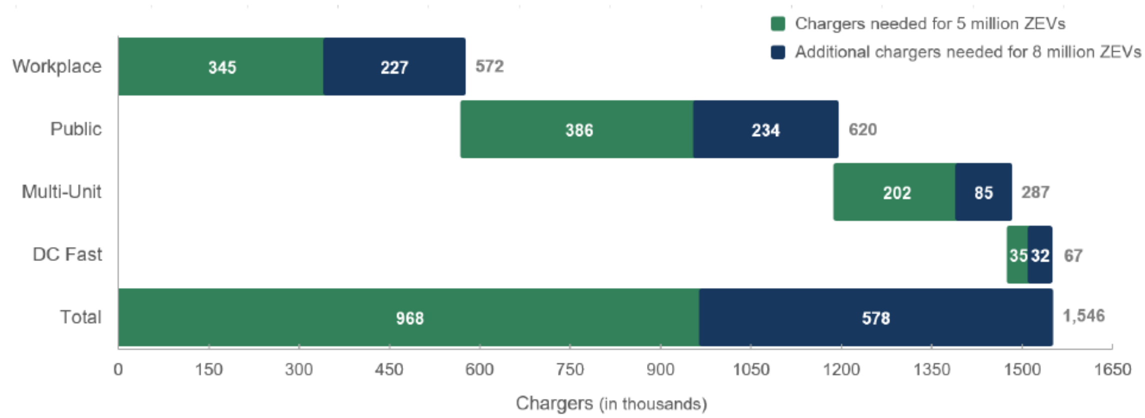
Additionally, the CEC AB2127 Report also projects the number of chargers needed to meet the ZEV populations associated with CARB's proposed MSS scenario that meets California's goal of 80% GHG emission reduction by 2050 from 1990 levels. As shown in **Figure 3-2**,

[28] CEC AB 2127 EV Charging Assessment. Available at: https://efiling.energy.ca.gov/getdocument.aspx?tn=236237. Accessed April 2021.

[29] CEC AB 2127 EV Charging Assessment, Table 3. Available at: https://efiling.energy.ca.gov/getdocument.aspx?tn=236237. Accessed April 2021.

[30] CEC AB 2127 EV Charging Assessment. Available at: https://efiling.energy.ca.gov/getdocument.aspx?tn=236237. Accessed April 2021.

CEC projects that over 1.5 million chargers (including 67,000 thousand DC fast chargers) are needed to meet the CARB 2020 Draft MSS's projected 8 million LD ZEV population in 2030. Further, CEC AB2127 Report projects that 157,000 thousand DC fast chargers are needed to support the CARB 2020 Draft MSS's population projection of 180,000 MD/HD ZEVs.



Models project that California will need 968,000 shared private and public chargers in 2030 to support 5 million ZEVs, and over 1.5 million chargers to support 8 million ZEVs. Counts for chargers at workplaces, public destinations, and multi-unit dwellings generally indicate the number of Level 2 chargers needed. In some cases, Level 1 chargers may be sufficient at select public destinations primarily serving transportation network company vehicles and at select multi-unit dwellings. These values do not include chargers at single family residences.

Source: CEC and National Renewable Energy Laboratory

Figure 3-2. CEC AB2127 Projected 2030 Charger Counts to Support 5 Million and 8 Million LDV ZEVs

Since the CEC AB2127 Report does not provide charging infrastructure estimates for 2035 or 2050 (the milestone dates for vehicle electrification set forth in the EO), Ramboll estimated the number of additional chargers needed to support projected levels of LD and MD/HD vehicle electrification in 2035 and 2050 based on the vehicle population projections from EMFAC2017,[31] fleet composition projections from CARB 2020 Draft MSS,[32] and vehicles-to-charger ratio from the CEC AB2127 projections. Additional detail on the methodology used to estimate of battery electric vehicle population for these 2035 and 2050 charger estimates is provided below:

- LD Vehicle Population: According to the CARB 2020 Draft MSS, approximately 50% of the LDV fleet would be zero emissions in 2035, with ~7% comprising of FCEV and the remaining 43% comprising of BEV. Similarly the 2020 Revised Draft MSS projects approximately 93% of the LDV fleet would be zero emissions in 2050, with 18% comprising of fuel cell electric vehicles (FCEV) and the remaining 75% comprising of battery electric vehicles (BEV). Based on this data, Ramboll assumed that 43% of the EMFAC2017 LD vehicle population in 2035 would be battery electric, which increases to 75% in 2050.

- MD/HD Vehicle Population: According to the CARB 2020 Draft MSS, 31% of the combined MD/HD vehicle fleet would be zero emission in 2035. Ramboll assumed that the fraction

[31] EMFAC2017 Web Database. Available at: https://arb.ca.gov/emfac/2017/. Accessed April 2021.

[32] CARB 2020 Revised Draft MSS. Available at: https://ww2.arb.ca.gov/resources/documents/2020-mobile-source-strategy. Accessed April 2021.

of FCEV in the in-state MD/HD fleet would be similar to the CARB 2020 Draft MSS fleet composition projections for LD vehicles, i.e., 7% of the in-state MD/HD fleet would be FCEV in 2035. Thus, Ramboll assumed that the remaining fraction (24%) of the in-state MD/HD vehicle population in 2035 would be converted to BEVs. Given that the State wants to achieve a target of 100% in-state MD/HD truck fleet turnover to ZEVs by 2045 (Table 1-1), Ramboll employed a similar assumption that 18% of the 2050 in-state MD/HD fleet would be FCEV (following CARB's 2020 Revised Draft MSS projections for LD vehicles) with the remaining fraction (82%) converted to BEVs. Additionally, Ramboll applied a vehicle replacement ratio of 1.2 to convert the EMFAC2017 MD/HD vehicle population to a BEV population for both 2035 and 2050. As noted in recent studies,[33,34] this vehicle replacement ratio would adjust population numbers to account for range and duty cycle limitations for MD/HD BEVs relative to a conventional vehicle.

Figure 3-3 below shows Ramboll's estimates for electric vehicle chargers in 2035 and 2050 alongside CEC's 2025 and 2030 estimates. The left side of the graph presents data for MD/HD electric vehicle chargers and the right side of the graph shows LD vehicle charger projections. The numbers in blue text above each bar represent the number of additional chargers needed beyond the 188,000 LD EV chargers expected to be installed in 2025. As noted in the figure below, an additional 1.7 million MD/HD EV chargers and 2.3 million LD EV chargers will be required by 2035, and an additional 6.4 million MD/HD EV chargers and 4.8 million LD EV chargers will be required by 2050 to meet the State's ZEV targets.

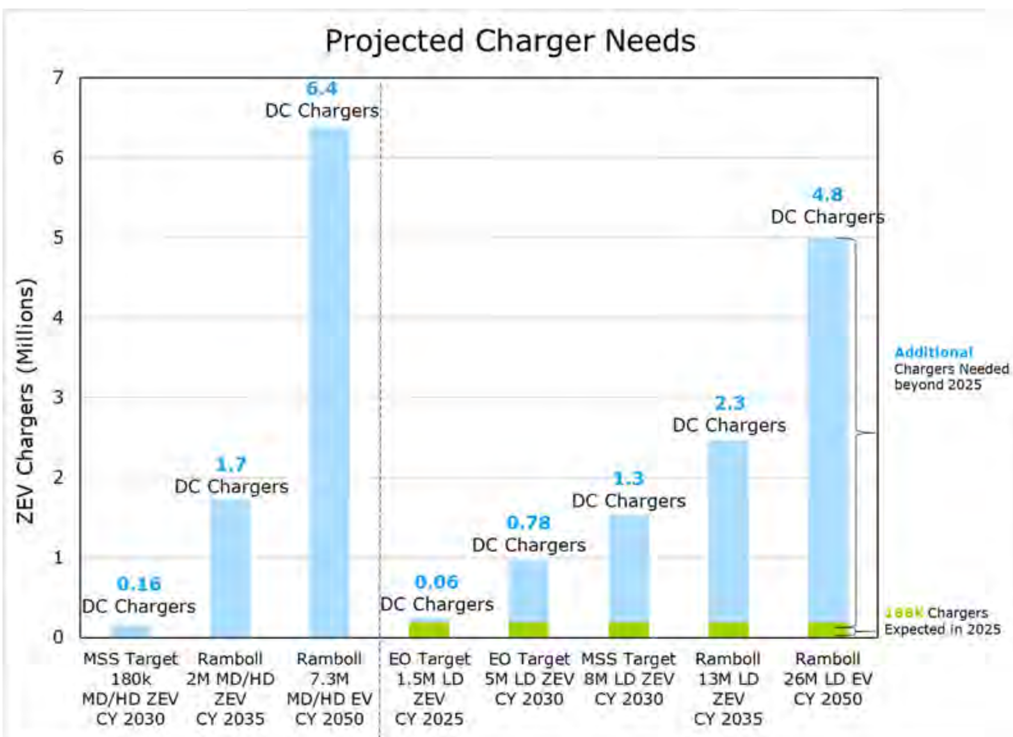


Figure 3-3. Projected Statewide MD/HD and LD EV Chargers

---

[33] E3 2018 Deep Decarbonization PATHWAYS Electricity Sector Results Spreadsheet. Available at: https://www.ethree.com/projects/deep-decarbonization-california-cec/. Accessed April 2021

[34] USC METRANS 2020 Report. Available at: https://www.metrans.org/research/developing-markets-for-zero-emission-vehicles-in-goods-movement. Accessed April 2021.

3.2 Electric Vehicle Charger Cost Estimates

Ramboll estimated the cumulative costs associated with the purchase and installation of additional EV chargers noted in **Figure 3-3** to meet the State's ZEV targets in 2030 and 2050 using cost data from the South Coast Air Quality Management District's (SCAQMD's) Warehouse Indirect Source Rule (ISR) Staff report.[35] A summary of these cost ranges are provided below in **Figure 3-4** and **Table 3-1**. **Table 3-2** summarizes the range of EV charger purchase and installation costs that were used to develop these cost estimates. As noted in **Figure 3-4**, an investment of ***up to $400 billion dollars may be necessary*** to support the projected number of LD and MD/HD BEVs within the State in 2035, and ***up to $1.5 trillion dollars may be necessary*** to support the projected number of LD and MD/HD BEVs within the State in 2050**.**

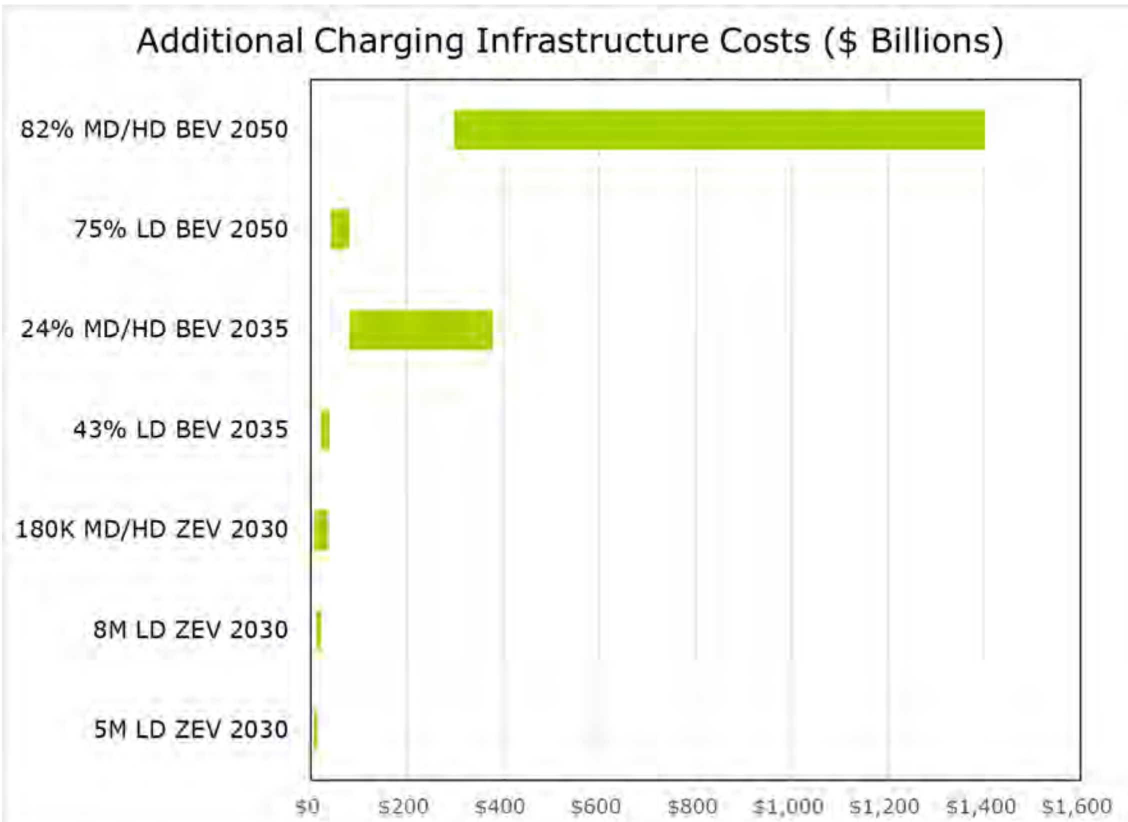


Figure 3-4. Cumulative Costs ($ Billions) for Purchase and Installation of EV Chargers

[35] Available at: http://www.aqmd.gov/docs/default-source/planning/fbmsm-docs/pr2305_draft-staff-report_03032021.pdf?sfvrsn=8. Accessed April 2021.

Table 3-1. Cumulative Costs for Purchase and Installation of EV Chargers

Year	Reference	Battery Electric Vehicle Population	Number of Additional Chargers Needed (in thousands)	Additional EV Charger Costs (in Billions)	
				Low Estimate	High Estimate
2030	CEC AB2127	5 million LD ZEVs	780	$6.7	$12.9
	CARB 2020 Draft MSS/ CEC AB2127	8 million LD ZEVs	1,358	$11.7	$22.5
	CARB 2020 Draft MSS/ CEC AB2127	180,000 MD/HD ZEVs	157	$7.3	$34.5
2035	Ramboll Estimate	43% LDV ZEV	2,283	$19.6	$37.9
	Ramboll Estimate	24% MDV/HDV ZEV	1,719	$80	$378
2050	Ramboll Estimate	75% LD vehicle population	4,801	$41	$80
	Ramboll Estimate	82% in-state MD/HD population	6,378	$297	$1,403

Table 3-2. Electric Vehicle Charger Purchase and Installation Costs				
			Cost Range[2] ($/charger)	
EV Charger Cost Item	**EV Charger Type[1]**	**EV Charger Level[2] (kW)**	**Low Estimate**	**High Estimate**
Purchase	HDV Charger	150-350	$60,000	$140,000
	MDV Charger	51-149	$30,000	$60,000
	LDV Fast Charger	19.2-50	$10,000	$30,000
	LDV Level 1 and Level 2 Chargers	up to 19.2	$3,000	$5,000
Installation	MDV/HDV Charger[3]	51-350	$16,518	$80,000
	LDV Fast Charger[3]	19.2-50	$10,000	$16,518
	LDV Level 1 and Level 2 Chargers	Level 2	$5,000	$10,000

Notes:

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

[2] Data obtained from Table 18 in Appendix B of SCAQMD's Warehouse Indirect Source Rule (ISR) Staff Report. Available at: http://www.aqmd.gov/docs/default-source/planning/fbmsm-docs/pr2305_draft-staff-report_03032021.pdf?sfvrsn=8. Accessed April 2021.

[3] The SCAQMD document presented a range of charger installation costs for 19.2 – 350 kW chargers. Ramboll interpolated high estimate for LDV fast charger and low-end estimate of MDV/HDV charger installation costs linearly based on the charger power level and assuming an upper end of LDV fast charger size of 50 kW.

Abbreviations:

$ - dollars, EV – electric vehicle, HDV – heavy duty vehicle, LDV – light duty vehicle, MDV – medium-duty vehicle, SCAQMD – South Coast Air Quality Management District

4. GRID INFRASTRUCTURE COSTS

Ramboll reviewed E3's 2018 Deep Decarbonization in a High Renewables Future Report[36,37] that was prepared for CEC ("E3 CEC Study") to identify the costs associated with grid infrastructure (production, transmission, and distribution) upgrades to achieve California's net carbon neutrality goals. The E3 CEC Study modeled costs for the following scenarios that are relevant to this analysis:

1. **Reference Scenario (CEC 2018 Policy)** that implements SB 350, which requires a 50% RPS by 2030 and a doubling of energy efficiency savings relative to historical goals, and any California policies in place as of 2016.
2. **High Electrification Scenario** that meets 2030 GHG target of 40% reduction from 1990 levels and the 2050 GHG target of 80% reduction from 1990 levels.

Figure 4-1 presents the E3 CEC Study's cumulative cost estimates for the grid infrastructure maintenance and upgrades needed by 2030 and by 2050 for the Reference Scenario (light blue bars) and the High Electrification Scenario (green bars). These costs estimates include the annual fixed costs associated with generation, transmission, and distribution infrastructure as well as annual variable costs. As shown in the figure, the cumulative grid infrastructure costs for the High Electrification Scenario are expected to be $0.52 trillion by 2030, $0.77 trillion by 2035, and $1.82 trillion by 2050.

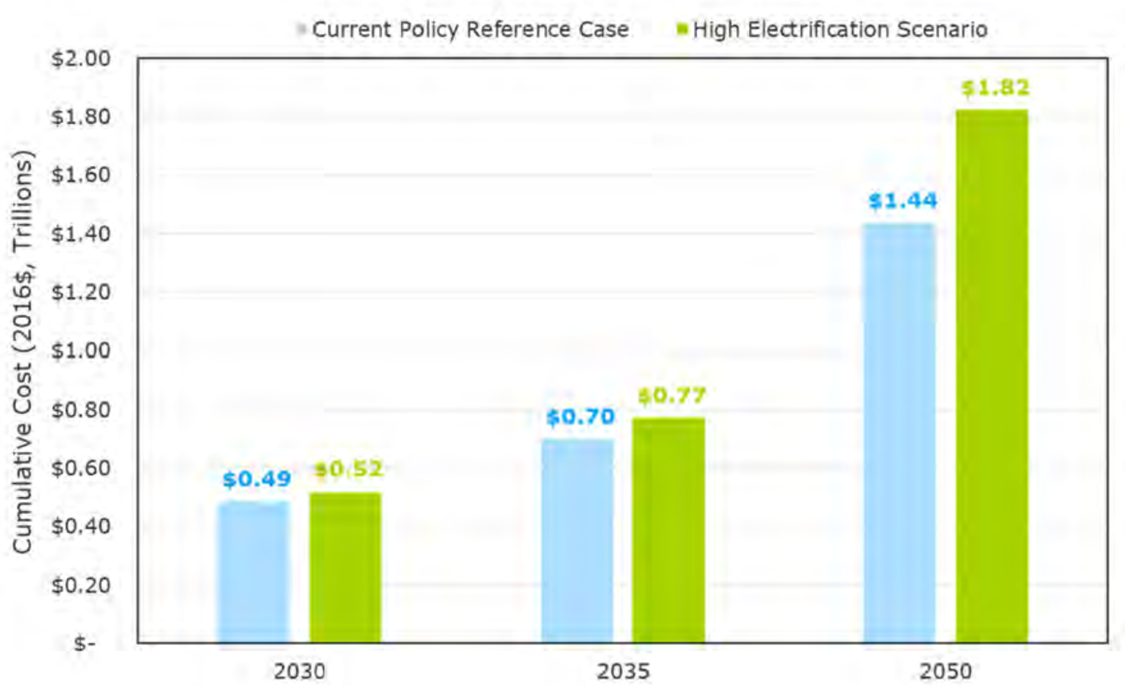


Figure 4-1. E3 CEC Study's Cumulative Grid Infrastructure Upgrade Cost Estimates from 2020 to Target Year

[36] E3 2018 Deep Decarbonization PATHWAYS Report. Available at: https://www.ethree.com/projects/deep-decarbonization-california-cec/. Accessed April 2021.

[37] E3 PATHWAYS Technical Appendix https://www.ethree.com/wp-content/uploads/2017/02/California_PATHWAYS_Technical_Appendix_20150720.pdf. Accessed April 2021.

Table 4-1 summarizes key parameters such as projected ZEV vehicle populations and electric grid mix for these E3 CEC Study's Reference Scenario and the High Electrification Scenario. Although the High Electrification Scenario meets the State's 2030 and 2050 LD ZEV targets, it only assumes an 18% penetration of ZEV in the in-state MD/HD vehicle fleet by 2050. As previously discussed, EO N-79-20 would require 100% of in-state MD/HD vehicles to be ZE by 2045. Therefore, the transportation electricity demand, and consequentially, the ***estimated cumulative grid infrastructure costs of 1.82 trillion dollars by 2050*** for the High Electrification Scenario ***are likely an underestimate for what would be needed to meet California's ZEV targets***.

In addition to the E3 CEC Study, Ramboll reviewed cost estimates for California grid infrastructure upgrades presented in the Princeton NZA Report. The Princeton NZA Report estimated an incremental cumulative infrastructure upgrade cost of $356 billion dollars for its E+ Scenario as compared to the 2050 Reference Scenario, which is similar to the E3 CEC Study's incremental cumulative costs of $388 billion for the High Electrification Scenario versus that study's 2050 Reference Scenario (**Figure 4-1**). **Table 4-1** provides further details on the key parameters of the scenarios in the Princeton NZE Report and the E3 CEC Study. As noted in this table the High Electrification Scenario in the E3 CEC Study is similar to the E+ (High Electrification) Scenario in the Princeton NZA Report. While there are some differences in the parameters for the Reference Scenarios in the E3 CEC Study and the Princeton NZA Report, the total electrical demand 2050 for these Reference Scenarios is similar. Therefore, it is reasonable to make a comparison of the incremental costs for grid infrastructure upgrades between the High Electrification and Reference Scenarios that are reported in these two studies and promising to see that the cost estimates from these two studies are similar.

Table 4-1. E3 CEC Study and Princeton NZA Report Scenario Descriptions

	E3 CEC Study[1]		**Princeton NZA Report**[2]	
Scenario Parameters	**Reference Scenario (CEC 2018 Policy)**	**High Electrification Scenario**	**Reference Scenario (AEO 2019**[3]**)**	**E+ (High Electrification) Scenario**
Meets California's 2050 GHG Emission Reduction Target?	No	Yes	No	Yes
Meets California's 2030 LD ZEV Targets?	No, 4M LD ZEVs	Yes, 6M LD ZEVs	No, 4.8M LD ZEVs	Yes, 7.3M LD ZEVs
2050 ZEV Population (percentages as fraction of EMFAC[3] in-state fleet in 2050)	24M LD ZEVs (68%) 303k MD/HD ZEVs (4%)	35M LD ZEVs (100%) 1.3M MD/HD ZEVs (18%)	14M LD ZEVs (41%) 11K MD/HD ZEVs (0.2%)	37M LD BEVs (100%) 988k MD/HD ZEVs (42%)

Table 4-1. E3 CEC Study and Princeton NZA Report Scenario Descriptions

	E3 CEC Study[1]		Princeton NZA Report[2]	
2050 Electric Grid Mix	50% Renewable (2030 through 2050)	95% Zero Carbon 70% Renewable	85% Zero Carbon	~100% Zero Carbon
2050 Building Electrification	None (2030)	91% Building Energy is Electric	24-40% Electric Residential Appliances	70-100% Electric Residential Appliances
2050 Total Electricity Demand (TWh)	378 TWh	456 TWh	362 TWh	602 TWh

Notes:

[1] E3 2018 Deep Decarbonization PATHWAYS Report. Available at: https://www.ethree.com/projects/deep-decarbonization-california-cec/. Accessed April 2021.

[2] Princeton Net Zero America. Available at: https://acee.princeton.edu/rapidswitch/projects/net-zero-america-project/. Accessed April 2021.

[3] Princeton NZA reference scenario uses baseline assumptions from the EIA Annual Energy Outlook (AEO) 2019. Available at: https://www.eia.gov/outlooks/archive/aeo19/. Accessed April 2021.

[4] EMFAC2017. Available at: https://arb.ca.gov/emfac/emissions-inventory. Accessed April 2021.

Abbreviations:

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

5. CONCLUSION

From this meta-study, Ramboll estimates ***the cumulative transportation infrastructure costs*** (generation, transmission, distribution, maintenance and electric vehicle chargers) ***from 2020 to 2050 to achieve a statewide on-road ZEV fleet to be at least at least $2.1 to $3.3 Trillion.*** This is equivalent to 12%-18% the 2019 gross domestic product (GDP) of United States of America, or roughly equivalent to the entire 2019 GDP of the United Kingdom or, alternatively, France.[38] Ramboll arrived at this estimate by summing the purchase and installation costs for LD and MD/HD EV chargers provided in **Figure 3-4** with the grid infrastructure costs presented in **Figure 4-1**.

This estimate included purchase and installation costs for electric vehicle charging infrastructure to achieve a 93% statewide on-road light duty ZEV fleet and a 100% medium-/heavy-duty ZEV fleet by 2050. It also included estimated grid infrastructure investments (i.e., generation, transmission, distribution) required to support increased grid loads and renewable energy targets, noting that such estimates are underestimated since they only accounted for infrastructure to electrify 18% of the in-state medium-duty/ heavy-duty (MD/HD) fleet to BEV (short of the State's 100% zero emission target) and did not include grid infrastructure costs to support electrification of the remaining 6.1 million in-state medium- and heavy-duty vehicles. Other cost components for which estimates were unavailable, but which could contribute additional costs include:

- Infrastructure upgrade costs for generation, transmission, and supply of renewable hydrogen that is needed for operating fuel cell electric vehicles;
- Additional costs associated with upgrades to the electric grid to address grid reliability issues that could arise from increased use of renewables, public safety power shutoffs (PSPS) to avoid wildfires, and/or aging infrastructure;
- Changes in energy prices for conversion to a ZEV fleet (replacing conventional fossil fuels with electricity and/or renewable hydrogen); and
- Potential stranded asset costs, if any, arising from policies implemented to achieve a statewide on-road ZEV fleet and zero-carbon electricity supply in 2050.

[38] GDP of United States of America, United Kingdom, and France in 2019 was 18.3, 3.0, and 2.9 trillion respectively in calendar year 2019. Available at: https://data.worldbank.org/indicator/NY.GDP.MKTP.KD?locations=US-GB-FR. Accessed: April 2021.

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.

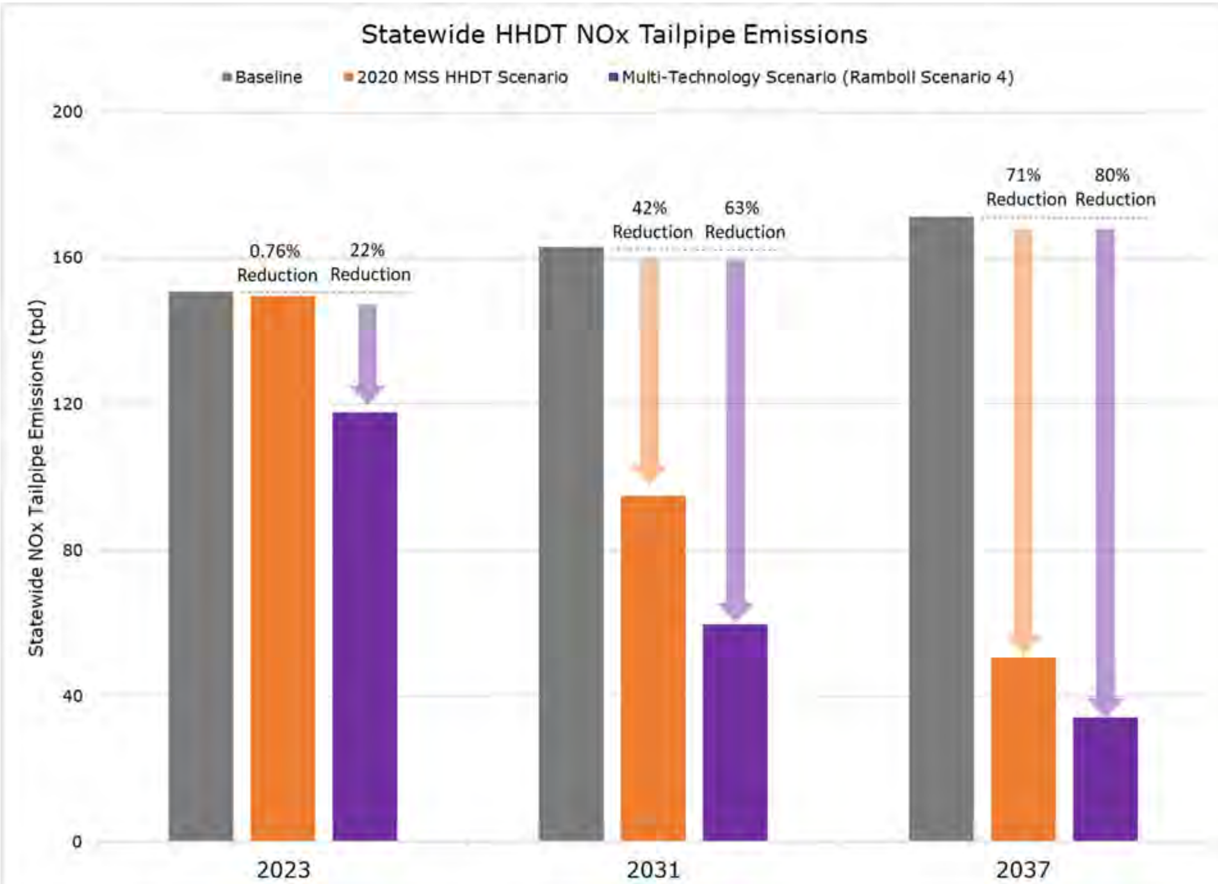


Figure ES-1. Statewide NO_X HHDT Tailpipe Emissions

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.

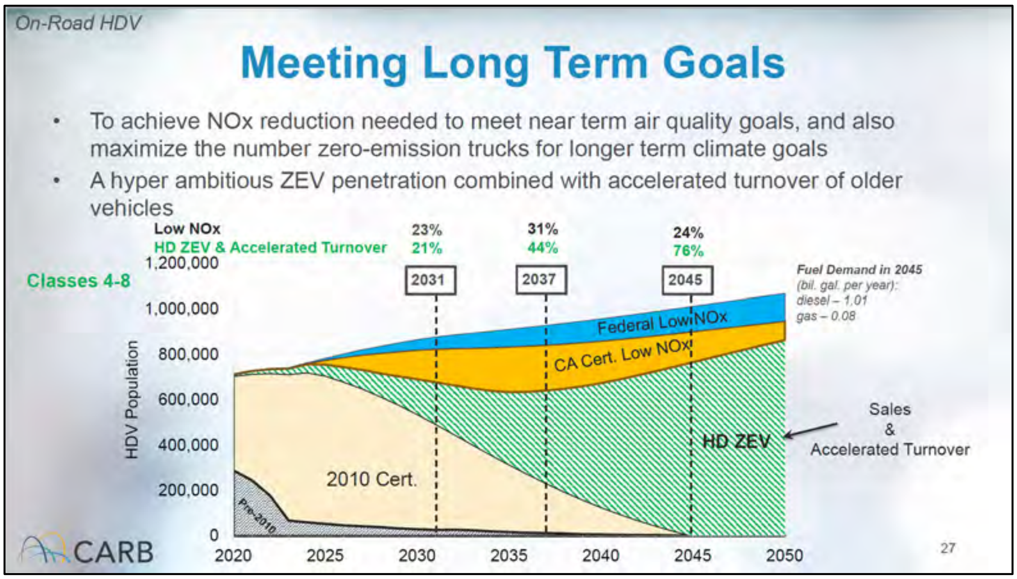


Figure 2-1. Heavy-Duty Vehicle Fleet Mix for 2020 MSS[13]

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.

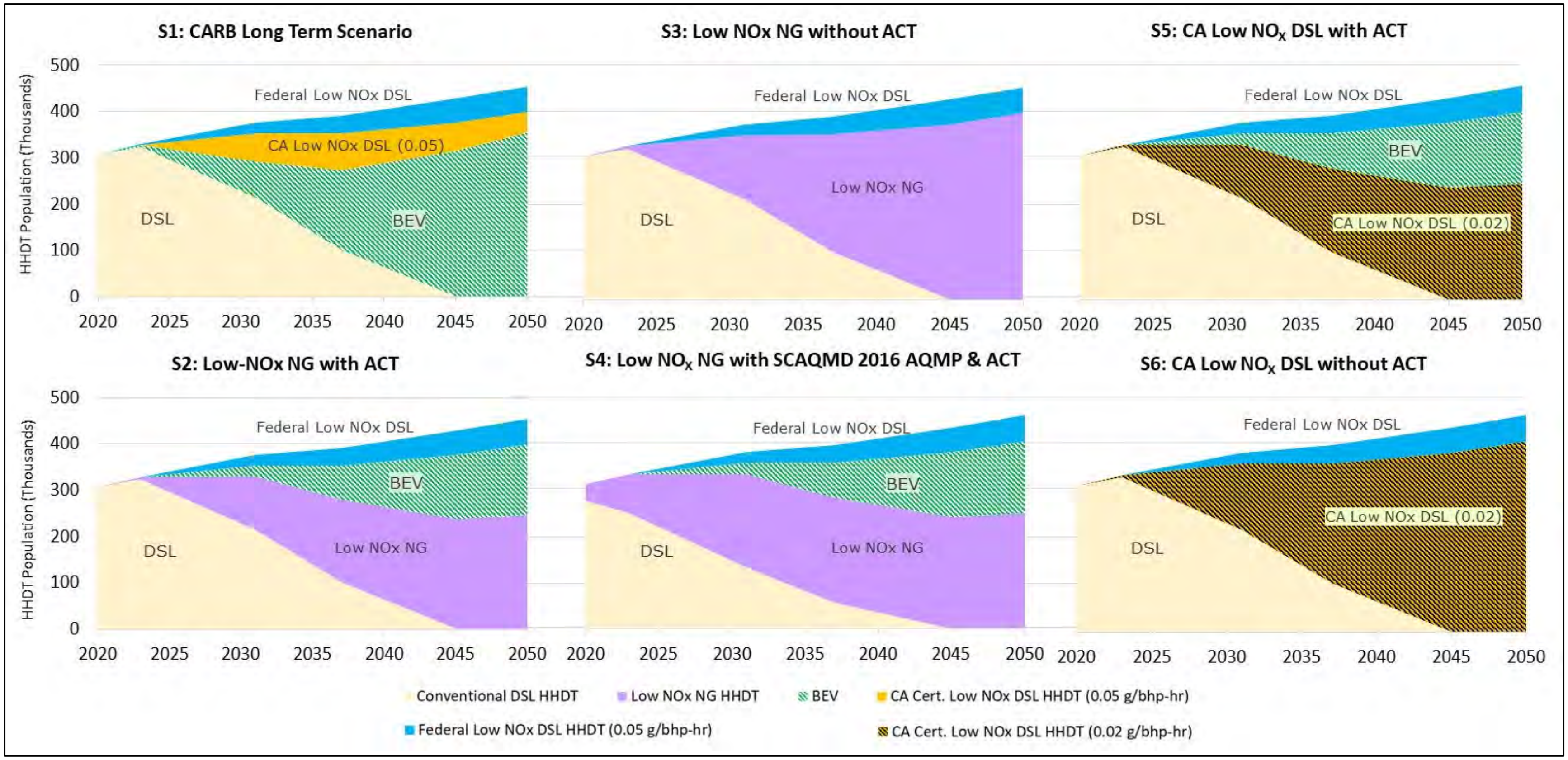


Figure 2-2. Diesel Heavy-Heavy-Duty Truck Fleet Mixes for Ramboll Scenario Analysis

- 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.

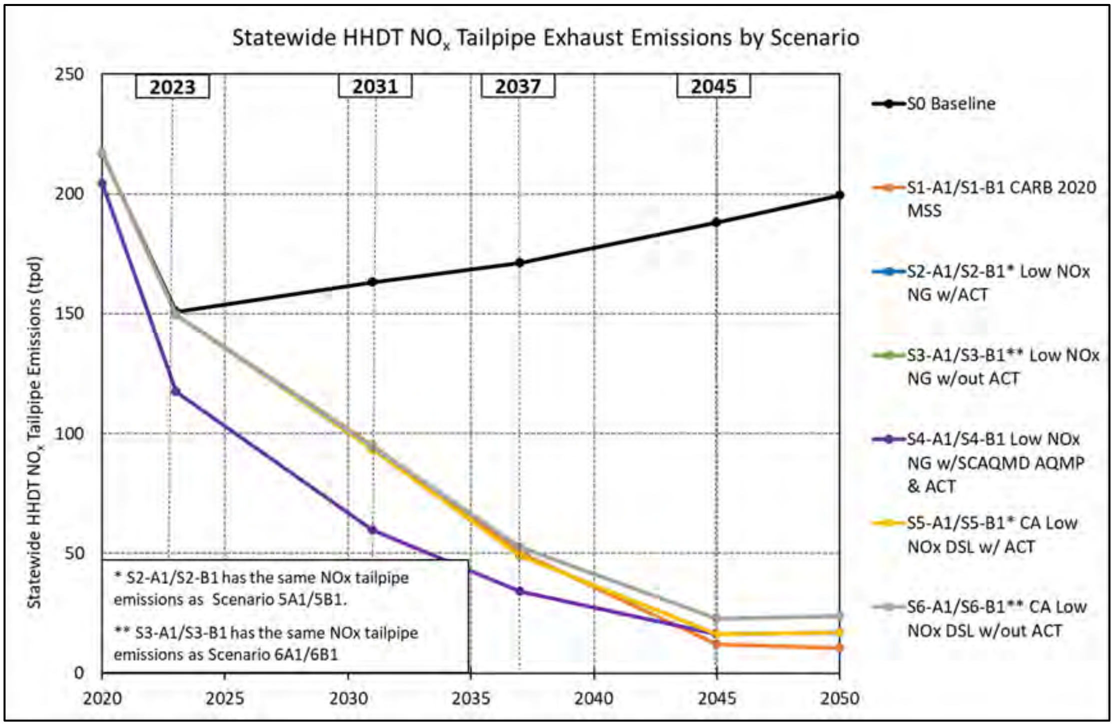


Figure 5-1. Statewide HHDT NO_X Tailpipe Exhaust Emissions by Scenario

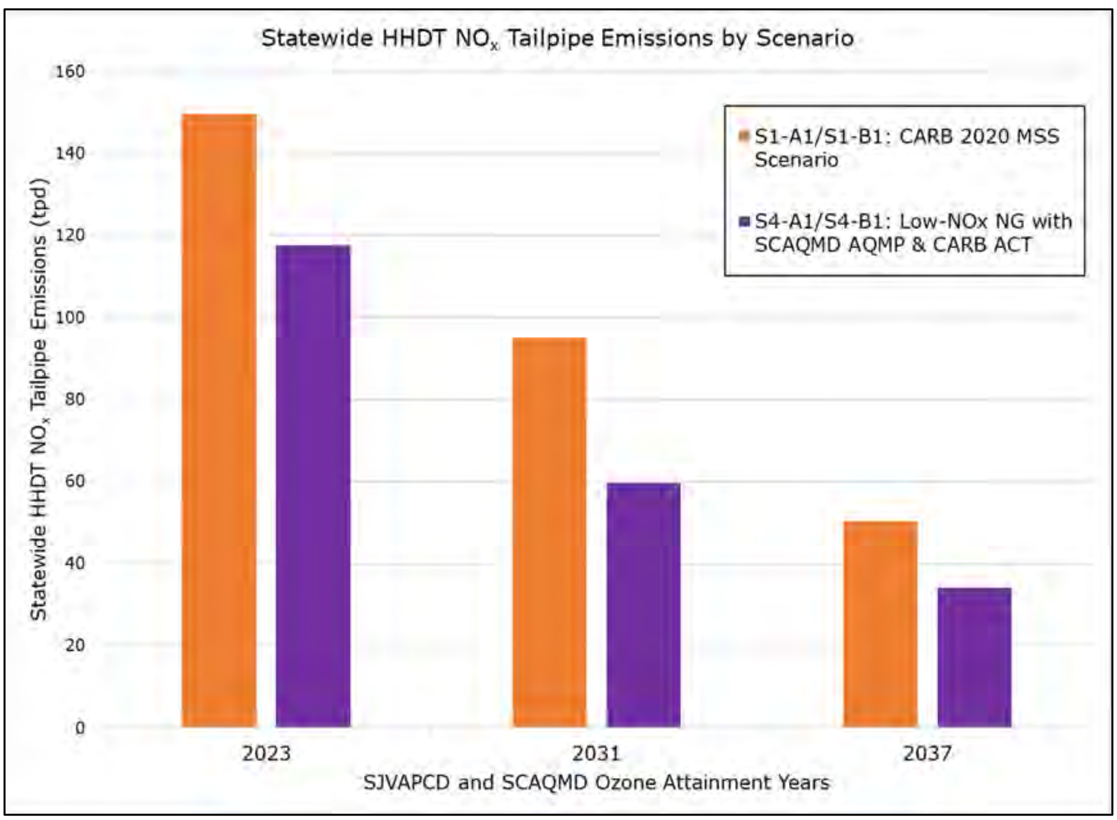


Figure 5-2. Statewide HHDT NO_X Emissions Comparison by Scenario

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.

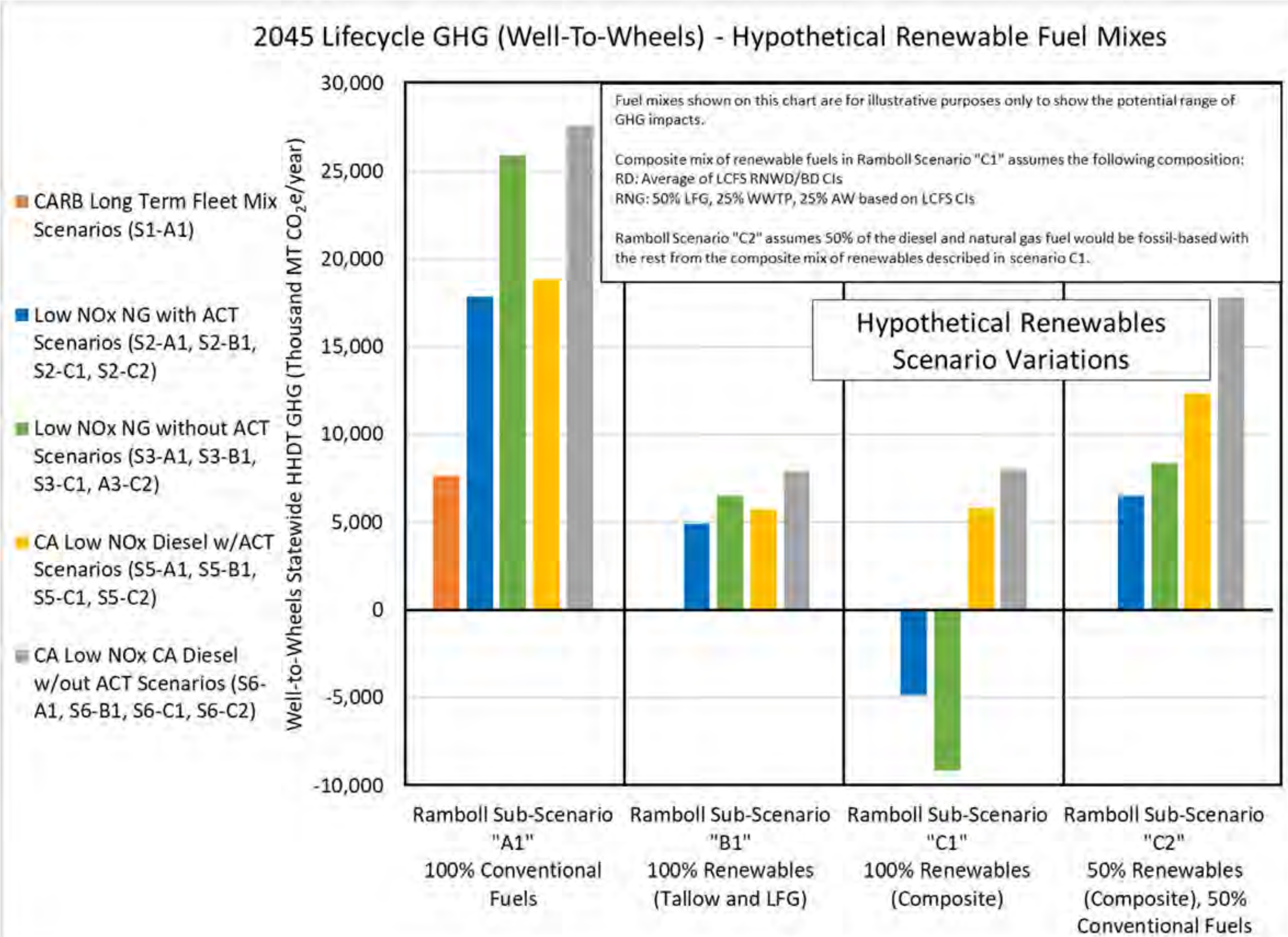


Figure 5-3. 2045 Well-to-Wheels GHG Emissions

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-NO_X 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-NO_X Diesel HHDT (blue), CA Low-NO_X Diesel HHDT (Orange), Low-NO_X 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-NO_X trucks is below that of BEVs, even without accounting for vehicle replacement ratio differences.

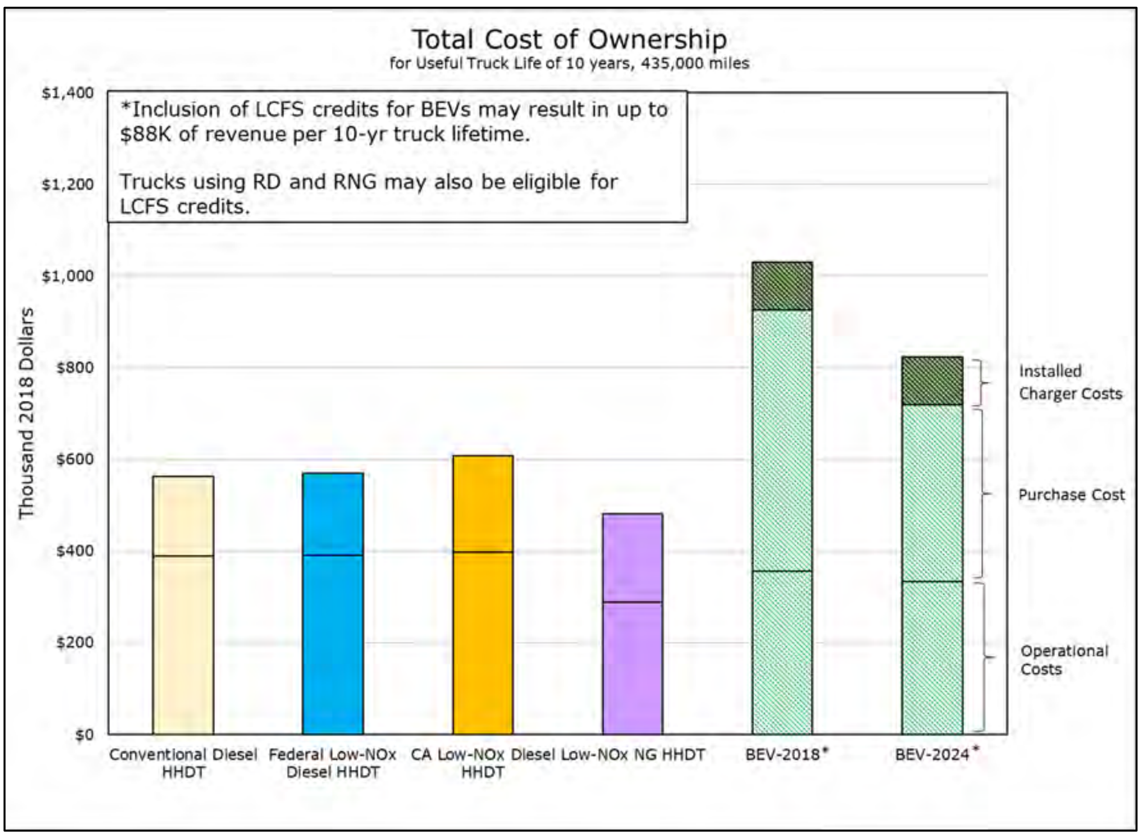


Figure 6-1. Total Cost of Ownership Results for a 10-year Useful Life

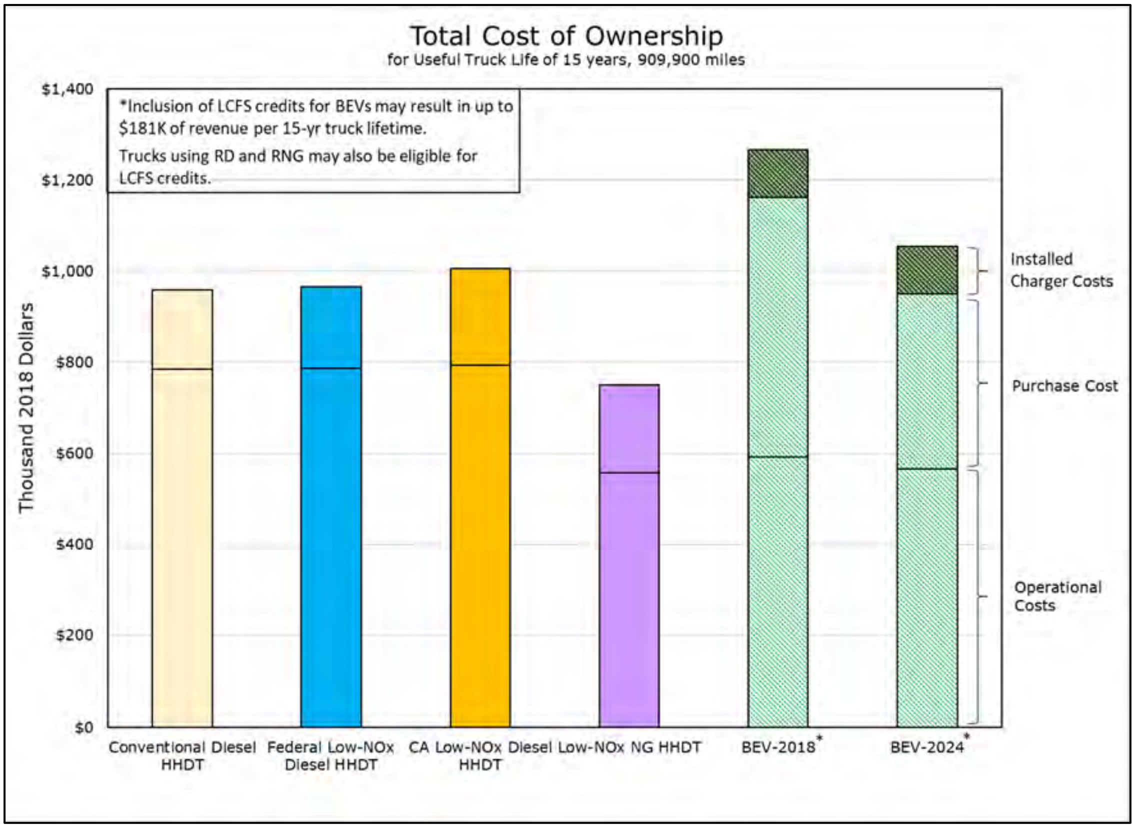


Figure 6-2. Total Cost of Ownership Results for a 15-year Useful Life

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.

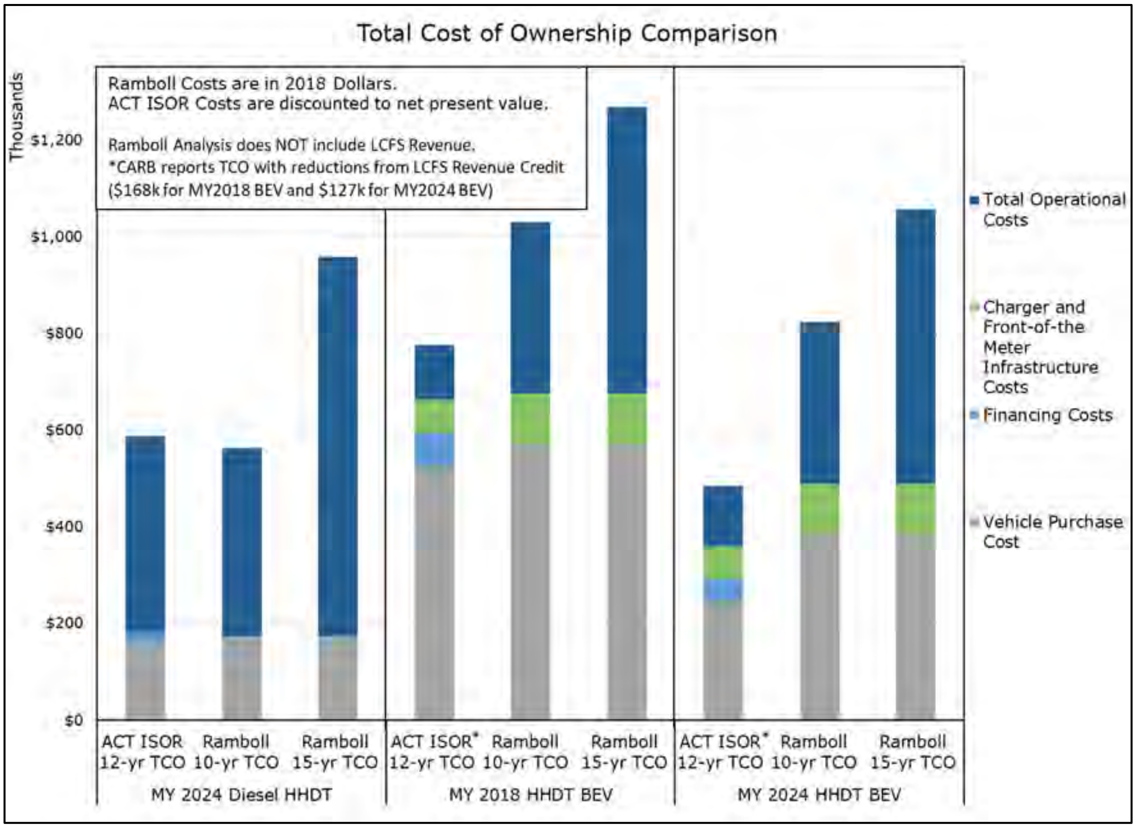


Figure 6-3. Comparison between Ramboll and CARB ACT TCO Analyses

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.

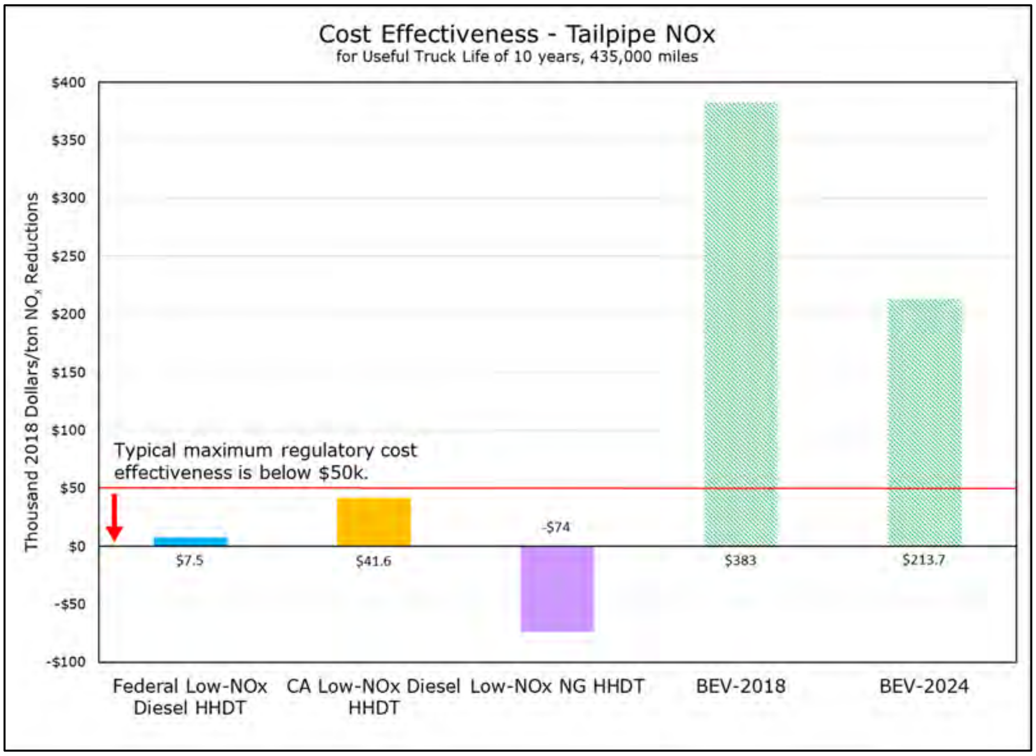


Figure 6-4. Tailpipe NO_X Cost-Effectiveness for a 10-year Truck Life

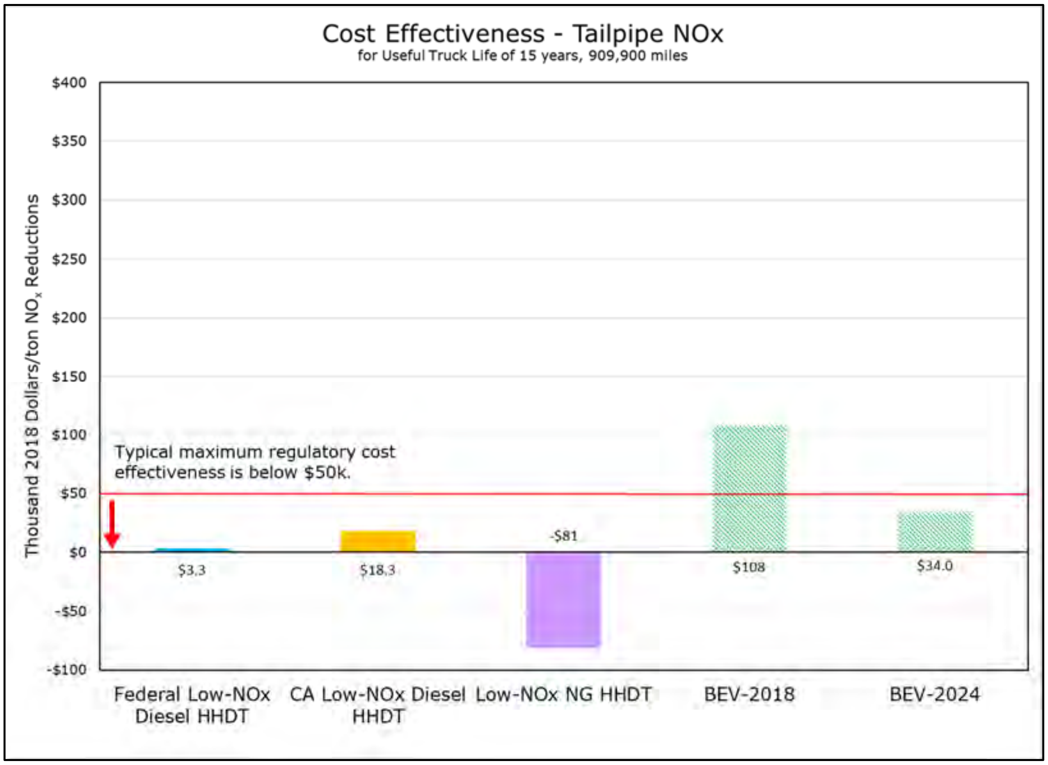


Figure 6-5. Tailpipe NO_X Cost Effectiveness for a 15-year Truck Life

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.

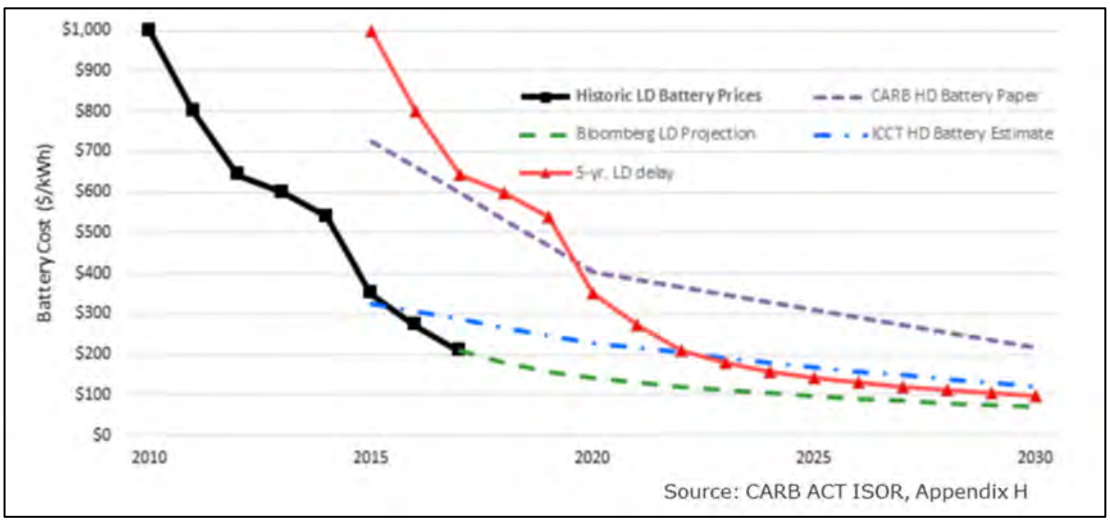


Figure 6-6. Battery Cost Projections from the CARB ACT ISOR[41]

[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.

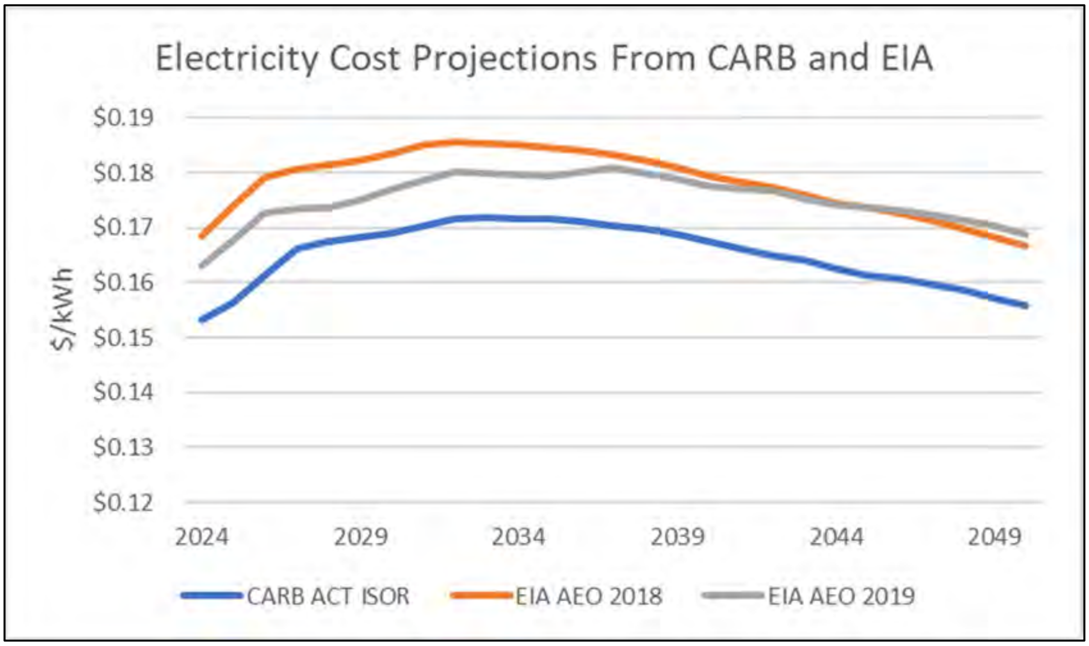


Figure 6-7. Electricity Cost Projections

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.

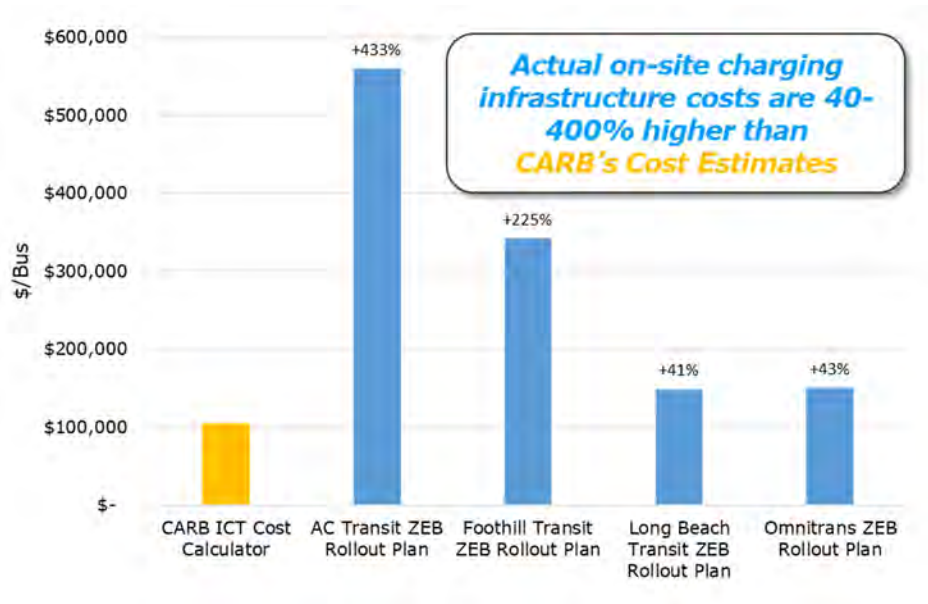


Figure 6-8. Zero Emission Bus (ZEB) Depot Charging Infrastructure Costs

[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

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

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)
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

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	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

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

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	0%	0	0	0%	0	0	0%	0	0

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

Model Year	EMFAC2017 Output[1] Population	NOx_TOTEX (tons/day)	CO2_TOTEX (tons/day)	CH4_TOTEX (tons/day)	N2O_TOTEX (tons/day)	Fuel Consumption (1000 gal/day)	Conventional DSL 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

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

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	0.10	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

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

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	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

Table A-5. NOx and GHG Tailpipe Emissions for Scenario 0 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	0.05	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

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

	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	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

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
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

	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

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	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

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

	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

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	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

	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

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

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	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
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-11. NOx and GHG Tailpipe Emissions for Scenario 1 in Calendar Year 2037
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)
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

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

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

	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

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	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

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	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

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	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

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	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

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

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

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	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

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

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

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

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

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

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

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	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-17. NOx and GHG Tailpipe Emissions for Scenario 2 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	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

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

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

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

	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			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

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
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

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

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

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	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

	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			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	90%	4,358	7,172,863

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	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

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

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	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

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	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

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

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	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

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

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

	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	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

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

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-25. NOx and GHG Tailpipe Emissions for Scenario 3 in Calendar Year 2050

	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

Table A-25. NOx and GHG Tailpipe Emissions for Scenario 3 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	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

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	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

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	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

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

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	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

	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

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

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	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

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	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

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	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

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	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

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	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

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	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
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)
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

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

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

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

	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	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

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

Model Year	Adjusted EMFAC2017 Output[1] Population	NOx_TOTEX (tons/day)	CO2_TOTEX (tons/day)	CH4_TOTEX (tons/day)	N2O_TOTEX (tons/day)	Fuel Consumption (1000 gal/day)	Conventional DSL 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

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	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

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

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	86%	4,141	6,132,798	0%	0	0

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

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

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	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

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

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	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

	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	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

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

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

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

	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			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	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

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

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

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

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	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

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

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	90%	4,358	6,455,577	0%	0	0

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	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

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

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

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	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

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

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	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

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

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

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	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

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

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	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

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	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.

Notes:

[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.

Abbreviations:

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.

[4] 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
CO_2e - carbon dioxide equivalent
EMFAC - Emission Estimator model
HHDT - heavy-heavy duty truck
g - gram
NG - natural gas
NO_X - nitrogen oxides
N_2O - nitrous oxide

Table B-12. Upstream Emission Factors

Calendar Year	Upstream Emission Factors by Fuel Type (g / MJ)					
	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