

Discussion Draft 2025 Mobile Source Strategy

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Executive Summary

California is home to almost 40 million people. This coupled with the perfect topography and climate conditions for pollution formation results in some of the worst air quality in the nation. The State of California and the California Air Resources Board (CARB or Board) have been at the forefront at not only addressing air quality, but also addressing climate change, and community risk with standards and targets that need to be met over the next 30 years. These three pillars - air quality, climate change and community risk - drive CARB's programs.

California has unique authority allowed by the federal Clean Air Act to set mobile source emissions standards that are more stringent than the U.S. Environmental Protection Agency (U.S. EPA). For over 55 years, CARB has exercised this authority and developed controls and programs that have reduced emissions from mobile sources resulting in substantial improvement in air quality. However, mobile sources including heavy-duty trucks, ocean-going vessels, locomotives, and aircraft, still contribute significantly to air and climate pollution and despite the dramatic progress CARB has made during this time, their emissions must be reduced further to meet air quality standards, climate change targets, and air toxics mandates. The 2025 Mobile Source Strategy (2025 MSS) is being developed to describe an integrated approach for meeting California's clean air mandates by identifying the technology pathways and programmatic concepts needed for the numerous mobile source sectors into the future.

As described in Senate Bill (SB) 44 (Skinner, Chapter 297, Statutes of 2019)¹, CARB is required to update the Mobile Source Strategy (MSS) every five years. The MSS uses scenario planning tools to quantify changes in ozone and fine particulate matter (PM2.5) precursor emissions, greenhouse gas (GHG) emissions, toxics emissions such as diesel particulate matter, and petroleum usage as various technologies are considered in the vehicle and equipment fleets. In using this type of planning, staff can evaluate scenarios that model the impacts of different types and timelines for control programs including emissions standards, fleet requirements, in-use requirements, and voluntary programs; the resulting scenarios are potential pathways toward achieving California's environmental mandates. While SB 44 specifically requires CARB to include a comprehensive strategy for the deployment of medium- and heavy-duty vehicles for the purpose of meeting air quality standards and reducing GHG emissions, CARB takes a holistic approach for the MSS such that it explores the deployment of both on- and off-road vehicles.

¹ SB 44, Skinner, Chapter 297, Statutes of 2019,
https://leginfo.ca.gov/faces/billNavClient.xhtml?bill_id=2019202005B44

In this Discussion Draft, CARB staff is setting the foundation for the 2025 MSS effort by providing core information about the current status of the various mobile source categories; this includes category descriptions with current and future emissions of oxides of nitrogen (NO_x), PM_{2.5}, and tailpipe carbon dioxide (CO₂), summaries of current regulatory and non-regulatory control programs, and lists of available technologies and discussions of their emission reduction potential. The current and future emissions reflect the mobile strategies already adopted by the Board. This Discussion Draft also provides an overview of the scenario modeling that will be included in later iterations of the 2025 MSS, and introduces other key considerations in development of the 2025 MSS including environmental justice and racial equity, and meeting California's zero-emission infrastructure needs.

Unlike the first draft of the 2020 MSS, this Discussion Draft does not include draft scenarios for public consideration. By establishing a foundational baseline of the inventories and building blocks in this first iteration, CARB is inviting the public and interested parties to help identify scenarios that CARB could consider to be evaluated as a part of the 2025 MSS. To date, CARB has hosted one public webinar in January 2024 to kick off this process, inform interested parties, and gather initial public input and thoughts on the 2025 MSS. Staff understands the public is better able to provide feedback when there is more substantive content available, so staff is releasing this foundational Discussion Draft and hosting a second webinar to further stimulate public discussion and facilitate meaningful feedback to incorporate into the 2025 MSS.

Moving forward, CARB staff intends to publish two additional iterations of the 2025 MSS:

- Draft 2025 MSS: Reflecting public input to date, the next iteration will introduce the first potential technology trajectory scenarios and discuss the associated emissions reductions, thereby identifying pathways toward achieving our environmental targets.
- Final 2025 MSS: Based on additional public input, staff plans for the final version of the 2025 MSS to illustrate a set of technology trajectory scenarios that can ensure the State's air quality, climate, and community risk reduction mandates are met. The final document will also discuss the existing CARB programs and those under development that will achieve the technology trajectories shown in the scenarios, as well as potentially identify new regulatory and programmatic concepts for the many off-road vehicle and equipment categories for which further programs are needed to ensure the deployment of the cleanest technologies, including zero-emission technologies.

While an MSS scenario developed through this process may outline the overall approach for a sector and highlight program concepts that will move the State in the needed direction, the specific strategies for each sector will continue to be refined after the completion of the 2025 MSS as the planning and public process for implementing specific actions moves forward. The scenarios and concepts in the final 2025 MSS may also inform CARB's other

planning efforts including the *State Implementation Plan*² (SIP), *AB 32 Climate Change Scoping Plan*³, and *Community Emission Reduction Programs*⁴ (CERP).

² CARB webpage, California State Implementation Plan, <https://ww2.arb.ca.gov/our-work/programs/california-state-implementation-plans>

³ CARB webpage, AB 32 Climate Change Scoping Plan, <https://ww2.arb.ca.gov/our-work/programs/ab-32-climate-change-scoping-plan>

⁴ CARB webpage, Community Air Protection Program Communities, <https://ww2.arb.ca.gov/capp-communities>

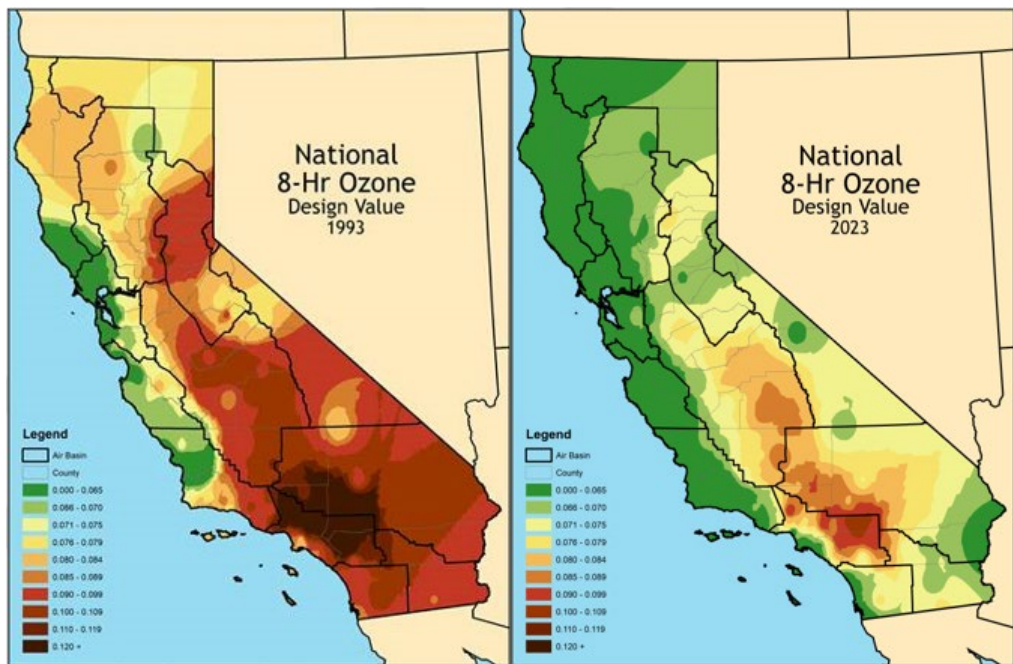
Chapter 1 - Introduction

Background

Purpose

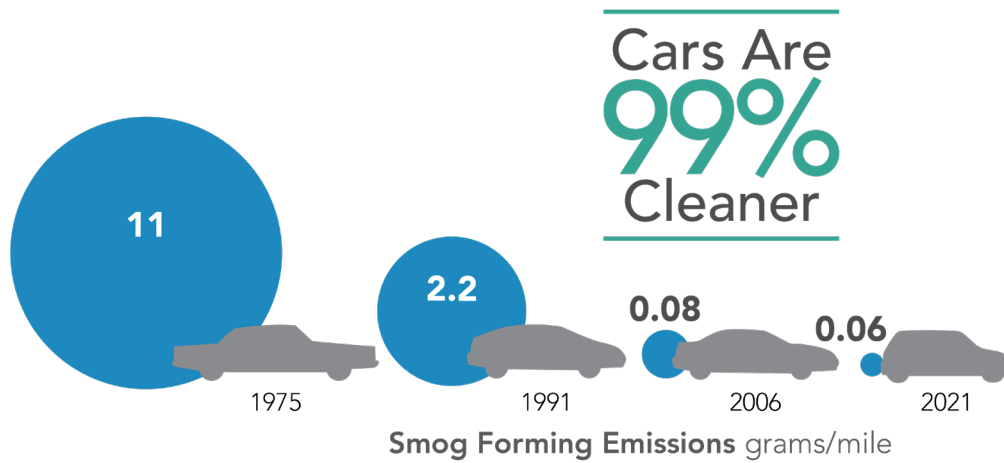
In California, mobile sources including on-road vehicles such as cars and heavy-duty trucks and off-road equipment including primarily federally-regulated ocean-going vessels, locomotives, and aircraft, contribute significantly to air and climate pollution. These mobile sources contribute a majority of NOx emissions. NOx is an important precursor to smog, also known as ozone, and PM2.5. Mobile sources also contribute the largest portion of GHG emissions, and a significant amount of toxic air contaminants that directly impact community health. Over the last 50 years, California's efforts to reduce emissions from mobile sources and other sources of air pollution have resulted in dramatic improvements in smog levels (Figure 1), as well as reductions in a variety of harmful pollutants in urban and rural areas. Despite this progress, the State still has more work to meet many federal and State ambient air quality standards and other health and climate stabilization targets over the next 30 years. Emissions must be reduced from all sources of air pollution in California to not only meet the federal standards, but to minimize negative health effects in the State's most impacted and disadvantaged communities, and to lessen climate impacts. The 2025 Mobile Source Strategy (2025 MSS) is being developed to take an integrated approach to identifying the technology pathways and programmatic concepts for mobile sources needed to meet our clean air mandates.

Figure 1 - California Ozone Progress



California has unique authority under section 209 of the Clean Air Act to set emissions standards that are more stringent than the federal government due to our unique air quality challenges. As a result, CARB has been able to implement a technology-forcing mobile source emissions control program that includes the most advanced emission standards and emission-related requirements for new motor vehicles and engines (Figure 2).

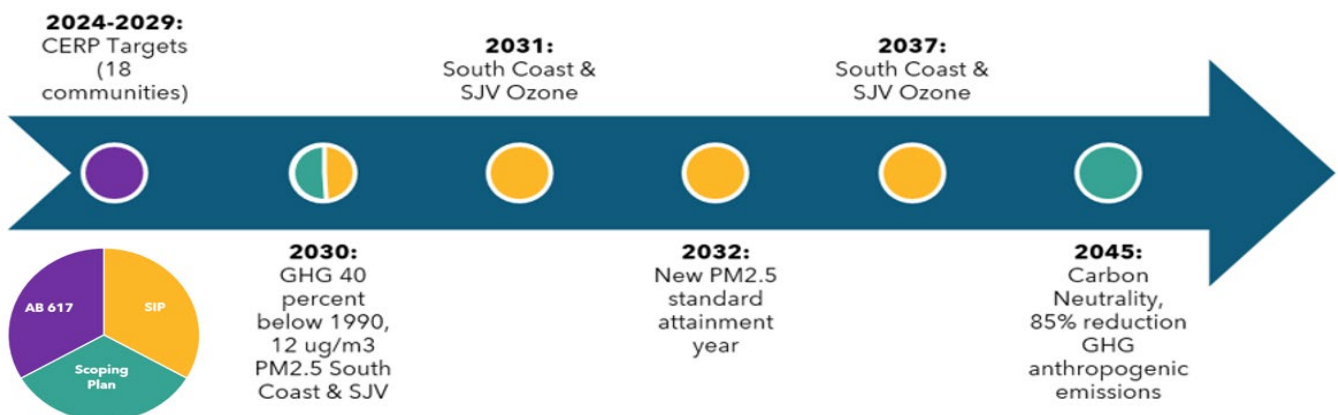
Figure 2 - CARB's Mobile Source Control Program for Light-Duty Vehicles



As a result, CARB has been able to implement a technology-forcing mobile source emissions control program that includes the most advanced emission standards and emission-related requirements for new motor vehicles and engines (Figure 2).

Consistent with section 209 of the Clean Air Act, CARB has submitted and obtained U.S. EPA approvals of more than 100 previous requests for waivers and authorizations of federal preemption. These approvals unlock CARB's ability to fully enforce our adopted mobile source regulations and achieve the maximum possible emissions reductions. As of October 2024, U.S. EPA has eight requests for waivers and authorizations of federal preemption pending before them for CARB regulations. It is critical that all eight requests are approved as soon as possible. These eight regulations, when fully implemented, are projected to achieve over \$115 billion in monetized public health benefits and save over 11,500 lives. California needs these, and all of our mobile source regulations covered by U.S. EPA waivers or authorizations, to meet air quality standards, climate change targets, and air toxics mandates (Figure 3).

Figure 3 - California's Air Quality, Climate, and Community Air Protection Mandates



GHG emissions from human activities, including the burning of fossil fuels from mobile sources, are the most significant driver of climate change. As GHG emissions build up in the atmosphere and alter the climate, this leads to many other changes around the world - in the atmosphere, on land, and in the oceans. In comparison, criteria air pollutants including PM2.5 and ozone are regional pollutants due to their formation processes coupled with geographical and meteorological impacts, and are often at their highest concentrations downwind from the main sources of the emissions of the relevant precursors. Since ozone formation is also dependent upon sunlight and high temperatures, a warming climate will lead to increased ozone levels and dramatically impact our ability to meet ozone air quality standards in the future.

The State's climate laws include the mid-term target in 2030 for at least 40% GHG emissions reductions below 1990 levels, codified under SB 32 (Pavley, Chapter 249, Statutes of 2016)⁵, and longer-term targets for economywide carbon neutrality in 2045 as codified under AB 1279 (Muratsuchi, Chapter 337, Statutes of 2022)⁶, which also expands upon these earlier targets by specifying that anthropogenic emissions must be reduced to 85% below 1990 levels by 2045. CARB developed the AB 32 Climate Change Scoping Plan specifically to chart the path toward achieving California's climate laws. The existential threat of climate change is a crisis of the present and is already causing extreme heat, torrential storms, historic droughts, and the devastating wildfires that California is currently experiencing. In order to forestall the most extreme impacts of climate change, it's critical that California continue to lead efforts to curb GHG emissions.

Toxic air contaminants (TACs or toxics) such as benzene from gasoline and diesel particulate matter from cars, trucks and off-road equipment are air pollutants which may cause or contribute to an increase in mortality or an increase in serious illness and often have no known safe levels. They are directly emitted pollutants and, as such, can have the most detrimental impacts on the people and communities nearest the pollution sources. CARB's air toxic program started in 1983 with the passage of AB 1807 (Tanner, Chapter 1047, Statutes of 1983) which aims to reduce exposure to air emissions of toxic chemicals for all Californians. Since 1983, CARB has identified more than 200 toxic air pollutants and has adopted and implemented 26 airborne toxic control measures. In 1998, CARB took a crucial step to controlling mobile source toxics and identified particulate matter (PM) from diesel-fueled engines as a TAC. In 2000, CARB adopted the Diesel Risk Reduction Plan, which recommended many control measures to reduce the risks associated with diesel particulate matter.

⁵ SB 32, Pavley, Chapter 249, Statutes of 2016,

https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201520160SB32

⁶ AB 1279, Muratsuchi, Chapter 337, Statutes of 2022,

https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=202120220AB1279

More recently, in 2017, AB 617, (C. Garcia, Chapter 136, Statutes of 2017)⁷ was enacted and directed CARB to focus on reducing exposure to communities throughout the State experiencing high cumulative exposure to air pollution including TACs. There is an immediate need to reduce emissions and exposure in these highly-impacted, including low-income communities and disadvantaged communities and communities of color throughout the State, including communities with CERPs developed as a part of CARB’s AB 617⁸ Community Air Protection Program⁹. Communities selected for CERPs set five and ten-year targets to reduce community exposure; the first CERPs adopted by the Board had targets as early as 2024, and included in many of these plans is a focus on mobile source measures and reductions.

For air quality, the Clean Air Act originally established national ambient air quality standards (NAAQS) and requires that U.S. EPA reevaluate the health science every 5 years to determine if a more stringent standard is needed to protect public health. For each new NAAQS that U.S. EPA promulgates based on updated information showing health impacts at lower levels of pollution, there are legally obligated deadlines by which areas must attain. California has the two areas with the most critical air quality challenges in the nation, the South Coast Air Basin and the San Joaquin Valley, as well as many other nonattainment areas across the State. The key attainment deadlines for these areas are outlined in Table 1, including new 9 ug/m³ annual NAAQS for PM2.5. Nonattainment areas for this new PM2.5 NAAQS will be established in February 2026, with an initial attainment year of 2032 for all areas. CARB works closely with local air districts across California to develop State Implementation Plans (SIP) to meet Clean Air Act requirements for each NAAQS.

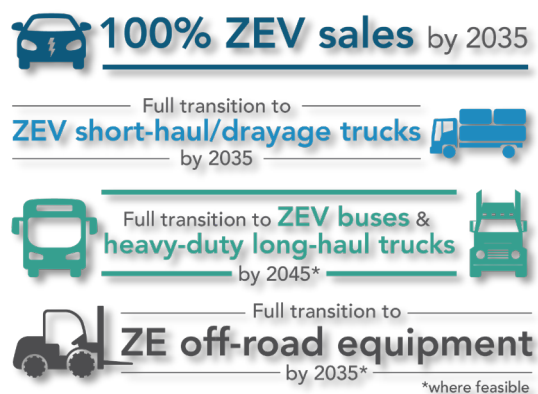
Table 1 – Key Attainment Deadlines for National Ambient Air Quality Standards

Attainment Year	Standard
2030	12 µg/m ³ annual PM2.5
2031	75 ppb 8-hour ozone
2032	9 µg/m ³ annual PM2.5
2037	70 ppb 8-hour ozone

⁷ AB 617, C. Garcia, Chapter 136, Statutes of 2017, https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201720180AB617
⁸ C. Garcia, Chapter 136, Statutes of 2017, https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201720180AB617
⁹ CARB webpage, Community Air Protection Program, <https://ww2.arb.ca.gov/capp>

In recognition of the severity of the air quality, climate, and community risk reduction challenges and the need for immediate action, Governor Newsom signed Executive Order N-79-20 on September 23, 2020 (Figure 4). This order established a first in-the-nation goal for 100% of in-state sales of new passenger cars and trucks to be zero-emission by 2035. In addition, the Governor's order set a goal to transition 100% of the drayage truck fleet to zero-emission by 2035, all off-road equipment where feasible to zero-emission by 2035, and the remainder of medium- and heavy-duty vehicles to zero-emission where feasible by 2045. As directed in the order, CARB is working with our State agency partners to develop regulations and strategies to achieve these goals taking into account technological feasibility and cost-effectiveness.

Figure 4 - Governor's Executive Order N-79-20



As research continues to show harmful effects from air pollution at increasingly lower levels, achieving the State's complementary mandates, targets, and standards will provide much needed public health protection for the millions of Californians that still breathe unhealthy air and will reduce exposure in the State's most highly-impacted communities. Meeting California's GHG emissions reduction targets is an essential part of the worldwide action needed to slow climate change and achieve climate stabilization, as California continues to serve as an example on climate action to many across the world. Finally, actions to meet California's public health and climate mandates will also provide economic benefits including increasing the demand for skilled labor in green jobs, reducing our dependence on petroleum and establishing a more secure energy future.

Defining the scope of actions necessary to implement a strategic vision to meet all of California's air quality, climate change, and community risk reduction mandates is best achieved via an integrated planning process. To identify the strategies and program concepts that will help CARB and the State meet all of its targets, it is imperative to look comprehensively at the potential benefits to all three categories of pollutants that CARB must reduce: criteria pollutants, GHGs, and toxics. Of CARB's many planning processes, the State SIP Strategy focuses on potential State actions to reduce criteria pollutant emissions to support attainment of the NAAQS, while the AB 32 Climate Change Scoping Plan looks comprehensively across all sectors to identify a path to achieve our climate change mandates while also improving air quality. The MSS is developed to provide a more concentrated focus on mobile sources from which significant emissions reductions are needed across all pollutants. This type of coordinated planning effort is essential to address the interplay between pollutants and sources, and consider the benefits of different technologies and fuels. CARB's planning efforts, such as the AB 32 Climate Change Scoping Plan and the MSS, serve as a foundation but does not substitute for the public regulatory or

program development process, including analyses and review as required under the California Environmental Quality Act (CEQA), that will take place if CARB pursues each of the individual program concepts.

The MSS uses scenario planning tools to quantify changes in ozone and PM2.5 precursor emissions, GHG emissions, diesel particulate matter emissions, and petroleum usage as various technologies are considered in the vehicle and equipment fleets thereby suggesting potential pathways towards achieving our various environmental mandates. CARB is now developing the 2025 MSS to provide an update on the progress made in adopting new, cleaner mobile source technologies and explore updated scenario technology mixes and potential new programmatic concepts since the 2020 MSS was released.

History

CARB developed the first MSS in 2016 and updated it in 2020. Both documents used scenario planning to take an integrated approach to identifying the technology trajectories and programmatic concepts to meet the State’s criteria pollutant, GHG, and toxic air contaminant reduction mandates from mobile sources. For reference, Figure 5 shows the three iterations of the MSS.

Figure 5 - Iterations of CARB’s Mobile Source Strategy



The *2016 Mobile Source Strategy* (2016 MSS) was the first iteration of the MSS and demonstrated how the State can simultaneously meet air quality standards, achieve GHG emission reduction targets, decrease health risk from mobile source emissions, and reduce petroleum consumption through 2031. In recognition of the value of the 2016 MSS in relation to the State’s ongoing air quality, climate, and community risk reduction challenges, and the ever-evolving vehicle market, the California Legislature passed SB 44, signed by Governor Newsom into law on September 20, 2019. SB 44 required CARB to update the MSS every five years, further acknowledging the ongoing need to evaluate opportunities for mobile source emissions reductions in California as the vehicle and equipment market continues to evolve. Specifically, SB 44 required CARB to update the 2016 MSS to include a

comprehensive strategy for the deployment of medium- and heavy-duty vehicles for the purpose of meeting air quality standards and reducing GHG emissions to meet climate mandates. In addition to providing a status on the measures in the 2016 MSS, SB 44 also directed CARB to set reasonable and achievable goals for reducing emissions from medium- and heavy-duty vehicles that are consistent with the State's overall goals. Because meeting the State's near- and longer-term goals requires action across the full spectrum of mobile sources, the *2020 Mobile Source Strategy* (2020 MSS) also discussed light-duty on-road vehicles, as well as a wide range of off-road equipment sectors including primarily-federally and internationally regulated sectors.

The 2020 MSS met the requirements of SB 44 through the inclusion of scenarios and programmatic concepts that could serve as the mechanisms to encourage the deployment of clean medium- and heavy-duty on-road vehicles. By including light-duty vehicles and off-road vehicles and equipment, the 2020 MSS was more comprehensive in scope than required by SB 44. The scenarios and concepts included in the 2020 MSS illustrated how the State could achieve emissions reductions needed to meet federal ambient air quality standards and substantially reduce GHG emissions from motor vehicles. It's important to note that while the final scenarios in the 2020 MSS were one potential pathway to meeting our mandates as identified at the time, regulations that have since been adopted each underwent specific and thorough analyses, as well as public processes, such that the programs as adopted by the Board may not look identical to what was originally conceptualized in the MSS. The final regulations must balance statutory direction that includes criteria such as being technologically feasible and cost-effective. The 2025 MSS will reflect the ways in which CARB programs have evolved and focus on the categories of mobile sources where additional requirements and programs are needed to accelerate the deployment of zero-emissions technologies.

Relationship to Other Planning Efforts

Similar to the 2016 MSS and *2016 State Strategy for the State Implementation Plan*, elements of the 2020 MSS were incorporated into the development of other planning efforts including the *2022 State Strategy for the State Implementation Plan*¹⁰ (2022 State SIP Strategy) which translated the concepts into concrete measures and commitments for specific levels of emissions reductions. The 2020 MSS also provided complementary efforts to the *2022 Scoping Plan for Achieving Carbon Neutrality*¹¹ (2022 Scoping Plan Update) and helped to inform CERPs required for communities selected as a part of CARB's Community Air Protection Program. Each of these documents drew elements from the 2020 MSS to

¹⁰ CARB webpage, 2022 State Strategy for the State Implementation Plan, <https://ww2.arb.ca.gov/resources/documents/2022-state-strategy-state-implementation-plan-2022-state-sip-strategy>

¹¹ CARB webpage, 2022 Scoping Plan Documents, <https://ww2.arb.ca.gov/our-work/programs/ab-32-climate-change-scoping-plan/2022-scoping-plan-documents>

incorporate and build upon the actions and policies relevant to meet individual CARB program mandates.

CARB plans for the 2025 MSS to build on the 2020 MSS and continue the multi-pollutant planning approach to illustrate the pathways forward for the various mobile sectors that are necessary in order to achieve California's numerous mandates over the next 20 years. In this Discussion Draft, we are hoping to set the foundation for this effort by providing core information about the status of the various mobile source categories including current control programs and potential technologies. This Discussion Draft also introduces other key considerations including environmental justice and racial equity and zero-emission infrastructure needs.

The final version of the 2025 MSS will likely illustrate scenarios for meeting the State's public health, climate, and community risk reduction mandates. While a scenario may outline the overall approach for a sector including program concepts that will move the State in the needed direction, the specific strategies for each sector will continue to be refined as the planning and public process for implementing specific actions moves forward balancing statutory direction including criteria such as being technologically feasible and cost-effective. As with the previous MSS, the concepts in the final 2025 MSS can inform the development of CARB's other planning efforts including the SIP, AB 32 Climate Change Scoping Plan, and CERPs (Figure 6).

Figure 6 - 2025 MSS Informs Other Planning Efforts



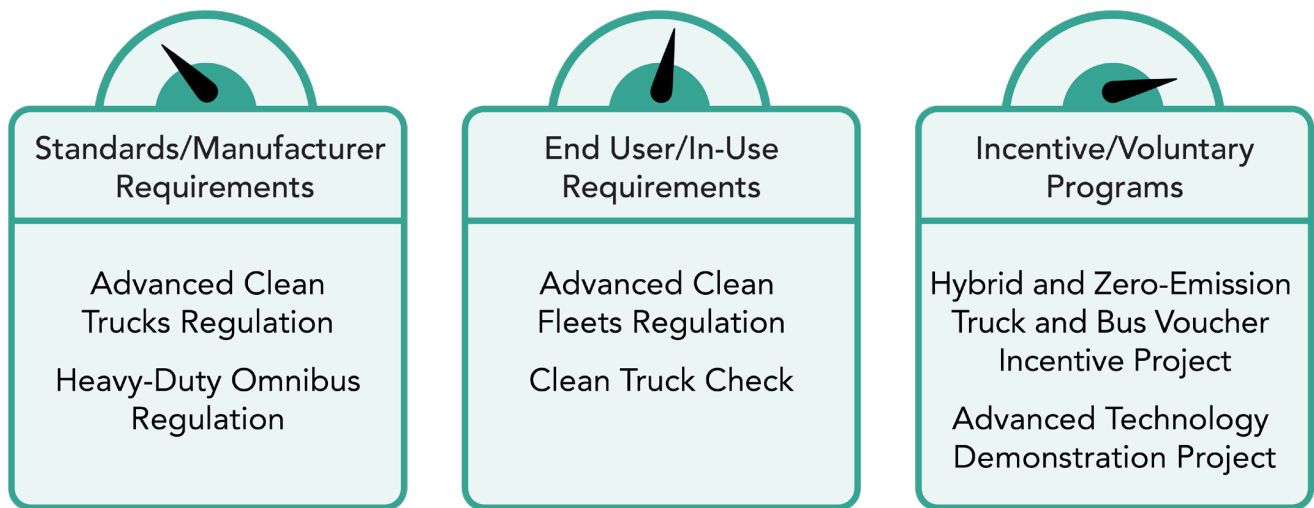
Building Blocks of the MSS Scenarios

The final 2025 MSS will include technology penetration scenarios for each mobile source sector that illustrate the technology mixes from the base year for this effort, 2020, through the out year, 2050, that could provide the emissions reductions needed from each transportation sub-sector to meet CARB’s air quality, climate, and community risk reduction targets. Scenarios are used to bound the range of potential future technology deployments depending on which regulatory and non-regulatory tools are used, and explore the differences in the technology mixes and emissions reductions between these possible futures. These potential pathways facilitate investigations into which scenarios produce the optimal results, and allow for staff to identify high-level programmatic concepts that could enable the State to achieve the technology trajectories identified in the scenarios.

As illustrated in Figure 7, development of a scenario could be visualized as pulling on levers for each type of regulatory and non-regulatory tool available in CARB’s toolbox. Figure 7 conveys just one example of scenario development in the on-road heavy-duty sector, and shows three different types of regulatory and non-regulatory mechanisms with levers to signify the intensity of which each mechanism is used in the scenario - a higher intensity could mean things including earlier implementation dates for standards, higher percentage

of zero-emission technologies being required for fleets, or more funding being dedicated for incentives. The lever intensity for each mechanism can be determined based on vehicle technology availability, opportunities for controls, and public input. Creating different scenarios with varying levers of intensity allows an investigation and discussion with the public to produce the most optimal results.

Figure 7 - MSS Scenario Development Example



CARB’s Mobile Emissions Toolkit for Analysis (META) and Vision for Clean Air are examples of past scenario planning tools used to conduct, evaluate, and visualize the scenario modeling in the MSS. CARB also used energy and technology scenario planning tools such as the E3 PATHWAYS model¹² to inform and support the development of the AB 32 Climate Change Scoping Plan. These tools evaluate the impacts of varying assumptions about potential technology and fuel mixes and explore different rates at which technologies could be adopted. Technologies, energy sources, and vehicle travel, as well as the best policy implementation approaches, will vary by transportation sub-sector based on the status of technology development in various applications, the multi-pollutant benefits, and the interactions between regulatory and programmatic concepts and public input. It is important to note that while zero-emission technology for on-road and off-road vehicles and equipment are becoming increasingly available, there are additional factors taken into consideration during concept and scenario development such as costs, infrastructure availability and deployment challenges, and for certain off-road categories, the benefits of deploying the cleanest available combustion technologies sooner versus zero-emission

¹² CARB, AB 32 GHG Inventory Sectors Modeling Data Spreadsheet, 2022, <https://ww2.arb.ca.gov/sites/default/files/2022-11/2022-sp-PATHWAYS-data-E3.xlsx>

technology further into the future. Additional information on CARB's regulatory and non-regulatory mechanisms are described below in another section.

Baseline Emissions Inventories

Emissions are the gases and particulates released into the atmosphere from a wide variety of sources. In order to evaluate potential futures through scenario modeling, it's important to establish a baseline level of emissions currently being released and what is expected into the future under current conditions including regulations already in place. CARB develops emissions inventories for this purpose; emissions inventories are estimations of the amount of pollutants discharged into the atmosphere that can be broken down by specified source categories in a certain geographical area and within a specified time span.

CARB staff continuously updates and improves emissions inventories to reflect most recent studies and data, typically updating each of the sector-specific mobile source models every four to six years. For this MSS, staff used the most recent mobile source inventories to present emissions in 2020, 2031, and 2050, which portray snapshots of emissions from each mobile source sector with regulations adopted and approved by the California Office of Administrative Law as of the beginning of 2024.

Staff selected a 2020 base year to best compare and review the progress made since the 2020 MSS. It is important to note that emissions estimates shown for 2020, 2031, and 2050 generally do not reflect the impacts of the COVID-19 pandemic. Differences between them are due to impacts of adopted CARB regulations, policies, and natural turnover. Staff acknowledges that activity in 2020 and subsequent years was impacted by the COVID-19 pandemic to some degree. For example, VMT from passenger vehicles declined substantially beginning in mid-March 2020, and activity from mobile sources supporting freight movement through seaports (such as ocean-going vessels and locomotives) increased in 2021 and 2022 relative to a pre-pandemic baseline. Nevertheless, these are short-term trends that are not wholly reflected in the emissions inventories. Some models have not been updated since the commencement of the COVID-19 pandemic in California, and those that have been updated use best available economic and other data to forecast emissions for a post-pandemic future.

Figure 8 shows Statewide emissions in the 2020 base year of NO_x and PM by sector including on-road (dark blue), off-road (teal), and primarily federally-regulated mobile sources (light blue). Figure 9 shows Statewide emissions in the 2020 base year of GHG by sector including passenger vehicles (blue), heavy-duty vehicles (light blue), aviation+rail+ships (teal), and off-road+unspecified (light teal). The sectors in Figure 9 are categorized consistent with and reflect data from GHG emissions from the current California

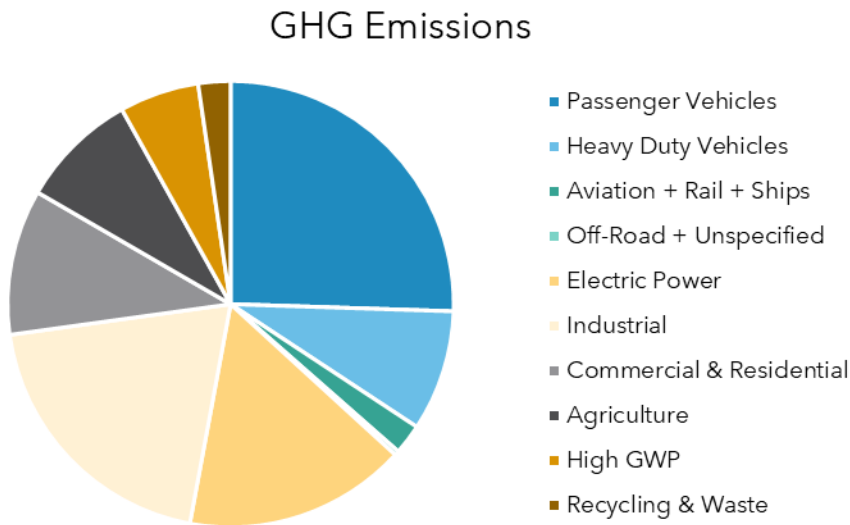
GHG emission inventory¹³. As shown in the Figures 8 and 9, mobile sources continue to contribute a majority of the NOx emissions, a significant precursor to ozone and PM, and are the largest portion of GHG emissions. While reactive organic gases (ROG) is also an important precursor to ozone, the pathway to attaining ozone standards requires substantial NOx reductions. NOx emissions reductions along with directly-emitted PM are the also the most effective emission control for reducing PM2.5 levels. Current air quality modeling show that ROG reductions have no benefit in improving PM2.5 levels. ROG reductions are associated with reductions of toxic air contaminants and will reduce ozone levels to an extent, however, in the 2025 MSS, we focus emissions profiles and control strategies on NOx, PM, and carbon dioxide (CO2). Similarly, although GHG emissions includes a variety of pollutants, in the 2025 MSS, we exclusively focus on tailpipe CO2, and do not account for other GHGs such as methane, nitrous oxide, and GHGs from refrigerants. Additional information on the NOx, PM, and tailpipe CO2 emissions inventories for each mobile source category are provided in Chapters 2 through 4.

Figure 8 - 2020 Statewide NOx and PM Emissions



¹³ CARB webpage, Current California GHG Emission Inventory Data, https://view.officeapps.live.com/op/view.aspx?src=https%3A%2F%2Fww2.arb.ca.gov%2Fsites%2Fdefault%2Ffiles%2F2023-12%2F2000-2021_ghg_inventory_trends_figures.xlsx&wdOrigin=BROWSELINK

Figure 9 - 2020 Statewide Greenhouse Gas Emissions



As shown in Figures 8 and 9, a large portion of NO_x, PM, and GHG emissions come from primarily federally-regulated mobile sources including aircraft, ocean-going vessels, and locomotives. For California to meet its air quality, GHG, and toxic mandates, it is imperative that the federal government act decisively to reduce emissions from primarily federally-regulated sources of air pollution. Baseline emissions projections show that absent federal action, by 2030, NO_x emissions from primarily federally-regulated sources will exceed emissions from California-regulated mobile sources.

In addition to taking action to regulate primarily federally-regulated mobile sources, it is also critical that the federal government act to approve California’s requests for waiver and authorization of federal preemption under Section 209 of the Clean Air Act. It is important to note that because these approvals unlock CARB’s ability to fully enforce our adopted mobile source regulations, without timely approval of these waivers and authorizations, CARB may be unable to achieve the full level of emissions reductions currently incorporated into the future projections in our baseline emission inventories.

Available Technologies

The 2025 MSS scenarios will consider a mix of zero-emission and cleanest combustion technologies available for each on- and off-road mobile source sector. Zero-emission technologies for mobile sources can be battery-electric or hydrogen fuel cell while combustion technologies are internal combustion engines fueled with diesel, natural gas, gasoline, or aviation specific fuel. Battery electric technology (BEV) uses batteries to store energy needed to power electric motors. Fuel cell electric technology uses hydrogen stored on board to power a fuel cell, in combination with a traction battery that produces electricity to power the electric motors. For mobile sources where zero-emission technology is not yet

available, the cleanest combustion technology and fuels may be the best available option (e.g. Tier 4 Final off-road engines) as zero-emission technologies continue to mature and be brought to market.

Due to various factors, on-road light-duty vehicles like passenger cars include the most mature zero-emission technologies while clean propulsion technologies for on-road heavy-duty vehicles like trucks used to transport freight have quickly followed suit and matured as well. There are off-road mobile source categories such as lawn and garden equipment and forklifts, for which established zero-emission technology is currently available, while zero-emission technology for other categories are still being developed. As zero-emission technologies for off-road vehicles and equipment mature, the cleanest internal combustion technology and fuels may be needed to fill the gap of market development and penetration. This is to ensure that industry can continue to operate while still maximizing the emission reduction benefits.

Among the various factors influencing the market penetration of newer technologies, CARB's authority to implement regulatory and non-regulatory mechanisms and tools is essential. The adoption of regulations by CARB establishes the market signals to manufacturers of on-road vehicles and off-road equipment as well as fueling infrastructure providers allowing them to make the business decisions and investments needed in cleaner technologies. Without these market signals, manufacturers would produce vehicles and equipment technologies at a slower rate than is needed to achieve our environmental mandates. Additional information about the status of the various technologies available for each on and off-road mobile source sectors can be found in Chapters 2 through 4.

Regulatory and Non-Regulatory Mechanisms/Tools

Given the severity of California's air quality, climate, and community risk reduction challenges and the need for ongoing emissions reductions, CARB has implemented the most advanced mobile source emissions control program in the nation. CARB's existing comprehensive mobile source control program has achieved substantial reductions across California, and will continue to provide further emissions reductions from ongoing implementation. These reductions have relied on a suite of regulatory and non-regulatory mechanisms that includes establishing emissions and performance standards for new vehicles and fuels, setting sales mandates and purchase requirements for advanced technologies, setting in-use and operational requirements for existing vehicle and equipment fleets, funding research and creating pilot programs to encourage development of new technologies, and implementing incentive and other programs to accelerate technology deployment. Together, these approaches are designed to achieve progressively cleaner emission levels for the entire mobile fleet and represent the different levers that CARB will consider for use within the scenarios for the 2025 MSS.

Regulations can take many forms and make use of several different forcing mechanisms to drive emissions reductions. Some CARB regulations set tailpipe emissions standards for

newly manufactured vehicles and engines (e.g., the Heavy-Duty Omnibus Regulation), while others establish sales requirements to ensure that vehicles are manufactured and supplied to the market (e.g., the Advanced Clean Trucks Regulation). In-use fleet or purchase requirements are a regulatory mechanism that accelerates adoption and use of the vehicles and equipment supplied by the manufacturers (e.g., Advanced Clean Fleets regulation). Regulations in the form of operational requirements for existing vehicles and equipment prevent harmful excess emissions from vehicles by limiting idling or setting other restrictions, while in-use testing programs identify high-emitting vehicles for repair (e.g., Clean Truck Check Program). Regulations can also establish requirements to encourage the production and use of the cleanest available fuels and increase deployment of zero-emission fueling infrastructure (e.g. the Low-Carbon Fuel Standard and the Cap-and-Trade Program). CARB's portfolio of regulations represents the most advanced mobile source emissions control program in the nation and provides many examples of the types of technology advancement and implementation scenarios that were considered in the MSS scenarios.

Non-regulatory mechanisms such as incentive programs help spur demand for these vehicles by encouraging consumers and fleet operators to purchase or lease the cleanest technology available by offsetting some of the additional costs of these technologies compared to internal combustion fueled vehicles (e.g., purchase rebates through the Clean Truck and Bus Vouchers or HVIP) or by developing and testing new technologies through demonstrations and pilot projects (e.g., the Advanced Technology Demonstration Project). The supporting programs also play a critical role in facilitating the cleanest technology market growth by providing the cleanest fuels and refueling infrastructure (e.g., the Clean Transportation Program), building clean technology awareness, and sharing best practices among different jurisdictions through collaboration. These regulatory and non-regulatory mechanisms work together to accelerate the clean technology market by fostering supply and demand across all phases of the cleanest technology commercialization and market development.

As it pertains to primarily-federally regulated mobile sources, CARB staff continues to explore all regulatory mechanisms within our authority; CARB and our local partners in California have taken concrete actions to not only petition federal agencies for action, but also to directly reduce emissions using programmatic mechanisms within our respective authorities. Unfortunately, complementary action by U.S. EPA to limit emissions from these sources has been minimal over the last 20 years, making it more challenging to meet federal air quality standards to reduce air pollution that harms public health in California and across the U.S. Even still, because the emissions from primarily federally regulated sources grows into the future and reductions are critically needed, the 2025 MSS will include scenarios and concepts for these sources both for potential consideration at the State level if under CARB's authority, or for potential development at the federal level.

Environmental Justice and Racial Equity

Advancing racial and environmental justice are core values of CARB and are critical to achieving CARB's air quality, climate, and community risk reduction mandates. CARB has a long history of public health and environmental protection, but despite significant emissions reductions and public health improvements, many communities continue to be disproportionately impacted by air pollution. Race remains the single most important determinant of who bears the burden of air pollution.¹⁴ Racist and discriminatory practices such as redlining have resulted in highly impacted low-income and disadvantaged communities and communities of color being disproportionately exposed to health hazards and pollution burdens.¹⁵ These communities which are often located near seaports, rail yards, warehouses, airports, and freeways, experience a higher concentration of regional and localized air pollution than other areas due to emissions from mobile sources, such as cars, trucks, locomotives, aircraft, and ships. *CalEnviroScreen 4.0*¹⁶, a mapping tool that helps identify the communities that are the most impacted by pollution sources, shows that Latino, Black, and Pacific Islander populations represent 89% of the population that live in the California communities that are most impacted by environmental pollution, while the population is 72% white in the least impacted census tracts.¹⁷

To understand the root cause of this trend, we must understand the role that structural racism has played in society, including in environmental outcomes. In 2023, CARB adopted the *Vision for Racial Equity*¹⁸ to guide our external work, including the implementation of CARB's Community Air Protection Program:

CARB commits to just social change by working at all levels within the organization and externally to address environmental injustices and advance racial equity in the achievement of its mission. CARB works toward a future where all Californians breathe healthy and clean air, benefit from actions to address climate change, and where race is no longer a predictor of life outcomes.

As development of the 2025 MSS continues, CARB staff is encouraging community members to engage in the public process and plans to consider scenarios and concepts

¹⁴ Tessum, Christopher W., et al. "PM2.5 polluters disproportionately and systemically affect people of color in the United States." *Science Advances* 7.18 (2021): eabf4491.

<https://www.science.org/doi/10.1126/sciadv.abf4491>.

¹⁵ CalEPA. 2021. Pollution and Prejudice: Redlining and Environmental Injustice in California. August 16., <https://storymaps.arcgis.com/stories/f167b251809c43778a2f9f040f43d2f5>

¹⁶ California Office of Environmental Health Hazard Assessment, CalEnviroScreen, <https://oehha.ca.gov/calenviroscreen>

¹⁷ Disparities in Air Pollution Exposure in the United States by Race/Ethnicity and Income, 1990–2010 | *Environmental Health Perspectives* | Vol. 129, No. 12 (nih.gov); <https://ehp.niehs.nih.gov/doi/full/10.1289/EHP8584>.

¹⁸ CARB webpage, Model of Change, <https://ww2.arb.ca.gov/equity/vision-racial-equity/model-change>

that can help to address longstanding environmental and health inequities from elevated levels of toxics, criteria pollutants, and secondary impacts of climate change. The concepts identified could have significant potential to address emissions and exposure in highly impacted communities. While CARB programs are driving deployment of zero-emission technologies statewide across numerous mobile source sectors, and the use of cleaner combustion and renewable fuels everywhere else, the State must strive to act even more quickly and target the introduction of cleaner and zero-emission vehicles and equipment in the communities that for generations have been bearing the brunt of fossil fuel extraction, refining, and combustion emissions. As the 2025 MSS scenarios are developed with public input, CARB's analysis will consider the potential benefits and impacts of implementing these scenarios on highly impacted communities. That said, both regional and near-source pollutants can have serious detrimental health impacts and are important to control, and the concepts in the 2025 MSS could address both along with implications for GHG emissions.

Public Engagement Process

CARB engages in a public process for all regulatory development and major planning efforts. This public process has evolved over time and varies depending on the types of actions being taken, but outreach and communication with community members and community-based organizations, health advocates, and other members of the public has become an ever more critical piece of the process. Working directly with people that are experiencing the negative and often serious impacts of air pollution, and representatives of these communities, elevates community lived experiences and allows CARB to better identify ways in which we can reduce emissions and exposure in those areas, and promote environmental justice through our programs and policies. CARB's actions on mobile sources will be inclusive of *environmental justice principles*¹⁹ as CARB strives to address longstanding environmental and health inequities from elevated levels of toxics, criteria pollutants, and GHGs.

With that said, CARB staff has and will continue to conduct meaningful engagement with interested parties throughout the development of the 2025 MSS. As part of that process, staff developed a *2025 Mobile Source Strategy factsheet*²⁰ that has been published on our webpage, and shared with a number of organizations including AB 617 community steering committee members.

CARB has reached out to tribes and the engagement has included tribal governments to ensure we build stronger government-to-government partnerships on CARB's efforts.

¹⁹ Principles of Environmental Justice, <https://www.ejnet.org/ej/principles.html>

²⁰ CARB webpage, 2025 Mobile Source Strategy Fact Sheet, <https://ww2.arb.ca.gov/sites/default/files/2023-10/2025%20MSS%20-%20Fact%20Sheet%20-%20October%202023.pdf>

Examples include staff sharing the 2025 MSS fact sheet at U.S. EPA's Region 9 Tribal Conference in October 2023 and upcoming Tribal conference in October 2024, and leveraging community events such as Native American Day at the State capitol on September 27, 2024.

CARB has also been participating in existing CARB stakeholder meetings over the last year to announce the start of the 2025 MSS process and invite early engagement and discussion. In January 2024, staff hosted a kick-off webinar for the 2025 MSS where they presented an overview of the MSS and its background, and established expectations and opportunities for the public to participate during the development of the 2025 MSS.

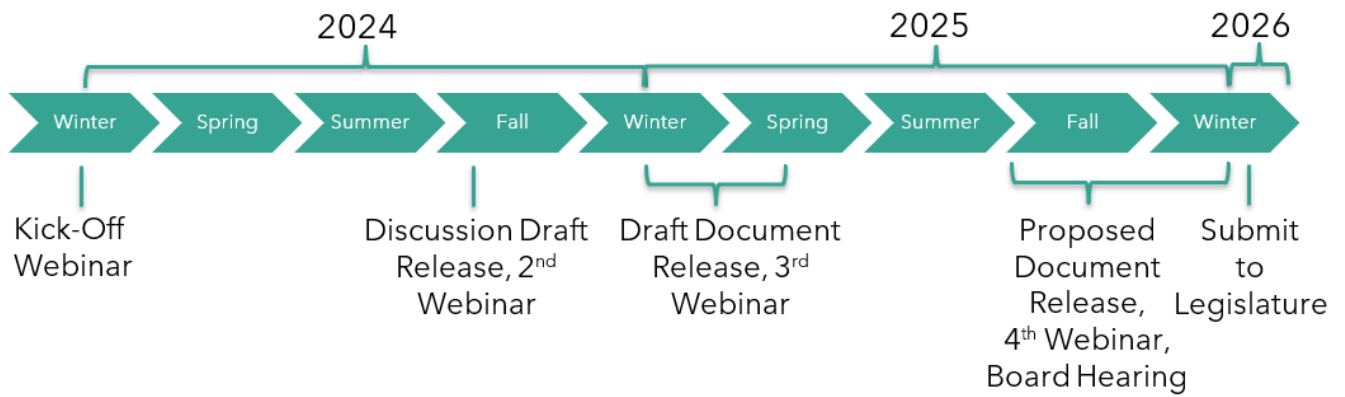
As we look forward, CARB staff is working to identify and engage with all interested parties on the 2025 MSS. Through previous experiences and discussions, CARB staff has seen that some parties prefer utilizing existing forums or groups to discuss new topics such as the 2025 MSS, whereas others may prefer starting new recurring small group or one-on-one meetings. In other planning processes, community members have conveyed that they would benefit from individual conversations especially when framing programs or issues and barriers the community faces. This and all CARB planning efforts are not possible without involvement and input from the public, and CARB staff developing the 2025 MSS strive to make themselves available for any meetings or conversations interested parties suggest could be useful to provide input. We hope that throughout this process, through individual engagement, the public releases and events, we can have productive conversations and find meaningful ways to incorporate suggestions and feedback, leading to a cleaner future for mobile sources in California.

Next Steps

After publication of the Discussion Draft, CARB staff will host a public webinar to present an overview of this document and receive feedback from participants including input on the types of scenarios that will be run. The feedback received will support development of the second iteration, the Draft 2025 MSS, planned to be released in Spring 2025. CARB staff will continue to engage with interested parties through all available means as we move forward. While the Discussion Draft establishes a baseline for future action, the Draft 2025 MSS will build on the Discussion Draft by including a range of potential technology penetration scenarios needed to achieve our air quality, climate, and toxic mandates.

After releasing the Draft 2025 MSS in Spring 2025, CARB staff plans to host a 3rd public webinar to discuss and receive suggestions. Again, following the Draft 2025 MSS, the plan is to continue our individual engagement process to refine and finalize the 2025 MSS into the Proposed Document which we plan to release in the Fall/Winter of 2025 with a Board hearing leading to Board adoption and staff submittal of a final document to the Legislature by the end of 2025. The planned document public releases and webinars are summarized below in Figure 10.

Figure 10 - 2025 MSS Planned Public Releases and Webinars



The following chapters describe the various mobile source categories, discuss current control programs including progress made since the 2020 MSS, and cover available technology where potential emissions reductions may exist for each sector.

Chapter 2 - On-Road Vehicles

Chapter 2 is an overview of the on-road transportation sectors including light-duty vehicles, motorcycles, and medium- and heavy-duty vehicles. Each on-road transportation sector overview includes Category Description, Current Control Programs, and Available Technology/Emission Reduction Potential. The Category Description provides facts such as the equipment gross vehicle weight rating (GVWR) and vehicle class, fuel type, vehicle population, and air pollution emissions in 2020 and 2050. The Current Control Programs section identifies CARB's current regulatory and non-regulatory mechanisms. Available Technology/Emission Reduction Potential describes the status of the vehicle propulsion technology and the associated emissions reductions from that technology and other potential emission reduction strategies such as reducing vehicle activity (i.e. vehicle miles traveled or hours of use).

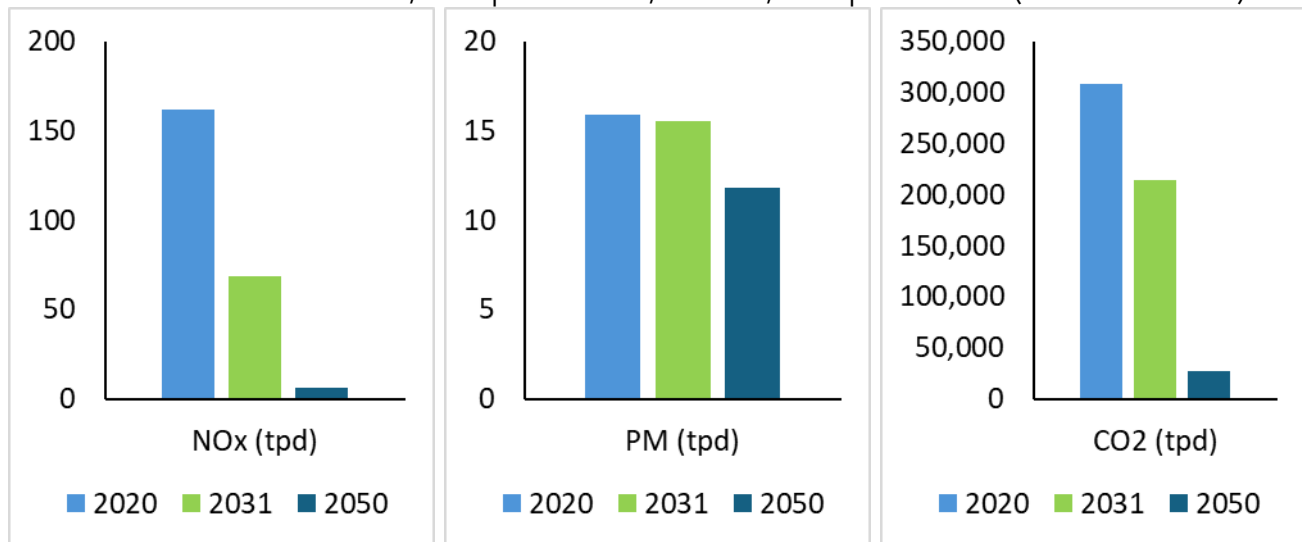
Light-Duty Vehicles

Category Description

- **Equipment:** Vehicles with a GVWR <8,500 lbs.
- **Fuel:**
 - For calendar year (CY) 2020, ~96% gasoline, 2% electric, with remainder including diesel, hydrogen, and natural gas
 - For CY 2050, ~12% gasoline, 77% electric, and 9% Plug-in Hybrid, with remainder including diesel and hydrogen
- **Population:** ~25 million

Emissions

- **NOx Emissions:** 162.0 tpd in 2020, and 6.1 tpd in 2050 (96% reduction)
- **PM Emissions:** 15.9 tpd in 2020, and 11.8 tpd in 2050 (26% reduction)
- **CO2 Emissions:** 308,321 tpd in 2020, and 27,767 tpd in 2050 (91% reduction)



Current Control Programs

- Advanced Clean Cars I (ACC I) was adopted in 2012 and combines several regulations including the Low Emission Vehicle (LEV III) criteria, greenhouse gas regulations, and zero-emission vehicle regulation.²¹
- LEV III standards establish increasingly stringent emissions standards for criteria pollutants and GHGs for new passenger vehicles through the 2025 model year.

²¹ CARB webpage, Advanced Clean Cars Program, <https://ww2.arb.ca.gov/our-work/programs/advanced-clean-cars-program/about>

- The zero-emission vehicle regulation set vehicle requirements for vehicle manufacturers through the 2025 model year to manufacture increasingly more zero-emission vehicles based on their total production volumes.
- Advanced Clean Cars II (ACC II) was adopted in 2022 and provided updates to the LEV and zero-emission vehicle regulation through the 2035 model year.^{22,23} Most notably, ACC II requires vehicle manufacturers to increase sales of ZE vehicles between 2026 and 2035 model years to achieve 100% zero-emission vehicle sales by 2035.
- CARB is amending the ACC II suite of regulations with the intention of presenting it to the Board in 2025. The amendments primarily focus on changes to the LEV greenhouse gas regulation.²⁴
- The Clean Miles Standard (CMS) was adopted by the Board in 2021 and is now being implemented by the California Public Utilities Commission (CPUC). This regulation requires Transportation Network Companies (TNCs) achieve a 90% electric VMT target by 2030, as well as a zero GHG emissions per passenger mile traveled target by the same year.
- Governor Newsom’s Executive Order N-79-20 established targets to end the sales of internal combustion passenger vehicles by 2035 to help put the State on the path to be carbon neutral by 2045.
- Clean Cars 4 All (CC4A) program provides incentives for lower-income consumers to replace higher-polluting vehicles with newer and cleaner transportation.
- CARB finalized a grant agreement with Community Housing Development Corporation (CHDC) to administer the Driving Clean Assistance Program (DCAP), which will expand access to CC4A that were not previously served by district programs. CC4A/DCAP will provide access to low-interest rate loans, and vouchers towards mobility options such as transit to offset cost of charging electric vehicles.
- California E-Bike Incentive Project will provide vouchers for the purchase of e-bikes for lower income households.

Available Technology/Emission Reduction Potential

- Zero-emission technology for passenger vehicles has improved with increased driving range, performance, and declining costs. For details on the current

²²CARB webpage, Advanced Clean Car II, <https://ww2.arb.ca.gov/our-work/programs/advanced-clean-cars-program/advanced-clean-cars-ii>

²³CARB webpage, for further details on the ACC regulation history, refer to Section 1 of the 2022 ACCII staff report here: <https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/accii/isor.pdf>

²⁴ CARB webpage, California to Propose New Greenhouse Gas Reductions from Passenger Vehicles, <https://ww2.arb.ca.gov/resources/fact-sheets/california-propose-new-greenhouse-gas-reductions-passenger-vehicles>

zero-emission vehicle technology and market conditions in California, refer to the 2022 ACC II staff report³.

- The California Energy Commission Zero-Emission Vehicle Dashboard has current information on total zero-emission vehicle registrations in California, along with a list of current zero-emission vehicle models available in the market.²⁵
- Particulate emissions from tire and brake wear, or non-exhaust emissions, is an active area of research, which includes the impact of zero-emission vehicle standards on expected tire lifetimes and non-exhaust emissions.
- Vehicle miles traveled (VMT) reduction strategies are necessary to achieve climate and air quality mandates. VMT reduction efforts reduce emissions and advance public health, equity, and the economy. Policies that target VMT reductions need to consider multiple factors as discussed in other CARB planning documents and reports:
 - The AB 32 Climate Change Scoping Plan outlines the importance of VMT reduction strategies and that reducing VMT will be necessary to reach climate mandated targets. Appendix E of the AB 32 Climate Change Scoping Plan identifies four areas of work, and for each, outlines a vision for 2045. Appendix D of the AB 32 Climate Change Scoping Plan also identifies the role that local governments can plan in supporting VMT reduction.
 - SB 150 (Allen, Chapter 646, Statutes of 2017)²⁶ progress reports quantify the progress on reducing VMT through transportation, housing, and land use strategies outlined in the Sustainable Communities Act, SB 375 (Steinberg, Chapter 728, Statutes of 2008)²⁷.
 - VMT reduction strategies can and need to be done in ways that prioritize benefits for historically marginalized communities and that advance racial equity.

²⁵ California Energy Commission, Light-Duty Vehicle Population in California, <https://www.energy.ca.gov/data-reports/energy-almanac/zero-emission-vehicle-and-infrastructure-statistics-collection/light>

²⁶ SB 150, Allen, Chapter 646, Statutes of 2017, https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201720180SB150

²⁷ SB 375, Steinberg, Chapter 728, Statutes of 2008, https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=200720080SB375

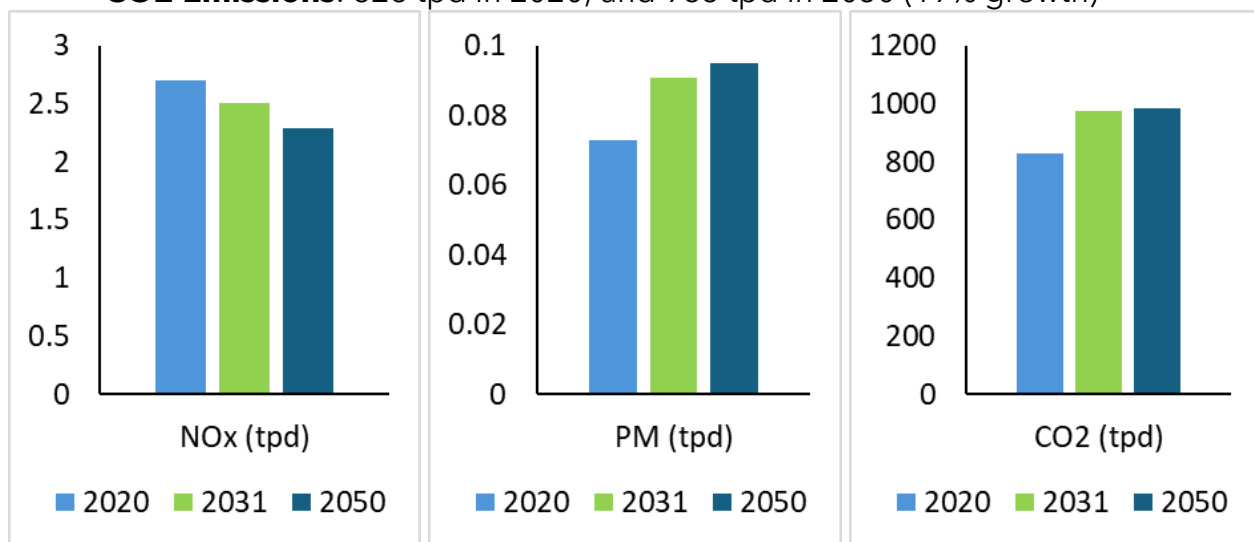
Motorcycles

Category Description

- **Equipment:** On-Road Motorcycles Class III²⁸
- **Fuel:** For CY 2020 and CY 2050, ~99.5% gasoline, with remainder including electric
- **Population:** ~700,000

Emissions

- **NOx Emissions:** 2.7 tpd in 2020, and 2.3 tpd in 2050 (15% reduction)
- **PM Emissions:** 0.07 tpd in 2020, and 0.10 tpd in 2050 (30% growth)
- **CO2 Emissions:** 826 tpd in 2020, and 985 tpd in 2050 (19% growth)



Current Control Programs

- CARB is developing a regulation for consideration by the Board at the November 2024 hearing requiring zero-emission motorcycle (ZEM) sales targets that would start in calendar year 2028 and gradually ramp up to 50% ZEM sales by 2035. Tradeable ZEM credits could be earned by manufacturers to give flexibility in meeting these goals.
- For gasoline motorcycles, CARB is considering adopting more stringent exhaust and evaporative emission standards and OBD requirements starting with 30% of new sales in 2029 and reaching 100% of new sales by 2031. Exhaust and OBD standards and test procedures will be harmonized with the current European Union "Euro 5" regulations.

²⁸ A motorcycle with a displacement of 280 cubic centimeters (cc) or greater.

Available Technology/Emission Reduction Potential

- California has no current Inspection and Maintenance (I/M) Program for on-road motorcycles. Analysis from EMFAC 2021 shows that emissions-related tamper rates for motorcycles is approximately 30% for motorcycles aged 19 and over. An I/M program could reduce the rates of tampering of motorcycle emission reduction systems, thereby reducing emissions from in-use motorcycles.

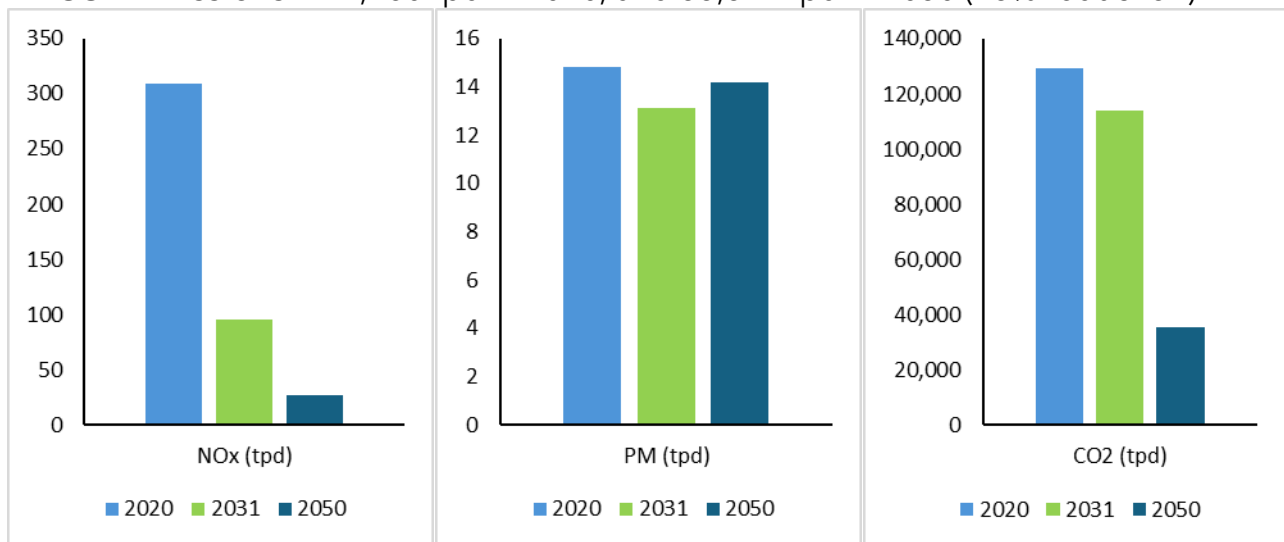
Medium- and Heavy-Duty Vehicles

Category Description

- **Equipment:** Vehicles with a GVWR >8,500 lbs.
- **Fuel:**
 - For CY 2020, ~55% diesel and 44% gasoline with remainder including natural gas, and electric
 - For CY 2050, ~49% electric, 33% hydrogen, 11% diesel, and 6% gasoline with remainder including natural gas.
- **Population:** ~1.7 million

Emissions

- **NOx Emissions:** 308.7 tpd in 2020, and 27.1 tpd in 2050 (91% reduction)
- **PM Emissions:** 14.8 tpd in 2020, and 14.2 tpd in 2050 (4% reduction)
 - In 2020, ~34% of the PM was tailpipe PM from diesel vehicles (DPM).
- **CO2 Emissions:** 129,280 tpd in 2020, and 35,394 tpd in 2050 (73% reduction)



Current Control Programs

- Truck and Bus Regulation had its last vehicle turnover schedule in 2023 which required all vehicles >14,000 lbs. GVWR to upgrade to 2010 or newer model year engines.
- Advanced Clean Trucks (ACT) Regulation accelerates sales of zero-emission medium and heavy-duty trucks (Class 2b to Class 8) by setting manufacturer sales requirements that gradually increase over time starting in 2024. These requirements were expanded with the Advanced Clean Fleets (ACF) regulation to require 100% of new vehicles sales over 8,500 GVWR be zero-emission by 2036.

- The ACF Regulation sets zero-emission targets for government fleets, drayage trucks, and private fleets that have either \$50 million or more in gross revenue or have ownership or control over 50 or more vehicles for vehicles greater than 8,500 lbs. GVWR starting in 2024.
- Clean Truck Check program requires periodic vehicle testing and enforcement strategies to identify and repair high emitting vehicles >14,000 lbs.
- Heavy-Duty Omnibus established more stringent NOx emissions for heavy-duty engines beginning with model year 2024.
- On July 5, 2023, CARB signed the Clean Truck Partnership agreement with the nation's leading truck and engine manufacturers. In this agreement manufacturers committed to meet California's vehicle standards including the sale and adoption of zero-emission technology in the State, while CARB committed to work collaboratively with manufacturers to provide reasonable lead time and flexibilities in meeting the standards while ensuring the state's climate and emission reduction commitments are achieved.
- Carl Moyer Memorial Air Quality Standards Attainment (Carl Moyer) Program provides incentive funds to purchase "cleaner-than-required" engines and equipment²⁹.
- Clean Truck and Bus Vouchers have provided funding since 2010 to support long-term deployment of ZEV's for heavy-duty vehicles³⁰.
- Funding incentives for school buses are available through numerous programs including the Zero-Emission School Bus and Infrastructure incentive project (ZESBI)³¹.
- Innovative Small e-Fleet Pilot Program provides vouchers for Class 2b through 8 zero-emission vehicles³².
- Volkswagen (VW) Environmental Mitigation Trust for California has provided \$423 million to California to mitigate excess NOx emissions from illegal emissions testing defeat devices in VW diesel vehicles³³.

²⁹ CARB webpage, Carl Moyer Memorial Air Quality Standards Attainment Program, <https://ww2.arb.ca.gov/our-work/programs/carl-moyer-memorial-air-quality-standards-attainment-program>

³⁰ CARB webpage, Clean Truck & Bus Vouchers (HVIP), <https://ww2.arb.ca.gov/our-work/programs/clean-truck-bus-vouchers-hvip>

³¹ CARB webpage, Funding for Clean School Buses, <https://ww2.arb.ca.gov/our-work/programs/school-buses/funding-clean-school-buses>

³² CARB webpage, Innovative Small e-Fleet Pilot Program, <https://ww2.arb.ca.gov/resources/fact-sheets/innovative-small-e-fleet-pilot-program>

³³ CARB webpage, Volkswagen Environmental Mitigation Trust for California, <https://ww2.arb.ca.gov/our-work/programs/volkswagen-environmental-mitigation-trust-california>

- Zero-Emission Truck Loan Pilot Project provides financing opportunities for heavy-duty zero-emission vehicles and charging/fueling infrastructure³⁴.
- Advanced Technology Demonstration Program provides funding to help accelerate next generation of vehicle, equipment or emission control technology that is not yet commercially available³⁵.

Available Technology/Emission Reduction Potential

- Regulatory actions have the potential to significantly reduce emissions from California’s fleet through the use of the lowest emitting technologies, battery electric and hydrogen fuel cell vehicles.
- Zero-Emission Truck measure outlined in the 2022 SIP aims to accelerate zero-emission adoption beyond existing measures (including ACF). CARB is evaluating a variety of options to achieve this commitment including, but not limited to, differentiated registration fees for higher emitting vehicles, increase vehicle turnover by requiring vehicles to be scrapped after reaching the end of their useful lives, introduction of differentiated fees that offset the battery electric and hydrogen fuel cell vehicle purchase price differential by collecting fees on higher emitting vehicles, and indirect source rule. Some of these options would require expanded authority for CARB or collaboration with air districts.
- CALSTART’s zero-emission technology inventory tool (ZETI) shows over 200 models of zero-emission trucks, vans and buses that are commercially available³⁶.
- There are on-going efforts to reduce PM emissions from non-exhaust sources, including tire wear. These sources are becoming increasingly important as exhaust standards become more stringent. CARB is tracking efforts to reduce PM tire wear emissions such as the European Parliament’s Euro 7 standards³⁷, which will start setting limits in 2028. There may be opportunities for CARB to work with tire manufacturers to reduce tire wear emissions in the future, for both heavy-duty and light-duty vehicles.

³⁴ CARB webpage, Zero-Emission Truck Loan Pilot Project, <https://ww2.arb.ca.gov/our-work/programs/zero-emission-truck-loan-pilot>

³⁵ CARB webpage, Advanced Technology Demonstration and Pilot Projects, <https://ww2.arb.ca.gov/advanced-technology-demo-projects>

³⁶ Global Commercial Drive To Zero Program – ZETI (Zero-Emission Technology Inventory), <https://globaldrivetozero.org/tools/zeti/>

³⁷ European Parliament’s Euro 7 standards, <https://unece.org/sites/default/files/2023-01/GRPE-87-37r1e.pdf>

Chapter 3 - Off-Road Equipment

Chapter 3 is an overview of the off-road mobile equipment sectors including agricultural equipment, cargo handling equipment, commercial harbor craft, construction and mining, oil drilling, airport ground support equipment, industrial, forestry, lawn and garden, light commercial and recreational equipment, portable equipment, recreational marine vessels, and transport refrigeration units. An overview for each off-road sector includes a Category Description, Emissions summary, Current Control Programs, and Available Technology/Emission Reduction Potential. The Category Description provides facts such as the types of equipment within the category, fuel type, and equipment population. The Emissions section provides statewide NO_x, PM, and CO₂ tailpipe emissions, measured in tons per day (tpd), for 2020, 2031, and 2050. The Current Control Programs section identifies CARB's current regulatory and non-regulatory mechanisms. Available Technology/Emission Reduction Potential describes the status of renewable diesel and engine technology and potential emission reductions from that technology.

Overview

CARB's off-road inventories are developed specifically for each category. Figure 11 and Figure 12 display stacked bar charts with total NO_x and PM emissions for the off-road mobile equipment categories for calendar years 2020 and 2050. From 2020 to 2050, overall NO_x and PM emissions under current control programs are projected to decline by 43% and 39%, respectively. The majority of PM emissions reductions are from diesel PM.

Figure 11 - Off-Road Mobile Source NOx Emissions

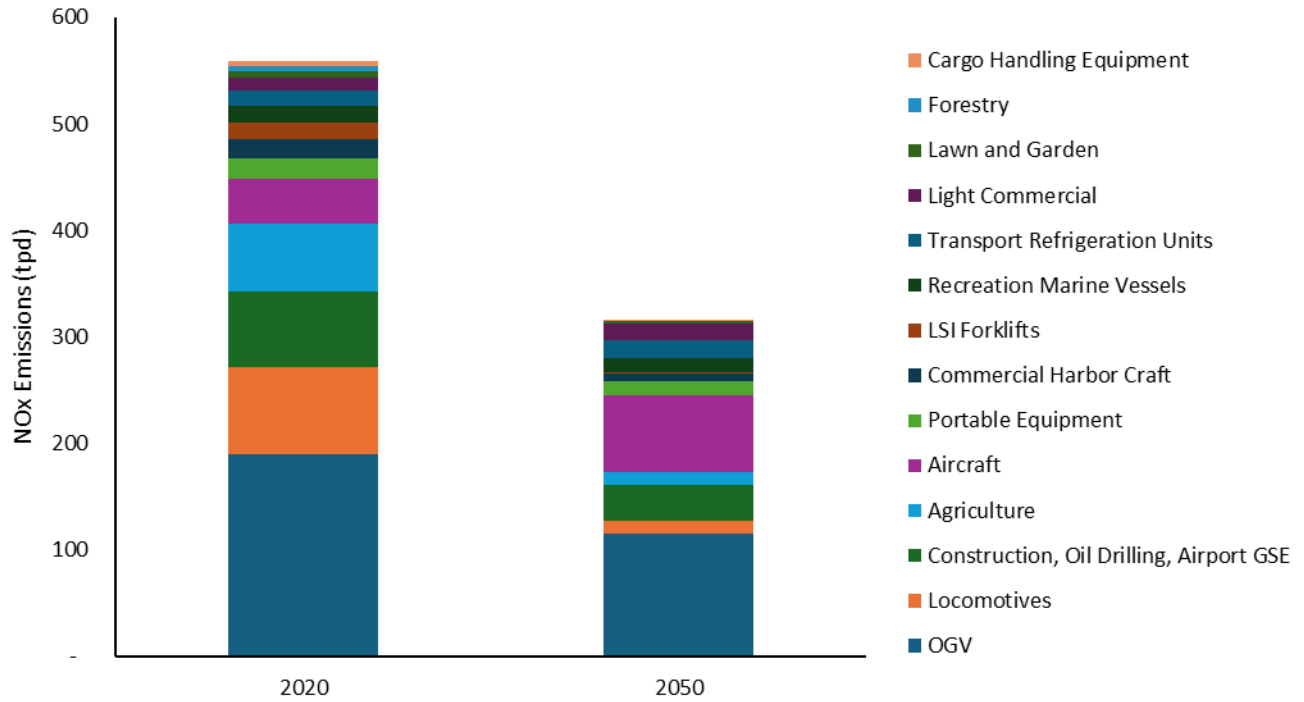


Figure 12 - Off-Road Mobile Source PM Emissions

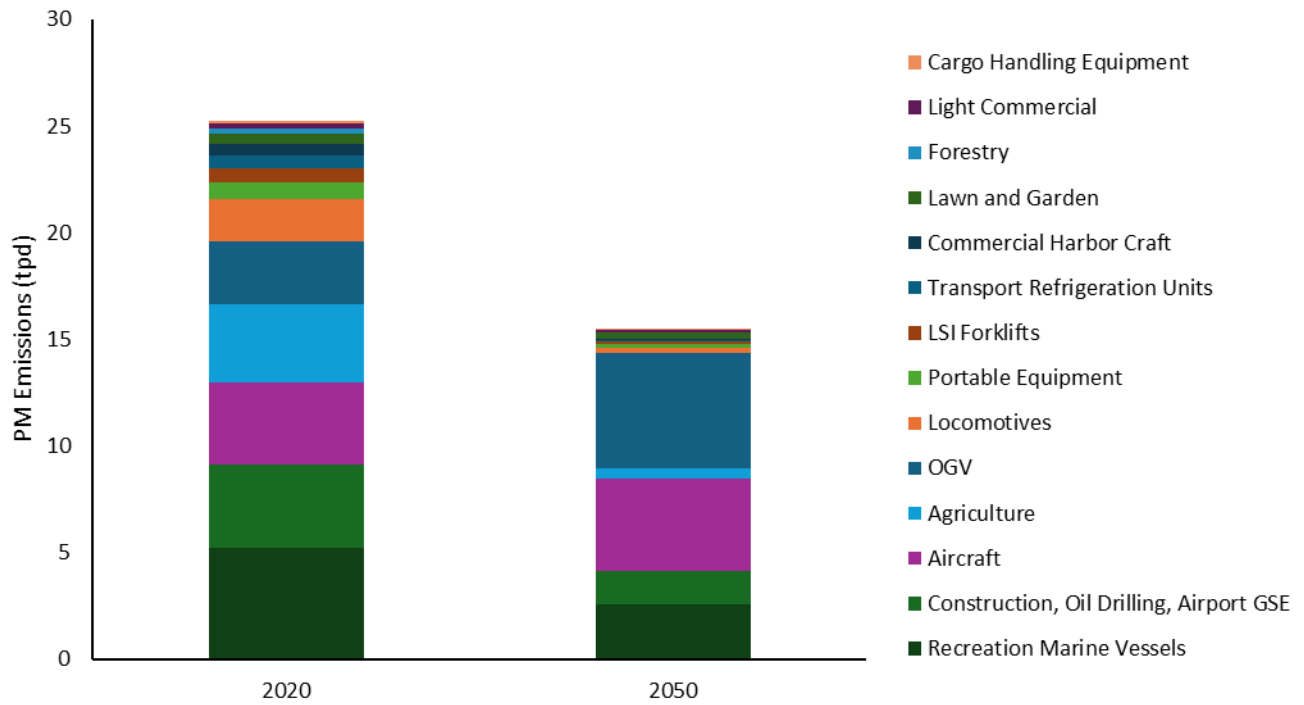


Table 2 lists the combined off-road mobile source NOx and PM emissions contributions allocated by air district, sorted from greatest to smallest. More than half of the total NOx contribution (54%) and PM contribution (58%) come from three air districts. This table excludes aviation emissions.

Table 2 - Off-road Mobile Source Emission Contribution by Air District

Air District	NOx (tpd)	Percent NOx	PM (tpd)	Percent PM
South Coast AQMD	113.81	22.9%	4.83	22.9%
Bay Area AQMD	82.73	16.7%	3.21	15.2%
San Joaquin Valley Unified APCD	72.27	14.6%	4.11	19.5%
Monterey Bay Unified APCD	39.13	7.88%	0.96	4.55%
Santa Barbara County APCD	31.15	6.27%	0.68	3.24%
Mojave Desert AQMD	27.29	5.50%	0.79	3.74%
San Diego County APCD	20.73	4.18%	1.18	5.63%
Ventura County APCD	18.59	3.74%	0.55	2.61%
North Coast Unified AQMD	16.56	3.33%	0.45	2.12%
San Luis Obispo County APCD	14.05	2.83%	0.38	1.80%
Imperial County APCD	7.03	1.42%	0.23	1.11%
Sacramento Metropolitan AQMD	6.05	1.22%	0.47	2.21%
Placer County APCD	5.07	1.02%	0.23	1.11%
Yolo/Solano AQMD	4.72	0.95%	0.28	1.35%
Butte County AQMD	4.10	0.83%	0.28	1.34%
Northern Sonoma County APCD	3.99	0.80%	0.13	0.62%
Feather River AQMD	3.67	0.74%	0.22	1.05%
Shasta County AQMD	3.38	0.68%	0.42	2.01%
Northern Sierra AQMD	3.04	0.61%	0.25	1.17%
Eastern Kern APCD	2.94	0.59%	0.13	0.60%
Siskiyou County APCD	2.65	0.53%	0.14	0.66%
Lassen County APCD	1.94	0.39%	0.12	0.55%
Tehama County APCD	1.77	0.36%	0.11	0.51%
Glenn County APCD	1.70	0.34%	0.11	0.53%
El Dorado County APCD	1.56	0.314%	0.23	1.07%
Antelope Valley AQMD	1.52	0.306%	0.07	0.33%
Colusa County APCD	1.50	0.302%	0.09	0.45%
Modoc County APCD	1.17	0.24%	0.05	0.26%
Great Basin Unified APCD	0.72	0.14%	0.14	0.67%
Tuolumne County APCD	0.66	0.13%	0.10	0.48%
Calaveras County APCD	0.48	0.10%	0.05	0.24%
Amador County APCD	0.41	0.08%	0.05	0.22%
Mariposa County APCD	0.18	0.04%	0.02	0.11%

Off-road Tier 5 Development

CARB is working on amendments to the new off-road diesel engine standards, called the Tier 5 rulemaking. The Tier 5 rulemaking aims to reduce NOx and PM emissions from new, off-road compression-ignition (CI) engines compared to what is allowed by today's Tier 4 Final emission standards. CARB is considering possible elements to achieve NOx standards up to 90% more stringent, and PM standards up to 75% more stringent than today's Tier 4 Final standards. First-time CO₂ emission standards for off-road engines may also be proposed³⁸. Tier 5 also introduces a Low Load Cycle (LLC) to specifically target emissions at low loads, depending on engine horsepower.

Tier 5 Timeline:

- October 2023 - Public Workshop release of the draft proposal
- October 8, 2024 - Public Workshop to release the draft regulation order
- October 2025 - Tier 5 Board Hearing
- 2029 - Tier 5 Interim equipment first available (depending on engine size)
- 2031 - Tier 5 Final equipment first available (depending on engine size)

³⁸ CARB webpage, Potential Amendments to the Off-Road New Diesel Engine Emission Standards: Tier 5 Criteria Pollutants and CO₂ Standards, <https://ww2.arb.ca.gov/our-work/programs/tier5/about>

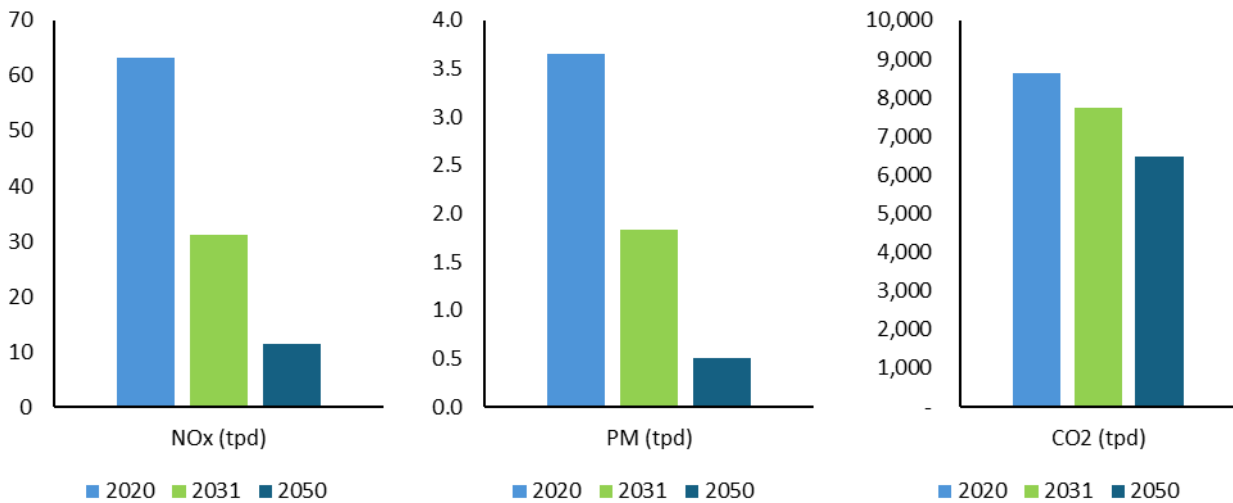
Agriculture

Category Description

- **Equipment:** Tractors, Harvesters, Balers, and more
- **Fuel:** For CY 2020, 99% Diesel, 1% Gasoline
- **Population:** 170,000

Emissions

- **NOx Emissions:** 63 tpd in 2020, and 11.3 tpd in 2050 (82% reduction)
- **PM Emissions:** 3.7 tpd in 2020, and 0.5 tpd in 2050 (86% reduction)
- **CO2 Emissions:** 8,600 tpd in 2020, and 6,500 tpd in 2050 (25% reduction)



Current Control Programs

- Incentive Programs include CARB’s Carl Moyer Program, the San Joaquin Valley Air Pollution Control District’s Tractor Replacement Program, the Natural Resources Conservation Service’s Environmental Quality Incentive Program (EQIP), and CARB’s Funding Agriculture Replacement Measures for Emission Reductions (FARMER) incentive program.
- Ongoing incentives include replacing existing agricultural equipment with the cleanest-available combustion or zero-emission equipment and internal combustion Utility Terrain Vehicles (UTVs) with zero-emissions.
- CARB’s Clean Off-Road Equipment Voucher Incentive Project (CORE) currently lists one zero-emission tractor option available for funding, and numerous manufacturers have models in development or early commercialization.
- FARMER Program incentives have replaced over 6,200 tractors/harvesters and 3,700 UTVs since 2018 with \$515 million in incentive funding. Incentives pay, on average,

slightly less than half the cost of new equipment, meaning the agricultural industry has paid the majority of costs for purchasing new cleaner equipment.

Available Technology/Emission Reduction Potential

Cleanest Diesel Options

- Tier 4 Final off-road diesel engines are the cleanest currently commercially available option for most equipment over 75 horsepower.
- Continuing incentive programs could turn over all remaining older equipment (Tier 0 to Tier 2) to Tier 4 Final by 2036, if funding remains consistent with 2019 to 2023 levels. CARB estimates 25,000 pieces of older equipment under 75 horsepower are currently in service in California.
- Use of renewable diesel instead of conventional CARB diesel would achieve 5% NO_x and 30% PM emissions reductions from Tier 3 and older equipment.
- Tier 5 emission standards may provide additional reductions for newly purchased equipment if adopted in California or nationally.

Zero-Emission Options

- Zero-emission options exist for some groups of lower-horsepower equipment, generally equivalent to under 75 horsepower. As with other categories, these options are viable where duty cycle is appropriate and charging infrastructure is feasible and available.
- Up to 20 different manufacturers are working toward electric models³⁹, including manufacturers that have traditionally made diesel tractors like John Deere and Kubota, but also new entries like Monarch and Rigitrac.
- CARB's Climate Investment demonstration projects⁴⁰ are in progress to deliver on-field mobile charging for farm tractors, aiming to test viability in different terrain and locations.

³⁹ CARB webpage, Advanced Clean Equipment, <https://ww2.arb.ca.gov/our-work/programs/msei/off-road-advance-clean-equipment>

⁴⁰ California Climate Investments, Electric Tractor Demonstration Supports Market Development and Pollution Reductions, <https://www.caclimateinvestments.ca.gov/2021-profiles-1/2021/4/27/advanced-technology-demonstration-and-pilot-electric-tractor-development-amp-demo-san-joaquin-valley>

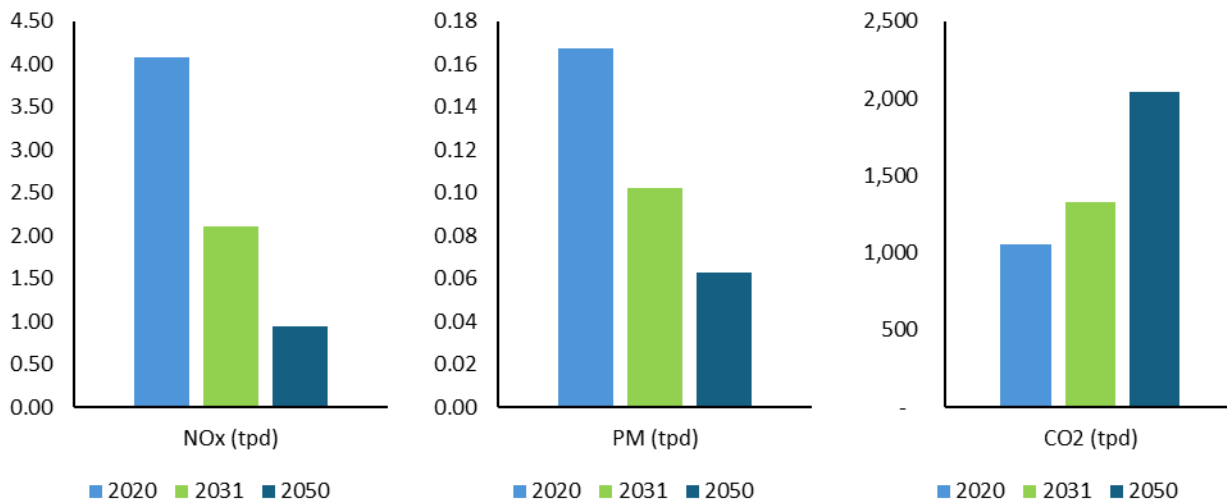
Cargo Handling Equipment

Category Description

- **Equipment:** used at seaports and intermodal rail yards, and includes equipment types such as yard trucks, container handling equipment, cranes, forklifts, and more
- **Fuel:** For CY 2020, 89% Diesel, 11% Electric
- **Population:** 5,600 and growing

Emissions

- **NOx Emissions:** 4.1 tpd in 2020, and 0.9 tpd in 2050 (77% reduction)
- **PM Emissions:** 0.17 tpd in 2020, and 0.06 tpd in 2050 (63% reduction)
- **CO2 Emissions:** 1,060 tpd in 2020, and 2,040 tpd in 2050 (93% growth)



Current Control Programs

- CARB's Cargo Handling Equipment (CHE)⁴¹ regulation, last amended in 2011, includes emission limits for both new and in-use diesel engines in mobile cargo handling equipment as well as requirements for reporting, recordkeeping, and fuel use.
- Sustainable Terminals Accelerating Regional Transformation Project (START) is a CARB \$50 million grant for demonstrations of a zero and near zero-emission supply chain.

⁴¹ CARB webpage, Cargo Handling Equipment, <https://ww2.arb.ca.gov/our-work/programs/cargo-handling-equipment>

- Zero-Emission Terminal Equipment Transition Project is a CEC \$9.7 million grant for battery electric equipment.
- CARB's CORE lists four eligible pieces of cargo handling equipment.
- C-Port Zero-Emissions Demonstration Project is a CARB \$5.3 million grant for electric and hydrogen fuel demonstrations.
- In 2021, the Port of Long Beach, completed development of a new terminal with 200 pieces of cargo handling equipment that run entirely on electricity and (at the time) made up the largest zero-emission fleet of any marine container terminal in the world⁴².

Available Technology/Emission Reduction Potential

Cleanest Diesel Options

- Use of renewable diesel instead of conventional CARB diesel would achieve 5% NOx and 30% PM emissions reductions from Tier 3 and older equipment.

Zero-Emission Options

- As described above in the Current Control Programs, full electric equipment options are available for CHE, including electric top handlers⁴³, yard tractors, ship to shore cranes⁴⁴, and more.
- Infrastructure supporting full electric operations at the ports and wireless charging options are in development or demonstration projects with support from California Energy Commission and the individual Ports⁴⁵.

⁴² Port of Long Beach, The Making of a State-of-the-Art Terminal, <https://polb.com/port-info/news-and-press/the-making-of-a-state-of-the-art-terminal-08-26-2021/>

⁴³ Port of Los Angeles, Everport Advanced Cargo Handling Demonstration Project, <https://kentico.portoflosangeles.org/getmedia/a374b9ef-59bf-4862-ab66-9b8f69c62315/cec-2016-fact-sheet>

⁴⁴ Port of Oakland, North America's tallest cranes rise at the Port of Oakland, <https://www.portoakland.com/press-releases/building-giant-cranes/>

⁴⁵ Port of Los Angeles, Zero Emission Freight Vehicle Advanced Infrastructure Demonstration (AID) Project, <https://kentico.portoflosangeles.org/getmedia/ffe04622-f7bc-47b4-afbd-5d385531a4d3/aid-cec-fact-sheet>

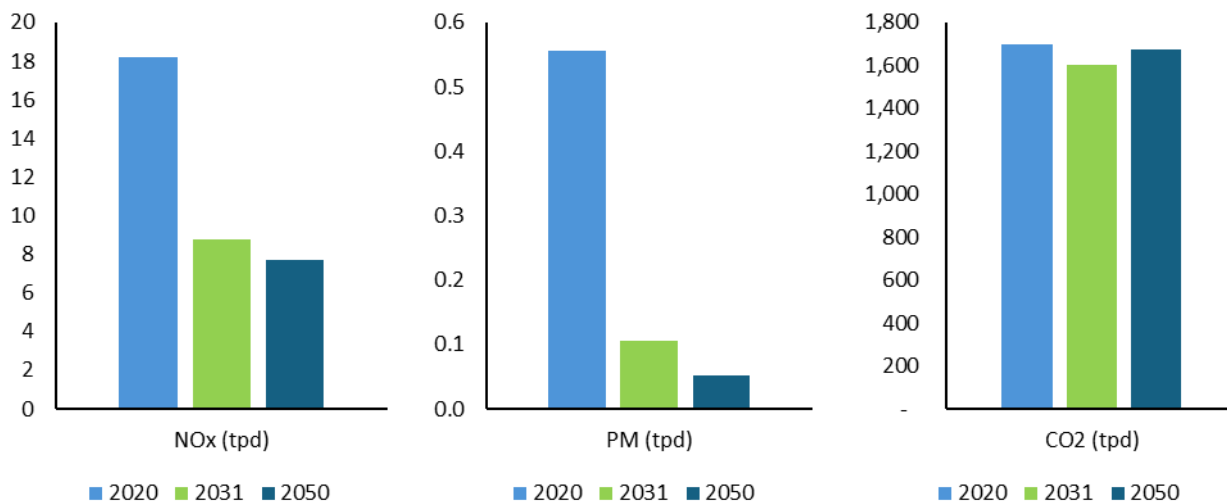
Commercial Harbor Craft

Category Description

- **Equipment:** commercial fishing, ferries, tugboats, and more
- **Fuel:** For CY 2020, 99% Diesel, 1% Electric
- **Population:** 3,300 Vessels with a hailing port in California

Emissions

- **NOx Emissions:** 18 tpd in 2020, and 7.7 tpd in 2050 (58% reduction)
- **PM Emissions:** 0.56 tpd in 2020, and 0.05 tpd in 2050 (91% reduction)
- **CO2 Emissions:** 1,700 tpd in 2020, and 1,670 tpd in 2050 (2% reduction)



Current Control Programs

- The Commercial Harbor Craft (CHC) Regulation approved in 2022 reduces emissions from tugboats and ferries operating near California’s coast. By 2035, the regulation is expected to provide an 89% PM reduction and a 54% NOx reduction.
- Incentive funding may exist through the Carl Moyer Program, Community Air Protection Incentives, Volkswagen Environmental Mitigation Trust, CARB’s CORE, and other opportunities such as the Advanced Technology Demonstration and Pilot Programs funding through the Low Carbon Transportation program⁴⁶.

⁴⁶ CARB webpage, CARB passes amendments to commercial harbor craft regulation, <https://ww2.arb.ca.gov/news/carb-passes-amendments-commercial-harbor-craft-regulation>

Available Technology/Emission Reduction Potential

Cleanest Diesel Options

- The current CHC Regulation will achieve most emission reductions by 2035 through cleaner combustion marine engines meeting a performance standard equivalent to marine engine Tier 3 or 4 standards plus using a diesel particulate filter (DPF).
- Renewable diesel is required under the regulation and would achieve 5% NO_x and 30% PM emissions reductions from Tier 3 and older equipment.

Zero-Emission Options

- The CHC Regulation requires zero-emission operations for short run ferries and new-build excursion vessels. In addition, it provides pathways to accelerate zero-emission in other vessel categories where feasible.
- Zero-emission marine technology is available for some ferries, pilot vessels, tugs, and workboats, where duty-cycle and infrastructure allow. CARB currently estimates that between 10 to 33% of these vessels may turn over to electric by 2031⁴⁷. Additional demonstration projects and technology development could increase these percentages.
- In 2024, CARB, the Bay Area Air Quality Management District, and SWITCH Maritime completed a hydrogen fuel-cell demonstration project⁴⁸ for ferries, providing another potential zero-emission option.

⁴⁷ CARB webpage, 2021 Update to the Emission Inventory for Commercial Harbor Craft: Methodology and Results, <https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2021/chc2021/apph.pdf>

⁴⁸ CARB webpage, LCTI: Zero-Emission Hydrogen Ferry Demonstration Project, <https://ww2.arb.ca.gov/lcti-zero-emission-hydrogen-ferry-demonstration-project>

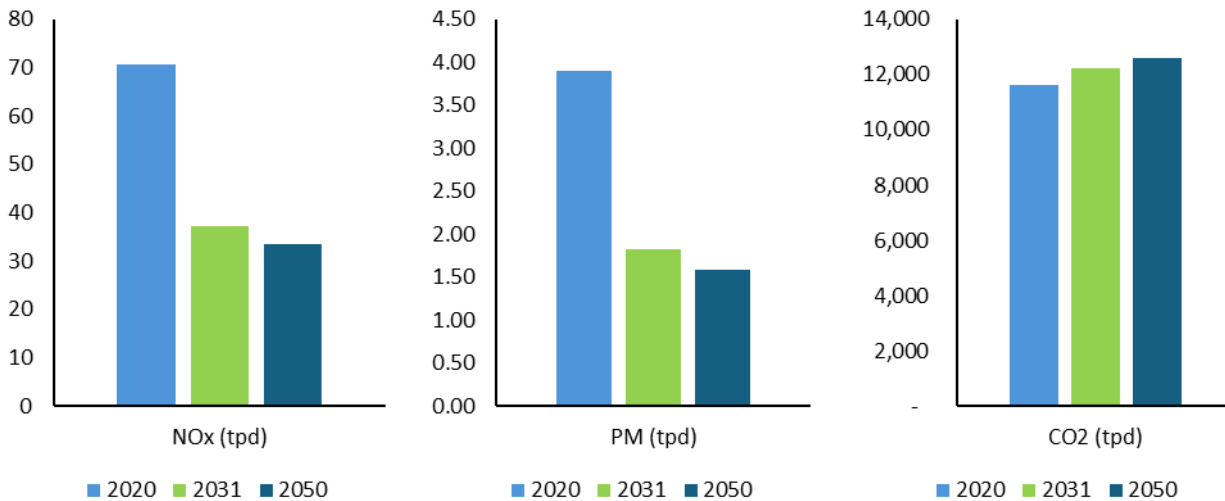
Construction and Mining, Oil Drilling, Airport Ground Support Equipment, Industrial

Category Description

- **Equipment:** Backhoes, loaders, diesel forklifts, paving equipment, oil rigs, aircraft tugs, and many other types of off-road diesel equipment subject to the In-Use Off-Road Diesel-Fueled Fleets Regulation (In-Use Regulation)
- **Fuel:** For CY 2020, 55% Diesel, 36% Gasoline, and 9% Natural Gas
- **Population:** 345,000

Emissions

- **NOx Emissions:** 71 tpd in 2020, and 33.6 tpd in 2050 (53% reduction)
- **PM Emissions:** 3.9 tpd in 2020, and 1.6 tpd in 2050 (59% reduction)
- **CO2 Emissions:** 11,600 tpd in 2020, and 12,600 tpd in 2050 (8% growth)



Current Control Programs

- The In-Use Regulation phases out the oldest off-road diesel engines with newer tiered engines, requiring a mix of Tier 3 or newer diesel equipment and the use of renewable diesel fuels in older equipment.

- CARB's CORE⁴⁹ offers incentives for zero-emission options. Also, CARB and the air district partnership with the Carl Moyer Program provides incentive funds to purchase "cleaner-than-required" engines and equipment⁵⁰.

Available Technology/Emission Reduction Potential

Cleanest Diesel Options

- CARB's In-Use Regulation covers equipment 25 horsepower or greater. Currently there are no requirements against the use of the oldest, dirtiest diesel equipment under 25 horsepower. Regulatory applicability could be expanded to cover all under 25 horsepower. The In-Use Regulation also exempts all equipment in agricultural use.
- Additionally, CARB has committed to further amend the In-Use Regulation, contingent on U.S. EPA first adopting next level Tier 5 standards and zero-emission standards for off-road equipment.
- Hybrid and range extended electric equipment has the potential to reduce emissions compared with traditional powertrains for a number of different equipment types, including but not limited to light towers, excavators, wheel loaders, person lifts, and forestry equipment.
- Use of renewable diesel instead of conventional CARB diesel would achieve 5% NO_x and 30% PM emissions reductions from Tier 3 and older equipment.

Zero-Emission Options

- Full electric options exist for many equipment categories covered in this sector, with CARB's website for Advanced Clean Equipment⁵¹ detailing options for zero-emission excavators, graders, off-highway trucks, rollers, loaders, pavers, trenchers, drill rigs, mining dumpers, cranes, and more. In total, CARB is tracking over 250 different commercially-ready or developing projects for zero-emission equipment.
- The recently amended In-Use Regulation offers two voluntary compliance options to encourage fleets to adopt zero-emission technology:
 - Lower requirements for fleets that replace at least half their diesel vehicles with zero-emission vehicles and
 - If a fleet adds a piece of zero-emission equipment, it can delay the phase-out of a similar piece of older diesel equipment by two years.

⁴⁹ CARB webpage, Clean Off-Road Equipment Vouchers, <https://ww2.arb.ca.gov/our-work/programs/clean-off-road-equipment-voucher-incentive-project>

⁵⁰ South Coast Air Quality Management District, Carl Moyer Off-Road ZE Program, just one example of Carl Moyer Program: [https://www.aqmd.gov/home/programs/business/carl-moyer-memorial-air-quality-standards-attainment-\(carl-moyer\)-program](https://www.aqmd.gov/home/programs/business/carl-moyer-memorial-air-quality-standards-attainment-(carl-moyer)-program)

⁵¹ CARB webpage, Off-Road Advanced Clean Equipment (ACE), <https://ww2.arb.ca.gov/our-work/programs/msei/off-road-advance-clean-equipment>

- CARB is pursuing a Zero-Emission Ground Operations Regulation that may reduce on-ground emissions of aircraft and ground support equipment at airports.
- Hydrogen fuel cells may provide alternative zero-emission options for categories such as excavators, forklifts, loaders, and cranes.
- Grid-electric options show potential for equipment used consistently in the same area, particularly material handling equipment.
- As with all categories, zero-emission equipment is viable where duty cycle is appropriate and where charging or fueling infrastructure is available to support it.
- CARB is working to develop a Clean Off-Road Fleet Recognition Program. The commitment is to create a non-monetary incentive to encourage off-road fleets to go above and beyond existing regulatory fleet rule compliance and adopt advanced technology equipment with a strong emphasis on zero-emission technology.

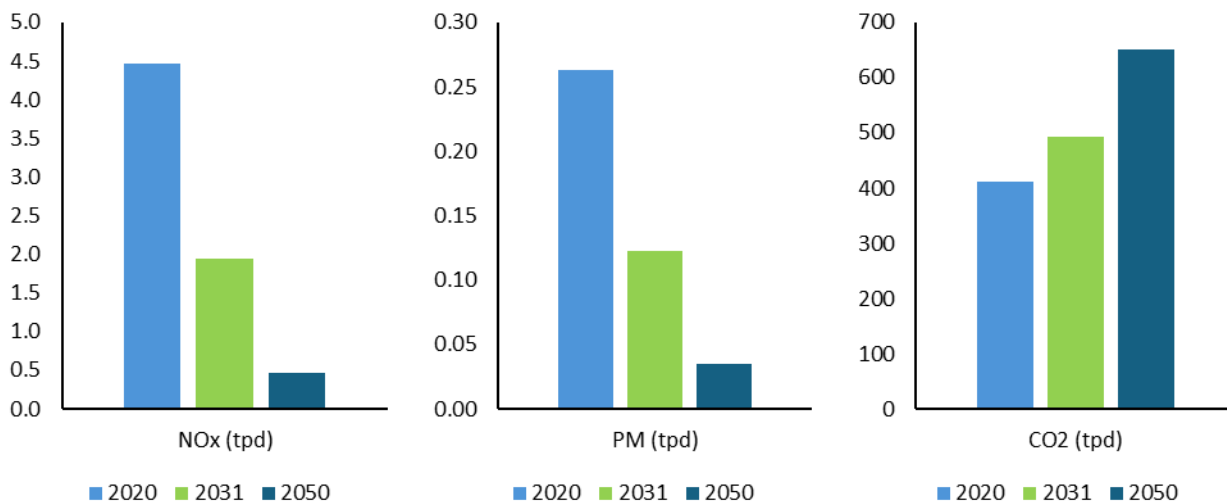
Forestry

Category Description

- **Equipment:** Tree-fellers, cranes, de-limbers, excavators, grinders, and more
- **Fuel:** For CY 2020, 100% Diesel
- **Population:** 2,300

Emissions

- **NOx Emissions:** 4.5 tpd in 2020, and 0.5 tpd in 2050 (89% reduction)
- **PM Emissions:** 0.3 tpd in 2020, and 0.03 tpd in 2050 (87% reduction)
- **CO2 Emissions:** 412 tpd in 2020, and 650 tpd in 2050 (58% growth)



Current Control Programs

- Not covered by any current CARB requirements.

Available Technology/Emission Reduction Potential

Cleanest Diesel Options

- Tier 4 Final off-road diesel engines are the cleanest option for most equipment over 75 horsepower.
- Use of renewable diesel instead of conventional CARB diesel would achieve 5% NOx and 30% PM emissions reductions from Tier 3 and older equipment.

Zero-Emission Options

- Forestry equipment generally uses larger horsepower equipment and is further from the electric grid, presenting some challenges for zero-emission equipment.

- There may be potential for zero-emission equipment used at mills or in some components of forestry operations, such as large forklifts and cranes used in moving logs for transportation⁵².

⁵² California CORE, Construction, <https://californiacore.org/equipment-category/construction/>

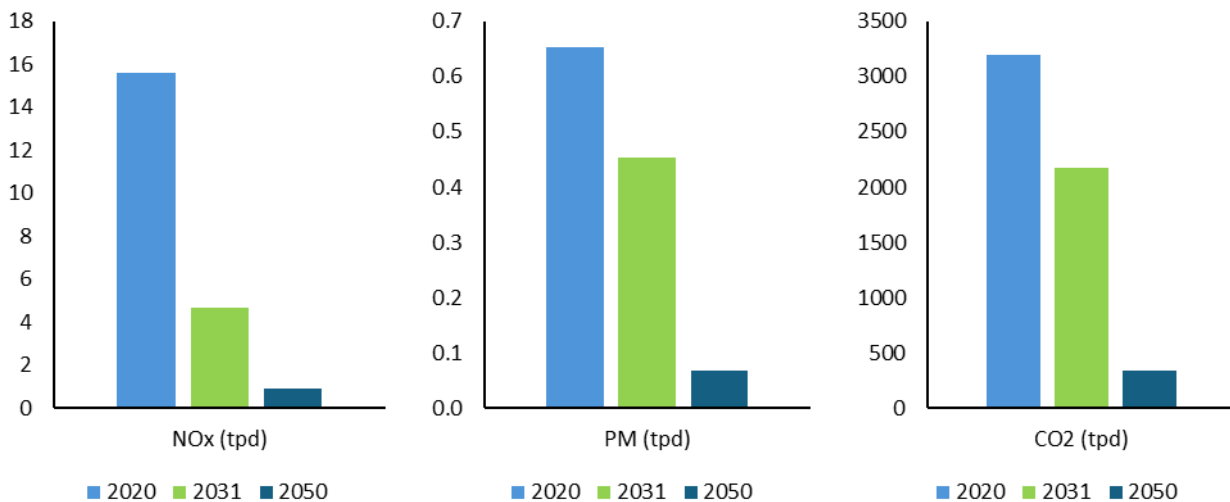
Large Spark-Ignition (LSI) Forklifts

Category Description

- **Equipment:** Forklifts used in indoor and outdoor industrial operations, including but not limited to manufacturing, wholesale, utilities, and retail. Does not include rough terrain forklifts or diesel forklifts.
- **Fuel:** For CY 2020, 92% Propane and 8% Gasoline
- **Population:** 94,700

Emissions

- **NOx Emissions:** 15.6 tpd in 2020, and 0.9 tpd in 2050 (94% reduction)
- **PM Emissions:** 0.65 tpd in 2020, and 0.07 tpd in 2050 (90% reduction)
- **CO2 Emissions:** 3,193 tpd in 2020, and 332 tpd in 2050 (90% reduction)



Current Control Programs

- CARB's 2024 Zero-Emission Forklift (ZEF) Regulation⁵³ will achieve emission reductions from forklifts using LSI engines, such as those running on propane and gasoline. Certain types of forklifts, such as rough-terrain forklifts and diesel forklifts, are not addressed under the 2024 ZEF Regulation. The Regulation includes requirements for LSI forklift Fleet Operators, Rental Agencies, Dealers, and Manufacturers, and is expected to result in a significant shift of the forklift segment in California to zero-emission technology.

⁵³ CARB webpage, <https://ww2.arb.ca.gov/our-work/programs/zero-emission-forklifts>

- Beginning 2026, purchases of new forklifts targeted by regulation must be zero-emission.
- Beginning 2028, fleets will begin the phase out schedule for targeted forklifts model years 2025 and older.
- LSI forklift phase out schedules vary depending on the size of the fleet, forklift lift capacity, forklift class, and whether the forklift is used in agricultural operations.

Available Technology/Emission Reduction Potential

Cleanest LSI Options

- LSI forklift engines are subject to the Fleet Average Emission Level (FAEL) standard as defined in the Large Spark Ignition Engine Fleet Requirements Regulation⁵⁴. However, the standards have not changed since the last compliance date of 2013.

Zero-Emission Options

- Zero-emission forklifts, such as those that run on battery-electric and fuel-cell powertrains, have been successfully used for decades. They have proven to be effective alternatives to internal combustion forklifts, particularly in the logistics industry.

⁵⁴ CARB webpage, Large Spark-Ignition (LSI) Engine Fleet Requirements Regulation, <https://ww2.arb.ca.gov/our-work/programs/large-spark-ignition-lsi-engine-fleet-requirements-regulation>

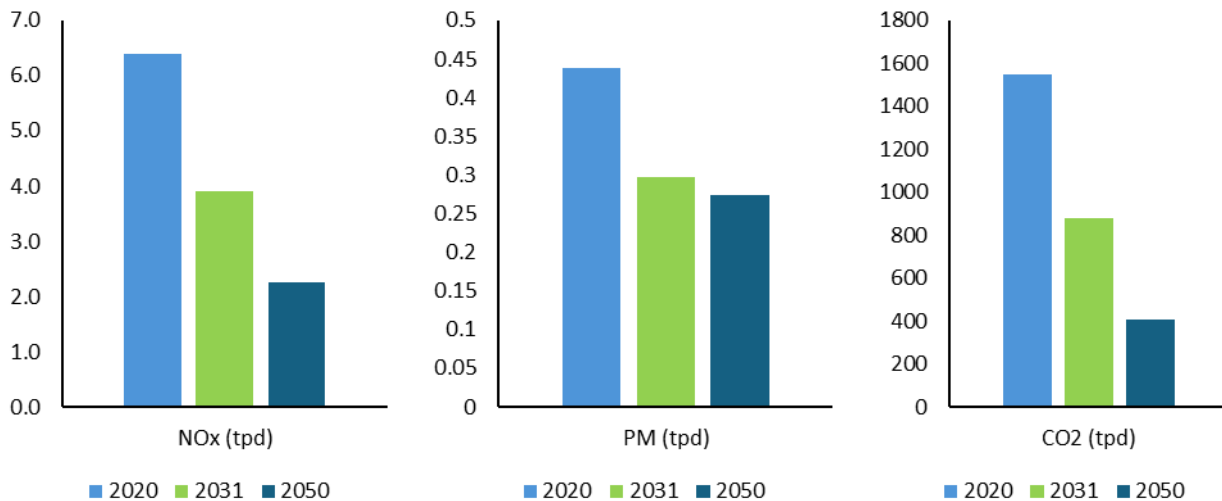
Lawn and Garden

Category Description

- **Equipment:** lawn mowers, leaf blowers, chainsaws, trimmers, and riding mowers
- **Fuel:** 52% Gasoline, 0.3% Diesel, and 48% Electric
- **Population:** 22 million

Emissions

- **NOx Emissions:** 6.4 tpd in 2020, and 2.3 tpd in 2050 (65% reduction)
- **PM Emissions:** 0.44 tpd in 2020, and 0.27 tpd in 2050 (38% reduction)
- **CO2 Emissions:** 1,550 tpd in 2020, and 400 tpd in 2050 (74% reduction)



Current Control Programs

- Most lawn and garden equipment are subject to the Small Off-Road Engine (SORE) Regulation⁵⁵. This regulation requires SORE engines sold in 2024 and later to be zero-emission except for generators and some pressure washers. Generators and pressure washers sold in 2028 and later must be full zero-emission.

⁵⁵ CARB webpage, Amendments to the Small Off-Road Engine Regulations: Transition to Zero Emissions, <https://ww2.arb.ca.gov/rulemaking/2021/sore2021>

Available Technology/Emission Reduction Potential

Zero-Emission Options

- Programs that incentivize or accelerate turnover of SORE equipment to meet the new zero-emission standards starting in 2024 could achieve additional reductions. Currently there are no requirements to prevent the continued use of combustion equipment, however the SORE regulation is projected to turn over close to 80% of the gasoline and propane small-off-road equipment to zero-emission by 2050.

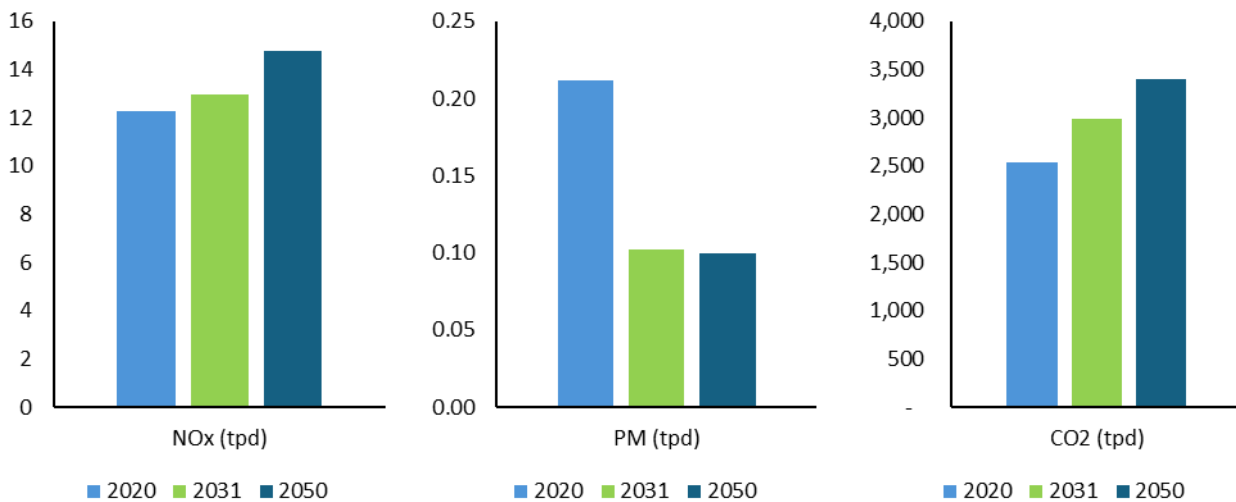
Light Commercial and Recreational

Category Description

- **Equipment:** Air compressors, gas compressors, generator sets, pressure washers, pumps, and welders
- **Fuel:** For CY 2020, 29% Gasoline, 0.3% Diesel, and 70% Electric
- **Population:** 11.9 million

Emissions

- **NOx Emissions:** 12.3 tpd in 2020, and 14.8 tpd in 2050 (20% growth)
- **PM Emissions:** 0.21 tpd in 2020, and 0.1 tpd in 2050 (53% reduction)
- **CO2 Emissions:** 2,500 tpd in 2020, and 3,400 tpd in 2050 (34% growth)



Current Control Programs

- Inventory projections include the increasing trend toward electrification.
- Equipment in this category is subject to the SORE Regulation⁵⁶, requiring SORE engines sold in 2024 and later to be zero-emission except for generators and some pressure washers. Generators and pressure washers sold in 2028 and later must be full zero-emission.

⁵⁶ CARB webpage, Amendments to the Small Off-Road Engine Regulations: Transition to Zero Emissions, <https://ww2.arb.ca.gov/rulemaking/2021/sore2021>

Available Technology/Emission Reduction Potential

Zero-Emission Options

- Electric equipment is already available for purchase in most categories.

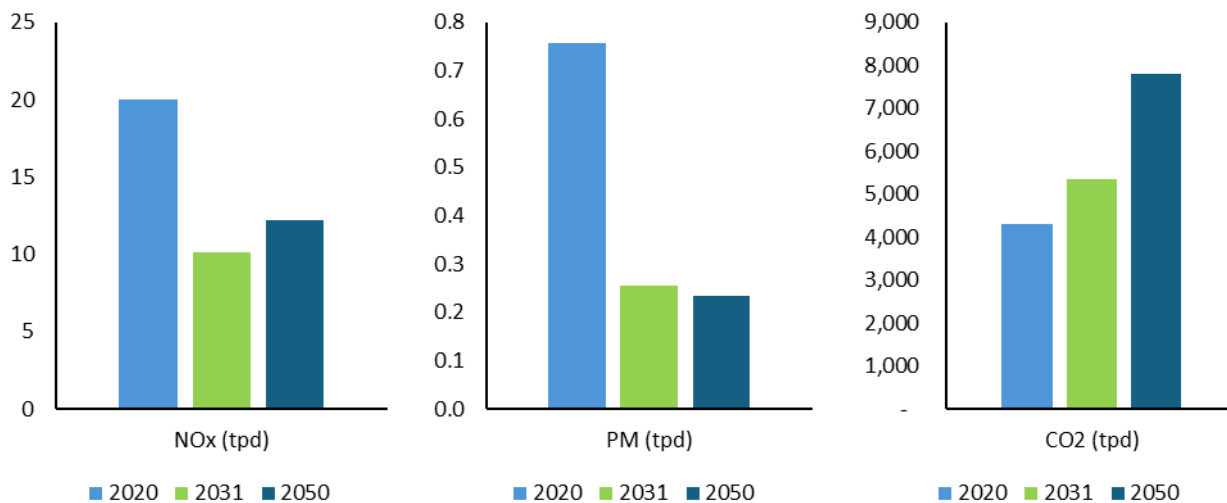
Portable Equipment

Category Description

- **Equipment:** Generators, Pumps, Compressors, and similar
- **Fuel:** For CY 2020, 100% Diesel
- **Population:** 34,000

Emissions

- **NOx Emissions:** 20 tpd in 2020, and 12.2 tpd in 2050 (39% reduction)
- **PM Emissions:** 0.76 tpd in 2020, and 0.23 tpd in 2050 (69% reduction)
- **CO2 Emissions:** 4,300 tpd in 2020, and 7,800 tpd in 2050 (81% growth)



Current Control Programs

- Portable diesel engines in California must be registered with either the local air district or CARB. Registration requirements vary by location but generally focus on phasing out older engines and limiting the registration and use of the dirtiest engines. The Airborne Toxic Control Measure (ATCM)⁵⁷ and applies to diesel portable engines of 50 horsepower or greater.
- The requirements of the statewide ATCM were relaxed with the 2017 amendments due to the availability of newer engines at the time. The 2017 amendments aimed to phase out Tier 2 engines by 2024 and Tier 3 engines by 2029.

⁵⁷ CARB webpage, Final Regulation Order, Airborne Toxic Control Measure for Diesel Particulate Matter from Portable Engines Rate at 50 Horsepower and Greater, https://ww2.arb.ca.gov/sites/default/files/2020-03/PERP_ATCM_12.5.18R.pdf

- There are a variety of zero-emission solutions for portable equipment applications, including generators. CARB’s CORE lists a variety of battery systems and a hydrogen fuel cell system that can replace a number of diesel generator applications, with power ranging from 50 kw-hr up to 800 kw-hr⁵⁸.

Available Technology/Emission Reduction Potential

Cleanest Diesel Options

- Use of renewable diesel instead of conventional CARB diesel would achieve 5% NOx and 30% PM emissions reductions from Tier 3 and older equipment.
- Tier 5 emission standards may provide additional reductions for newly purchased equipment if adopted in California.

Cleaner Combustion Options

- Free Piston Linear Generators are a unique internal combustion engine using natural gas, among other fuels, in a low-temperature combustion chamber enclosed in two oscillating pistons. Linear Generators achieve near zero-emission while maintaining high efficiency rates, similar to a turbine. South Coast Air Quality Management District’s Board adopted Rule 1110.3 in October 2023, which requires them to establish a certification program. Although this equipment type primarily uses fossil fuels, it can achieve a reduction in emissions compared to conventional combustion ignition or spark ignition engines.

Zero-Emission Options

- Additional options include ZE portable air compressors⁵⁹, ZE portable concrete pumps⁶⁰, ZE portable woodchipper⁶¹, and ZE light towers (battery and solar)⁶².
- Zero-emission hydrogen fuel-cell generators are already on the market in some horsepower ranges where diesel generators operate, but may be more costly.

⁵⁸ California CORE, Mobile Power Units, <https://californiacore.org/equipment-category/mobile-ground-power-units/>

⁵⁹ Atlas Copco, Matter powered portable air compressor, B-Air 185-12, <https://www.atlascopco.com/en-us/construction-equipment/products/mobile-air-compressors-usa/b-air-185-12-usa>

⁶⁰ Liebherr, 70 E, Electric trailer-mounted concrete pump, <https://www.liebherr.com/en/gbr/products/construction-machines/concrete-technology/concrete-pumps/stationary-concrete-pumps/details/68822.html>

⁶¹ TP Reliable Chipping, TP 215 Mobile ZE, <https://www.tpchipper.com/chippers/tp-215-mobile-z-e/#OpenChipperGallery>

⁶² Atlas Copco, Light Towers, <https://www.atlascopco.com/en-us/construction-equipment/products/light-towers-us>

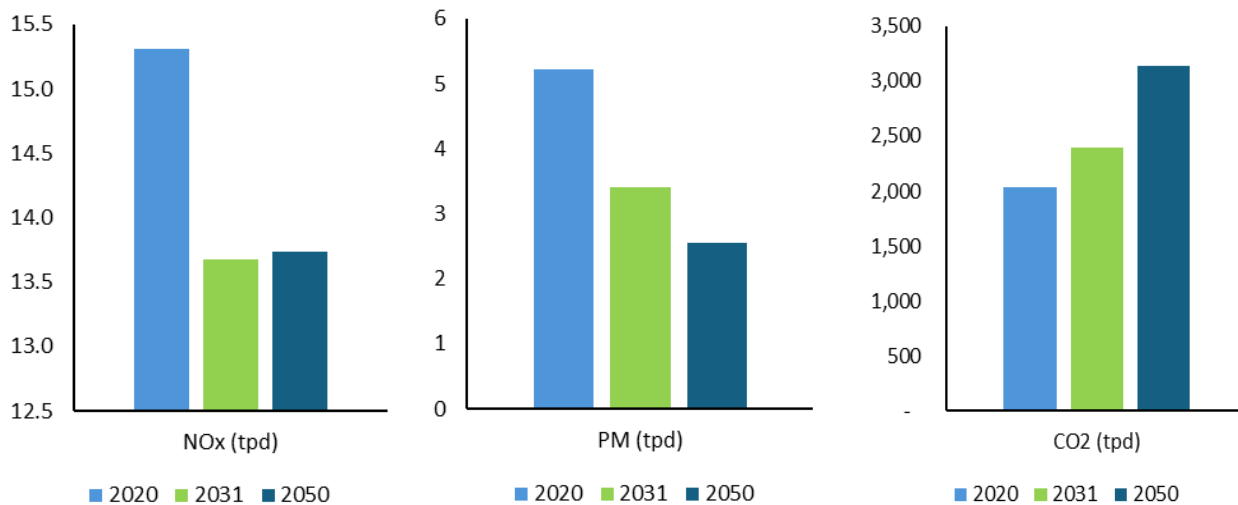
Recreational Marine Vessels (formerly Pleasure Craft)

Category Description

- **Equipment:** Outboard, Inboard, Sterndrive, Personal Watercraft, Jet Boat, and Auxiliary Sailboat
- **Fuel:** 98% Gasoline, 2% Diesel or Electric
- **Population:** 780,000

Emissions

- **NOx Emissions:** 15.3 tpd in 2020, and 13.7 tpd in 2050 (10% reduction)
- **PM Emissions:** 5.2 tpd in 2020, and 2.5 tpd in 2050 (51% reduction)
- **CO2 Emissions:** 2,040 tpd in 2020, and 3,100 tpd in 2050 (54% growth)



Current Control Programs

- In the 2022 State Implementation Plan, for outboard and personal watercraft engines, CARB committed to reduce the standards by approximately 70% below the current HC+NOx standard (≈ 16.5 grams per kilowatt-hour (g/kW-hr)) for engines greater than or equal to 40 kilowatts (kW) in power, and by approximately 40% for engines less than 40 kW in power.
- CARB will evaluate adopting zero-emission standards for outboard and personal watercraft.

Available Technology/Emission Reduction Potential

Zero-Emission Options

- Battery electric recreational vessels are commercially available for a portion of this industry sector⁶³, but account for only a small fraction of total sales. Some estimates show around 2% of boats are electric⁶⁴. Adoption of zero-emission options could be accelerated with incentives or regulatory requirements.

⁶³ The Liquid Grid, Recreational Electric Boat Data, <https://theliquidgrid.com/electric-boats/>

⁶⁴ The Slate Group, Bring On the E-Boats, <https://slate.com/business/2023/08/e-boats-electric-candela-iziboat-faroboats-budsin-hesselink.html>

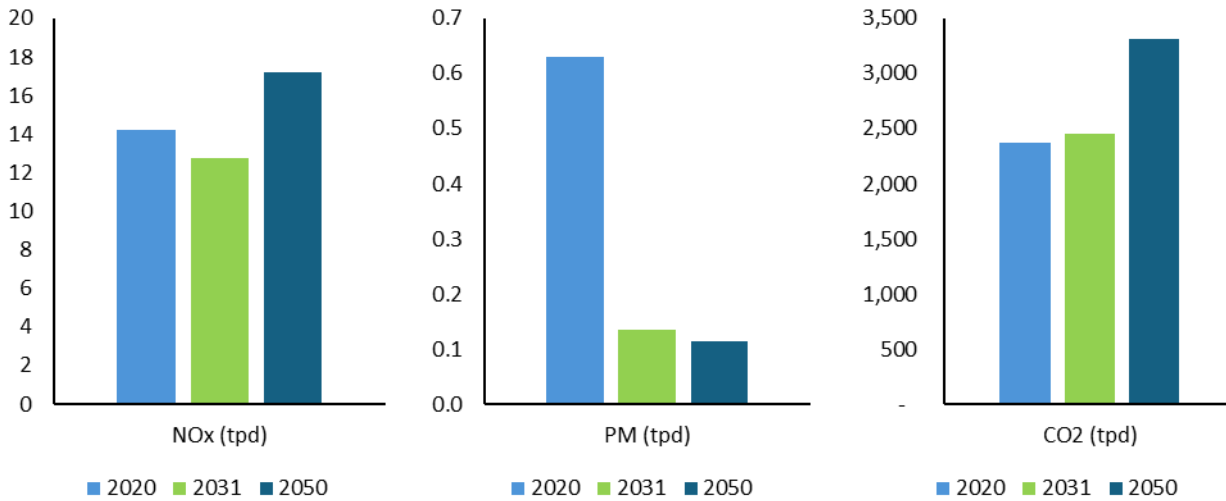
Transport Refrigeration Units (TRU)

Category Description

- **Equipment:** Single-Body Truck, Trailer, Shipping Container, and Railcar TRUs; TRU Generator Sets
- **Fuel:** 96% Diesel and 4% Electric by 2030 (Single-Body Trucks)
- **Population:** 200,000

Emissions

- **NOx Emissions:** 14.2 tpd in 2020, and 17.2 tpd in 2050 (21% growth)
- **PM Emissions:** 0.63 tpd in 2020, and 0.1 tpd in 2050 (82% reduction)
- **CO2 Emissions:** 2,400 tpd in 2020, and 3,300 tpd in 2050 (40% growth)



Current Control Programs

- The TRU Airborne Toxic Control Measure (ATCM),⁶⁵ last amended in 2022, includes requirements for zero-emission truck TRUs, a PM emission standard for newly manufactured non-truck TRU engines, and the use of lower global warming potential refrigerant.
- Beginning in 2024, TRU owners are required to turn over 15% of their truck TRU fleet to zero-emission each year. By 2030, all truck TRUs operating in California are required to be zero-emission.

⁶⁵ CARB webpage, Transport Refrigeration Units Regulation, <https://ww2.arb.ca.gov/rulemaking/2021/tru2021>

- Beginning in 2023, all newly manufactured trailer TRU, shipping container TRU, railcar TRU, and TRU generator set engines are required to meet a PM emission standard of 0.02 g/hp-hr or lower.⁶⁶
- Beginning in 2023, all newly manufactured truck TRUs, trailer TRUs, and domestic shipping container TRUs are required to use a refrigerant with a global warming potential value less than or equal to 2,200, or no refrigerant at all.

Available Technology/Emission Reduction Potential

Cleanest Diesel Options

- Use of renewable diesel instead of conventional CARB diesel would achieve 5% NOx and 30% PM emissions reductions from Tier 3 and older equipment.

Zero-Emission Options

- CARB is currently developing a regulation that focuses on zero-emission requirements for non-truck TRUs, which include trailer TRUs, domestic shipping container TRUs, railcar TRUs, and TRU generator sets. Draft concepts and workshop presentations are available online.⁶⁷

⁶⁶ PM emission standard of 0.02 g/hp-hr aligns with the U.S. EPA Tier 4 final PM emission standard for engines greater than 25 horsepower.

⁶⁷ CARB webpage, New Transport Refrigeration Unit Regulation in Development, <https://ww2.arb.ca.gov/our-work/programs/transport-refrigeration-unit/new-transport-refrigeration-unit-regulation>

Chapter 4 - Off-Road Primarily-Federally and Internationally Regulated Sources

Chapter 4 is a continuation of off-road mobile sources but focuses specifically on federally and internationally regulated sources such as aviation, locomotives, and ocean-going vessels (OGV).

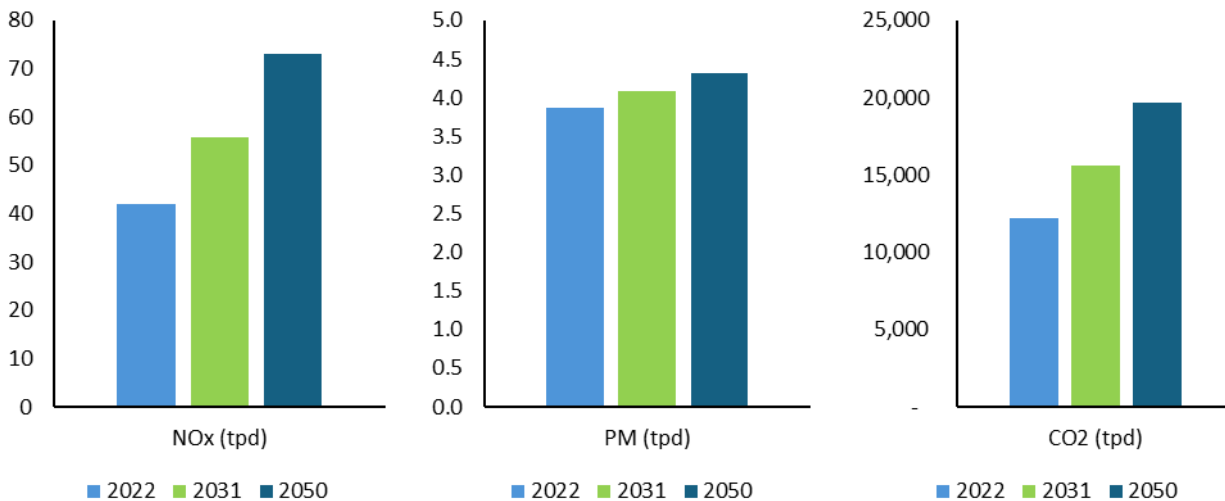
Aviation

Category Description

- **Equipment:** Commercial aviation, military, general aviation, agricultural crop dusting, and rotorcraft (helicopters)
- **Fuel:** CY=2020, 91% Jet Fuel (Jet-A fuel) and 9% high-octane leaded gasoline (avgas)
- **Population:** ~6.4 million operations per year (operation = 1 landing + 1 takeoff)

Emissions

- **NOx Emissions:** 42.1 tpd in 2020, and 73.2 tpd in 2050 (74% growth)
- **PM Emissions:** 3.9 tpd in 2020, and 4.3 tpd in 2050 (12% growth)
- **CO2 Emissions:** 12,227 tpd in 2020, and 19,686 tpd in 2050 (61% growth)



Current Control Programs

- The International Civil Aviation Organization (ICAO) sets international emissions standards for HC, CO, NOx, PM, and CO2 with U.S. EPA adopting the same emission standards. The NOx standard was last updated in 2011.
- California included Sustainable Aviation Fuel (SAF) as an eligible LCFS credit generating fuel in 2019, and SAF production has increased by a factor of twelve times between 2019 and 2023. As of 2023, SAF makes up less than 1% of jet fuel sold in California.
- In 2019, the South Coast Air Quality Management District signed individual MOUs with five commercial airports to target reductions in NOx emissions for on-ground operations at airport facilities. NOx emissions reductions are expected to be approximately 0.4 tons/day by 2031.

- CARB’s airport shuttle bus regulation requires the 13 largest airports to move to zero-emission starting in 2027 and phasing through 2035.
- There are no regulations targeting ground support equipment at airports, beyond current State regulations (Off-Road Diesel regulation and Large Spark-Ignition regulation) that would apply to some ground support equipment at airports.

Available Technology/Emission Reduction Potential

Policy Options

- CARB is pursuing a Zero-Emission Ground Operations Regulation that will reduce on-ground emissions of aircraft and ground support equipment at airports. The regulation would include three requirements including:
 - Aircraft to “plug-in” at gate, meaning using gate infrastructure to power aircraft while at the gate rather than using Auxiliary Power Units (APUs);
 - Aircraft ground support equipment (GSE) be replaced with zero-emission alternatives (electric/hydrogen); and
 - Use of zero-emission taxiing technology (e.g. SAS’s Taxibot) to tow the aircraft to and from the runway.
- Directing cleaner aircraft to California
 - Directing cleaner aircraft to California, which would involve incentivizing airlines to use aircraft with lower NOx emissions in California, could help achieve emission reductions. This could be achieved through differentiating landing fees such that lower landing fees are provided to the cleanest aircraft. Airlines could:
 - Redirect their cleaner aircraft that are already in-use to be used in California.
 - Purchase aircraft with lower NOx emissions that are already in production.
 - In the future, airlines can prioritize purchasing cleaner aircraft for their California based fleets that use NOx reduction technologies, such as those outlined in the “cleaner aircraft engine development” section above.

Cleanest Combustion Options

- As a result of the Inflation Reduction Act (IRA), FAA developed the FAST grants program which will allocate \$291 million to build infrastructure related to SAF production, transportation, blending, and storage. Additionally, funding is available to develop and demonstrate new aviation technologies that can improve fuel efficiency and reduce emissions⁶⁸.

⁶⁸ Federal Aviation Administration, Fueling Aviation’s Sustainable Transition (FAST) Grants, <https://www.faa.gov/general/fueling-aviations-sustainable-transition-fast-grants>

- There are multiple SAF-related incentives including U.S. EPA’s Renewable Fuel Standard, the IRA 40B, and CARB’s Low Carbon Fuel Standard (LCFS), which provide credits to produce SAF.
- FAA provides funding for projects that reduce air pollution emissions through the voluntary airport low emissions (VALE) program. To date, VALE has funded 141 projects for a total of \$305 million in funding for the reduction of on-airport emissions. Between 2009 and 2021, 11 projects (~\$37 million in grants) have been funded in California at four airports: San Francisco International, Norman Y. Mineta San Jose International, Metropolitan Oakland International, and San Diego International.
- Updating operational practices at airports, such as de-rated take-offs and decreasing taxiing time, have the potential to reduce emissions at airports.
- FAA’s Continuous Lower Energy, Emissions and Noise (CLEEN) program has funded various aircraft and engine technologies with the goal to reduce noise, emissions, and fuel burn.
- Rolls-Royce tested its UltraFan® demonstrator with a new geared design, achieving greater fuel efficiency and 100% SAF compatibility. This technology could be a scalable solution for future aircraft by the early 2030s⁶⁹.
- MIT’s research on water injection systems shows promise for reducing NOx by lowering combustion temperatures with modern adaptations. If the FAA approves, and engine manufacturers incorporate this technology into their manufacturing process, this technology could enter service by the 2030s⁷⁰.
- Research conducted on SAF production and processing in lab-scale gas turbine combustors shows potential for reducing NOx emissions by enhancing fuel properties, such as increasing hydrogen content⁷¹.
- NASA’s Electrified Aircraft Propulsion (EAP) research program has numerous projects that are focused on reducing energy and fuel usage in aviation^{72, 73}. One example includes the integration of jet engines with electric motors to cut fuel use

⁶⁹ Rolls Royce, UltraFan, The Ultimate TurboFan, <https://www.rolls-royce.com/innovation/ultrafan.aspx>

⁷⁰ Massachusetts Institute of Technology Libraries, *Impact of Water Injection on Emissions of Nitrogen Oxides from Aircraft Engines*, Issued May 2022, <https://dspace.mit.edu/handle/1721.1/144573>

⁷¹ MDPI, *Biofuels in Aviation: Exploring the Impact of Sustainable Aviation Fuels in Aircraft Engines*, Issued May 2024, <https://doi.org/10.3390/en17112650> & <https://doi.org/10.1115/1.4048243>

⁷² National Aeronautics and Space Administration, Glenn Research Center, Electrified Aircraft Propulsion (EAP), <https://www1.grc.nasa.gov/aeronautics/eap/>

⁷³ National Aeronautics and Space Administration, Glenn Research Center Publications, <https://www1.grc.nasa.gov/aeronautics/eap/eap-overview/publications/>

and emissions, especially during takeoff and landing. This electrified powertrain project also involves industry partners including GE Aviation and magniX.

Zero-Emission Options

- Airbus's ZEROe program aims to achieve the world's first hydrogen-powered commercial aircraft by 2035.
- Rolls-Royce has conducted small-scale testing on combusting hydrogen using modified aircraft engines.
- CARB has funded a limited number of pilot projects related to aircraft emissions including a project to use FAA-approved ZE autonomous aircraft to apply agricultural chemicals to crops⁷⁴.
- Numerous companies, including Joby Aviation, have developed an electric aircraft to be used for aerial ridesharing. Joby taxi planes had a demonstration in New York City, with plans for further demonstrations in the United Arab Emirates.
- A Newsom Administration directive and AB 32 Climate Change Scoping Plan goal is for 20% of aviation to use zero-emission "tailpipe" fuels (electricity and hydrogen) by 2045, with SAF supporting the remaining operations.
- Numerous companies have invested in ZE aircraft development, currently focusing on short-distance flight carrying 9-30 passengers. CARB is closely tracking the status of demonstration projects and technology readiness as they become commercialized.

⁷⁴ CARB webpage, Low Carbon Transportation Investments, Fiscal Years 2021-22 and 2023-23, Advanced Technology Demonstration and Pilot Project Solicitation, List of Applications Received and Project Summaries, [*Fiscal Years 2021-22 and 2022-23 Advanced Technology Demonstration and Pilot Project Summary of Applications Received*](#)

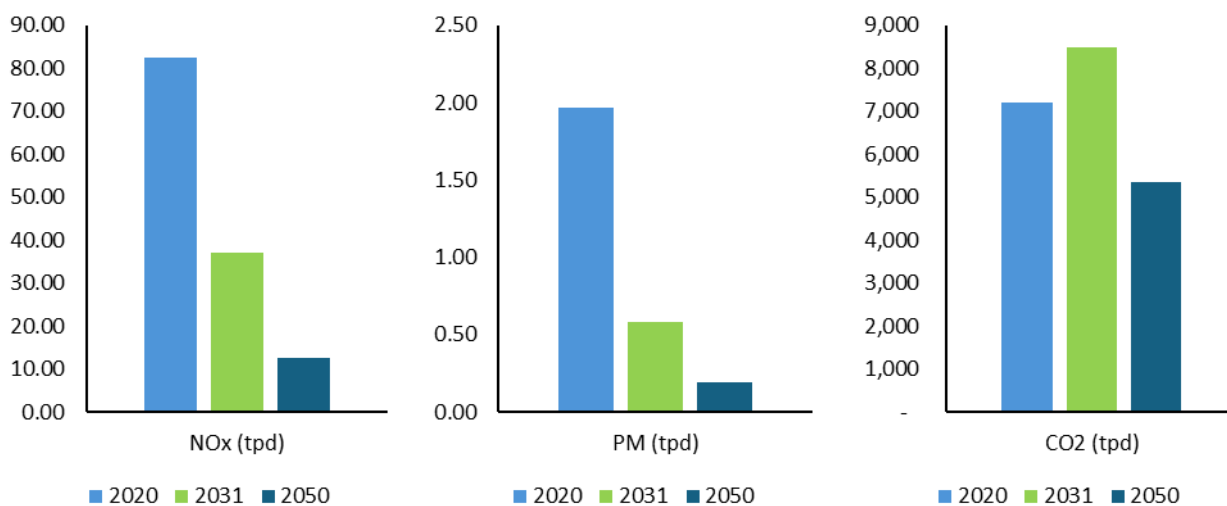
Locomotives

Category Description

- **Equipment:** Class I Line Haul, Class I Switchers, Short Line Freight, Passenger, and Industrial railroads
- **Fuel:**
 - For CY 2020, 100% diesel
 - For CY 2050, 20% diesel and 80% electric
- **Population:** about 11,000 Line Haul locomotives, 600 Class I Switchers, 160 Short Line Freight, 130 Passenger, and 70 Industrial locomotives

Emissions

- **NOx Emissions:** 82.4 tpd in 2020, and 12.5 tpd in 2050 (85% reduction)
- **PM Emissions:** 1.97 tpd in 2020, and 0.2 tpd in 2050 (90% reduction)
- **CO2 Emissions:** 7,200 tpd in 2020, and 5,400 tpd in 2050 (25% reduction)



Current Control Programs

- CARB's 2023 In-Use Locomotive Regulation⁷⁵ will achieve emission reductions from diesel-powered locomotives and increase the use of zero-emission technology. As part of the regulation:
 - Locomotive operators will be required to fund their own trust account based on the emissions created by their locomotive operations in California, where

⁷⁵ CARB webpage, Locomotive Fact Sheets, <https://ww2.arb.ca.gov/our-work/programs/reducing-rail-emissions-california/locomotive-fact-sheets>

the dirtier the locomotive, the higher the cost. These funds can only be used in the following manner:

- Until 2030, to purchase, lease, or rent Tier 4 or cleaner locomotives
 - To purchase, lease, or rent zero-emission locomotives, zero-emission capable locomotive(s), zero-emission rail equipment, or to repower to zero-emission locomotive(s) or zero-emission capable locomotive(s).
 - For zero-emission infrastructure associated with zero-emission locomotive(s), zero-emission capable locomotive(s), zero-emission rail equipment.
 - To pilot or demonstrate zero-emission locomotives or zero-emission rail equipment technologies.
- Beginning in 2030, the in-use operational requirement states only locomotives less than 23 years old will be able to be used in California, unless they are operated in a zero-emission configuration.
 - Locomotives with automatic shutoff devices will not be permitted to idle for longer than 30 minutes, unless for an exempt reason.

Available Technology/Emission Reduction Potential

Cleanest Diesel Options

- Railroad operators must increase their purchase and use of Tier 4 Final locomotives, in place of older, dirtier locomotives. Beginning in 2030, the In-Use Operational Requirement regulates the operating age to prohibit units over 23 years old from operating in California, unless operating in a zero-emission configuration.
- Renewable diesel is available and could potentially have emissions reduction benefits for certain locomotive tiers.

Zero-Emission Options

- Zero-emission line haul locomotive infrastructure to be built in preparation for zero-emission line haul locomotives becoming commercially available for purchase.
- CARB's Zero Emission Rail Project Dashboard⁷⁶ lists projects for Battery Electric, Hydrogen Fuel Cell, Overhead Catenary Electric, and Dual Mode: battery and overhead catenary projects demonstrating use of zero-emission technologies for Passenger, Switcher, Line haul, and Railcar Movers, to include:
 - Pacific Harbor Line Battery-Electric Locomotive Project
 - Port of Long Beach System-Wide Investment in Freight Transport (SWIFT)
 - BNSF - Progress Rail Battery-Electric Locomotive Demonstration Project
 - SCAQMD - Wabtec Hydrogen Fuel Cell Locomotive Demonstration

⁷⁶ CARB webpage, Zero Emission Rail Project Dashboard, <https://ww2.arb.ca.gov/applications/zero-emission-rail-project-dashboard>

- Sierra Northern Railway Hydrogen Fuel Cell Locomotive Demonstration

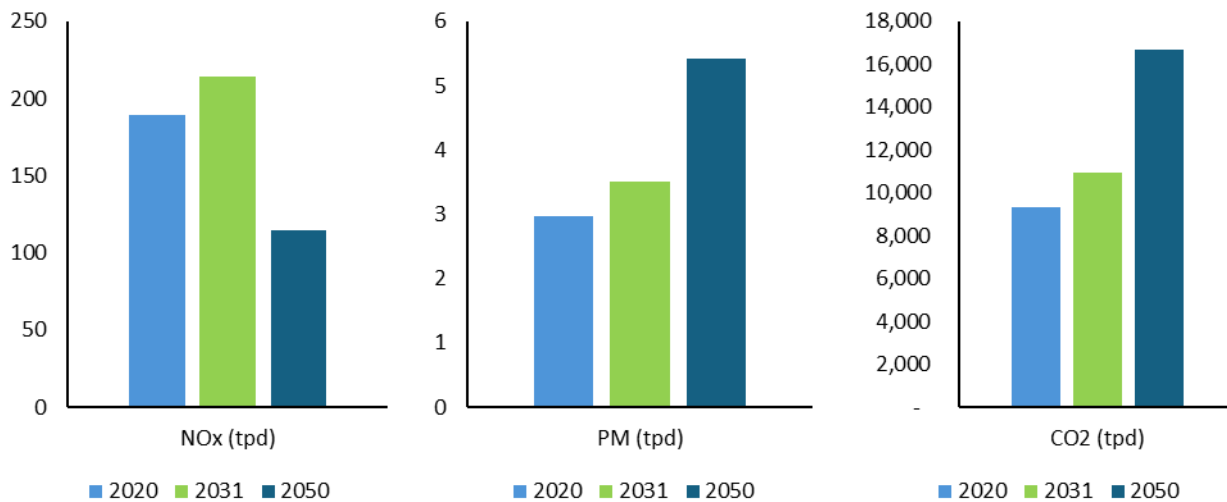
Ocean-Going Vessels

Category Description

- **Equipment:** Container, Cruise, Refrigerated Cargo, Bulk Cargo, Tankers, Auto Carriers (roro)
- **Fuel:** For CY 2020, 100% Marine Diesel Oil (MDO) - distillate grade, 0.1% sulfur
- **Population:** 1,470 unique vessels per year, roughly 7,800 vessel visits per year

Emissions (out to 100 nm)

- **NOx Emissions:** 189 tpd in 2020, and 115 tpd in 2050 (39% reduction)
- **PM Emissions:** 3 tpd in 2020, and 5.4 tpd in 2050 (82% growth)
- **CO2 Emissions:** 9,300 tpd in 2020, and 16,700 tpd in 2050 (79% growth)



CO2 estimates consider the reductions expected from the At Berth and OGV Fuel Regulations. However, they do not include any potential reductions from IMO initiatives to decarbonize the shipping sector.

Current Control Programs

- Marine engine standards: established by the International Maritime Organization (IMO), consist of three tiers of NOx emission standards. Tier III standards, applicable to vessels with keels laid in 2016 and later that operate within NOx Emission Control Area (ECA) zones, represent the most stringent standards, resulting in a reduction of approximately 80% in NOx emissions when compared to a Tier I engine. Presently, less than 5% of California vessel visits meet the Tier III standards.
- CARB's emissions inventory accounts for elevated NOx emissions at low load, and additionally assumes Tier III engines operating under 25% load have the same emissions

factors as Tier II engines. These emissions factor increases can be attributed to emission control systems, such as Exhaust Gas Recirculation (EGR) and Selective Catalytic Reduction (SCR), being less effective at low load. More research is needed to refine NOx emissions levels of Tier III vessels at low loads, especially under 25%.

- Marine fuel: CARB requires vessels within 24 nautical miles (nm) off the California coast to use distillate-grade MDO (0.1% sulfur), which reduces NOx, PM, and SOx emissions.
- At Berth: CARB requires vessels at berth in California ports to reduce emissions by up to 80% by using a CARB approved emissions control strategy (CAECS) in lieu of running their auxiliary engines at berth. CAECS includes, but is not limited to, shore power, barge or land-based capture and control systems, batteries, fuel cells, alternative fuels, etc.
- Vessel Speed Reduction (VSR): the Ports of Los Angeles/Long Beach, U.S. EPA, South Coast Air Quality Management District, the Pacific Merchant Shipping Association (PMSA), the Marine Exchange of Southern California, and CARB signed a voluntary MOU to establish a VSR program within 20 miles of the Ports of LA/LB, which reduces fuel use and pollution. The Ports of San Diego and Bay Area have a similar program.

Available Technology/Emission Reduction Potential

Cleaner Combustion Options

- Incentivizing more Tier III vessels to visit California from the International fleet.
- Developing new marine engine tier standards through IMO.
- “Not to exceed” limit for existing OGV engines (within California or U.S. ECA zones) to ensure that vessel engines do not have periods of emission far higher than the engine standard.
- Alternative fuels (such as methanol, renewable diesel, and others) and/or fuel technologies (such as water-in-fuel emulsion) to reduce tailpipe emissions.
- Operational changes, such as using zero-emission or tugboats to tow OGVs while transiting in California waters, or in regions closest to sensitive receptors
- At anchor controls (i.e., capture and control technologies or idling limits) to reduce emissions while vessels are at anchor.
- Control tanker inert gas system emissions at berth, reducing emissions from the release of air stored in fuel tanks.
- Carbon capture systems.
- Improved hull designs and coatings reduce friction and resistance, reducing overall power needed and fuel used.
- A container fee based on engine tier or fuel used could provide funding for cleaner options and provide an incentive for cleaner vessel visits.

Zero-Emission Options

- Batteries for short-sea shipping are a zero-emission option.
- Wind-assisted propulsion can potentially be used to supplement battery-powered vessels or reduce fuel needed for other vessels.

Chapter 5 - Meeting California's Zero-Emission Infrastructure Needs

Zero-emission charging and hydrogen fueling infrastructure for mobile source vehicles and equipment are critical elements toward meeting California's air quality, GHG, and toxic mandates from mobile source emissions. Significant progress has been made over the last 5 years in the planning needed to coordinate widespread zero-emission infrastructure deployment across California, much of which has been led by our State agency partners at the California Energy Commission (CEC), California Public Utilities Commission (CPUC), California Transportation Commission (CTC), and California Department of Transportation (Caltrans). CARB continues to coordinate and collaborate with State agency partners and local government bodies to ensure that zero-emission fueling and charging infrastructure planning, development, and investments are complementary. For example, CARB's Low Carbon Fuel Standard (LCFS) is designed to decrease the carbon intensity of California's transportation fuel pool and provide an increasing range of low carbon and renewable alternatives, which reduce petroleum dependency, and helps to facilitate deployment of zero-emission infrastructure. The Direct Current Fast Charging Infrastructure and Hydrogen Refueling Infrastructure provisions and ongoing crediting in LCFS provide significant investments for zero-emission infrastructure deployment. To date, CARB has approved 75 hydrogen stations and over 3,200 direct current fast chargers at 511 sites.⁷⁷ In addition, CARB participates in the *Alliance for Renewable Clean Hydrogen Energy Systems*, or *ARCHES*,⁷⁸ which is another key incentive program designed to accelerate renewable hydrogen projects and the necessary infrastructure. ARCHES was awarded up to \$1.2 billion from the U.S. Department of Energy with a commitment for up to \$11.4 billion in public and private matching funds⁷⁹ for hydrogen production, deployment of transportation and distribution, and uses cases like heavy-duty vehicles, ports, and industry.

As we move from the startup phase of zero-emission charging and hydrogen fueling infrastructure and initiate expansion into the full everyday market, there are various challenges that CARB and infrastructure lead agencies must address. Zero-emission fueling and charging infrastructure development must address the needs of all Californians, especially given the large-scale transformation that is required to meet California's clean transportation mandates. Equity considerations play a significant role, ensuring that all Californians benefit from, and have an opportunity to participate in, this change. In particular, living (e.g. single-family homes, multi-unit dwellings, etc.) and working conditions (e.g. availability of workplace charging) must be considered. Solutions are needed that support improvements in infrastructure access in all communities across the State, especially for those that have historically experienced the greatest environmental challenges in their

⁷⁷ CARB webpage, LCFS ZEV Infrastructure Crediting webpage, <https://ww2.arb.ca.gov/resources/documents/lcfs-zev-infrastructure-crediting>

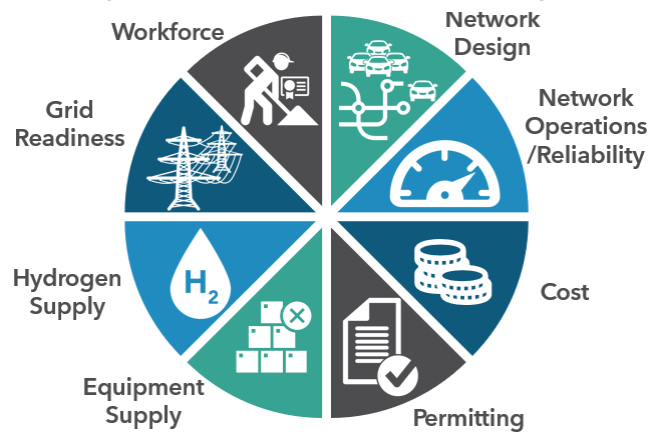
⁷⁸ Alliance for Renewable Clean Hydrogen Energy Systems, <https://archesh2.org/>

⁷⁹ California's renewable hydrogen hub officially launches, <https://archesh2.org/arches-officially-launches/>

communities. The location, cost, and capacity of zero-emission infrastructure plays an important role in these considerations. Equally important considerations include open access (e.g. the availability of multiple payment options, non-proprietary hardware, etc.), charger and station reliability (e.g. high uptime and consistent supply of hydrogen fuel), and availability (e.g. zero-emission infrastructure is available as close to 24/7 as local provisions allow).

Figure 13 summarizes some of the challenges faced with widespread deployment of zero-emission charging and hydrogen fueling infrastructure. These challenges include network design such as where stations should be placed, network operations/reliability, reducing cost structures, decreasing permit timelines, and keeping and maintaining supply of new pieces of equipment. In the case of hydrogen, a new fuel supply, grid readiness for the anticipated load of converting combustion vehicles to electric, and finally, zero-emission charging and hydrogen fueling infrastructure are new projects that require new and specialized training.

Figure 13 - ZEV Infrastructure Challenges



Government will play a vital role in conquering these zero-emission charging and hydrogen fueling infrastructure challenges. Figure 14 identifies the framework of the many tools available to address these challenges, all of which are being pursued by CARB and our many agency partners.

Figure 14 - Government Roles in Zero-emission Infrastructure



CARB along with other government entities are making direct investments of billions of dollars in zero-emission charging and hydrogen infrastructure. CARB and other agencies also each have different authorities to adopt and enforce regulations directly impacting zero-emission infrastructure. There are market development mechanisms such as the *Zero-Emission Vehicle Market Development Strategy*⁸⁰, Figure 15, led by the Governor’s Office of Business and Economic Development (GO-Biz) which is structured to break down barriers and ensure collaboration throughout the California State government to achieve our zero-emission commitments. CARB and other agencies contribute a significant number of resources in the planning, advisement, outreach, and education efforts in order to understand the challenges and available solutions and make sure that we are moving ahead on schedule. Codes and standards such as the energy and building codes must also be updated to support California’s environmental mandates and not impede them. Finally, partnerships among CARB, CEC, CPUC and other State and local bodies are critical to align the various resources and authorities towards a concerted effort. This framework will allow government entities to overcome the challenges related to zero-emission infrastructure.

Figure 15 - Zero-Emission Vehicle Market Development Strategy



Of the government entities involved, CEC, as the lead State agency for zero-emission infrastructure, is responsible for planning for the State’s infrastructure needs to ensure drivers of zero-emission vehicles have accessible and convenient access to charging and hydrogen fueling stations. The CEC efforts toward zero-emission infrastructure can be summarized into three categories: research and analysis, regulations, and investment. There are various publications CEC has released on zero-emission infrastructure which cover what is in place today, the amount needed to meet our mandates, and the strategies to meet those mandates. These publications include the following:

- *Zero-emission Vehicle Infrastructure Plan or ZIP*⁸¹ is a statewide infrastructure strategy involving collaboration with CARB, CPUC, GO-Biz, and others

⁸⁰ California Governor’s Office of Business and Economic Development webpage, *ZEV Strategy - California Governor’s Office of Business and Economic Development*, <https://business.ca.gov/industries/zero-emission-vehicles/zev-strategy-2/>

⁸¹ California Energy Commission, *Zero-Emission Vehicle Infrastructure Plan (ZIP)*, <https://www.energy.ca.gov/publications/2022/zero-emission-vehicle-infrastructure-plan-zip>

- *AB 2127: Second Electric Vehicle Charging Infrastructure Assessment: Assessing Charging Needs to Support Zero-Emission Vehicles in 2030 and 2035*⁸² identifies the number of chargers needed in 2030 and 2035 for zero-emission light-, medium-, and heavy-duty vehicles
- *SB 643: Clean Hydrogen Fuel Production and Refueling Infrastructure to Support Medium- and Heavy-Duty Fuel Cell Electric Vehicles and Off-Road Applications*⁸³ identifies the number of hydrogen stations needed for medium- and heavy-duty vehicles
- *AB 8: 2023 Annual Assessment of the Hydrogen Refueling Network in California*⁸⁴ is the light-duty hydrogen refueling network assessment that is accompanied by *CARB's companion report*; the Clean Transportation Program was reauthorized by AB 126 (Reyes, Chapter 319, Statutes of 2023)⁸⁵, including requirements for hydrogen network analysis and reporting
- *SB 1000: Electric Vehicle Infrastructure Deployment Assessment*⁸⁶ is an equity analysis on charger distribution
- *SB 1389: Integrated Energy Policy Report or IEPR*⁸⁷ is an integrated assessment of the grid impacts
- *2024 Tracking and Improving Reliability of California's Electric Vehicle Chargers: Regulations for Improved Electric Vehicle Charger Recordkeeping and Reporting, Reliability, and Data Sharing*⁸⁸ proposes new regulations for electric vehicle chargers installed outside certain homes

⁸² California Energy Commission, Assembly Bill 2127 Second Electric Vehicle Charging Infrastructure Assessment: Assessing Charging Needs to Support Zero-Emission Vehicles in 2030 and 2035 | California Energy Commission, <https://www.energy.ca.gov/publications/2024/assembly-bill-2127-second-electric-vehicle-charging-infrastructure-assessment>

⁸³ California Energy Commission, Senate Bill 643: Clean Hydrogen Fuel Production and Refueling Infrastructure to Support Medium- and Heavy-Duty Fuel Cell Electric Vehicles and Off-Road Applications | California Energy Commission, <https://www.energy.ca.gov/publications/2023/senate-bill-643-clean-hydrogen-fuel-production-and-refueling-infrastructure>

⁸⁴ California Energy Commission, Joint Agency Staff Report on Assembly Bill 8: 2023 Annual Assessment of the Hydrogen Refueling Network in California, <https://www.energy.ca.gov/sites/default/files/2023-12/CEC-600-2023-069.pdf>

⁸⁵ Reyes, Chapter 319, Statutes of 2023, https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=202320240AB126

⁸⁶ California Energy Commission, Electric Vehicle Infrastructure Deployment Assessment - SB 1000 (ca.gov), <https://www.energy.ca.gov/programs-and-topics/programs/clean-transportation-program/electric-vehicle-infrastructure>

⁸⁷ California Energy Commission, 2024 Integrated Energy Policy Report Update (ca.gov), <https://www.energy.ca.gov/data-reports/reports/integrated-energy-policy-report/2024-integrated-energy-policy-report-update>

⁸⁸ California Energy Commission, 2024 Tracking and Improving Reliability of California's Electric Vehicle Chargers, <https://www.energy.ca.gov/publications/2023/tracking-and-improving-reliability-californias-electric-vehicle-chargers>

- *Investment Plan Update for the Clean Transportation Program*⁸⁹ establishes funding allocations based on identified needs and opportunities, including a focus on zero-emission vehicle infrastructure

CEC is also pursuing regulations affecting chargers such as reliability, inventory, utilization, payments, uptime recordkeeping and standards, and real-time availability and tire efficiency of replacement tires. Finally, zero-emission infrastructure investments are a significant effort at CEC with base funding at approximately \$100 million annually through the Clean Transportation Program. The legislature has also allocated substantial additional funds for ZEV infrastructure through the finalized budgets in recent years. CEC and Caltrans are also managing approximately \$384 million over 5 years for charging infrastructure from the U.S. Department of Energy's National Electric Vehicle Infrastructure Formula Program. Finally, CEC also led the California application for funds to repair and replace broken chargers through the U.S. Department of Transportation's Electric Vehicle Charger Reliability and Accessibility Accelerator Program; California was awarded nearly \$64 million in federal funds for about 1,300 charging ports.

Moreover, there are zero-emission infrastructure efforts currently underway beyond those at CARB and CEC. Based on CEC's IEPR, the CPUC plans for grid infrastructure through two processes, the Integrated Resource Planning (IRP) and the Distribution Planning Process (DPP). The scope of IRP includes electrical generation and storage and feeds into the transmission planning while the scope of DPP includes identifying electrical distribution upgrades to address reliability issues or energize new loads. Additionally, the CPUC *Transportation Electrification Proactive Planning*⁹⁰ will initially focus on zero-emission planning related to freight charging infrastructure and similar loads like light-duty charging plazas. GO-Biz has permitting guidebooks that help local agencies and station developers understand the technology, safety issues, codes, and standards related to the zero-emission charging and hydrogen stations. GO-Biz is also the lead for the ARCHES program which, as discussed earlier, is a key initiative to accelerate renewable hydrogen projects and the necessary infrastructure. The CTC is responsible for developing the *Clean Freight Corridor Efficiency Assessment*⁹¹ which will support zero-emission infrastructure for freight applications by identifying the number of zero-emission charging and hydrogen fueling stations needed along key freight corridors. The CEC is supporting this effort by using the Clean Transportation Program funding to target infrastructure along these corridors.

⁸⁹ California Energy Commission , 2024-2025 Investment Plan Update for the Clean Transportation Program, <https://www.energy.ca.gov/publications/2024/2024-2025-investment-plan-update-clean-transportation-program>

⁹⁰ California Public Utilities Commission, Transportation Electrification Proactive Planning, <https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/infrastructure/transportation-electrification/transportation-electrification-proactive-planning>

⁹¹ California Transportation Commission, Senate Bill 671, <https://catc.ca.gov/programs/sb671>

In recent years, the US federal government has initiated several additional programs to support the development of zero-emission vehicles and infrastructure. The US EPA has launched two funding opportunities within its *Clean Ports Program*⁹², one focused on air quality planning and analysis activities and another on zero-emission technology deployment. Both solicitations have closed and applications are currently under consideration for award selection. The Joint Office of Energy and Transportation awarded five California projects from the first round⁹³ of *Charging and Fueling Infrastructure (CFI) Discretionary Grant Program*⁹⁴. Two of the awardees are tribal governments while another was over \$100 million for a tri-state (California, Oregon, and Washington) network of charging and hydrogen fueling stations for zero-emission trucks along Interstate 5 and other key freight corridors⁹⁵. In addition, the Joint Office of Energy and Transportation accepted applications through September 11, 2024 for the second round of CFI program. The CFI program acts as a counterpart to the NEVI Formula Program by providing funding for hydrogen and charging infrastructure either along designated corridors (similar to NEVI) or in strategic locations to support community needs for ZEV infrastructure. CEC and Caltrans had invited stakeholder input for concepts to include in California's application for Round 2 CFI grants. Finally in March 2024, the Joint Office of Energy and Transportation also released the *National Zero-Emission Freight Corridor Strategy*⁹⁶, which outlines a four-phase approach to developing an interconnected nationwide system of zero-emission highways. The analysis in the report is meant to help guide state and local government planning. The corridor designations in the strategy are also meant to guide federal funding opportunities; the CFI Round 2 funding opportunity serves as an example, as proposals will be judged on "the extent to which projects support the National Zero-Emission Freight Corridor Strategy."

Numerous strategies and mechanisms to scale infrastructure development will contribute to the State's portfolio of solutions to overcome barriers. While a network of grid-connected permanent and stationary charging and fueling stations will form the backbone of California's zero-emission infrastructure for mobile source vehicles and equipment, other innovative solutions have already begun to play a role. For example, the local utility may need significant time to complete needed expansion of the electric grid or interconnection to a charging site. In this case, some station developers have begun to integrate on-site generation to temporarily supply the needed electrical service until the electric grid work

⁹² U.S. Environmental Protection Agency Clean Ports Program, <https://www.epa.gov/ports-initiative/cleanports>

⁹³ U.S. Department of Transportation, Federal Highway Administration, CFI Round 1B Grant Award Recipients, https://www.fhwa.dot.gov/environment/cfi/grant_recipients/round_1b/

⁹⁴ U.S. Department of Transportation Federal Highway Administration Charging and Fueling Infrastructure Discretionary Grant Program, <https://www.fhwa.dot.gov/environment/cfi/>

⁹⁵ Governor Gavin Newsom, California Scores Big Clean Transportation Boost From Biden-Harris Administration, <https://www.gov.ca.gov/2024/08/27/california-scores-big-clean-transportation-boost-from-biden-harris-administration/>

⁹⁶ Joint Office Energy and Transportation National Zero-Emission Freight Corridor Strategy, <https://driveelectric.gov/files/zef-corridor-strategy.pdf>

can be completed. Similarly, some hydrogen fueling station providers have begun to pursue a strategy that establishes temporary fueling stations that can later be replaced with larger and more permanent infrastructure as the demand grows in the future. The temporary solution is mobile and can then be relocated to provide early fueling access in a new local market. Some of these solutions may provide additional benefits like reduced permitting requirements and timelines. These innovative solutions can also support zero-emission deployment in sectors, such as construction, where operations dictate alternative fueling strategies. CARB staff continue to monitor these developments and work to ensure that these solutions continue to support ZEV market growth and provide the expected GHG and pollutant emission reductions. Local permitting will also play a role in ensuring communities are protected from harmful emissions, including toxics and PM. In the long term, fully zero-emission on-site generation solutions and integration with a clean electric grid are the preferred solutions.

In September 2020, Governor Newsom signed Executive Order N-79-20 furthering the state's transition from its reliance on climate change-causing fossil fuels while retaining and creating jobs, spurring economic growth, and maximizing environmental, health, and safety benefits. While the zero-emission infrastructure need is significant, there is an opportunity to transition existing energy assets and infrastructure in addition to building out new energy assets. Transforming our fossil-energy landscape will need to happen with intention and project-by-project. It will be critical to have labor, local government, the private sector, advocates, and public support for action on the ground to deliver the benefits of a clean energy future for all Californians. CARB and other State agencies recognize the challenges California will face for this multi-billion dollar shift and have moved aggressively to accelerate infrastructure deployment in collaboration with each other and stakeholders.