October 28, 2021

2020 Mobile Source Strategy

CALIFORNIA
AIR RESOURCES BOARD

October 28, 2021

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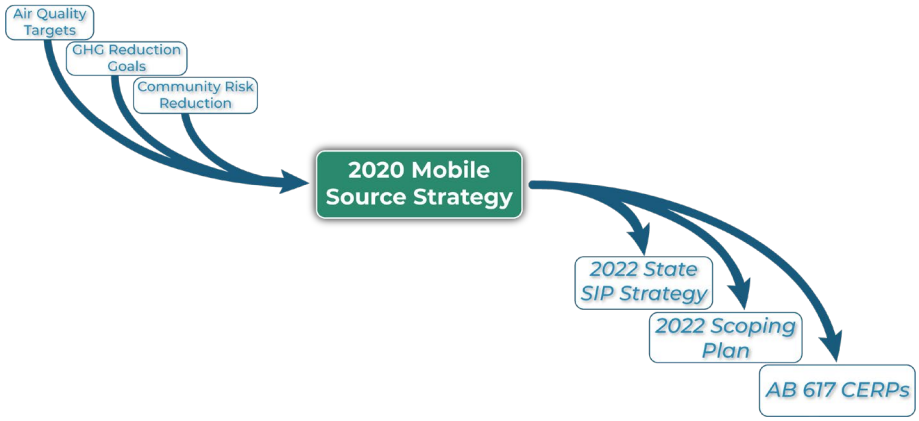
Executive Summary

The *California Air Resources Board* (CARB or Board) *2020 Mobile Source Strategy* (2020 Strategy) uses scenario planning to take an integrated approach to identifying the technology trajectories and programmatic concepts to meet our criteria pollutant, greenhouse gas, and toxic air contaminant reduction goals from mobile sources. It's imperative that we optimize our mobile source control programs to maximize emissions reductions from all types of air pollutants in order to meet our many goals and provide immediate benefits in the communities that continue to bear the brunt of poor air quality. Similar to the *2016 Mobile Source Strategy* (2016 Strategy), the 2020 Strategy is a framework that identifies the levels of cleaner technologies necessary to meet our many goals and high-level regulatory concepts that would allow the State to achieve the levels of cleaner technology.

The 2020 Strategy will inform the development of other planning efforts including the State Implementation Plan (SIP) which will translate the concepts included here into concrete measures and commitments for specific levels of emissions reductions, the 2022 Climate Change Scoping Plan (2022 Scoping Plan Update), and Community Emissions Reduction Plans (CERPs) required for communities selected as a part of CARB's Community Air Protection Program. Central to all of these planning efforts, and CARB actions on mobile sources going forward, will be environmental justice as CARB strives to address longstanding environmental and health inequities from elevated levels of toxics, criteria pollutants, and secondary impacts of climate change.



CARB has over 50 years of experience reducing mobile source emissions that have improved air quality and reduced climate pollutants. Through these efforts, the State and our most polluted regions have seen dramatic improvements in ambient air quality and, as a byproduct, CARB has helped California become a world leader in environmental policies and clean technologies. Even with our progress, many areas of the State exceed current health-based ambient air quality standards that the State must legally meet; in addition, many near-source, low-income and disadvantaged communities continue to experience disproportionately high levels of air pollution and the resulting detrimental impacts to their health. Further, climate change is causing extreme heat, devastating wildfires, historic

droughts, torrential storms, causing billions of dollars in property damage and threatening human health and the economy of the residents of California – the unprecedented number of acres burned by wildfires in 2020 reemphasizes that climate change is here now. These immediate threats of climate change demand action and have resulted in a number of State of California and CARB policies to date.

Mobile sources including cars, trucks, tractors, and a myriad of other on-road vehicles and off-road equipment, contribute a majority of smog-forming oxides of nitrogen (NOx), the largest portion of greenhouse gas (GHG) emissions, and are a significant source of toxic air contaminants that directly impact community health. The 2016 Strategy was CARB's first integrated planning effort looking specifically at mobile sources to identify complementary policies to reduce emissions of criteria pollutants, greenhouse gases, and toxics.

In recognition of the value of the 2016 Strategy 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 *Senate Bill (SB) 44*,[1] signed by Governor Newsom into law on September 20, 2019. SB 44 acknowledges the ongoing need to evaluate opportunities for mobile source emissions reductions and requires CARB to update the 2016 Strategy by 2021 and every five years thereafter. Specifically, SB 44 requires CARB to update the 2016 Strategy 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. It also directs CARB to set reasonable and achievable goals for reducing emissions by 2030 and 2050 from medium- and heavy-duty vehicles that are consistent with the State's overall goals and maximizes the reduction of criteria air pollutants.

This document, the 2020 Strategy continues 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 goals and targets over the next 30 years. As specified in SB 44, the 2020 Strategy includes scenarios and programmatic concepts that comprehensively address the mechanisms needed to provide for the deployment of clean medium- and heavy-duty on-road vehicles. Because achieving all of the State's near- and longer-term goals requires action across the full spectrum of mobile sources, this document also discusses light-duty on-road vehicles, as well as a wide range of off-road equipment sectors. By including light-duty vehicles and off-road equipment, the 2020 Strategy is more comprehensive than what was required under SB 44 and allows for consideration of fuel and energy use by the light-duty and off-road sectors in addition to the on-road medium- and heavy-duty sectors. The scenarios and concepts included in the 2020 Strategy provide emissions reductions for the purpose of meeting federal ambient air quality standards and substantially reducing greenhouse gas emissions from motor vehicles.

[1] Skinner, Chapter 297, Statutes of 2019

Last year, Governor Newsom signed *Executive Order N-79-20*[2] which established a goal that 100 percent of California sales of new passenger cars and trucks be zero-emission by 2035. In addition, the Governor's order set a goal to transition all drayage trucks to zero-emission by 2035, all off-road equipment to zero-emission where feasible by 2035, and the remainder of medium- and heavy-duty vehicles to zero-emission where feasible by 2045. With this order and many other recent actions, Governor Newsom has recognized that air pollution remains a challenge for California that requires bold action, and that climate change is happening now, affecting the health and safety all Californians. Under the order, CARB is tasked to work with our State agency partners to develop regulations to achieve these goals taking into account technological feasibility and cost effectiveness.

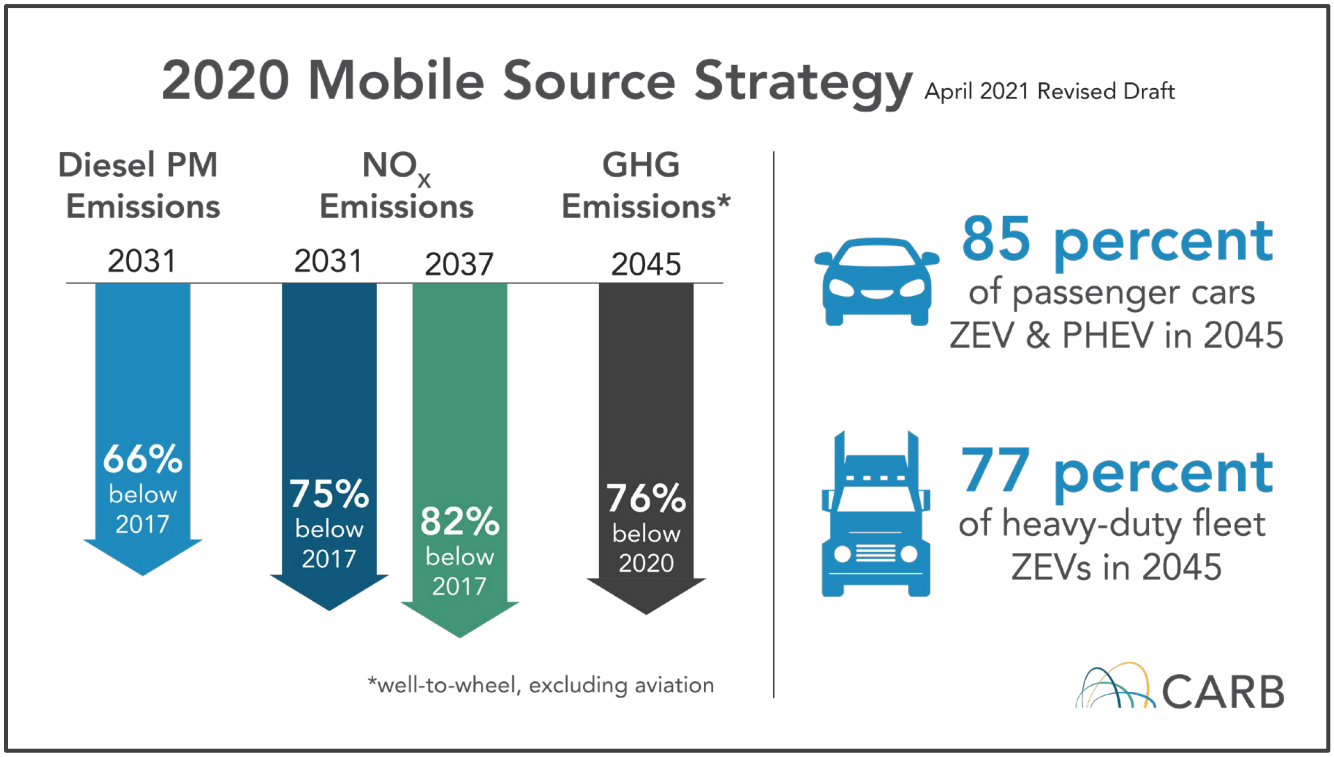
On April 21, 2021, Governor Newsom joined a bipartisan group of twelve governors from across the country calling for the Biden Administration to build on its early action to tackle climate change by creating a path to ensure that all new vehicles sold in the U.S. will be zero-emission in the near future, and by amplifying states' investments in ZEV charging and fueling infrastructure. The *letter* from the coalition of states calls on the Administration to bolster the clean vehicle transition's growing momentum nationwide by setting standards to require all new passenger cars and light-duty trucks sold to be zero-emission by 2035 and all new medium-duty and heavy-duty vehicles sold to be zero-emission by 2045, consistent with the pathways that are identified in the 2020 Strategy for California.

Further, on July 16, 2021, the Governor signed the *2021-22 State Budget* which included unprecedented levels of investment in zero-emission vehicles and the infrastructure needed to support them. The ZEV budget package includes $2.7 billion in 2021-22 and $3.9 billion collectively over three years for CARB, the California Energy Commission, the California State Transportation Agency, and GO-Biz. For CARB, the ZEV incentive provides over $1.5 billion for clean trucks, buses, and off-road equipment, including an initiative to deploy more than 1,000 zero-emission drayage trucks, 1,000 zero-emission school buses, and 1,000 transit buses, and the necessary infrastructure, to clean up the air in disadvantaged communities. There is also over $900 million in CARB funding to invest in consumer adoption of ZEVs and in clean mobility for low-income and disadvantaged communities. With the 2021-22 State Budget, Governor Newsom is taking a strong stance and proposing the types of investment necessary to move the State forward towards attainment of ambient air quality standards, the State's zero-emission future, and to meeting the goals of Executive Order N-79-20.

[2] Executive Order N-79-20 https://www.gov.ca.gov/wp-content/uploads/2020/09/9.23.20-EO-N-79-20-Climate.pdf

2020 Mobile Source Strategy Concepts

Consistent with Executive Order N-79-20 and SB 44, in the 2020 Strategy, staff have identified a suite of strategy concepts, many of which CARB is actively pursuing through individual public processes, that will enable the State to achieve the technology trajectories identified through scenario planning and, consequently, meet California's many goals.



Further, these concepts maximize the criteria pollutant reductions by going to zero-emission where feasible. Specifically, for medium- and heavy-duty vehicles, the scenarios call for the deployment of approximately 1.4 million medium- and heavy-duty zero-emission vehicles (ZEVs) in California by 2045. Statewide, the concepts in the 2020 Strategy could achieve criteria pollutant NOx reductions of over 590 tons per day in 2037, and reduce mobile source fuel consumption by 9.5 billion gallons of gasoline and 3.0 billion gallons of diesel equivalent in 2045. This equates to a well-to-wheel GHG emissions reduction of approximately 94 million metric tons of carbon dioxide equivalent in 2045.

For on-road light-duty vehicles, the 2020 Strategy includes the concepts within the following scope to move the State towards the goal that 100 percent of sales will be ZEVs by 2035:

- Manufacturer requirements to foster clean technology production and sales;
- In-use requirements to accelerate penetration of newer technology;
- Incentive programs to promote and accelerate the use of advanced clean technologies;

- Outreach and education to increase consumer awareness and acceptance of advanced vehicle and equipment technologies; and
- Infrastructure planning and development to support the transition to cleaner technologies.

For on-road medium- and heavy-duty vehicles, the 2020 Strategy includes the concepts within the following scope to move the State towards the goal that 100 percent of California-registered trucks will be ZEVs by 2045 where feasible:

- Manufacturer requirements to foster clean technology production and sales;
- In-use requirements to accelerate penetration of newer technology;
- Incentive programs to promote and accelerate the use of advanced clean technologies;
- Enhanced enforcement strategies to ensure programs are achieving their anticipated benefits;
- Outreach and education to increase consumer awareness and acceptance of advanced vehicle and equipment technologies; and
- Infrastructure planning and development to support the transition to cleaner technologies.

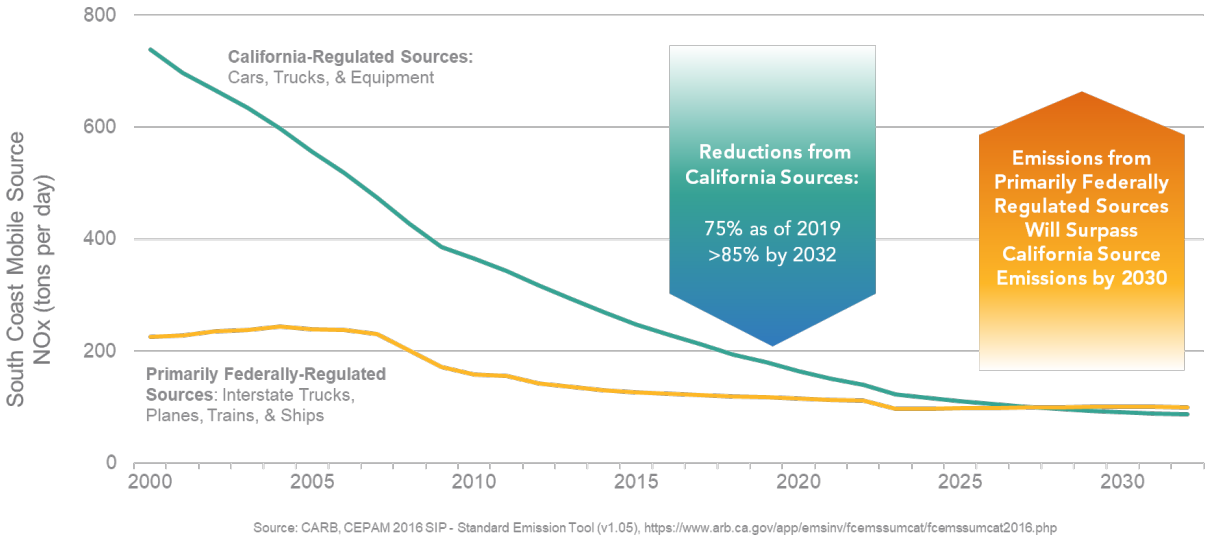
For off-road vehicles and equipment, the 2020 Strategy includes the concepts within the following scope to move the State towards the goal that 100 percent of equipment will be zero-emission by 2035 where technologically feasible:

- Manufacturer requirements to foster clean technology production and sales;
- In-use requirements to accelerate penetration of newer technology;
- Incentive programs to promote and accelerate the use of advanced clean technologies;
- Outreach and education to increase consumer awareness and acceptance of advanced vehicle and equipment technologies; and
- Infrastructure planning and development to support the transition to cleaner technologies.

Tenets of the 2020 Mobile Source Strategy

As outlined above, a key focus of the 2020 Strategy is advancing the use of zero-emission technologies wherever feasible. Regulatory mechanisms will continue to be the core of CARB's programs and provide the vast majority of emissions reductions identified in the 2020 Strategy. That said, in the near-term, incentive programs to promote and accelerate the use of these and other clean technologies will be essential to meeting our pre-2030 air quality goals and setting us on the trajectory for the future goals. In addition to funding, it is critical that we structure programs so that clean transportation is accessible to all Californians, particularly those in low-income and disadvantaged communities who experience a disproportionate share of pollution impacts.

Further, for California to meet air quality standards, it is imperative that the federal government act decisively to reduce emissions from federally-regulated sources of air pollution, including interstate trucks, ships, locomotives, aircraft, and certain categories of off-road equipment. Absent federal action, by 2030, NOx emissions from federally-regulated sources will exceed emissions from California-regulated mobile sources in the South Coast, California's most challenging ozone nonattainment area.



Source: CARB, CEPAM 2016 SIP - Standard Emission Tool (v1.05), https://www.arb.ca.gov/app/emsinv/fcemssumcat/fcemssumcat2016.php

Since the release of the 2016 Strategy, 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, action by the U.S. Environmental Protection Agency (U.S. EPA) to limit emissions from these sources have not yet materialized, making it more challenging to meet federal air quality standards and reduce air pollution that harms public health in California and across the U.S. The 2020 Strategy is a call to action, not only for California, but for the federal government as well.

Public Process for the 2020 Mobile Source Strategy

Staff has engaged in a robust public process throughout development of the 2020 Strategy, including release of the *Workshop Discussion Draft 2020 Mobile Source Strategy* on September 30, 2020, and the *Draft 2020 Mobile Source Strategy* on November 24, 2020. As part of the public comment processes on these earlier drafts, staff received numerous comments that emphasized the importance of near-term mobile source emissions reductions, and further requested that CARB expand upon the discussions of programmatic concepts that could reduce emissions in the next five years. Staff understands the critical importance of reducing emissions in the near-term for attainment of federal standards and to improve air

quality in the most impacted communities and, as such, has identified in subsequent drafts the programs and new concepts that can achieve emissions reductions in the near-term.

In addition, an informational update on the Draft 2020 Strategy was presented to the Board in December 2020. At that time, the Board directed staff to continue to develop the 2020 Strategy for the primary purpose of building on efforts to reduce emissions to meet near-term SIP targets and provide benefits in disadvantaged communities. In addition, the Board directed staff to accelerate the adoption and implementation of the Heavy-Duty Inspection and Maintenance Program, targeting benefits in low-income and disadvantaged communities where possible; and to add to the discussion on efforts to reduce vehicle miles travelled (VMT), while considering how we can better partner with locals and other agencies to tackle housing and land use, and to support transit and biking options.

Staff released the *Revised Draft 2020 Mobile Source Strategy* on April 23, 2021, which incorporated public feedback provided on earlier drafts and also addressed Board direction given at the December hearing. In addition to informational updates to the Board, three public webinars were also held on the 2020 Strategy on March 25, 2020, October 7, 2020, and May 6, 2021, each of which saw high levels of public engagement with more than 200 participants attending each, and staff answering questions through the end of the scheduled time.

Updates Since the Draft Release

In response to public feedback and Board direction received at the December hearing, a number of updates were included in the Revised Draft and this Proposed 2020 Strategy. Chapter 4 of this document discusses in detail the newly-identified and ongoing efforts to achieve reductions in the next five to ten years. This includes measures from the 2016 Strategy and associated *2016 State Strategy for the State Implementation Plan*, for which implementation is ongoing – many of the measures committed to in those plans will achieve substantial near-term reductions. CARB staff have continued to work to identify and develop additional near-term actions to reduce emissions, and find ways to accelerate emissions and target benefits of regulatory programs already in development in priority communities.

In Chapter 2, we further explore the actions that CARB has taken and current efforts to ensure a focus on environmental justice and equity in CARB's programs into the future. CARB has long worked to reduce negative effects from air pollution in the State's most highly-impacted populations, through programs to control emissions from freight transport and other significant sources affecting low-income and disadvantaged communities. In recent years, CARB and the State have been further enabled through *Assembly Bill (AB) 617*[3] programs, *Senate Bill 350*[4] (SB 350) equity efforts, and Low Carbon Transportation to renew

[3] C. Garcia, Chapter 136, Statutes of 2017
[4] De León, Chapter 547, Statutes of 2015

our focus on and engagement with these communities, but disadvantaged communities continue to experience the highest levels of air pollution impacts in California. CARB and the State of California are committed to prioritizing the needs of historically under-served communities in our work – as such, environmental justice will be a core consideration within all CARB actions and programs moving forward.

Concepts included in the 2020 Strategy that will reduce emissions in low-income and disadvantaged communities are shown below and described in further detail in Chapter 2 and Chapter 6.

- Cars and Trucks
    - Cars: Cleaner combustion and zero-emission requirements
    - Trucks and Buses: Zero-emission requirements and regulations to ensure in-use combustion equipment remains clean
    - Vehicle Miles Travelled: Increased access to alternative mobility options such as walking, bicycling, transit, and equitably address land use issues through accelerated infill housing development and other means
- Near-Port Emissions Sources
    - Drayage Trucks: Full transition to zero-emission by 2035
    - Ocean-going Vessels: Cleaner marine engine standards and cleanest vessel visits requirements
    - Commercial Harbor Craft: Clean combustion, renewable fuel and zero-emission requirements
    - Cargo Handling Equipment: Full transition to zero-emission equipment starting in 2026 at ports and railyards
- Commercial/Industrial and Warehouse Emissions Sources
    - Small Off-Road Engines, Forklifts, and Transport Refrigeration Units: Full transition to zero-emission equipment starting in 2024
    - Locomotives: Accelerated turnover to cleanest combustion
    - Construction, Industrial and Mining: Replace dirtiest vehicles with cleanest available technology
- Other Emissions Sources
    - Recreational Boats: Cleanest combustion and zero-emission requirement
    - Aircraft: Cleaner engines, efficiency improvements and zero-emission operation

CARB and the State of California are committed to dismantling embedded systems of disenfranchisement and discrimination, and to prioritizing the needs of historically under-served communities in our work. In order to comprehensively address equity in California's transportation system, we must do more than reduce emissions by transforming the fleet to cleaner and zero-emission vehicles – we must also find ways to provide increased mobility options to the communities who need them and state and local governments must address the land use issues that stand in the way of progress. Historic decision-making favoring single-occupancy vehicle travel shaped many communities. Where and how communities plan and build housing imposes and often reinforces long-standing racial and

economic injustices that leave residents with little choice but to spend significant time and money commuting long distances in search of an affordable place to live. This places a disproportionate burden on low-income Californians, who end up paying the highest proportion of their wages for housing and transportation. In the *Beyond ZEVs* section of Chapter 6, we identify strategies CARB can undertake to help address these issues, which would simultaneously reduce VMT, achieve additional emissions reductions and support implementation of regional planning efforts.

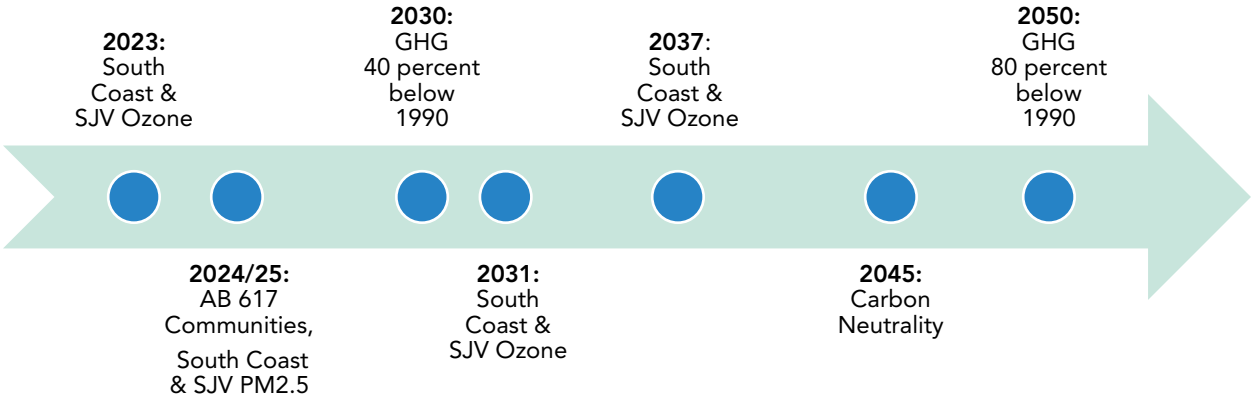
Moving forward, the concepts contained in the 2020 Strategy will be translated into federally-enforceable measures and commitments that will be included in the next *State Implementation Plan* strategy being developed for the 70 parts per billion (ppb) 8-hour ozone standard. Further, the 2020 Strategy will inform mobile source elements of the 2022 Scoping Plan Update, and be incorporated into community emission reduction plans and other CARB planning documents to be released in the coming years. As such, in addition to a final Board hearing on the 2020 Strategy this fall, the concepts included here will see many opportunities for public input as they are incorporated into additional planning documents, and further developed into regulations and other programs through formal rulemaking processes.

Chapter 1 - Introduction

Over the last 50 years, California air pollution control efforts have resulted in dramatic improvements in smog levels, 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.

To that end, much needs to be accomplished. The State of California and CARB have many air quality standards, targets and goals to meet over the next 30 years (Figure 1).

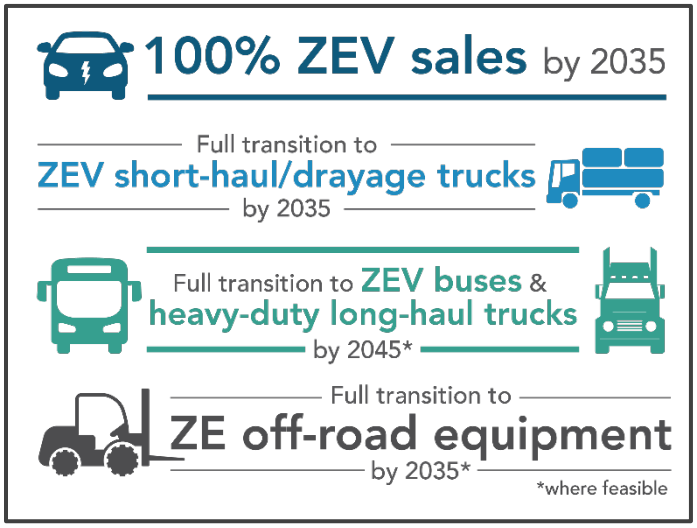
Figure 1 – California's Air Quality Targets and Greenhouse Gas Reduction Goals



The State's climate goals include the mid-term target in 2030 for 40 percent GHG emissions reduction below 1990 levels, codified under *Senate Bill 32*,[5] and longer-term targets for economy-wide carbon neutrality in 2045 as set in *Executive Order B-55-18*, and 80 percent GHG emissions reduction below 1990 levels by 2050 as directed by *Executive Order S-3-05*,

[5] Pavley, Chapter 249, Statutes of 2016

a target that was reinforced by Governor Brown's *Executive Order B-16-2012* that added a 80 percent reduction goal specific to the transportation sector. While our future climate goals are 10, 25, and 30 years into the future, 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 of impacts of climate change, it's pivotal that we act this decade to curb greenhouse gas emissions.



In recognition of the severity of the climate crisis and the need for immediate action, Governor Newsom signed Executive Order N-79-20 on September 23, 2020. This order established a first-in-the-nation goal for 100 percent 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 percent 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. Under the order, CARB will work with our State agency partners to develop regulations and strategies to achieve these goals taking into account technological feasibility and cost-effectiveness.

For the national ambient air quality standards (standards), there are legally-obligated deadlines by which areas must attain; these are established by the federal Clean Air Act (Act) and implemented by the U.S. EPA each time a new standard is promulgated based on updated information showing health impacts at increasingly lower levels. 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. The near-term targets for these areas are our outlined in Table 1, alongside the mid-term attainment years of 2031 and 2037 for the more recent 8-hour ozone standards.

Table 1 – Attainment Deadlines for National Ambient Air Quality Standards

Attainment Year	Standard
2023	80 ppb 8-hour ozone
2024	35 $\mu g/m^3$ 24-hour PM2.5
2025	12 $\mu g/m^3$ annual PM2.5
2031	75 ppb 8-hour ozone
2037	70 ppb 8-hour ozone

In addition to regional air pollutant levels, many communities in the State experience measurable harm in the form of negative health impacts from high levels of localized pollution. There is an immediate need to reduce emissions and exposure in these highly-impacted, low-income and disadvantaged communities throughout the State, and specifically, communities with Community Emissions Reduction Plans (CERPs) under *AB 617*.[6] Communities selected for CERPs set five and ten-year targets to reduce community exposure; the targets for the first CERPs adopted by the Board begin in 2024, and included in many of these plans is a focus on mobile source measures and reductions.

As research continues to show harmful effects from air pollution at increasingly lower levels, achieving the State's complementary goals, 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 and disadvantaged communities. Meeting California's GHG emissions reduction targets is an essential part of the worldwide action needed to slow global warming 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 goals will also provide economic benefits including increasing the demand for skilled labor in green jobs, and will reduce our dependence on petroleum and establish a more secure energy future.

Further, national parks and wilderness areas in California are known for their dramatic landscapes and striking vistas. Views of these natural landscapes are diminished when pollutants from anthropogenic and natural sources scatter and absorb light, reducing clarity, color, and overall visibility. The presence of pollutants that diminish visibility is known as haze. The Act requires states to reduce haze and protect visibility at Class 1 areas known for their vistas. California has 29 Class 1 areas located throughout the State and is required to develop state implementation plans every 10 years to remedy visibility impairment and prevent future visibility degradation at our Class I areas. Mobile source emissions are the dominant source of visibility reducing particulate matter at California's Class I areas. Continued efforts to control emissions from

[6] C. Garcia, Chapter 136, Statutes of 2017

mobile sources is necessary to meet the State's obligation to improve visibility required by the Act.

Mobile sources and the fossil fuels that power them continue to contribute a majority of NOx emissions, a significant precursor to smog and particulate matter, and are the largest portion of GHG emissions in California. The 2016 Strategy demonstrated how the State could target strategies that simultaneously meet air quality standards, achieve greenhouse gas emission reduction targets, decrease health risk from transportation emissions, and reduce petroleum consumption through 2031 through a combination of efforts including widespread actions to deploy both zero-emission and cleaner combustion technologies. The 2016 Strategy included scenarios and measures to deploy zero-emission technologies across a broad spectrum of mobile sources including passenger vehicles, targeted truck and bus applications, forklifts, and other off-road equipment and transport refrigeration units. Actions were also discussed to require cleaner combustion technologies for sectors such as heavy-duty trucks, locomotives, and ocean-going vessels; these measures would provide the bulk of the NOx reductions needed to meet federal air quality standards by statutory deadlines in 2031.

Elements of the 2016 Strategy were incorporated into the *2016 State SIP Strategy* and supported complementary efforts including the *2017 Climate Change Scoping Plan*, the *California Sustainable Freight Action Plan*, and CARB's *Short-Lived Climate Pollutant Reduction Strategy*. Each of these documents drew from the 2016 Strategy to incorporate and build upon the actions and policies relevant to meet individual program goals.

With the passing of SB 44, the California Legislature acknowledged the value of the 2016 Strategy in relation to the State's many air quality, climate, and community risk reduction challenges. By requiring CARB to update the Mobile Source Strategy every five years, SB 44 further acknowledged 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 requires CARB to update the 2016 Strategy 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. In addition to providing a status on the measures in the 2016 Strategy, it also directs 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 all of the State's near- and longer-term goals requires action across the full spectrum of mobile sources, this document also discusses light-duty on-road vehicles, as well as a wide range of off-road equipment sectors.

The 2020 Strategy meets the requirements of SB 44 through the inclusion of scenarios and programmatic concepts that comprehensively address the mechanisms needed to provide for the deployment of clean medium- and heavy-duty on-road vehicles. By including light-duty vehicles and off-road equipment, the 2020 Strategy is more comprehensive than what was required under SB 44, and allows for consideration of fuel and energy use by the light-duty and off-road sectors in addition to on-road medium- and heavy-duty vehicles. The

scenarios and concepts included in the 2020 Strategy can illustrate how the state can obtain emissions reductions for the purpose of meeting federal ambient air quality standards and substantially reducing greenhouse gas emissions from motor vehicles.

Defining the scope of actions necessary to implement a strategic vision to meet all of California's goals requires an integrated planning process. In order to identify the strategies and program concepts that will best 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 strives to reduce: criteria pollutants, toxics, and greenhouse gases. As we know that significant emission reductions from mobile sources are needed from 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 energy sources. This planning effort serves as a foundation, but does not substitute for the public 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.

To take an integrated approach, CARB uses scenario planning tools to quantify changes in ozone and PM2.5 precursor emissions, GHG emissions, diesel toxics emissions, and petroleum usage as various technologies are projected to populate the vehicle and equipment fleets. CARB's tools, known as the *Mobile Emissions Toolkit for Analysis (META)* and *Vision*, are used to evaluate scenarios with varying assumptions about potential technology and fuel mixes, and explore different rates at which those technologies could become widely used. These tools are discussed further in Chapter 6.

The analysis in the 2020 Strategy illustrates scenarios for meeting the State's public health, climate, and community risk reduction goals with a strategy consisting of cleaner vehicle technologies, energy and fuel supply sources, and a reduction in vehicle miles traveled. Technologies, energy sources, and vehicle travel, as well as the best policy tools, will vary by sector based on the status of technology development in various applications, the multi-pollutant benefits, and the interactions between regulatory and programmatic strategies. The scenario analysis identifies the types of technologies and level of penetration into the respective fleets that will be necessary to meet the various goals. While a scenario may outline the overall approach for a sector and include 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. The concepts contained in the 2020 Strategy are less defined than the measures included in the 2016 Strategy, in part due to the accelerated timeframe for completing the 2020 Strategy as defined under SB 44. The concepts in the 2020 Strategy will continue to be developed and then translated into more clearly defined measures for the next State SIP Strategy and other CARB planning documents over the coming years.

It is clear that the rate of natural vehicle fleet turnover will not be sufficient to meet near- and long-term air quality or climate goals; as such, actions to accelerate the deployment of

cleaner technologies through regulations, incentives, system efficiency improvements, and support for the use of advanced transportation technologies such as intelligent transportation systems and autonomous and connected vehicles, are critical to achieving both near- and long-term goals in California. Existing mobile source regulatory programs and the many regulatory efforts underway will drive technology development and provide for significant reductions in emissions, but more will be needed. Given that the development and implementation of new regulations takes substantial time, strategic use of incentive funding is essential to achieve earlier penetration of cleaner combustion and zero-emission technologies than would happen through natural turnover, and the associated emissions reductions which are necessary to meet near-term goals.

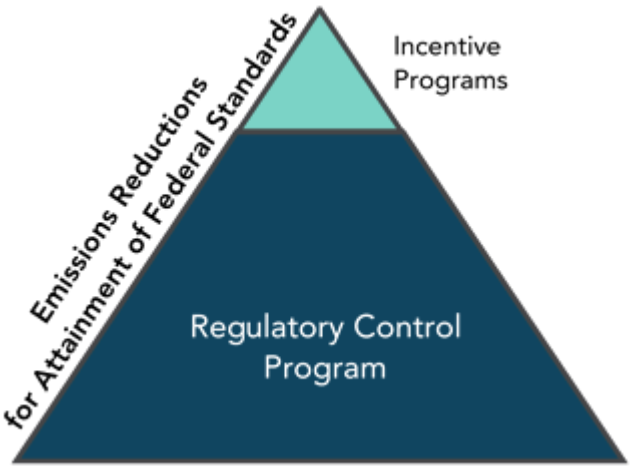
Where We Are Today

While CARB has made substantial progress through its many regulatory and programmatic efforts, there remains a great need for emissions reductions in the immediate future to alleviate negative health impacts and meet federal and State air quality deadlines. Statewide, more than 28 million Californians live in areas that exceed the federal ozone and PM2.5 standards;[7] within those, there are many low-income and disadvantaged communities that experience pollutant levels significantly higher than the federal standards, as well as exposure to toxics, which can have immediate and detrimental health effects.

Of CARB's many goals, the air quality standards that need to be met in the next five years pose immediate challenges and will drive policies and the need for considerable, strategic investment to accelerate the transition to cleaner technologies beyond what would occur through natural fleet turnover. Attainment of the ozone standard in 2023 remains a challenge for the South Coast Air Basin. While some of the needed reductions will be achieved through regulatory measures included in the 2016 Strategy and related SIPs, reductions from federal measures and/or additional incentive funding are needed to achieve a majority of the remaining NOx reductions that are necessary to meet this standard.

[7] Based on 2019 monitored ozone and PM2.5 design values contoured over population by census tract

In the San Joaquin Valley, attainment of PM2.5 standards in 2024 and 2025 is the near-term challenge driving many policies. The *2018 Plan for the 1997, 2006, and 2012 PM2.5 Standards* and the *San Joaquin Valley Supplement to the 2016 State SIP Strategy* (Valley State SIP Strategy) included State commitments to achieve 32 tpd of NOx and 0.9 tpd of PM2.5 emissions reductions in the San Joaquin Valley beyond the existing emission controls. Almost 90 percent of the reductions needed to meet these PM2.5 standards will come from ongoing implementation of the existing control program, combined with regulatory measures identified in the Valley State SIP Strategy. Since deployment of cleaner technologies through new incentive funding will also be critical, CARB continues to look for innovative opportunities to reduce emissions in the San Joaquin Valley in the near-term.



Reducing exposure to air pollution for residents of low-income and disadvantaged communities throughout the State is a critical near-term driver. The passage of AB 617 and creation of CARB's *Community Air Protection Program* (CAPP) has given the State the opportunity to take a closer look at and dedicate targeted resources towards helping to reduce exposure to harmful pollutants in the State's most heavily-impacted communities. Under the direction of AB 617 and guidelines created under the CAPP, beginning in 2018, CARB annually considers low-income and disadvantaged communities to begin new monitoring programs and emission reduction programs. CERPs are developed through coordination between CARB, local air districts, and community groups, and set five and ten-year targets to reduce community exposure – the targets of current CERPs adopted by the Board begin in 2024, with many programs including a focus on the turnover of dirty mobile sources and their engines to zero-emission technologies, as sought by communities and their representatives.

In support of the goals of AB 617 and the CAPP, the Legislature has appropriated funding to support early actions to address localized air pollution through targeted incentive funding to deploy cleaner technologies in these communities, as well as grants to support community participation in the AB 617 process. Further, AB 617 includes new requirements for the accelerated retrofit of pollution controls on industrial sources, increased penalties, and greater transparency and availability of air quality and emissions data, which will help advance air pollution control efforts throughout the State. The legislation also requires the development of new resources that work together to support emissions reductions in communities, including a *Technology Clearinghouse* to be used to identify rules, regulations, technologies, or practices that could offer emissions or exposure reduction opportunities

within the selected community. Once complete, this tool will allow users to easily find existing rules and identify next generation technologies that are beyond existing regulatory requirements. CARB will prioritize adding sources that are of high importance to existing AB 617 community members to the system as it is developed.

To ensure clean transportation is available to all Californians, SB 350 directed CARB to study the barriers for low-income Californians to access clean transportation options, including those in disadvantaged communities, as well as recommendations on how to increase access. In February 2018, CARB released the Final Guidance Document – *Low-Income Barriers Study, Part B: Overcoming Barriers to Clean Transportation Access for Low-Income Residents* (SB 350 Barriers Report). CARB's SB 350 Barriers Report is an initial step in identifying the main barriers low-income residents, including those in disadvantaged and tribal communities, face in accessing clean transportation and mobility options. This effort, together with the CAPP, provide an opportunity to better integrate community, regional, and State-level programs to increase access to clean transportation and provide clean air for all Californians. Ongoing funding will be critical to support the CAPP and related programs and to provide the reductions needed in these impacted communities.

In 2006, California's first GHG reduction target was established under the Assembly Bill 32,[8] the *Global Warming Solutions Act of 2006*. AB 32 created a comprehensive, multi-year process to reduce GHG emissions in California and required CARB to develop a Climate Change Scoping Plan. The first Climate Change Scoping Plan, completed in 2008, described California's approach to achieving the goal of reducing GHG emissions to 1990 levels by 2020. In 2016, four years ahead of schedule, California emissions fell below the 1990 levels of 431 million metric tons carbon dioxide equivalent. Going forward, the next GHG reduction target is a 40 percent reduction from 1990 levels by 2030 as codified in SB 32. The 2017 Climate Change Scoping Plan demonstrated how California will meet the 2030 target and showed that there are substantial emissions reductions still needed. CARB will be working to develop the 2022 Scoping Plan Update over the coming year, which will map out the path to achieving Statewide carbon neutrality in 2045, and the 2050 goal of 80 percent reduction in GHG emissions below 1990 levels. Additionally, the 2022 Scoping Plan Update will be looking to move the State away from the combustion of fossil fuels as much as possible. We know that the transition of the transportation sector to zero-emission vehicles, and more accessible, efficient mobility, will be major factors in meeting these and other future climate goals.

What We Are Learning from the COVID-19 Lockdown

The COVID-19 pandemic and the resulting health and economic crisis have had drastic and wide-ranging impacts on the lives, livelihoods, and behaviors of people around the world. To

[8] Núñez and Pavley, Chapter 488, Statutes of 2006

date, it has taken millions of lives worldwide, and has had a direct impact on countless more. As it pertains to air quality, this pandemic has reemphasized the need to reduce emissions and achieve cleaner air, as air pollution may be a key factor in increasing the vulnerability of individuals to contracting COVID-19, as well as increasing the severity of illness and mortality risk from the virus.[9] CARB is currently funding additional studies to look at the connection between air quality and health impacts of COVID-19.

The measures put into place to slow the spread of COVID-19 resulted in significant changes in human activity that present opportunities to evaluate the real-world effect of those changes on air quality. Most notable are the short-term reductions in both heavy-duty and light-duty VMT across the State's highways and local roads, and the resulting emission reductions. In California, VMT fell to its lowest point in early- to mid-April, with an approximately 25 percent reduction in heavy-duty VMT and 50 to 60 percent reduction in light-duty VMT. Since that time, both heavy-duty and light-duty VMT have steadily increased, with heavy-duty VMT returning to pre-lockdown levels in early June. However, the reductions in VMT in April and May provide an opportunity to test the real-world implications of emissions reductions associated with the on-road mobile sector. Such analysis, though, is complicated by several factors:

1. There is a natural, seasonal reduction in pollution levels (e.g., NOx and carbon monoxide) from March to May, which occurs every year as winter transitions to spring, and separating meteorological effects from VMT-related emissions changes is non-trivial;
2. The largest reductions in heavy-duty VMT occurred outside of the peak ozone season, and ozone chemical regimes can change from spring to summer due to seasonal variations in emission sources including biogenic emissions; and
3. The largest reductions in VMT occurred over a relatively short time period (less than two months), making analysis of impacts more difficult.

CARB staff are working on finalizing an analysis of the effect of reduced VMT on ambient pollution levels and putting those findings in the context of long-term ozone trends and the State's emission control strategy moving forward. Findings will be published in a peer reviewed scientific journal. While the 2020 Strategy is a long-term planning document and COVID-19 stay-at-home orders and related closures are temporary measures, there is potential for changes made during this time to have far-reaching implications for transportation mode choice, shared mobility, vehicle choice, and VMT into the future.

Before the COVID-19 pandemic, Californians were continuing to drive more, and carpool less to work. Auto ownership was increasing and transit ridership was falling across California, and

[9] Petroni et al (2020). Hazardous air pollutant exposure as a contributing factor to COVID-19 mortality in the United States. Environ. Res. Lett. 15 0940a9; Liang, Donghai et al. "Urban Air Pollution May Enhance COVID-19 Case-Fatality and Mortality Rates in the United States." medRxiv : the preprint server for health sciences 2020.05.04.20090746. 7 May. 2020, doi:10.1101/2020.05.04.20090746. Preprint.

there continues to be a relatively small percentage of people that walk and bike to work.[10] Mobility in California dropped dramatically after shelter-in-place orders were enacted early in the COVID-19 pandemic, as people and organizations (including CARB) successfully operationalized widespread teleworking, and continued teleworking is a promising source of commute VMT reduction into the future. However, telework is not a panacea for VMT reduction – only a subset of jobs can support a telework arrangement. Essential workers largely cannot telework, many of whom are lower income or depend on transit services. Transit service has been decimated by fears raised by the pandemic, and we must provide viable modes of transportation that can support our essential workforce.

Mobility and VMT rebounded as mandates eased, but vehicle travel in California became more distributed throughout the day and the roadway network was not as congested in many cities. We have experienced the profound impacts that getting cars off the road has on reducing congestion, especially during peak commute times. We know building more roads only leads to more congestion[11] and now we have seen a future where we can be more efficient with, and prioritize fixing and maintaining, our existing rights-of-way. Total light-duty VMT in California will continue to grow as the State's population grows. As discussed in more detail later, per capita VMT growth must be reduced but continue to accommodate essential travel. Our roadway network was extremely congested prior to the pandemic, and as travel restrictions ease, it is becoming so again. It's critical that we provide viable alternatives to single occupancy vehicle travel as we move forward, with 10 million vehicles expected to be added to our roadways in coming decades.

Health Impacts

Despite decades of progress in improving air quality, large areas of California still suffer some of the worst air quality in the nation. Mobile source emissions contribute to a wide range of heart and lung illnesses, chronic health conditions, increased cancer rates, and premature death. Every year, over 5,000 premature deaths and hundreds of illnesses and emergency room visits for respiratory and cardiovascular disease in California are linked to PM2.5

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[10] CARB. 2018. *2018 PROGRESS REPORT: California's Sustainable Communities and Climate Protection Act.* Available: *https://ww2.arb.ca.gov/sites/default/files/2018-11/Final2018Report_SB150_112618_02_Report.pdf*

[11] S. Handy, M. Boarnet. 2014. *Impact of Highway Capacity and Induced Travel on Passenger Vehicle Use and Greenhouse Gas Emissions. https://ww2.arb.ca.gov/sites/default/files/2020-06/Impact_of_Highway_Capacity_and_Induced_Travel_on_Passenger_Vehicle_Use_and_Greenhouse_Gas_Emissions_Policy_Brief.pdf*

pollution, of which more than half is produced by mobile sources. [12] Recent research demonstrates that fine particulate pollution impacts not only the heart and respiratory system, but also brain health and adverse birth outcomes.[13] During the COVID-19 pandemic, we have learned that air pollution may be a key factor in increasing the vulnerability of individuals to contracting COVID-19, as well as increasing mortality risk from the virus, and the severity of illness in people suffering from COVID-19.[14] Moreover, for the millions of California residents living in low-income and disadvantaged communities and experiencing disproportionate levels of negative health impacts from air pollution,[15] actions to reduce fossil fuel combustion and move to cleaner power sources are even more important.

Health Impacts from Mobile Source Emissions

Fossil fuel combustion from cars, trucks, buses, and on- and off-road equipment emits criteria air pollutants and their precursors, including NOx and oxides of sulfur (SOx) emissions. While NOx and SOx emissions are harmful in themselves, NOx is also a precursor to ozone, which can cause irritation and damage lung tissue, worsen asthma and chronic illnesses including obstructive pulmonary disease and reduce lung function. [16] Studies have linked short-term ozone exposure with increased risk of death.[17]

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[12] CARB. (2016). Mobile Source Strategy. *https://ww2.arb.ca.gov/resources/documents/2016-state-strategy-state-implementation-plan-federal-ozone-and-pm25-standards*

[13] USEPA. (2019a). Integrated Science Assessment for Ozone and Related Photochemical Oxidants (External Review Draft). Retrieved from *https://cfpub.epa.gov/ncea/isa/recordisplay.cfm?deid=344670*.
U.S. EPA (2019b). Policy Assessment for the Review of the National Ambient Air Quality Standards for Particulate Matter, External Review Draft

[14] Petroni et al (2020). Hazardous air pollutant exposure as a contributing factor to COVID-19 mortality in the United States. Environ. Res. Lett. 15 0940a9;
Liang, Donghai et al. "Urban Air Pollution May Enhance COVID-19 Case-Fatality and Mortality Rates in the United States." medRxiv : the preprint server for health sciences 2020.05.04.20090746. 7 May. 2020, doi:10.1101/2020.05.04.20090746. Preprint.

[15] American Lung Association. (2020). State of the Air; Union of Concerned Scientists, U. (2019). Inequitable Exposure to Air Pollution from Vehicles in California (2019); Cushing et al. (2015). Racial/ethnic disparities in cumulative environmental health impacts in California: evidence from a statewide environmental justice screening tool (CalEnviroScreen 1.1). American journal of public health, 105(11), 2341-2348.

[16] U.S. EPA (2019b). Policy Assessment for the Review of the National Ambient Air Quality Standards for Particulate Matter, External Review Draft.

[17] Ibid.

In addition to contributing to ozone, the biggest impact on health from NOx and SOx emissions comes when they are converted to PM2.5 in the atmosphere. PM2.5 pollution contributes to more fatalities than other air pollutants, and can lodge deep in the lungs or pass through the lungs to enter the blood stream and affect the heart, brain, and other organs.[18] Short-term exposure to PM2.5 pollution is associated with increased hospitalizations and emergency room visits for heart and lung illnesses, and can lead to premature death.[19] Adverse health effects from long-term exposure to PM2.5 pollution include increased risk of heart attacks and heart disease, impaired lung development in children, the development and exacerbation of asthma, and premature death.[20] Other possible impacts from PM2.5 exposure that are being investigated include low birth weight and impacts to the brain.[21]

Diesel engines emit a complex mixture of air pollutants, including both gaseous and solid material. The solid material in diesel exhaust is known as diesel particulate matter (DPM or diesel PM). More than 90 percent of DPM is less than 1 µm in diameter (about 1/70th the diameter of a human hair), and thus is a subset of PM2.5.[22] DPM is typically composed of carbon particles ("soot", also called black carbon) and numerous organic compounds, including over 40 known cancer-causing organic substances such as benzene and formaldehyde. In 1998, CARB identified DPM as a toxic air contaminant which has been linked to increased cancer risk, respiratory and cardiac illnesses and premature deaths.[23] CARB estimates that about 70 percent of total known cancer risk related to air toxics in California is attributable to DPM.[24] Diesel exhaust also contains gaseous pollutants, including volatile organic

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[18] U.S. EPA. (2019a). Integrated Science Assessment for Ozone and Related Photochemical Oxidants (External Review Draft).

[19] Ibid.

[20] Ibid.

[21] Boothe, V. L., Shendell, D. G. (2008). Potential health effects associated with residential proximity to freeways and primary roads: review of scientific literature, 1999–2006. Journal of Environmental Health, 70(8), 33-41.; Wang et al (2020). Traffic-related Metrics and Adverse Birth Outcomes: A Systematic Review and Meta-analysis. Environmental Research, 109752.
Woods et al (2017). The influence of the built environment on adverse birth outcomes. Journal of Neonatal-Perinatal Medicine, 10(3), 233-248.
CARB (2018) Air Pollution and the Brain *https://ww2.arb.ca.gov/resources/fact-sheets/air-pollution-and-brain*

[22] CARB (2020). Overview: Diesel Exhaust & Health *https://ww2.arb.ca.gov/resources/overview-diesel-exhaust-and-health*

[23] Ibid.

[24] Ibid.

compounds and NOx that lead to the formation of PM2.5 and ozone. Most major sources of diesel emissions, such as ships, trains, and trucks, operate in and around ports, rail yards, and heavily traveled roadways, which are often located near highly-populated and disadvantaged communities.

Health Impacts of Climate Change

As stated earlier, mobile sources are the largest contributor of GHG emissions in California; on- and off-road vehicles produce GHG emissions from burning gasoline and diesel, contributing to almost 40 percent of the total State GHG emissions. Diesel engines also emit black carbon, a short lived climate pollutant with over 1,000 times the climate forcing potential of carbon dioxide. Several recent summaries and reports discuss in detail the ways that climate change can impact human health[25] including increased smog formation;[26] a lengthened pollen season; more frequent and severe wildfires;[27] an increased number of extreme heat days[28] which could result in more heat-related sickness and deaths;[29] more pronounced drought extremes;[30] more frequent and severe extreme precipitation events leading to severe flooding;[31] and an increased prevalence of infectious diseases.[32] Climate change is already taking a toll on human health, proving in many ways that taking action to reduce greenhouse gas emissions is urgently needed.

Public Process for the 2020 Mobile Source Strategy

CARB staff has engaged in a robust public process throughout the development of the 2020 Strategy. Staff first invited public and stakeholder participation in March 2020 with a public webinar at which preliminary scenarios, and the expected direction of the 2020 Strategy were presented. Subsequent to that, staff presented the preliminary scenarios and concepts to the Board at an *April 23, 2020* public hearing to obtain feedback from Board members and allow for additional public input.

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[25] USGCRP. (2018). Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II. U.S. Global Change Research Program; World Health Organization. (2003). Climate change and human health: risks and responses: World Health Organization; NRDC. (2019). Climate Change and Health in California

[26] Kleeman et al. (2010). Climate change impact on air quality in California: California Environmental Protection Agency, Air Resources Board

[27] Singleton et al. (2019). Increasing trends in high-severity fire in the southwestern USA from 1984 to 2015

[28] Milanes, C. (2011). Indicators of Climate Change in California

[29] CARB (2020). Health & Air Pollution. Retrieved from *https://ww2.arb.ca.gov/resources/health-air-pollution*

[30] Mann, M. E., & Gleick, P. H. (2015). Climate change and California drought in the 21st century

[31] Swain et al. (2018). Increasing precipitation volatility in twenty-first-century California; Dettinger, M. (2011). Climate change, atmospheric rivers, and floods in California–a multimodel analysis of storm frequency and magnitude changes; Solomon et al. (2006). Airborne mold and endotoxin concentrations in New Orleans, Louisiana, after flooding, October through November 2005

[32] Lindgren et al. (2012). Monitoring EU emerging infectious disease risk due to climate change

The scenario planning tools, META and Vision, are used to evaluate scenarios with varying assumptions about potential technology and fuel mixes, and explore different rates at which those technologies could become widely used. Staff released a Beta version of META on August 5, 2020, and a Draft version of META alongside on-road light-duty vehicle assumptions from Vision on October 2, 2020, to allow the public and stakeholders to review and provide feedback on detailed assumptions for, and visualization of, the scenarios in the 2020 Strategy.

Further, staff released the *Workshop Discussion Draft 2020 Mobile Source Strategy* on September 30, 2020 with a request for public comment, and held a second public webinar on October 7, 2020. The Workshop Discussion Draft presented the draft scenarios, concepts, and potential reductions as envisioned at that time, and allowed for the public and stakeholders to review every facet of the 2020 Strategy for the first time. Public engagement at the October webinar, as well as the March webinar, was high with more than 300 participants attending each, and staff answered questions through the end of the allotted time and provided additional written responses on the CARB webpage after each webinar.

On November 24, 2020, staff released the *Draft 2020 Mobile Source Strategy* in advance of providing a second informational update to the Board at the December public hearing. At that meeting, the Board directed staff to take more time to develop certain aspects of the 2020 Strategy, before returning to the Board for consideration. Specifically, direction was given to expand in the 2020 Strategy on near-term efforts focused on meeting SIP targets and providing benefits in disadvantaged communities. In addition, the Board directed staff to accelerate the adoption and implementation of control programs, with a focus on targeting benefits in low-income and disadvantaged communities where possible; to include an estimation of technology costs; and to add to the discussion on VMT reduction concepts, while considering how we can better partner with locals and other agencies to tackle housing and land use, and to support transit and biking options.

CARB staff incorporated the Board's direction into the *Revised Draft 2020 Mobile Source Strategy*, released on April 23, 2021. Chapter 2 was added to discuss the actions that CARB has taken and current efforts to ensure a focus on environmental justice and equity in CARB's programs into the future. Staff also added Chapter 4 to provide detail on CARB's newly-identified and ongoing efforts to achieve emissions reductions in the next five to ten years, including measures from the 2016 Mobile Source Strategy and associated 2016 State SIP Strategy for which implementation is ongoing. Staff took comments on the Revised Draft at a public webinar on May 6, 2021 and through a written comment period, and have incorporated feedback as appropriate into this Proposed 2020 Strategy.

In addition to the formal events and releases specific to the 2020 Strategy, staff engaged with the public and stakeholders through a variety of other venues. Updates on the 2020 Strategy were presented at various working groups for other CARB programs; staff participated in stakeholder-facilitated calls with industry and other groups to answer

questions on the 2020 Strategy and scenarios; and throughout the process, staff has engaged with interested parties through individual phone and email correspondence. As we move forward, staff will be continuing to directly seek input and recommendations from community groups both as we finalize the 2020 Strategy, and on the forthcoming planning documents that will translate the concepts contained here into measures and legally-enforceable commitments.

The public process for the programmatic concepts within the 2020 Strategy will continue into the future as these concepts are translated into formal measures in the forthcoming State SIP Strategy and other CARB planning documents to be released over the next few years, and further developed into regulations through formal rulemaking processes. In addition, CEQA analyses will be undertaken as a part of the development of the next State SIP Strategy and other CARB planning documents, as well as for each concept if it is pursued and developed into a regulatory action to be brought to the Board.

Chapter 2 – Prioritizing Environmental Justice & Targeting Benefits in Communities of Concern

The regulatory and programmatic concepts in the 2020 Strategy, especially those targeting the freight sector, have significant potential to reduce emissions and exposure in low-income and disadvantaged communities. While the 2020 Strategy seeks rapid transition to 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 combustion emissions.

The *California Environmental Protection Agency* (CalEPA) defines "disadvantaged communities" as the top 25 percent most impacted census tracts in the State, as identified by the California Communities Environmental Health Screening Tool, known as *CalEnviroScreen*. Together with low-income communities and low-income households, disadvantaged communities are described in California as "priority populations." CalEnviroScreen is an important tool used to evaluate and quantify the environmental and health disparities experienced by communities in California. Developed by the California Office of Environmental Health Hazard Assessment, CalEnviroScreen uses environmental, health, and socioeconomic information to produce mapped scores for every census tract in the state.

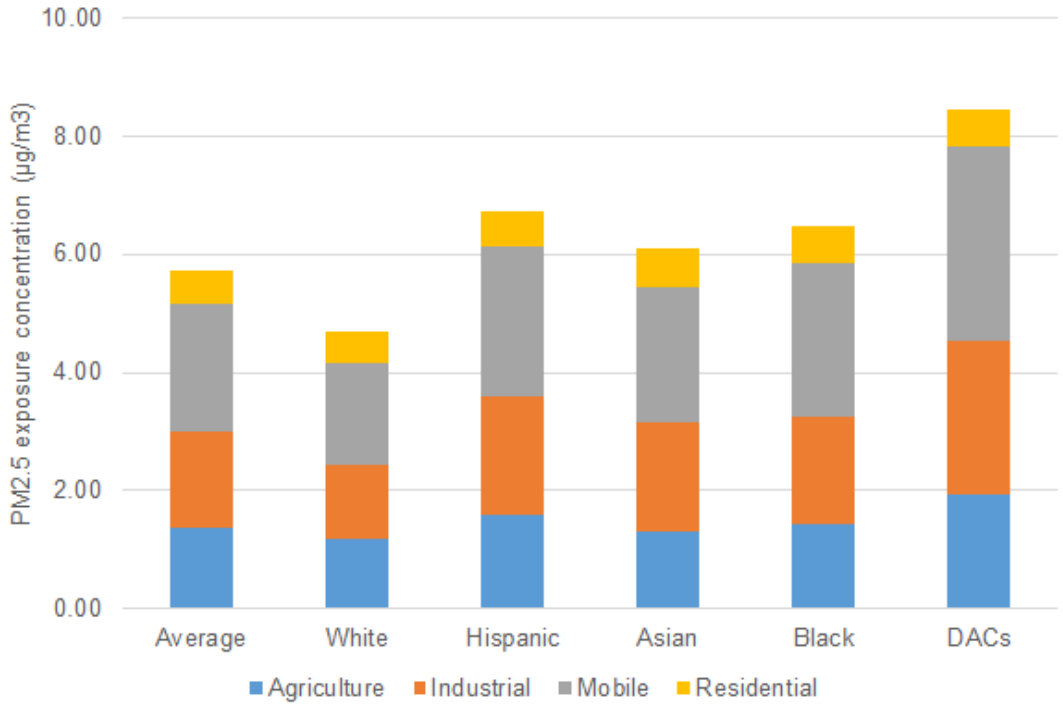
In discussing ways to target benefits in the communities most disproportionately affected by air pollution, it is important to note that certain communities experience significantly higher levels of many types of air pollutants. Due to their formation processes coupled with geographical and meteorological impacts, criteria air pollutants including PM2.5 and ozone are known as regional pollutants and are often at their highest levels in a community that is many miles from the main sources of the emissions of the relevant precursors. In contrast, toxic air contaminants (TACs or toxics) are directly emitted pollutants and, as such, can have the most detrimental impacts on the people and communities nearest the pollution sources. Toxics are, by definition, 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 – it is for these reasons that CARB has been working for over 35 years to control emissions of TACs. That said, both regional and near-source pollutants can have serious detrimental health impacts and are important to control, and the concepts in the 2020 Strategy address both.

Environmental Justice and Pollution Exposure Disparities

Low-income and disadvantaged communities have long faced disproportionate burdens from exposure to air pollution. Research shows large disparities in exposure to pollution between white and non-white populations in California, and between disadvantaged communities and other communities, with Black and Latino populations experiencing significantly greater air

pollution impacts than white populations. Mobile source pollution shows some of the highest disparities; a CARB-funded study indicated that on average, mobile sources account for over 30 percent of total PM2.5 exposures.[33] Figure 2 compares the contributions of several top PM2.5 sources to average PM2.5 exposure concentration by race and in disadvantaged communities. This figure shows that mobile sources are the largest sources of pollution exposure disparity for Black populations and disadvantaged community residents, when compared to the average population in California. Specifically, mobile sources accounted for 45 percent of exposure disparity for the Black population, and 37 percent of exposure disparity for people in disadvantaged communities.

Figure 2 – Top Sources of PM2.5 and their Contribution to PM2.5 Exposures by Race and in Disadvantaged Communities



Communities located near major roadways are also at increased risk of asthma attacks and other respiratory and cardiac effects; often, these communities are low-income communities and communities of color. Studies consistently show that mobile source pollution exposure near major roadways contributes to and exacerbates asthma, impairs lung function, and increases cardiovascular mortality.[34] The exposure to mobile sources' mixture of gaseous and particulate pollutants (including PM, NOx, and benzene) is associated with higher rates of

[33] Apte et al (2019). A Method to Prioritize Sources for Reducing High PM2.5 Exposures in Environmental Justice Communities in California. CARB Research Contract Number 17RD006

[34] Hot Spot Pollution, 1052 and 1057.

heart attacks, strokes, lung cancer, autism, and dementia.[35] Individuals living in communities located near ports and freight hubs are also subject to higher cancer risks than surrounding communities.[36]

People living in areas near freight and other significant sources, and those who work near diesel engines, are at risk of exposure to high quantities of diesel emission fumes.[37] Prolonged exposure to diesel emissions over many years is associated with an increase in workers' risk of cardiovascular, cardiopulmonary and respiratory disease, and lung cancer.[38] The use of diesel-powered on- and off-road equipment can be a major source of exposure to toxic diesel exhaust for workers in a wide range of occupations including agriculture, construction, energy extraction, mining, rail, shipping, transport/logistics, tunneling, vehicle repair, and warehousing.

Children living in these communities are also unduly burdened by adverse health impacts. Results from a groundbreaking, long-term study demonstrated that particle pollution may significantly reduce lung function growth in children,[39] and indicates these effects are likely permanent.[40] Additionally, increased exposure to vehicular traffic pollution was associated with a number of adverse childhood health impacts, including slower lung development,[41]

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[35] USC Environmental Health Centers. (2018). Living Near Busy Roads or Traffic Pollution.

[36] South Coast AQMD (2015). Multiple Air Toxics Exposure Study in the South Coast Air Basin

[37] Garshick et al. (2012). Lung cancer and elemental carbon exposure in trucking industry workers; Pronk et al. (2009). Occupational exposure to diesel engine exhaust: a literature review

[38] HEI. (1995). Diesel Exhaust: A Critical Analysis of Emissions, Exposure and Health Effects. A Special Report of the Institute's Diesel Working Group. Health Effects Institute; Garshick et al. (2008). Lung cancer and vehicle exhaust in trucking industry workers; Brown-McCammon, J. (1988). NIOSH Current Intelligence Bulletin 50-carcinogenic effects of exposure to diesel exhaust; Mauderly, J. L. (1992). Diesel Exhaust, Chapter 5, Environmental Toxicants: Human Exposures and Their Health Effects; Wade, J. F., 3rd, & Newman, L. S. (1993). Diesel asthma. Reactive airways disease following overexposure to locomotive exhaust

[39] Peters et al. (1999). A study of twelve Southern California communities with differing levels and types of air pollution: II. Effects on pulmonary function. American journal of respiratory and critical care medicine, 159(3), 768-775.; Avol, E. L et al. (2001). Respiratory effects of relocating to areas of differing air pollution levels. American journal of respiratory and critical care medicine, 164(11), 2067-2072; Gauderman et al. (2002). Association between air pollution and lung function growth in southern California children: results from a second cohort. Am J Respir Crit Care Med, 166(1), 76-84. doi:10.1164/rccm.2111021

[40] Gauderman et al. (2004). The effect of air pollution on lung development from 10 to 18 years of age. New England Journal of Medicine, 351(11), 1057-1067

[41] Gauderman et al. (2007). Effect of exposure to traffic on lung development from 10 to 18 years of age: a cohort study. The Lancet, 369(9561), 571-577

increased symptoms and medication use in asthmatic children,[42] and even increases in the development of asthma in children.[43]

Historical Inequities

Although it has not always been acknowledged, pronounced inequities have been experienced by minority groups and have permeated society in the United States and within California throughout our history. As just described, certain communities continue to experience environmental and health inequities from elevated levels of toxics, criteria pollutants, and secondary impacts of climate change. Communities near ports, rail yards, warehouses, and freeways are often low-income and disproportionately communities of color, and they experience a higher concentration of air pollution than other areas due to emissions from mobile sources such as cars, trucks, locomotives, and ships. Many of the same communities also experience pollution impacts from large industrial facilities such as oil refineries. Proximity to smaller sources like chrome platers, metal recycling facilities, oil and gas operations, agricultural burning, and fugitive dust likewise contribute to localized air toxics impacts in many communities across the State.

While discussing the negative impacts from air pollution on low-income and disadvantaged communities, it must be acknowledged that one of the primary causes of the disparities that many communities experience today is the way that land use decisions have historically been, and are still often today, made. This has led to a place where many Californians are too often left with a choice between spending significant time and money commuting long distances, or living in areas that are exposed to unhealthy levels of numerous pollutants, or both. Where we put transportation and housing also imposes and often reinforces long-standing racial and economic injustices by placing a disproportionate burden on low-income Californians, who end up spending the highest proportion of their wages on a place to live and travelling. As is discussed further in Chapter 6, it is imperative that California rethink transportation and housing.

CARB's Programs and Progress in Priority Communities

CARB has been working for over 50 years to reduce exposure to air pollution in California, and a key element for more than 35 years has been the program to control TACs. Several pieces of legislation created the foundation for California's air toxics program. The program started in 1983 with the passage of Assembly Bill 1807 (Tanner, Statutes of 1983), which requires CARB to identify and control toxic air pollutants. Since then, CARB has identified

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[42] Gauderman et al. (2005). Childhood asthma and exposure to traffic and nitrogen dioxide. Epidemiology, 737-743; McConnell et al. (2006). Traffic, susceptibility, and childhood asthma. Environmental Health Perspectives, 114(5), 766-772

[43] McConnell et al. (2010). Childhood incident asthma and traffic-related air pollution at home and school. Environmental Health Perspectives, 118(7), 1021-1026. doi:10.1289/ehp.0901232

more than 200 toxic air pollutants and has adopted and implemented 26 airborne toxic control measures, or ATCMs.

The passage of the Hot Spots Information and Assessment Act (Assembly Bill 2588) in 1988 created a program that requires commercial facilities to report their air toxics emissions, identify facilities that pose significant health risks and to reduce their emissions. Air toxics that have been identified and controlled include numerous substances that are primarily emitted from stationary sources like dry cleaners and chrome platers. Two notable toxics historically emitted by mobile sources are benzene in gasoline and diesel PM from cars and trucks.

CARB identified diesel PM as a TAC in August 1998. Following its identification pursuant to the AB 1807, CARB determined the need and degree to further control diesel PM. With the participation of local air districts, industry, and interested public, CARB prepared a risk management guidance document and the *Diesel Risk Reduction Plan* to inform the regulatory process and achieve further diesel PM emission reductions. The reduction plan proposed new regulatory standards for all new on-road, off-road, and stationary diesel-fueled engines and vehicles to reduce diesel PM emissions by about 90 percent overall from 2000 levels; new retrofit requirements for existing on-road, off-road, and stationary diesel-fueled engines and vehicles where determined to be technically feasible and cost-effective; and new Phase 2 diesel fuel regulations to reduce the sulfur content levels of diesel fuel to no more than 15 ppm to provide the quality of diesel fuel needed by the advanced diesel PM emission controls. Since the Diesel Risk Reduction Plan was completed in 2000, CARB has adopted ATCMs and regulations in alignment with the plan, including the landmark *Truck and Bus Regulation*, and has achieved a statewide reduction in ambient diesel PM levels of over 70 percent from 2000 levels.

In an effort to establish CARB's commitment to prioritizing environmental justice and integrating it into all programs, the Board adopted the *Policies and Actions for Environmental Justice* in December 2001. This established a framework for incorporating environmental justice into CARB's programs consistent with the directives of State law, and identified policies intended to promote the fair treatment of all Californians and cover the full spectrum of CARB activities. Underlying the policies was a recognition that meaningful engagement with community members as we carry out our activities is necessary. People should have the best possible information about the air they breathe and what is being done to reduce unhealthful air pollution in their communities.

Although CARB has been working towards environmental justice for decades, it was through bills passed over the last 5 years that we were given a renewed opportunity to focus and engage directly in community-level planning to benefit priority populations. As directed by SB 350, CARB studied the barriers for low-income Californians to access clean transportation options including those in disadvantaged communities. In February 2018, CARB released the SB 350 Barriers Report which was an initial step in identifying the main barriers that

low-income residents, including those in disadvantaged and tribal communities, face in accessing clean transportation and mobility options.

The passage of AB 617 and creation of CARB's CAPP has given the State the opportunity to take a closer look at and dedicated targeted resources towards helping to reduce exposure to harmful pollutants in the State's most heavily-impacted communities. Under the direction of AB 617 and guidelines created under the CAPP, beginning in 2018, CARB annually considers low-income and disadvantaged communities to begin new monitoring programs and emission reduction programs. CERPs are developed through coordination between CARB, local air districts, and community groups, and set five and ten-year targets to reduce community exposure – the targets of current CERPs adopted by the Board begin in 2024, with many programs including a focus on the turnover of dirty mobile sources and their engines to zero-emission technologies, as sought by communities and their representatives.

In support of the goals of AB 617 and the CAPP, the Legislature has appropriated funding to support early actions to address localized air pollution through targeted incentive funding to deploy cleaner technologies in these communities, as well as grants to support community participation in the AB 617 process. Further, AB 617 includes new requirements for the accelerated retrofit of pollution controls on industrial sources, increased penalties, and greater transparency and availability of air quality and emissions data, which will help advance air pollution control efforts throughout the State. CAPP, together with efforts under SB 350, provide an opportunity to better integrate community, regional, and State-level programs to increase access to clean transportation and provide clean air for disproportionately impacted Californians.

In addition to funding provided through the CAPP, CARB funds a suite of *projects* through the Low Carbon Transportation Program that prioritize equity by providing mobility and advanced technology transportation access to people in low-income and disadvantaged communities. *Clean Cars 4 All* is a program that focuses on providing incentives to lower-income California drivers to scrap their older, high-polluting car and replace it with a zero- or near zero-emission replacement. The *Financing Assistance for Lower-Income Consumers Program*, otherwise known as the Clean Vehicle Assistance Program, and local financing assistance project in the Bay Area, helps lower-income residents finance used or new conventional hybrid electric, plug-in hybrid electric, battery electric, or fuel cell electric vehicles. And finally, the *Clean Mobility Voucher Pilot Program* project supports zero-emission car-sharing, ride-sharing, bike-sharing, and innovative transit services for low-income and disadvantaged communities. All of these projects are specifically designed to benefit members of California's communities most vulnerable to the effects of climate change and poor air quality, and support SB 350 and the State's equity goals.

Other significant factors in CARB's ability to target benefits in disadvantaged communities are the investment minimums for GGRF created under *Assembly Bill 1550*.[44] AB 1550 requires at least 25 percent of California Climate Investment funds go to projects within and benefitting disadvantaged communities, and at least an additional 10 percent is for low-income households or communities. CARB and other State agencies are continually striving to go beyond the requirements of AB 1550, with 57 percent of projects implemented using California Climate Investment funds to date benefiting California's disadvantaged communities and low-income communities and households.[45] Because mobile sources are such a significant source of emissions throughout the State, much of California Climate Investment funding allocated to CARB, including a considerable portion of CAPP funds, is used to incentivize development and deployment of cleaner mobile source technology.

Alongside the planning efforts and specific incentive funding requirements, CARB has recently adopted many regulations, and is in the process of developing others described later in this document, to control emissions from sources that contribute the majority of emissions in many priority communities. These include regulations to control emissions from ocean-going vessels at berth and a number to control emissions from heavy-duty diesel trucks and buses.

Recommendations from Community and EJ Groups

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 environmental justice advocates is now a 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, allows CARB to better identify the ways in which we can reduce emissions and exposure in those areas, and promote environmental justice through our programs and policies.

One of the first direct and significant efforts to engage with environmental justice advocates was borne out of the development of the Climate Change Scoping Plan. AB 32 directed CARB to convene an environmental justice advisory committee (EJAC) to advise the Board in policies and programs involved in implementing AB 32. The EJAC is comprised of representatives from communities in the State with the most significant exposure to air pollution, including, but not limited to, communities with minority populations or low-income populations, or both. CARB reconvenes new EJACs for the development of each updated Scoping Plan, and this process is currently underway for the 2022 Scoping Plan Update.

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[44] Gomez, Chapter 369, Statutes of 2016

[45] 2020 California Climate Investments Annual Report
https://ww2.arb.ca.gov/sites/default/files/classic//cc/capandtrade/auctionproceeds/2020_cci_annual_report.pdf

In addition, communities have been actively engaged as a part of the rulemaking process for many regulations; one such regulatory effort was the 2019 amendments to the Low Carbon Fuel Standard (LCFS). In alignment with additional comments received throughout the regulatory process, provisions were added within the LCFS regulation that require regulated entities to, in specified situations, use credits to support transportation electrification primarily serving low-income and disadvantaged communities, rural areas, or low-income individuals. Additionally, the regulatory amendments added provisions that promote coordination with local environmental justice advocates and local community-based organizations to develop and implement projects that promote transportation electrification in low-income and disadvantaged communities.

Since 2017, CARB has engaged directly with members and representatives of priority populations and their community representatives at an unprecedented level through the CAPP, and through other planning and regulatory processes in part due to new outreach and engagement opportunities created through the CAPP process. Community groups have the most direct stake in the programs that will be implemented in their areas, and as such, have vital perspectives and recommendations for ways that such programs can achieve the most benefits.

With the Revised Draft 2020 Strategy, CARB requested input and recommendations from community groups, and we will continue to do so as we finalize the 2020 Strategy, and progress in the development process to translate the concepts contained here into measures and legally-enforceable commitments in the State SIP Strategy, and incorporate the concepts into the 2022 Scoping Plan Update and CERPs. As with all ongoing and future planning processes across CARB, we will strive to reflect priorities of community members as we move forward in the process to develop the regulatory and programmatic concepts.

Looking forward – Prioritizing Benefits in CARB's Programs

It is thanks to the recommendations from community groups and environmental justice advocates over the last 20 years that have directed CARB staff on ways that our programs can provide direct and sustained benefits to low-income and disadvantaged communities in California. That said, it remains a challenge to incorporate immediate actions into CARB regulations and programs. CARB staff recognizes that a considerable amount of work remains to realize environmental justice and racial equity, and continues to work toward those goals.

Within the 2020 Strategy, there are many programmatic concepts that have the potential to significantly reduce emissions in low-income and disadvantaged communities, as well as promote equity across the State. These concepts that could provide benefits to priority communities are outlined in Table 2.

Table 2 – 2020 Strategy Concepts Providing Benefits in Priority Communities

Type of Community	Source	Strategy Concepts
All (especially those near heavily traveled roads)	Cars	• More aggressive zero-emission sales requirements and strengthened pollutant controls for gasoline and diesel engines starting in 2026 • Vehicle Miles Traveled reduction through increased access to alternative mobility options such as walking, bicycling, transit, and equitably addressing land use issues through accelerated infill housing development and other means
	Trucks	• Accelerate the transition of California truck fleets to zero-emission technology starting in 2023 through both manufacturer and fleet requirements • Clean combustion engines starting in 2024 along with a smog check program for heavy-duty trucks and buses to ensure clean in-use operation starting in 2023
Near-Port	Drayage Trucks	• Starting 2023 only zero-emission trucks can be added to drayage truck registry with a requirement for all drayage trucks to be zero-emission by 2035
	Ocean-Going Vessels	• Require cleanest vessel visits to California ports starting in 2023 • Introduce cleaner marine engine standards (require federal and international actions) in late 2020s
	Commercial Harbor Craft	• Replace older and dirtier vessels with cleanest vessels by 2031 • Renewable diesel required for all vessels starting in 2023 • Zero-emission or hybrid technology requirements for certain vessel types like ferries and excursions
	Cargo Handling Equipment	• Full transition to zero-emission equipment starting in 2026 at ports and railyards

Type of Community	Source	Strategy Concepts
Commercial / Industrial & Warehouse	Small Off-Road Equip, Forklifts, Transport Refrigeration Units	• Full transition to zero-emission equipment starting in 2024 • 100% of lawn & garden and light commercial equipment (e.g., pressure washers) sales being zero-emission starting 2024 • Full transition to zero-emission transport refrigeration unit (TRU) by 2033
	Locomotives	• Replace old locomotive with cleanest ones starting in 2024 • Limit idling time and remanufacturing to reduce in-use emissions in 2030 • Introduce cleaner locomotive engines (U.S. EPA action needed) in late 2020s
	Construction, Industrial & Mining	• Replace older and dirtier equipment with cleanest ones by 2033 • Cleaner off-road engine emission standards in 2027 • Zero-emission and hybrid requirements in late 2020s
Other	Recreational Boats	• New emission standards along with electrification of small outboard and personal watercraft engines
	Aircraft	• Require cleaner aircrafts visiting California's airports • Improve aircraft operational efficiency during landing and takeoffs • Transition to zero-emission auxiliary power units that provide electrical power when the main engines are off

Each of these concepts will be further developed into concrete and enforceable measures as a part of the 2022 State SIP Strategy, as appropriate, and also incorporated into the 2022 Scoping Plan Update, CERPs, as well as other high-level planning efforts. Thus, in addition to a final Board hearing on the 2020 Strategy this summer, the concepts included here will see many opportunities for public input through the processes for these related planning documents and beyond that as they are further developed into regulations and other programs through formal rulemaking processes. As a part of the 2022 State SIP Strategy, CARB will be looking to identify opportunities for focusing implementation and reduction in priority communities.

Chapter 3 – Implementing the 2016 Mobile Source Strategy

The 2016 Strategy included a suite of ambitious emission reduction measures designed to help the State meet a number of challenging air quality standards, achieve GHG emission reductions, decrease health risks from transportation emissions, and reduce petroleum consumption through 2031.

Completed 2016 Mobile Source Strategy Measures

Since the 2016 Strategy, a number of measures have been developed into regulations and, where applicable, adopted by the Board. These measures are listed in Table 3.

Table 3 - Completed 2016 Mobile Source Strategy Measures

2016 Mobile Source Strategy Measure Title	Final Regulation / Project Title	Adopted / Completed
Innovative Technology Certification Flexibility	Regulation to Provide Certification Flexibility for Innovative Heavy-Duty Engines	October 2016
More Stringent National Locomotive Emission Standards (CARB Petition)	CARB Locomotive Emission Standards Petition to U.S. EPA for Rulemaking	April 2017
Medium and Heavy-Duty GHG Phase 2	GHG Emissions Standards for Medium- and Heavy-Duty Engines and Vehicles (Phase 2)	February 2018
Incentive Funding to Achieve Further Emission Reductions from On-Road Heavy-Duty Vehicles	South Coast On-Road Heavy-Duty Vehicle Incentive Measure	March 2018
Lower In-Use Emission Performance Level	• Amendments to the Heavy-Duty Vehicle Inspection Program and Periodic Smoke Inspection Program • Amendments to the Emission Control System Warranty Regulations and Maintenance Provisions • Heavy-Duty Omnibus Regulation	• May 2018 • June 2018 • August 2020
Advanced Clean Transit	Innovative Clean Transit Regulation	December 2018
Zero-Emission Airport Shuttle Buses	Zero-Emission Airport Shuttle Bus Regulation	June 2019
Last Mile Delivery	Advanced Clean Truck Regulation	June 2020
Low-NOx Engine Standard – California Action	Heavy-Duty Omnibus Regulation	August 2020

2016 Mobile Source Strategy Measure Title	Final Regulation / Project Title	Adopted / Completed
At-Berth Regulation Amendments	Control Measure for Ocean-Going Vessels At Berth	August 2020

To address federally-regulated locomotives, *CARB petitioned the United States Environmental Protection Agency (U.S. EPA) to undertake rulemaking to strengthen the existing Emission Standards for Locomotives and Locomotive Engines regulation*. The petition, submitted pursuant to the Act and relevant codes,[46] was sent to U.S. EPA in April 2017 and California air districts, as well as environmental groups and other entities, submitted letters to U.S. EPA in support of the petition. Since that time, there has been no action at the federal level, but CARB is moving forward with the programmatic mechanisms available under State authority to reduce emissions from locomotives in California – this is described further in Chapter 2 and Chapter 6.

Progress has been made in finalizing actions to control emissions from heavy-duty vehicles. The first regulatory success was the adoption of California's *Regulation to Provide Certification Flexibility for Innovative Heavy-Duty Engines*.[47] This regulation encouraged manufacturers to accelerate development and market launch of a diversity of cleaner medium- and heavy-duty vehicles and engines by providing defined certification and on-board diagnostic (OBD) compliance flexibility. The *GHG Emission Standards for Medium- and Heavy-Duty Engines and Vehicles (Phase 2)* regulation was adopted by the Board in February 2018. This new round of vehicle and engine GHG standards built upon the Phase 1 standards adopted federally in 2011 and in California in 2013. In addition to harmonizing with the federal Phase 2 standards finalized by U.S. EPA in October 2016, the CARB regulation includes some more stringent, California-only provisions that are necessary to meet California's unique air quality challenges. Shortly thereafter, the Board adopted the *South Coast On-Road Heavy-Duty Vehicle Incentive Measure* in March 2018 and submitted it to U.S. EPA for inclusion in the California SIP. This action consisted of a measure to report on emission reductions from the turnover of heavy-duty trucks to cleaner technologies funded through the *Carl Moyer Memorial Air Quality Standards Attainment Program* (Moyer Program) in the South Coast Air Basin.

[46] Title 5, United States Code (U.S.C.) section 553(e)

[47] *https://ww3.arb.ca.gov/regact/2016/itr2016/itr2016.htm*

In mid-2018, two elements of the Lower In-Use Emission Performance Level were adopted, the lower opacity limits for heavy-duty vehicles included as part of the Amendments to the *Heavy-Duty Vehicle Inspection Program and Periodic Smoke Inspection Program* in May 2018,[48] and Amendments to the Emission Control System Warranty Regulations and Maintenance Provisions in June 2018.[49] Together, these two regulatory changes ensure lower levels of engine deterioration while heavy-duty vehicles are in operation. The lower opacity levels also provide CARB's enforcement team with the tools needed to take corrective action against trucks with high exhaust PM emissions.

The *Innovative Clean Transit (ICT) Regulation* targets reductions in transit fleets by requiring transit agencies to gradually transition their buses to zero-emission technologies. ICT was adopted by the Board in December 2018 and has helped to advance heavy-duty ZEV deployment, with buses acting as a beachhead in the heavy-duty sector. The *Zero-Emission Airport Shuttle Regulation* was adopted in June 2019 and targets airport shuttle buses, another beachhead market for zero-emission heavy-duty vehicles. The regulation requires airport shuttle operators to begin adding zero-emission shuttles to their fleets in 2027, and to complete the transition to ZEV by the end of 2035.

The Last Mile Delivery measure in the 2016 Strategy envisioned a regulation with a strong focus on last mile delivery vehicles. Through the regulatory development process, the program has evolved substantially into the *Advanced Clean Trucks (ACT) Regulation,* adopted in June 2020, which requires medium-and heavy-duty manufacturers to sell ZEVs as an increasing portion of their annual sales beginning with model year 2024. The rule expanded well beyond the scope of the original measure to include many other heavy-duty vehicle applications beyond last mile delivery, and at the direction of the Board, has been strengthened in order to achieve greater reductions earlier than previously planned. Moreover, in addition to the ACT manufacturer sales requirements adopted last year, CARB staff is now working on complementary fleet requirements that will be brought to the Board for consideration in 2021 and begin implementation in 2023. The ultimate goal of this rulemaking is to transition the State's fleet to zero-emission by 2045 where feasible, and move quicker in certain well suited segments such as last mile delivery, public fleets, drayage, refuse, buses, and utility fleets.

The need for more stringent heavy-duty engine standards at both the State and federal level was discussed in the 2016 Strategy. Because vehicles originally purchased out-of-state contribute approximately 50 percent of the on-road heavy-duty vehicles miles travelled in California, a more stringent national heavy-duty engine standard to complement the State program is needed to achieve the emissions reductions required from this sector. While CARB recently adopted the *Heavy-Duty Omnibus Regulation*, efforts at the federal level are

[48] *https://ww2.arb.ca.gov/rulemaking/2018/heavy-duty-vehicle-inspection-program-and-periodic-smoke-inspection-program*
[49] *https://ww2.arb.ca.gov/rulemaking/2018/hd-warranty-2018*

not expected to be finalized until 2021 or 2022. The national program, known as the U.S. EPA *Cleaner Trucks Initiative*, was announced in November 2018, and an Advanced Notice of Proposed Rulemaking was released on January 21, 2020.[50]

CARB staff is coordinating closely with U.S. EPA technical staff to ensure that the California program will meet the State's needs while preserving the ability to harmonize with the federal program. Furthermore, CARB's *Heavy-Duty Omnibus Regulation* also contains other requirements including longer useful life emission compliance, longer warranty periods, and more stringent in-use performance standards, all of which will improve the real world emissions performance of heavy-duty vehicles. The Omnibus Regulation will result in 23.2 tpd of NOx emission benefits in 2031, the equivalent of taking 16 million light-duty cars off the road. This regulation is estimated to prevent 3,900 premature deaths and 3,150 hospitalizations statewide over the life of the regulation.

The Control Measure for Ocean-Going Vessels At Berth is designed to reduce emissions from ships while docked at a port or marine terminal, otherwise known as at berth. While docked, vessels generate toxic and harmful exhaust that impacts surrounding communities, many of which are disadvantaged. Since 2014, emissions from container, refrigerated cargo (reefer), and cruise vessels have been controlled at berth through CARB's existing At-Berth Regulation which results in a reduction of 80 percent of NOx and PM emissions from those vessel types (around 4,000 visits) by 2020. The recently adopted Control Measure for Ocean-Going Vessels At Berth expands the regulation to include additional vessel types and visits, as well as additional ports and terminals, as originally envisioned in the 2016 Strategy. At the direction of the Board, implementation has been accelerated in order to achieve reductions earlier than previously planned.

[50] *Control of Air Pollution from New Motor Vehicles: Heavy-Duty Engine Standards*, 85 Fed. Reg. 3306 (Jan. 21, 2020). *https://www.govinfo.gov/content/pkg/FR-2020-01-21/pdf/2020-00542.pdf*

2016 Mobile Source Strategy Measures in Progress

In addition to those measures already adopted, there are number of other measures that are progressing through the regulatory development process and are slated to be considered by the Board in the next 12 months. These measures are listed in **Table 4**.

Table 4 – 2016 Mobile Source Strategy Measures in Progress

2016 Mobile Source Strategy Measure Title	Working Regulation / Project Title	Anticipated Adoption / Completion
Transport Refrigeration Units Used for Cold Storage	Transport Refrigeration Units	2021
Small Off-Road Engines	Small Off-Road Engines	2021
Lower In-Use Emission Performance Level	Heavy-Duty Inspection and Maintenance Program	2021
Advanced Clean Cars 2	Light-duty Regulations for ZEVs, Criteria Emissions and GHG Emissions	2022
Low-Emission Diesel Requirement	Low-Emission Diesel Requirement	2021
Zero-Emission Forklift Regulation Phase 1	Zero-Emission Forklift Regulation	2022
Lower In-Use Performance Assessment	Lower In-Use Performance Assessment	Ongoing
Incentivize Low-Emission Efficient Ship Visits	Incentivize Low-Emission Efficient Ship Visits	Ongoing

The *Heavy-Duty Inspection and Maintenance Program*, otherwise known as Heavy-Duty I/M, was part of the Lower In-Use Emission Performance Level measure in the 2016 Strategy and the 2016 State SIP Strategy, but was developed further in the *Valley State SIP Strategy* (October 2018). The Heavy-Duty I/M Program will ensure that in-use emission control components and systems on heavy-duty trucks (those above 14,000 pounds gross vehicle weight rating) are properly functioning, so that these vehicles continue to operate at their cleanest possible levels for the duration of their on-road operation. In the past two years, CARB staff has held a series of public workshops and workgroup meetings, and expects to bring a regulation to the Board in 2021. To expand on the emission reduction opportunities, California *Senate Bill 210*[51] was passed by the Legislature and signed into law by Governor Newsom on September 20, 2019. SB 210 enhanced the relevant regulatory authority by requiring that on-road heavy-duty diesel vehicles comply with the forthcoming Heavy-Duty

[51] Leyva, Chapter 298, Statutes of 2019

I/M program in order to register annually with the California Department of Motor Vehicles. This direct tie-in to vehicle registration ensures that the program will achieve maximum emissions reductions.

The Advanced Clean Cars (ACC) regulatory program, adopted in 2012 to control emissions from passenger vehicles, combined the control of smog-causing pollutants and GHG emissions into a single coordinated package of regulations: the Low-Emission Vehicle III Regulation for criteria (LEV III Criteria) and GHG (LEV III GHG) emissions, and a technology-forcing mandate for ZEVs. The program was developed in coordination with U.S. EPA and the National Highway Traffic Safety Administration (NHTSA) and includes emissions standards for vehicle model years through 2025. Because federal agencies have since reversed course and rolled back the national standards for model years 2021 through 2026, in addition to their decision to preempt California's authority to regulate light-duty vehicle GHG emissions and ZEV technology, it is even more important that CARB move forward with California standards for model years 2026 and beyond to preserve the critical emissions reductions from the passenger vehicle sector.[52] The Advanced Clean Cars II measure as discussed in the 2016 Strategy would increase the number of new ZEVs and plug-in hybrid electric vehicles (PHEVs) sold in California, and maximize criteria and GHG emissions reductions by setting standards for post-2025 model year vehicles. Advanced Clean Cars II is currently planned for consideration by the Board in 2022.

The "Lower In-Use Emission Performance Assessment" measure is an ongoing effort to ensure in-use light-duty vehicles continue to operate at their cleanest possible level. As such, both CARB and the Bureau of Automotive Repair (BAR) are continuously improving both the *Smog Check Program* and the *On-Board Diagnostic Program* through various activities. Since the 2016 Strategy was released, CARB staff have presented results of an internal study that documented the effectiveness of the OBD program in improving air quality at the 2019 SAE OBD Symposium, implemented a test program to investigate and analyze in-use vehicles that had passing OBD smog check inspections but high tailpipe emissions,[53] and proposed

[52] *See* The Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule Part One: One National Program, 84 Fed. Reg. 51,310 (Sept. 27, 2019). Enforcing new California light-duty vehicle greenhouse gas emission and zero-emission vehicle regulations will depend on restoration of the State's authority to do so.
[53] Project no. 2S19V01, May 2019

changes to the OBD regulation to improve OBD functionality (2021 proposed board hearing date). Additionally, BAR staff have created yearly Smog Check Performance Reports that include various assessments of Smog Check Program data and data collected as part of BAR's Random Roadside Inspection Program. BAR staff have also implemented improved smog inspection procedures and methods to mitigate fraud, such as implementing permanent diagnostic trouble codes as new inspection failure criteria, blocking vehicle inspection certification if fraudulent vehicle testing is suspected, and improving enforcement efforts against smog stations and technicians performing fraudulent inspections.

Other efforts that were included as measures in the 2016 Strategy focused on the off-road and fuels sectors. The Zero-Emission Forklift Regulation is under development by CARB staff, and is anticipated to be considered by the Board in early 2022. The Low-Emission Diesel Fuel Requirement has been discussed at CARB workshops and is planned to be brought to the Board in 2021. Finally, the measure from the 2016 Strategy to Incentivize Low-Emission Efficient Ship Visits is continuing to be explored by staff in conjunction with the South Coast Air Quality Management District and other local entity partners.

Role of Incentive Programs in Reducing Emissions from California's Mobile Fleet

The 2016 Strategy identified a need for incentive funding for mobile source turnover in specific regions and throughout the State. Moving forward, the scenarios detailed Chapter 6 show that in order to meet ambient air quality standards, reduce near-term risk in our most disadvantaged communities, and meet climate targets, a sweeping transformation of the mobile sector will be needed. While regulatory mechanisms have and will continue to achieve a majority of the necessary emissions reductions, incentive funding is of critical importance, especially in the near-term to advance technology development and deployment and accelerate the rate of fleet turnover to the levels needed to meet targets. Since release of the 2016 Strategy, the Legislature has identified and appropriated significant amounts of funding to a variety of CARB's incentive programs. As the State moves forward, it is important to recognize that significant continued public and private investment will be necessary in order to reach the levels of cleaner technology needed in the specified timeframes.

The State, in partnership with the local air districts, has a well-established history of using incentive programs to advance technology development and deployment, and to achieve early emission reductions. Since 1998, CARB and air districts have been administering incentive funding for cleaner vehicles, starting with the Moyer Program. In recognition of the key role that incentives play in complementing State and local air quality regulations to reduce emissions, the scope and scale of California's air quality incentive programs has since greatly expanded, with many new programs building on the success of the Moyer Program.

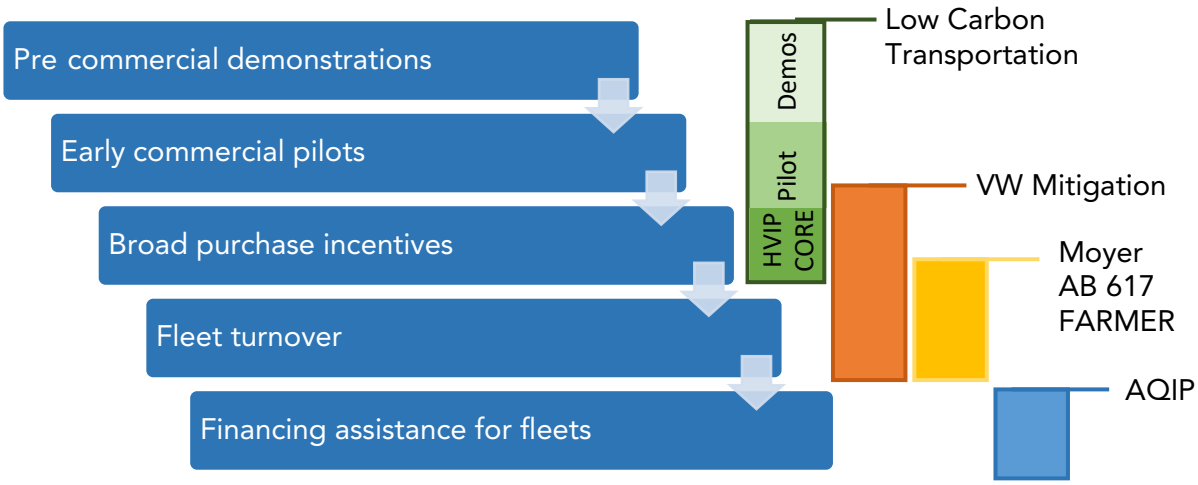
Each of CARB's incentive programs has its own statutory requirements, goals, and categories of eligible projects to make the portfolio diverse and far-reaching. In total, these programs address multiple goals, including:

- Turning over the legacy fleet to achieve cost-effective, emission reductions in support of SIP, air toxics, and community air protection goals;
- Accelerating the introduction and deployment of zero-emission technologies to meet California's air quality and mid-century climate change goals;
- Improving access to clean transportation for low-income households, and investing in the disadvantaged and low-income communities most impacted by pollution; and
- Supporting a green economy.

CARB works each year to prioritize expenditure of available funding between the programs and projects described below to achieve the complementary program goals. This is accomplished with input from the public and interested stakeholders as part of an ongoing public process. The annual Funding Plan for Clean Transportation Incentives is adopted by the Board and is the principal result of this prioritization effort, serving as the blueprint for expending the Clean Transportation Incentives funds appropriated to CARB each year in the State budget. The plan establishes CARB's priorities for the funding cycle, describes the projects CARB intends to fund, and sets funding targets for each project. While the annual Funding Plan for Clean Transportation Incentives includes only programs funded through Low Carbon Transportation Investments and AQIP, funding to the rest of CARB's incentive portfolio is also prioritized on a regular basis to meet the respective program goals.

As can be seen in Figure 3, CARB's portfolio of incentive programs are used to accelerate all stages of technology commercialization by promoting the purchase of cleaner vehicles and equipment, assisting vehicle and equipment owners with the cost of upgrading their vehicles, and increasing development and deployment of cleaner and advanced zero-emission technologies. These programs include the Moyer Program, Low Carbon Transportation Investments, AQIP, the Truck Loan Assistance Program, and the Proposition 1B: Goods Movement Emission Reduction (Prop 1B) Program. More recently established programs include the FARMER Program, AB 617 CAPP incentives, and funds available through the Volkswagen (VW) Environmental Mitigation Trust.

Figure 3 - CARB's Incentive Portfolio



The Moyer Program, funded by dedicated revenue from the Department of Motor Vehicle smog abatement fee and a fee on the purchase of new tires, provides approximately $94 million in grant funding annually through local air districts for cleaner-than-required engines and equipment. Due to the enactment of *Assembly Bill 1274*,[54] funding for the Moyer Program is expected to increase in future years. The Low Carbon Transportation and AQIP programs provide incentive funding with goals of improving access to clean transportation and mobility and reducing greenhouse gas emissions, criteria pollutants, and air toxics by funding accelerated development and early commercial deployment of the cleanest technologies. AQIP, while a related program, is appropriated from a different funding source, the Air Quality Improvement Fund.

Along with the multitude of grant and rebate opportunities available under the Low Carbon Transportation investments and AQIP, the Truck Loan Assistance Program was created through a one-time appropriation of approximately $35 million in the 2008 State Budget to implement a heavy-duty loan program that assists on-road fleets affected by the Truck and Bus Regulation and the Heavy-Duty Tractor-Trailer Greenhouse Gas Regulation. Since that time, CARB has continued to operate this program with subsequently-appropriated AQIP funds of around $28 million annually to provide financing opportunities to small-business truckers who fall below conventional lending criteria and are unable to qualify for traditional financing for cleaner trucks.

In addition to these programs, the Prop 1B Program was created to reduce exposure for populations living near freight corridors and facilities that were being adversely impacted by emissions from goods movement. This program provided incentives to owners of equipment used in freight movement to upgrade to cleaner technologies sooner than required by law or

[54] O'Donnell, Chapter 633, Statutes of 2017

regulation. Voters approved $1 billion in total funding for the air quality element of the Prop 1B Program to complement $2 billion in freight infrastructure funding under the same ballot initiative. While all Prop 1B Program funds have been awarded to the local air districts for implementation, the program framework exists to serve as a mechanism to award clean truck funds through newer funding programs.

In 2015, after a CARB-led investigation, in concert with U.S. EPA, VW admitted to deliberately installing emission defeat devices on nearly 600,000 VW, Audi, and Porsche diesel vehicles sold in the United States, approximately 85,000 of which were sold in California. The VW California settlement agreement includes both a Mitigation Trust to mitigate the excess NOx emissions caused by the company's use of illegal defeat devices in their vehicles, as well as a ZEV Investment Commitment to help grow the State's expanding ZEV program. The Mitigation Trust includes approximately $423 million for California to be used as specified in the settlement agreement. Per the Beneficiary Mitigation Plan approved by CARB in 2018, this funding will be used to replace older heavy-duty trucks, buses, and freight vehicles and equipment with cleaner models, with a focus on zero-emission technologies where available and cleaner combustion everywhere else, as well as to fund light-duty ZEV infrastructure. In addition, there have been mitigation funds established as the result of other settlements from which funding is used to support clean technologies.

Since 2017, the Legislature through various budget bills has established a number of new incentive programs that are implemented through CARB. In addition to the planning and monitoring aspects of the aforementioned AB 617 CAPP, the State Legislature provided funding to achieve early emissions reductions in the communities most impacted by air pollution. Despite the fact that there is not a dedicated funding source for the Community Air Protection Incentives, funding appropriated from GGRF by the Legislature has been substantial. Alongside the 2018 funding allocation, the Legislature expanded the possible uses of AB 617 funds to include: Moyer and Proposition 1B eligible projects with a priority on zero-emission projects; zero-emission charging infrastructure; stationary source projects; and additional projects consistent with the CERPs. CARB and air districts partner to run the program, with CARB developing guidelines and the districts administering funds for their regions. In most cases throughout the State, selected communities have identified mobile source emissions as a target for reductions; therefore, it is likely that a significant portion of the AB 617-allocated funding will incentivize the accelerated turnover to cleaner vehicles and equipment in and around low-income and disadvantaged communities.

As mentioned, CARB funds a suite of *projects* through the Low Carbon Transportation Program that prioritize equity by providing mobility and advanced technology transportation access to people in low-income and disadvantaged communities. *Clean Cars 4 All* is a program that focuses on providing incentives to lower-income California drivers to scrap their older, high-polluting car and replace it with a zero- or near zero-emission replacement. The *Financing Assistance for Lower-Income Consumers Program*, otherwise known as the Clean Vehicle Assistance Program, and local financing assistance project in the Bay Area, helps lower-income residents finance used or new conventional hybrid electric, plug-in hybrid

electric, battery electric, or fuel cell electric vehicles. The *Sustainable Transportation Equity Project* (STEP) is a new pilot that takes a community-based approach to overcoming barriers to clean transportation in disadvantaged and low-income communities throughout California. STEP aims to address community residents' transportation needs, increase residents' access to key destinations (e.g., schools, grocery stores, workplaces, community centers, medical facilities), and reduce greenhouse gas emissions. And finally, the *Clean Mobility Voucher Pilot Program* project supports zero-emission car-sharing, ride-sharing, bike-sharing, and innovative transit services for low-income and disadvantaged communities. All of these projects are specifically designed to benefit members of California's communities most vulnerable to the effects of climate change and poor air quality, and support SB 350 and the State's equity goals.

As part of the 2017 State Budget, the Legislature appropriated $135 million to CARB to reduce agricultural sector emissions through grants, rebates, and other financial incentives for agricultural harvesting equipment, trucks, agricultural pump engines, tractors, and other equipment used in agricultural operations. CARB developed the FARMER Program and approved guidelines that establish the program framework, eligible projects, reporting requirements, and oversight provisions. CARB is directing this funding to air districts to administer for agricultural truck and equipment replacement projects.

Another more recently-established project under the Low Carbon Transportation investments is the Clean Off-Road Equipment Voucher Incentive Project, known as CORE. CORE is designed to accelerate deployment of cleaner off-road technologies by providing a streamlined way for fleets ready to purchase specific zero-emission equipment to receive funding to offset the higher cost of such technologies. This project is analogous to the Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP), but specifically targets zero-emission off-road freight equipment that is currently in the early stages of commercial deployment. Borne out of a $40 million allocation of Low Carbon Transportation funds in the Fiscal Year 2017-18 CARB Low Carbon Transportation and AQIP Funding Plan, CORE provides vouchers to California purchasers and lessees of zero-emission off-road freight equipment on a first-come, first-serve basis, with increased incentives for equipment located in disadvantaged communities.

Given the COVID-19 pandemic and the resulting health and economic crisis, California's 2020 State Budget was drastically different from those enacted in recent years reflected estimated spending of $5.7 billion to respond directly to the COVID-19 pandemic. Despite this fact and the initial budget deficit last year, California has rebounded and proved resilient through the

COVID-19 pandemic such that the fiscal outlook for 2021 is significantly better, as demonstrated by the 2021 State Budget. Among other things, the 2021-22 State Budget includes an unprecedented level of investment in ZEVs, with $2.3 billion for CARB over the next three years as part of a $3.9 billion comprehensive, multi-agency package to accelerate progress toward the state's 2035 and 2045 zero-emission vehicle goals.

Ongoing Push to Identify Potential New Controls

Regardless of near-term challenges with levels of incentive funding or timing of federal regulatory action, CARB is moving forward to address mobile source emissions and will take action where possible to lower emissions now. For the near-term, there is potential for emissions reductions from newer programs that are expected to be considered by the Board over the next couple of years; these could provide significant benefits in communities of concern and the broader regions that need further reductions for attainment of air quality standards. In addition, there are newer regulatory concepts that are in earlier phases of development, but will likely achieve reductions in time for the mid-term 2030, 2031, and 2037 deadlines. These are described in detail in the following chapter.

Chapter 4 - CARB Actions to Achieve Near Term Emissions Reductions

As outlined earlier, California has the two areas with the most critical near-term air quality challenges in the nation, the South Coast and the San Joaquin Valley air basins. The near-term targets for these areas are attainment of the 80 ppb 8-hour ozone standard by 2023, the 35 microgram per cubic meter (μg/m^3) 24-hour fine particulate matter (PM2.5) standard by 2024, and the 12 μg/m^3 annual PM2.5 standard by 2025. Additionally, by 2031, both regions are required to meet the 75 ppb 8-hour ozone standard. Also, there is an immediate need to reduce emissions and exposure in communities that are disproportionately impacted by high levels of localized pollution. The selected communities under California's AB 617 CAPP have five and ten-year targets to reduce exposure, with 2024 being the target date for the first tranche of Community Emissions Reduction Plans (CERPs). Achieving emission reductions through mobile source regulatory actions (e.g., emissions standards) takes time. Emission standards for new vehicles and engines adopted today will not realize substantial emission reductions until years in the future due to the need for manufacturers to design and put into production new models, and the subsequent time for the existing fleet to turnover to newer, cleaner equipment. To achieve near-term emission reductions, CARB has focused on in-use emissions, incentives, and sectors in which proven technology can be more rapidly deployed. Emission reductions from federal and local sources are also critical to achieving near-term targets and are discussed in greater depth later in this chapter.

With respect to regional air quality issues, the overall attainment strategies are defined through the SIP process,[55,56] which considers all sources, mobile, stationary and area sources. Through the SIPs for South Coast and San Joaquin Valley, CARB and the local air districts have committed to NOx and PM emissions reductions from all sectors through various measures, while recognizing that additional measures are needed to attain the standards. For example, to meet the 8-hour ozone standards in South Coast Air Basin, an additional 108 tpd and 88 tpd of NOx emission reduction is needed in 2023 and 2031 respectively,[57] relative to the baseline emissions included in the most recent attainment plans. In San Joaquin Valley, an additional 13 tpd of NOx and 0.1 tpd of PM2.5 emissions reduction are needed to meet the 2024 and 2025 targets,[58] respectively. This section of the 2020 Strategy highlights the major near-term mobile source measures that CARB will consider to make progress towards

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[55] CARB. 2019. South Coast 8-Hour Ozone SIP Update. Available: *https://ww3.arb.ca.gov/planning/sip/planarea/scabsip/2019o3update.pdf*

[56] *https://ww3.arb.ca.gov/board/books/2020/102220/20-11-5pres.pdf*

[57] *https://www.aqmd.gov/docs/default-source/clean-air-plans/air-quality-management-plans/2016-air-quality-management-plan/1997-ozone-contingency-measure-plan/scab-1997-8-hour-ozone---public-consultation-meeting---presentation.pdf?sfvrsn=6*

[58] *https://ww3.arb.ca.gov/board/books/2020/102220/20-11-5pres.pdf*

attaining the national ambient air quality standards and reducing exposure in impacted communities. As CARB develops the State SIP Strategy and subsequent SIP commitments for submittal to U.S. EPA, we will also consider, in coordination with other local and state agencies, opportunities for emission reductions for other sectors, such as new and existing buildings.

On-Road Vehicles

As previously described, CARB has recently adopted a number of regulations for the on-road heavy-duty sector, including Heavy-Duty Warranty Phase 1, Periodic Smoke Inspection Program (PSIP) Amendments, Innovative Clean Transit (ICT), Zero-Emission Airport Shuttle Bus, Advanced Clean Trucks (ACT), and Heavy-Duty Omnibus (see Chapter 3 for more details). In addition to these adopted measures, CARB is considering a suite of enhanced or new measures to further reduce emissions from heavy-duty vehicles in California such as:

- Heavy-Duty Inspection and Maintenance Program; and
- Advanced Clean Fleets including Zero-Emission Drayage

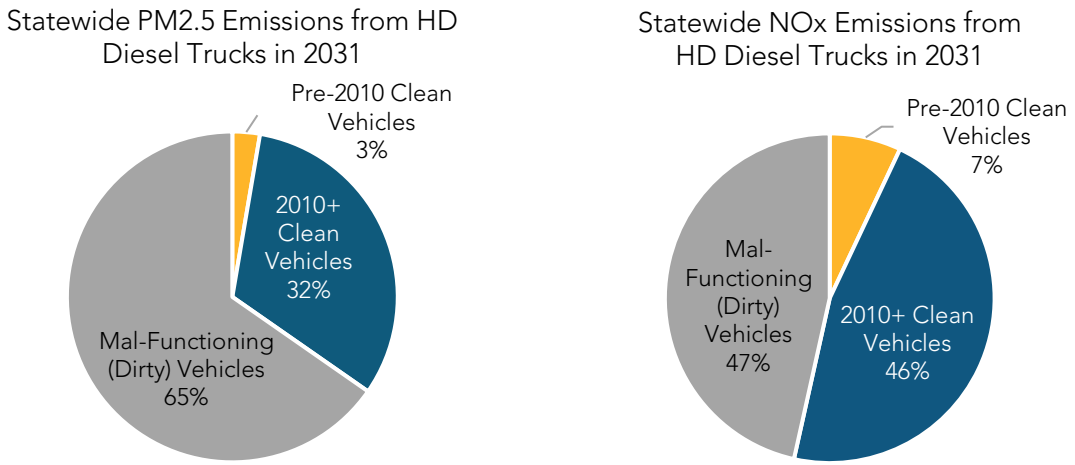
In addition to heavy-duty regulations, CARB is considering Advanced Clean Cars II for the on-road light and medium-duty vehicles.

These measures are further described in the following sections.

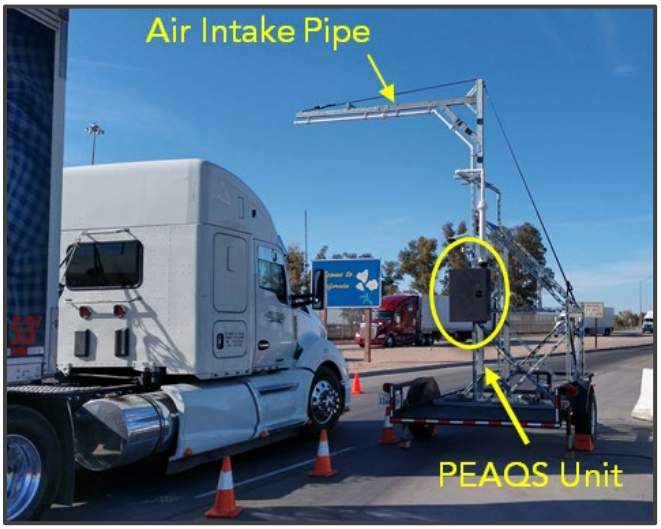
Heavy-Duty Inspection and Maintenance Program – Implementation in 2023

Over the years, CARB has adopted regulations designed to reduce emissions from heavy-duty truck fleets by mandating vehicles to meet stricter emissions standards, and requiring replacement of older engines with cleaner engine technology that includes diesel particulate filters, NOx controls, and OBD. As a result of these collective efforts, emissions from heavy-duty vehicles are lower than in previous years and are continuing to decline. While emissions from heavy-duty trucks are declining, they are still significant; and the majority of heavy-duty truck emissions are now coming from a small percentage of vehicles whose engines and emissions control systems are malfunctioning or are poorly maintained. As shown in Figure 4, CARB staff estimate that by 2031, 65 percent of PM emissions and 47 percent of NOx emissions from heavy-duty diesel trucks will be due to emissions control systems that are malfunctioning or poorly maintained.

Figure 4 – NOx and PM2.5 Emission Contributions from Malfunctioning Heavy-Duty Diesel Trucks in California



CARB staff, in consultation with its state agency partners,[59] is developing a comprehensive heavy-duty vehicle inspection and maintenance program (Heavy-Duty I/M) as directed by Senate Bill 210 (Leyva; Statutes of 2019). The proposed program would apply to all on-road non-gasoline[60] heavy-duty vehicles with a gross vehicle weight rating over 14,000 pounds that operate in California, including vehicles registered out of state and out of country. This robust program would be the first-of-its-kind to rely on remote telematics to periodically download and transmit engines' OBD data to CARB for use in identifying malfunctioning emissions-related components and requiring timely repairs. The periodic testing component would be complemented by roadside emissions monitoring (remote sensing devices and/or CARB's Portable Emissions AcQuisition System, known as PEAQS) to detect high emitting vehicles between periodic test cycles and require additional testing and repair to ensure emissions control components are operating properly. Vehicle owners would be required to demonstrate that their vehicles' emissions



[59] The California Department of Motor Vehicles (DMV), California Highway Patrol (CHP), the Bureau of Automotive Repair (BAR), and the California Department of Food and Agriculture (CDFA).
[60] Heavy-duty gasoline vehicles with a gross vehicle weight rating over 14,000 pounds are already required to comply with BAR's Smog Check program.

control systems are properly functioning, thereby reducing excess NOx and PM emissions resulting from mal-maintenance and tampering. Key program elements include: 1) streamlined testing processes that nearly eliminates vehicle downtime for inspections; 2) requirements for all heavy-duty vehicles to possess a valid compliance certificate accessible upon request by CARB or CHP inspectors; and 3) the ability for DMV to withhold vehicle registration on non-compliant California vehicles. The regulation is projected to begin implementation starting January 1, 2023.

To ensure that the benefits of the Heavy-Duty I/M program will be maximized in the near-term, CARB is planning to deploy a network of PEAQS sensors in the South Coast and San Joaquin Valley regions. PEAQS captures a portion of the emissions from the exhaust plumes of passing heavy-duty vehicles and, within seconds, reports the concentration of pollutants, including carbon dioxide (CO2), black carbon particulate matter (BC), and nitrogen oxide (NO), in the vehicle exhaust.

Since early 2019, CARB has been working to adapt PEAQS into a rugged, autonomous, remote sensing device that can be deployed at locations throughout the state and transmit data back to CARB data servers. These autonomous units also capture identifying characteristics of the vehicle associated with a particular emissions plume.

In August of 2019, CARB staff installed the first autonomous, roadside plume capture, remote sensing device in San Bernardino County. Following that successful rollout, CARB installed the second autonomous PEAQS unit in Riverside County in August of 2020. These systems have monitored thousands of vehicles and are used to enforce opacity emissions standards established by current CARB regulations.

Moving forward, CARB plans to retrofit these two systems with NOx sensors and will install all future systems with NOx sensors to support enforcement of the forthcoming Heavy-Duty I/M Program, which regulates both particulate matter and NOx emissions. Under this regulation, enforcement action will be initiated on high emitting trucks screened by PEAQS and repairs will be required if follow up tests indicate the need for maintenance.

Because of the immediate need for PM and NOx emissions reductions to achieve air quality targets, in advance of the Heavy-Duty I/M regulation, CARB plans to install eight more units within the San Joaquin Valley and South Coast Air Basins by January 1, 2023 bringing the network to a total of 10 systems. Two to three of these systems will be installed over the course of 2021 in Madera, Kern, and Los Angeles Counties. In 2022, CARB will install the remaining five to six systems in Los Angeles, Merced, and Riverside Counties.

CARB staff has conducted a series of public workshops and workgroup meetings for Heavy-Duty I/M to engage stakeholders and invite their input throughout CARB's public process for program development and will continue to do so throughout 2021. The Board will consider the proposed Heavy-Duty I/M regulation at its December 2021 Board hearing.

Advanced Clean Fleets and Zero-Emission Drayage – Implementation in 2023

Besides the Heavy-Duty I/M regulation, CARB is also considering measures to accelerate the turnover of the heavy-duty diesel vehicles by setting zero-emission requirements for fleets. The proposed Advanced Clean Fleets (ACF) regulation will focus on strategies to ensure that the cleanest vehicles are deployed by government, business, and other entities in California to meet their transportation needs. This effort is part of a comprehensive strategy to achieve a zero-emission vehicle truck and bus fleet by 2045 everywhere feasible, and significantly earlier for certain well-suited market segments as directed by the Advanced Clean Trucks resolution and Executive Order N-79-20. The initial focus is on high priority private fleets, public fleets, and drayage fleets, where the initial transition to zero-emission would occur in applications where zero-emission technologies are well suited for use.

The proposed ACF regulation will have multiple components including requirements for public fleets, private and federal fleets, and drayage trucks. In order to make sure fleets have enough ZEVs to meet the ACF requirements, they will likely need to turn over some older vehicles that are past their useful life and replace them with ZEVs. Staff plans to bring a recommendation to the Board in December 2021 with a final decision in early 2022. Implementation would begin in 2023 to complement the approved Advanced Clean Trucks regulation.

To support ACF's drayage targets, CARB is developing zero-emission drayage truck requirements. The current concept will require all Class 7 and 8 drayage trucks operating at intermodal seaports or railyards to be full zero-by 2035. To achieve this target, all trucks that are added to the statewide drayage truck registry shall be zero-emission starting in 2023. In 2035, any truck entering seaports or intermodal railyards would be required to be zero-emission. Over the last couple of months, CARB staff held several workgroup meetings focused on how to transition public fleets, private and federal fleets, and drayage trucks to zero-emissions.[61] CARB also recently initiated an effort called "Project 800" to support the deployment of zero-emission trucks serving California ports with the goal of having 800 zero-emission drayage truck orders in 2021 and to address financial and other technical issues associated with large-scale zero-emission truck deployments in California. As discussed in the December 2020 CARB

[61] *https://ww2.arb.ca.gov/our-work/programs/advanced-clean-fleets/advanced-clean-fleets-meetings-events*

Board hearing, CARB staff are also proposing funding and incentive plans to further accelerate the transition of fleets to zero-emission technology.[62]

In addition to near-term measures discussed earlier, it is noteworthy to mention that U.S. EPA is planning to adopt new NOx emission standards for heavy-duty vehicles through an effort known as the Cleaner Trucks Initiative (CTI).[63] U.S. EPA released an Advanced Notice of Proposed Rulemaking in 2020 with potential program elements, including lower NOx emission standards, improvements to in-use testing procedures, lengthened warranty for emission-related components, lengthened useful life, consideration of rebuilding, and incentives to transition to newer technology. These new standards are planned for model year 2027 and newer vehicles. Proposed rulemaking for CTI is expected to take place in 2021.

Advanced Clean Cars (ACC) II – Implementation in 2026

The Advanced Clean Cars (ACC) regulations are responsible for setting criteria pollutant and GHG emission standards for light-duty and medium-duty vehicles and establishing a ZEV requirement. Building on ACC I which reduced fleet average non-methane organic gas (NMOG)+NOx emissions from roughly 0.1 g/mile for new model year 2016 vehicles to 0.03 g/mile for model year 2025 vehicles, ACC II is currently in development to strengthen criteria pollutant control measures beyond model year 2025 and ensure that the regulatory requirements translate into real-world emission benefits and contribute to 2031 attainment of regional SIP targets. Additionally, staff will be proposing how to increase the ZEV requirement towards the 100 percent target established by the Governor's Executive Order N-79-20, as well as creating new requirements for ZEVs to ensure that they can serve as full replacement vehicles for conventional combustion vehicles for further emission reductions. The regulatory package is anticipated for Board consideration in summer 2022.

Given the fleet average basis for NMOG+NOx criteria standards, staff is currently considering various options to prevent new combustion vehicles from being certified at higher emission levels as a greater volume of ZEVs enter the market. Staff is considering whether to exclude ZEVs from the fleet average calculation or lower the fleet average to account for the growing share of ZEVs as well as further promote a transition to cleaner combustion. Staff is also proposing to eliminate some of the highest certification bins to ensure conventional vehicles are forced to certify to cleaner emission levels. The proposed changes further reduce NOx emissions reductions by accounting for aggressive driving conditions and better controlling cold start emissions. Changes to the plug-in hybrid (PHEV) test procedures will also help reduce NOx emissions that are generated by PHEV cold starts that occur during high-power driving.

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[62] *https://content.govdelivery.com/accounts/CARB/bulletins/2b59347*

[63] *https://www.epa.gov/regulations-emissions-vehicles-and-engines/cleaner-trucks-initiative*

Additionally, staff will propose changes for medium-duty vehicles that were recently included in the Heavy-Duty Omnibus Regulation. As this vehicle class can also certify using light-duty chassis certification procedures, staff is currently investigating changes to these procedures and requirements to ensure that equivalent emission reductions are achieved regardless of which regulation a medium-duty vehicle certifies under.

Finally, increasing ZEV market shares as proposed in ACC II will also contribute to NOx emission reductions, but only if these ZEVs are displacing miles driven by combustion vehicles. To ensure these emission benefits are sustained over the full life of the vehicle, proposed new ZEV assurance measures will require manufacturers to provide a warranty and meet a durability requirement, similar to what is required for emission control systems on conventional vehicles. A battery state of health indicator is also being proposed to facilitate warranty claims and ensure consumers can be fully informed on the battery's condition. Lastly, should an older ZEV eventually need repair, staff is proposing that service information be provided by the manufacturer to all licensed repair technicians and not just dealer service centers.

Table 5 lists NOx emission reductions in the South Coast and San Joaquin Valley from the near-term on-road measures discussed above including those that are already adopted by the Board. Targeting in-use malfunctioning vehicles, Heavy-Duty I/M will bring immediate and essential emission reductions once it is implemented. The Heavy-Duty I/M program is anticipated to reduce NOx by 3.5 tpd from South Coast air basin baseline emissions levels in 2023. By 2031, other new measures will provide additional emissions reductions, resulting in overall NOx emission reductions of 38-42 tpd. Similarly, in 2024, near-term measures will provide 11 tpd NOx benefits from the baseline in the San Joaquin Valley. Roadside emissions monitoring with PEAQS through Heavy-Duty I/M and ZE Drayage and ACF will achieve some additional NOx emissions reductions beyond CARB's mobile source commitments in 2016 State SIP Strategy. Note that Heavy-Duty I/M provides more emissions benefits starting in 2024, after the program is fully phased in.

Table 5 – On-Road NOx Emissions Benefits

Measure(s)	South Coast 2023	San Joaquin Valley 2024	South Coast 2031
ACT and Omnibus	<0.1 tpd	<0.1 tpd	7 tpd
Federal CTI	0 tpd	0 tpd	4 tpd
Heavy-Duty I/M	3.5 tpd	11 tpd	18 tpd
ZE Drayage and ACF	0 tpd	<0.1 tpd	6-10 tpd
ACC II	0 tpd	0 tpd	3.2 tpd
Total	3.5 tpd	11 tpd	38-42 tpd

CARB's efforts to reduce PM2.5 emissions statewide are expected to have significant co-benefits in communities that are disproportionately impacted by poor air quality. While exposure to cancer-causing diesel particles has decreased substantially in all communities,

including reductions in disadvantaged communities that are three times greater than other communities, exposure to diesel particles in disadvantaged communities remains on average twice that experienced in non-disadvantaged communities.[64] Consistent with the 2018 CERPs, the near term measures listed in this chapter go beyond existing efforts to further reduce air pollution disparities and will further reduce cumulative exposure to air pollution in disadvantaged communities.[65] In particular, ZE Drayage will result in lower PM2.5 emissions in communities located near ports. Substantial PM2.5 emission reductions from Heavy-Duty I/M will also have co-benefits in communities adjacent to warehouses, ports, railyards and other facilities that generate heavy-duty truck traffic. The near-term on-road measures discussed in this chapter are expected to reduce PM2.5 emissions by 0.6 tpd and 0.9 tpd in 2025 and 2030, respectively. Table 6 provides further details on PM2.5 emission reductions from each measure.

Table 6 – Statewide PM2.5 Benefits from On-Road Measures

Measure(s)	Statewide 2024	Statewide 2025	Statewide 2030
ACT	<0.01 tpd	<0.01 tpd	0.03 tpd
Heavy-Duty I/M	0.5 tpd	0.6 tpd	0.8 tpd
ZE Drayage and ACF	<0.01 tpd	<0.01 tpd	0.2 tpd
ACC II	0 tpd	0 tpd	NYQ
Total	**0.5 tpd**	**0.6 tpd**	**1.0 tpd**

For programs that have not yet been adopted, staff made the following assumptions to estimate emissions benefits. Note that these estimates may be refined later, as these regulations are still under development:

- **ACC II:** Staff used the light-duty vehicle scenario outlined in Chapter 6 of this document to estimate the NOx benefit associated with this program.
- **CTI:** The program requirements are not yet defined. Therefore, initial benefits were estimated by assuming new federally-certified trucks with model year 2027 and newer would have 90 percent cleaner in-use NOx emissions.
- **ACF and Zero-Emission Drayage:** Staff modelled upper-bound emissions benefits by assuming accelerated turnover of vehicles that are older than 18 years of age, or reach 15 years of age and 800,000 miles, to ZEVs for calendar years 2030 and 2031. Similar assumptions were made for lower-bound estimates, but accelerated turnover was only modelled for specific fleet groups, including drayage, refuse, public, utility, and buses. Staff are mainly using these assumptions for modeling the benefit of ACF above and

[64] California Air Resources Board, Air Quality Progress in California Communities, July 23, 2016, available at: *https://www.arb.ca.gov/board/books/2016/062316/16-6-2pres.pdf*
[65] *https://ww2.arb.ca.gov/resources/ab-617-statewide-strategy-summary*

beyond ACT for year 2031. In early years (i.e., 2023 and 2024), staff are assuming that ACF may not provide additional benefit beyond ACT. Staff are currently conducting more detailed level analysis of ACF utilizing the EMFAC2021 model.[66] Preliminary results from these analyses were presented at the March 2021 workshops of Advanced Clean Fleet regulation[67] and the Mobile Source Working Group for Heavy-Duty Trucks Meeting #2.[68] Please note that the emissions benefits presented in this document are based on an earlier version of the EMFAC model, EMFAC2017.

- **Heavy-Duty I/M:** For initial implementation in 2023, staff assumed the program would result in a 27 percent reduction in deterioration for California-registered vehicles and a 14 percent reduction for out-of-state registered vehicles that travel to California. From 2024 to 2030, staff modelled a 74 percent reduction in deterioration for California-registered vehicles and 55 percent for out-of-state vehicles. Finally, for 2031 and subsequent calendar years, an 83 percent reduction in deterioration was assumed for California vehicles and 62 percent for out-of-state. These assumptions are based on the impacts of the whole Heavy-Duty I/M program, including periodic OBD data submission, opacity testing, and high emitter screening.

Off-Road Vehicles and Equipment

For the off-road sector, CARB has recently adopted a Control Measure for Ocean-Going Vessels (OGV) At Berth that expands the regulation to include additional vessel types and visits, as well as additional ports and terminals. The updated regulation expands requirements to include auto carriers (roll-on/roll-off vessels) and tankers, and new ports and terminals, reducing emissions from an additional 2,300+ vessel visits per year. The rule requires that every vessel coming into a regulated California port either use shore power (e.g., plug in to the local electrical grid) or a CARB-approved control technology to reduce harmful emissions. It also requires boiler emission controls for tanker vessels operating boiler-powered, steam-driven pumps to off-load cargo (typically crude petroleum products). The updated rule starts implementation in 2023 for container, reefer and cruise vessels, auto carriers in 2025, and tanker vessels in 2025 for Los Angeles and Long Beach and 2027 for Northern California. While the 2016 State Strategy assumed South Coast NOx reductions of 0.3 and 1 tpd in 2023 and 2031, respectively, the adopted measures result in almost four times higher reductions than previously assumed (i.e., 1.1 and 3.6 tpd of NOx reduction in 2023 and 2031, respectively).

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[66] *https://arb.ca.gov/emfac/*

[67] *https://ww2.arb.ca.gov/sites/default/files/2021-03/210302emissions_ADA.pdf*

[68] *http://www.aqmd.gov/home/air-quality/clean-air-plans/air-quality-mgt-plan/2022-aqmp-mobile-source-working-groups*

In addition to the recently adopted OGV At Berth Control Measure, CARB is developing a number of measures for other off-road sectors. The measures include an in-use locomotive regulation, amendments to commercial harbor craft (CHC) regulation, TRU Airborne Toxic Control Measure amendments, and zero-emission requirements for small off-road engines (SORE) and forklifts. For the cargo handling equipment (CHE) and construction sectors, the concepts outlined later in the document will serve as guidelines for future rule-making.

These measures are not limited to specific communities and will provide benefits statewide. However, because they are aimed at freight and industrial facilities, they will provide substantially more benefits to communities near ports, railyards, and industrial facilities. These communities have been among the most negatively impacted by air pollution. These measures are further described in the following sections.

Commercial Harbor Craft (CHC)

The proposed amendments to the regulation for CHC will expand existing requirements to cover more vessel types, have more stringent emission requirements, mandate zero-emission and advanced technologies for certain vessel types, and require the use of renewable diesel for all vessels. Under the new rule, most engines on vessels would need to be turned over to the cleanest available engine (Tier 3 or 4) and be retrofitted with Diesel Particulate Filters (DPFs) starting in 2023, phasing in through 2034. Commercial fishing vessels, which are currently not subject to in-use engine requirements, would need to have Tier 2 or newer engines. New excursion vessels would be required to be zero-emission capable hybrid starting in 2025, and all short-run ferries (those traveling 3 nautical miles or less on a single run) would be required to be full zero-emission by 2026. Renewable diesel would be required for all vessels starting in 2023. Besides climate benefits, renewable diesel has been found to reduce NOx emissions by 10 percent and PM by 30 percent for older engines that do not employ Selective Catalytic Reduction (SCR) systems or DPFs.[69] The proposed regulations could reduce NOx emissions in South Coast by 0.8 tpd and 2.5 tpd in

[69] Durbin, T.D. et al. CARB Assessment of the Emissions from the Use of Biodiesel as a Motor Vehicle Fuel in California "Biodiesel Characterization and NOx Mitigation Study," October 2011. Table ES-6, xxxvii.

2023 and 2031, respectively. Since the majority of CHC emissions occur near ports, those emission benefits are especially important for disadvantaged communities surrounding ports such as Los Angeles, Long Beach, and Oakland. The regulation is expected to be considered by the Board in November 2021.

Transport Refrigeration Units

The upcoming regulatory measure for TRUs includes the transition of diesel truck TRUs to zero-emission, a more stringent diesel PM emission standard for the remaining TRU categories, and lower global warming potential refrigerant. The transition of diesel truck TRUs to zero-emission supports the development of zero-emission infrastructure and is in alignment with Executive Order N-79-20. To reduce PM emissions and address the increasing population of TRUs equipped with diesel engines less than 25 horsepower, which have less stringent PM standards, trailer TRUs, domestic shipping container TRUs, railcar TRUs, and TRU generators sets manufactured in 2023 and later would be required to meet the most stringent standard for PM (Ultra-Low Emission TRU or ULETRU). While this measure does not focus on NOx reductions, CARB is evaluating the category for longer-term measures focused on full zero-emission operation of TRUs. This measure is planned for Board consideration in fall 2021 (staff proposal released in summer 2021). The PM reductions focus on protecting public health in and around areas where TRUs congregate, specifically distribution facilities and industrial complexes. Facilities are more likely to be found in disadvantaged communities and low-income neighborhoods, and reducing PM provides near term benefits focused on community health risks. Staff plan to assess zero-emission options for trailer TRUs and the remaining TRU categories in a second rulemaking for Board consideration in the 2023-2024 timeframe.

Locomotives

The draft in-use locomotive regulatory concepts include a Spending Account, Useful Life Limit, a 30-minute idling limit as well as reporting and recordkeeping requirements. The Spending Account rule would require railroads to deposit funds into an account, with a tentative schedule starting in 2023. The funds deposited are calculated based on the locomotive emission levels (NOx and PM) and the annual work performed in California. The deposited funds will be held in each individual railroad's Spending Account and would be required to be used to purchase Tier 4 or cleaner locomotives. CARB is also proposing to ban operation of very old locomotives in California. Railroads traditionally remanufacture locomotives many times to extend their usage. The regulation would restrict the use in California of the oldest, dirtiest locomotives—those that exceed double their useful life and have already been rebuilt several times. The concepts will include mechanisms to transform California's locomotives to zero emissions as directed by Executive Order N-79-20. Based on the current concepts, the Spending Account and Useful Life Limit together could reduce NOx emission in South Coast by 7.0 tpd in 2030. The regulation is expected to be considered by the Board in 2022.

Small Off-Road Engines and Forklifts

SORE and the broad forklift categories of equipment are both excellent candidates for a complete transition to zero-emission operation. CARB is currently moving forward with parallel zero-emission requirements for both sectors, which are expected to be implemented starting with model year 2024.

SORE are spark-ignition engines rated at or below 19 kilowatts (i.e., 25 horsepower). The SORE sector has become increasingly important, and smog-forming emissions from them will exceed light-duty passenger cars in the state in 2021. At the same time, the potential for full zero-emission operation is clear as 48 percent of the lawn and garden equipment and over 70 percent of the light commercial equipment in California are already electric. Note that the fraction of small (i.e., less than 25 hp) generators that are zero-emission lags significantly behind that for other light commercial equipment like air compressors and pressure washers.

CARB is currently developing a proposal to implement significantly tightened exhaust and evaporative emission standards for generator engines and emission standards of zero for

other engines by model year 2024[70]. Starting in model year 2024, the new emission standards will accelerate a transition of all SORE regulated by CARB – or about 90 percent of all SORE in the state – to ZEE. The regulation is expected to be considered by the Board in fall 2021. The remaining 10 percent of SORE includes new engines which are used in construction equipment/vehicles or used in farm equipment/vehicles which are smaller than 175 horsepower that fall under section 209, subsection (e)(1)(A) of the Act. The Act does not grant CARB the authority to regulate the emissions from engines used in these equipment.

CARB staff are also preparing zero emissions requirements for forklifts, which are widely used in industrial and construction applications. The zero emissions requirements, currently in development for feasibility and cost effectiveness, cover all forklifts from all applications, including gasoline, natural gas, and diesel forklifts of all sizes. This measure could be brought before the Board as early as 2022 with implementation starting in 2025.

While these measures may narrowly miss providing benefits in 2023 in South Coast, they will provide significant reductions in the late 2020s and, by 2031, will achieve a combined 6.7 tpd of NOx reductions in South Coast.

Table 7 lists NOx emission reductions in the South Coast and San Joaquin Valley from the near-term off-road measures discussed above. Combined, these off-road measures will achieve approximately 2 tpd of NOx reductions in South Coast in 2023, while achieving 24 tpd of NOx reductions by 2031, and nearly 3 tpd of PM2.5 across the state in 2030. These measures will have a particularly large impact in communities near the ports (especially the Ports of Los Angeles, Long Beach and Oakland), railyards, and distribution centers.

Table 7 – Near-Term Emissions Reductions from the Off-Road Sector

Off Road Sector	NOx (tpd)			PM2.5 (tpd)
	SC 2023	SJV 2024	SC 2031	Statewide 2030
OGV At Berth	1.1	<0.1	3.6	0.09
Locomotive	0	0.55	7	1.1
SORE	0	<0.1	2.8	0.3
TRU	0	<0.1	0.4	0.34
CHC	0.8	<0.1	2.5	0.3
Forklift	0	0	3.7	0.3
CHE	0.1	<0.1	0.9	<0.1
Construction & Mining	<0.1	<0.1	3.4	0.4
Total Off-road	**2.0**	**0.55**	**24.3**	**2.83**

[70] *https://ww2.arb.ca.gov/resources/documents/march-24-2021-workshop-slides*

Potential Near-term Emissions Reductions

Table 8 summarizes total on-road and off-road NOx emissions benefits in the South Coast and San Joaquin Valley. Please note that some of the regulations and programmatic concepts listed in Table 8 were identified as measures in the 2016 State SIP Strategy; however, some of the new proposals are expected to provide additional emissions reductions beyond what was anticipated in the 2016 State SIP Strategy. For example, while the SORE measure was anticipated to provide 2 tpd of NOx emissions benefit in 2031 in South Coast, the new regulatory proposal is estimated to reduce emissions by almost 3 tpd. Please refer to Table 4 of the 2016 State Strategy for the State Implementation Plan[71] for more details on measures and their anticipated benefits. Measures included in the 2016 State SIP Strategy are marked with an asterisk in Table 8 of this document.

It is important to note that, aside from regulatory actions, achieving our air quality and toxics risks reduction goals depends on incentive funds to advance clean technologies and to accelerate the replacement of older engines with new cleaner technologies. Because the success of incentive measures depends on future funding allocation, staff conservatively opted to only list the incentive measures that are most likely to be implemented and result in near term emission reductions. An example of these measures is the "San Joaquin Valley Agricultural Equipment Incentive Measure" where staff demonstrated a NOx emissions reduction of almost 5.9 tpd as a result of agricultural equipment turnover that occurred between 2015 and 2019 through various incentive programs such as Carl Moyer, FARMER, and the Natural Resources Conservation Service (NRCS) grant program provided by U.S. Department of Agriculture. It is worth noting that the Governor has proposed as part of the 2021-22 State Budget an additional $363 million be allocated over two years for continued replacement and upgrades of agricultural diesel engines through the FARMER Program (this proposal is still under consideration by the Legislature). Based on the State Budget approved in July 2021, the pending FARMER Program funding, and funding provided through Carl Moyer and NRCS grant programs, staff anticipates that an additional 5.1 tpd of emissions reductions can be achieved through 2024 to meet the overall emissions reduction commitment of 11 tpd for agricultural equipment replacement. This is presented as "San Joaquin Valley Agricultural Equipment Incentive Measure 2" in Table 8.

Included in Table 8 are also the anticipated emissions reductions from *Clean Truck Fund Rate* (CTF Rate) which has been under development since 2018 by the San Pedro Bay Ports. This measure has been adopted, but has yet to be acted on. Once implemented, the measure is anticipated to generate approximately $120 million per year, enough to replace 1,200 diesel

[71] *https://ww3.arb.ca.gov/planning/sip/2016sip/rev2016statesip.pdf*

trucks a year with cleaner technologies. The measure is further described later in this document.

Table 8 - Overall NOx (tpd) Emissions Reductions in South Coast (SC) and San Joaquin Valley (SJV) for Mobile Source Measures (Adopted and In-progress)

Measures	Adoption	Implementation	SC 2023	SJV 2024	SC 2031
Amendments to HDVIP and PSIP*	2018	2019	N/A	N/A	N/A
Innovative Clean Transit*	2018	2023	<0.1	<0.1	0.2
South Coast On-Road Heavy-Duty Vehicle Incentive Measure*	2018	2019	1	N/A	N/A
San Joaquin Valley Agricultural Equipment Incentive Measure 1**	2019	2015	N/A	5.9	N/A
San Joaquin Valley Agricultural Equipment Incentive Measure 2**	2025	2015	N/A	5.1	N/A
Zero-Emission Airport Shuttle*	2019	2027	<0.1	<0.1	<0.1
Ocean Going Vessels At Berth*	2020	2024	1.1	<0.1	3.6
ACT and Heavy-Duty Omnibus*	2020	2024	<0.1	<0.1	7
U.S. EPA CTI*	2021	~2027	0	0	4
Commercial Harbor Craft	2021	2023	0.8	<0.1	2.5
Heavy-Duty I/M**	2021	2023	3.5	11	18
Zero-Emission Drayage and Advanced Clean Fleet	2021	2023	0	<0.1	6-10
Small Off-Road Engines*	2021	2024	0	<0.1	2.8
Transport Refrigeration Unit*	2021	2024	0	<0.1	0.4
In-Use Locomotive	2022	2024	0	0.55	7
Advanced Clean Cars II*	2022	2026	0	0	3.2
Zero-Emission Forklift*	2022	2025	0	0	3.7
Cargo Handling Equipment	TBD	TBD	0.1	<0.1	0.9
Construction & Mining	TBD	TBD	<0.1	<0.1	3.4
San Pedro Bay Ports Clean Truck Fund Rate	2020	TBD	1.4***	N/A	N/A
TOTAL			**7.9**	**22.55**	**63-67**

* Identified in 2016 State SIP Strategy

** Identified in San Joaquin Valley Supplement to the 2016 State Strategy for the State Implementation Plan[72]

*** Assuming that the San Pedro Bay Ports Clean Truck Fund Rate program can generate $240M between 2022 – 2023 (total of two years). Of course, with further delay in the program implementation the emissions reduction will end up being lower.

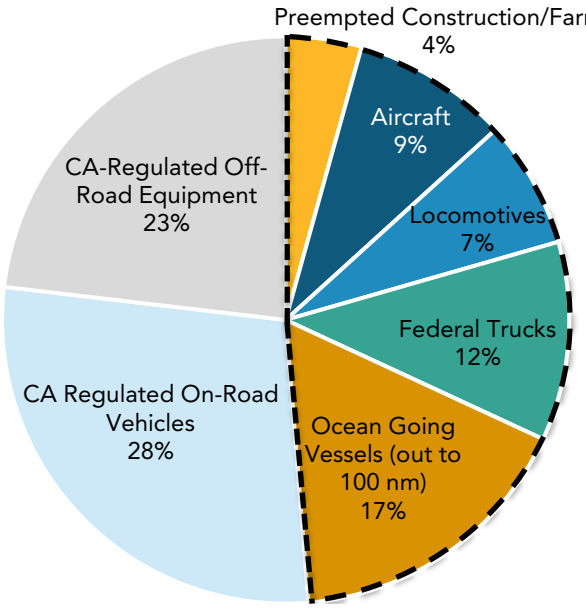
[72] *https://ww3.arb.ca.gov/planning/sip/2016sip/valleystrategy.pdf*

Achieving Near Term Air Quality Goals Requires Further Emissions Reductions at Federal and Local Level

As illustrated in Table 8, while the proposed measures achieve significant near-term emission reductions in both South Coast and San Joaquin Valley, they do not fully address the emissions reductions needed to meet federal air quality standards in 2023, 2024, and 2031. For South Coast, the measures listed in Table 8 will achieve an additional nearly 8 tpd of NOx emissions reductions in 2023 which is significantly less than the 108 tpd NOx emissions reductions needed to meet the 8-hour ozone standard of 80 ppb. Despite a significant number of regulatory actions and incentive programs considered by CARB, it will be very challenging for the South Coast and San Joaquin regions to attain the federal ambient air quality standards for ozone and particulate matter without additional emissions reductions by local, federal, and international entities.

For California to meet federally mandated air quality standards, it is imperative that through a combination of regulatory action and infusion of incentive funding, the federal government act decisively to significantly reduce emissions from federally regulated sources of air pollution in California, including interstate trucks, ships, locomotives, aircraft, and certain categories of off-road equipment. Figure 5 shows that in 2023, NOx emissions from federally regulated sources contribute almost 50 percent of mobile source NOx emissions in the South Coast air basin. This graphic clearly demonstrates why the lack of action by the previous federal administration has hindered the region in achieving the emissions reductions needed to attain ambient air quality standards in 2023 and emphasizes the need for aggressive and immediate actions to address emissions from these sources.

Figure 5 - NOx Emission Contributions from Primarily Federally Regulated Sources in South Coast Air Basin in 2023



In 2023, primarily-federally regulated sources account for almost 50 percent of mobile source NOx emissions in the South Coast Air Basin

In order to achieve necessary reductions from these sources, staff proposed the following actions for each of the mobile source sectors that are primarily regulated by the federal government. These measures are further discussed in Chapter 6 of this document through the proposed scenario concepts.

I. **Heavy-Duty Trucks (Lead Agency: U.S. EPA) – Actions needed by 2021**
   - Adopt federal Low-NOx heavy-duty truck emission standards
   - Adopt national level zero emission truck requirements along with more stringent GHG standards for medium- and heavy-duty vehicles
   - Enable state leadership on zero emission trucks by prioritizing federal grants toward zero emission technology and their associated infrastructure

II. **Locomotives (Lead Agency: U.S. EPA) – Actions needed by 2022**
   - Adopt more stringent standards for new locomotives and require remanufactured locomotives to meet current standards
   - Establish zero emission standards for switchers and provide funding toward technology and infrastructure development for zero emission line-haul locomotives

III. **Off-Road Engines (Lead Agency: U.S. EPA) – Actions needed by 2022**
   - Adopt more stringent emission standards for off-road engines (gasoline and diesel) including preempted categories
   - Establish zero emission standards for off-road engines where feasible
   - Prioritize federal technology demonstration funding to zero emission off-road equipment

IV. **Marine Vessels (Lead Agency: U.S. EPA) – Actions needed by 2023**
   - Advocate in International Maritime Organization (IMO) for more stringent NOx and PM standards for marine engines
   - Establish clean fuel and clean vessel visit requirements for ocean going vessels at national level

V. **Aviation (Lead Agencies: U.S. EPA/Federal Aviation Administration) – Actions needed by 2023**
   - Develop more stringent criteria and GHG standards for aircraft engines
   - Establish clean visit, clean fuel, and zero emission on-ground operation requirements for aircrafts

CARB will continue to work closely with U.S. EPA and other federal agencies on these proposed concepts to ensure that they achieve the needed emissions reductions for meeting national ambient air quality standards and support development of future state implementation plans. While regulatory action at the federal and international level will help drive the introduction of cleaner technologies, fuels, and fueling infrastructure, their emissions reductions rely on the pace of natural fleet turnover which is not always sufficient

to meet California's immediate near-term needs, especially in 2023. Additional funding mechanisms, partnerships, research and demonstration projects, and other innovative strategies can incentivize accelerated deployment of the cleanest technologies. As noted earlier, the 2021-22 State Budget includes unprecedented levels of investment in zero-emission vehicles and the infrastructure needed to support them. Specifically, the final budget devotes $3.9 billion over the next three years to fast-forward the State's zero-emission vehicle goals. While this proposal can significantly accelerate the pace of market development for zero emissions technologies and achieve further near-term emissions reductions, federal funding will be crucial to fully address the NOx reductions needed in the South Coast air basin by 2023. If provided, the federal funding can help recoup the necessary emissions reductions from federal sources that were not achieved during the previous federal administration.

Aside from actions at the federal and international level, efforts at local levels are needed to help the non-attainment regions in California meet the national ambient air quality standards. Efforts like road pricing could contribute to reducing air pollution. In addition, freight operations at major ports in California generate significant emissions from ships, trucks, trains, tugboats, and terminal equipment, thus contributing to regional air quality issues and local health risk. According to the *2017 Clean Air Action Plan,* despite significant progress in reducing diesel toxics as well as NOx emissions, the Ports of Los Angeles and Long Beach remain the largest source of pollution in Southern California. Additionally, the recent increases in cargo movement during the pandemic demonstrate the necessity for additional actions to reduce the freight industry's impacts on regional air quality as well as local communities' exposure to air toxics. According to recent container statistics provided by the Ports, in the past two years the San Pedro Bay Ports (SPBP) have seen an average increase of 50 percent in cargo movement (twenty-foot equivalent units - TEU). This rapid increase in cargo movement has resulted in unprecedented levels of marine vessel congestion and resulting regional and near source pollution impacts. When marine vessel congestion peaked in February 2021, up to 40 vessels were queued near the SPBP. In comparison, in previous years, only one vessel on average was waiting to enter the Ports.

Table 9 – Container Statistics at San Pedro Bay Ports

Ports	Container Statistics (twenty foot equivalent units TEU)			
	March 2019	March 2020	March 2021	Percent increase since 2019
Port of Los Angeles	650,977	449,568	957,599	47%
Port of Long Beach	552,821	517,664	840,387	52%
Total	**1,203,798**	**967,232**	**1,797,986**	**49%**

The *2017 Clean Air Action Plan* developed by the Ports of Los Angeles and Long Beach has identified several emission reduction and efficiency improvement strategies that can be implemented locally to further reduce emissions within the next few years. These actions rely on accelerating the adoption of cleaner engine technologies and operational changes

through incentives and new requirements. An important part of these strategies is the proposed modification to the Clean Trucks Programs with a goal of transitioning to zero emission trucks by 2035. A critical element in the implementation of the Clean Trucks Program is the establishment of a *Clean Truck Fund Rate* (CTF Rate) which has been under development since 2018. As outlined in the *2017 Clean Air Action Plan*, beginning in 2020, the Ports were planning to charge a rate for loaded containers hauled by heavy-duty trucks that enter or exit the Ports' terminals, with exemptions for trucks that have engines certified to the CARB Heavy-Duty Omnibus manufacturing standard or better (i.e., zero emission). The funds collected through this process would be allocated to a clean truck funding program that would incentivize the purchase of cleaner drayage trucks. Despite the Ports' *economic analysis* demonstrating minimal cargo diversion if the Ports charged upward of $70 per TEU, the Long Beach and Los Angeles Port Commissions adopted a CTF Rate of $10 per TEU for loaded containers hauled by heavy-duty trucks that enter or exit Port terminals. Based on recent cargo volumes and anticipated rebates, this CTF Rate could generate approximately $120 million per year[73] which could be used to annually replace up to 1,200 trucks a year with cleaner technologies. Although, the CTF Rate was adopted by the Ports in March 2020, it has not yet been implemented due to concerns about the economic impacts of COVID on the worldwide economy. The delayed implementation of this program is resulting in a loss of potential air pollution mitigation revenue of approximately $10 million per month for incentivizing the introduction of cleaner trucks in the South Coast region. If this program had been implemented as planned, it would have generated a minimum of $480 million between 2020 and 2023 (Table 10), enough to replace almost 4,800 diesel trucks with cleaner technology. This is equivalent to replacing almost one-third of the population of active drayage trucks operating at these ports and would have resulted in approximately 2.5 tpd of additional NOx emissions reductions in South Coast by 2023. This illustrates the critical role that these local programs can play in maximizing near term emission reductions, and why it is important to implement them as quickly as possible. CARB will continue working closely with the Ports and other local authorities to further develop and implement the local measures needed to improve air quality and reduce near source exposure in the region.

Table 10 - Actual and Anticipated Revenue from Ports' CTF Rate Program Between 2020 and 2023

Year	Anticipated Revenue	Actual Revenue
2020	$120 million	$0
2021	$120 million	TBD
2022	$120 million	TBD
2023	$120 million	TBD
Total	**$480 million**	TBD

[73] According to Ports' statistics, in 2020 more than 11.8 million TEU of loaded containers were have either entered or exited the San Pedro Bay Ports' terminals

Chapter 5 - Pathways Forward to Meet California Goals

Defining the scope of actions necessary to implement a strategic vision to meet all of California's goals requires an integrated planning process. In order to identify the strategies and program concepts that will best 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 strives to reduce: criteria pollutants, toxics, and greenhouse gases. To do this, CARB uses scenario planning tools to quantify changes in ozone and PM2.5 precursor emissions, GHG emissions, diesel toxics emissions, and petroleum usage as various technologies are projected to populate the vehicle and equipment fleets. CARB's tools, known as the *Mobile Emissions Toolkit for Analysis (META)* and *Vision*, are used to evaluate scenarios with varying assumptions about potential technology and fuel mixes, and explore different rates at which those technologies could become widely used.

Integrated planning is critical to evaluate strategy concept scenarios for meeting the State's public health, climate, and community risk reduction goals. Technologies, energy sources, and vehicle travel, as well as the best policy tools, will vary by sector based on the status of technology development in various applications, the multi-pollutant benefits, and the interactions between regulatory and programmatic strategies. CARB staff have identified in the 2020 Strategy a suite of strategy concepts, many of which CARB is actively pursuing through individual public processes, that will enable the State to achieve the technology trajectories identified in the scenarios and, consequently, meet California's many goals. The concepts contained in the 2020 Strategy will continue to be developed and translated into measures for the next State SIP Strategy and other CARB planning documents over the coming years. By maximizing the use of zero-emission technology, these concepts maximize the emission reductions of criteria pollutants, greenhouse gases, and toxics.

For on-road light-duty vehicles, these concepts include:

- manufacturer requirements to foster clean technology production and sales;
- in-use requirements to accelerate penetration of newer technology; and
- incentive programs to promote and accelerate the use of advanced clean technologies
- outreach and education to increase consumer awareness and acceptance of advanced vehicle and equipment technologies; and
- infrastructure planning and development to support the transition to cleaner technologies.

For on-road medium- and heavy-duty vehicles, concepts include:

- manufacturer requirements to foster clean technology production and sales;
- in-use requirements to accelerate penetration of newer technology;
- incentive programs to promote and accelerate the use of advanced clean technologies;

- enhanced enforcement strategies to ensure programs are achieving their anticipated benefits;
- outreach and education to increase consumer awareness and acceptance of advanced vehicle and equipment technologies; and
- infrastructure planning and development to support the transition to cleaner technologies.

For off-road vehicles and equipment, concepts include:

- manufacturer requirements to foster clean technology production and sales;
- in-use requirements to accelerate penetration of newer technology;
- incentive programs to promote and accelerate the use of advanced clean technologies;
- outreach and education to and increase consumer awareness and acceptance of advanced vehicle and equipment technologies; and
- infrastructure planning and development to support the transition to cleaner technologies.

In the near term, incentive programs to promote and accelerate the use of advanced technologies will be key to meeting our pre-2030 air quality goals.

Potential Emissions Reductions of Scenario Trajectories

A summary of scenario assumptions, along with the total statewide fuel use and NOx emissions reductions from the 2020 Strategy scenarios, is provided in Table 11, and Figure 6 and Figure 7. As shown, the scenarios in the 2020 Strategy would achieve an overall statewide NOx emissions reduction of 531 and 592 tpd in 2031 and 2037 respectively, which are equivalent to 48 and 55 percent reduction from projected baseline NOx emissions (including stationary and area source) in those years.[74] Also, as a result of these strategies, mobile source NOx emissions in 2031 and 2037 will be 75 and 82 percent below 2017 baseline. The scenarios will also reduce mobile source fuel consumption by 9.5 billion gallons of gasoline and 3.0 billion gallons of diesel equivalent in 2045. This equates to a well-to-wheel (WTW) GHG emissions reduction of approximately 94 million metric tons of carbon dioxide equivalent (MMT CO2e) in 2045, or 76 percent reduction from 2020.

[74] According to 2016 South Coast AQMP, the preliminary projections, based upon ozone "isopleths" developed for the 2031 emission scenarios indicate that 2037 Basin NOx carrying capacity to meet the 70 ppb standard could be as low as 75 tpd. This is additional 62 percent NOx reduction beyond the projected 2037 baseline and 25 tpd of additional NOx emission reductions between 2031 and 2037.

Table 11 - Summary of the 2020 MSS Scenarios

Category		Scenario Assumptions
On-Road	Light-Duty Vehicles	• 70% ZEV + PHEV sales in 2030 • 100% ZEV + PHEV sales in 2035 • 7.9 M ZEV by 2030 • 27.9 M ZEV+PHEV by 2045
	VMT	• ~15% reduction in statewide light-duty VMT by 2050 compared to business as usual
	On-Road Motorcycles	• Alignment with EU5 standard for MY2024+ motorcycles • 100% ZEM sales in 2035 and onward
	Medium-Duty Vehicles	• 100% ZEV sales starting 2035
	Heavy-Duty Vehicles	• Reflect Heavy-Duty Omnibus, ACT, and Heavy-Duty I/M starting in 2024, and federal 0.02 g/bhp-hr starting in 2027 • 100% of model year 2035 and newer vehicles registered in California will be ZEV • Accelerated turnover of older trucks
Off-Road	Off-Road Efficiency Improvement[75]	• Zero-emissions and hybridization where feasible with the goal of 12 percent reduction in GHG by 2030, and 30 percent by 2040
	Off-Road Tier V Standard	• Tier 5 being introduced starting in 2028-2030 • 50 – 90% NOx reduction from current Tier 4f standard
	Rail	• 100% of replaced locomotives will be Tier 4 • Remanufacturing limit • Tier 5 being introduced in 2028

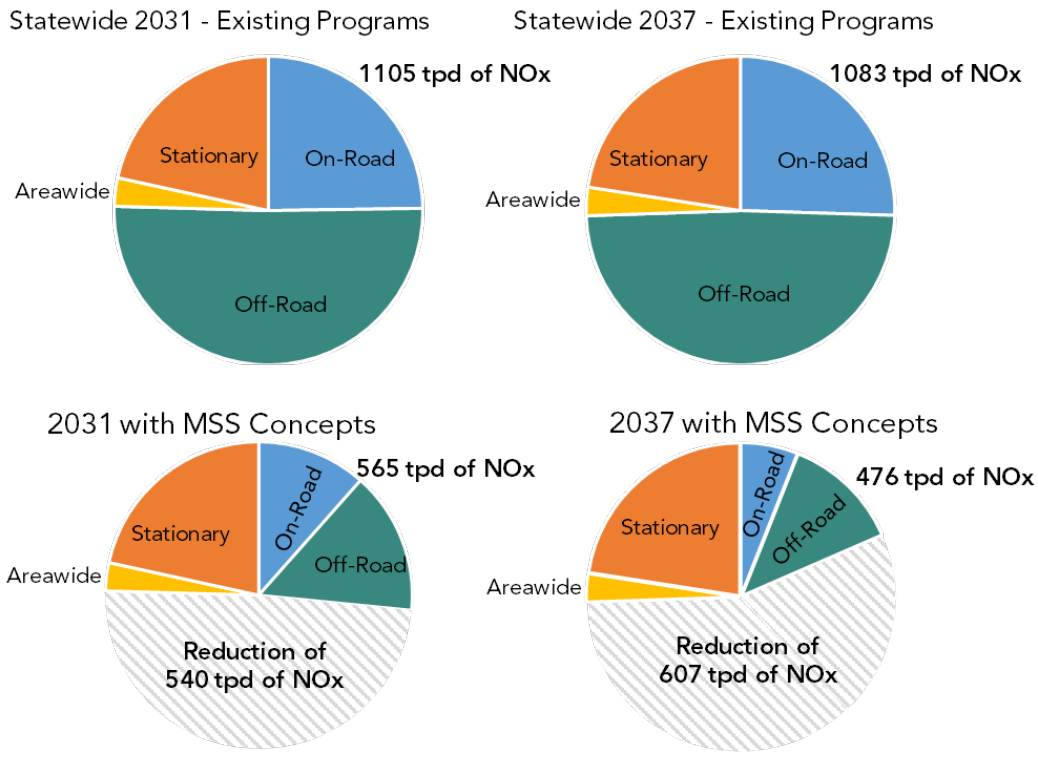
[75] Excluding categories such as CHE and TRU that are going to zero-emission in other scenarios. This is done to avoid double counting

Category		Scenario Assumptions
	Ocean Going Vessels *(out to 100 nm)*	• 100% of Tier 0/1/2 visits are phased out by 2031 • Tier 3 visits begin in 2025 (begin replacing all Tier 0-2) • Tier 4 visits begin in 2028 (no additional Tier 3 visits)
	Construction	• Full turnover of Tier 0/1/2 to Tier 4f by 2033
Off-Road	SORE	• All non-federally preempt SORE sales except for generators will be zero-emission by 2024 (2028 for generators)
	Aircraft	• 25 percent derate during take-off • 40 percent reduction in Taxi time • Single engine taxiing • 40 percent reduction in APU usage
	Transport Refrigeration Units	• Accelerated penetration of electric TRU (from 10% in 2024 to 100% in 2033)
	Commercial Harbor Craft	• All vessels (including commercial fishing) being Tier 4/5 by 2031 • Introduction of Plug-in hybrid for excursions and diesel-electric for tugs by 2030
	Cargo Handling Equipment	• Begin transition to full electric operation beginning in 2026 (accelerated turnover)
	Agriculture	• An incentive based concept consistent with the 2018 SJV SIP
	Airport Ground Support Equipment	• Full electrification transition from 2025-2034
	Forklifts	• Transition to zero-emission technology starting in 2025 with fully electric fleet by 2034
	Recreational Watercraft	• New THC + NOx standards of 40 and 70 percent below current levels • Electrification of small outboard and PWC engines

CARB staff will continue to develop the concepts in order to translate them into measures that will be included in the State SIP Strategy being developed for the 70 ppb 8-hour ozone standard, along with other CARB planning documents to be released in the coming years.

The 2020 Strategy scenarios illustrate that even with extremely aggressive electrification, accelerated turnover, coupled with aggressive VMT reductions and fuel decarbonization,[76] the mobile source sector alone cannot become carbon neutral by 2045. This emphasized the importance of CDR strategies such as mechanical and land-based sequestration. This economy-wide approach that includes consideration of CDR is introduced in a recent report by Energy and Environmental Economics (E3). [77] The E3 report provides insights into the types of economy-wide transformation that will be necessary to achieve carbon neutrality by mid-century.

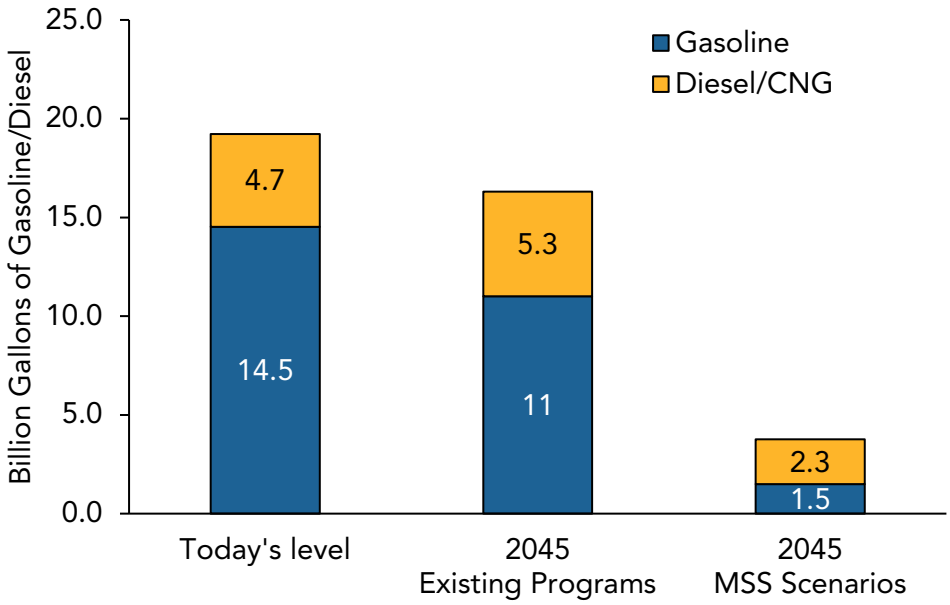
Figure 6 - Impact of the 2020 Strategy Scenario on Statewide NOx Emissions in 2031 and 2037



* Emissions from ocean going vessels are considered out to 100 nm

[76] Fuel decarbonization refers to a group of strategies, including SB 100 electric grid requirements, liquid fuel carbon reductions through the Low Carbon Fuel Standard (LCFS), and other actions.
[77] Achieving Carbon Neutrality in California: PATHWAYS Scenarios Developed for the California Air Resources Board *https://ww2.arb.ca.gov/sites/default/files/2020-08/e3_cn_draft_report_aug2020.pdf*

Figure 7 - Impact of the 2020 Strategy Scenario on Mobile Source Liquid Fuel Consumption in 2045



Additional Health Benefits of the Transition Away from Combustion

Shifting to electric transportation will reduce pollution-related death and illness. State and regional emissions will decline substantially as fossil fuel burning vehicles are replaced by ZEVs and vehicles using renewable energy sources. The potential health benefits of phasing out fossil fuels in the transportation and off-road sectors and of reducing emissions of air pollutants and climate pollutants are substantial.

A 2018 literature review looking at 65 articles demonstrated there was consistent agreement that increasing the adoption of ZEVs would reduce emissions of GHGs and some criteria pollutants.[78] Few studies have been conducted looking at the health impacts of switching to cleaner cars, but a study completed in the U.S. estimates that 3700 to 6400 premature deaths would be avoided with a transition to hydrogen fuel cell vehicles in combination with a renewable energy infrastructure for vehicle charging.[79]

Active and public modes of transportation can play a critical role in low-income and disadvantaged community mobility and access, and provide critical connectivity opportunities

[78] Requia et al. (2018). How clean are electric vehicles? Evidence-based review of the effects of electric mobility on air pollutants, greenhouse gas emissions and human health. Atmospheric Environment.
[79] Jacobson et al. (2005). Cleaning the air and improving health with hydrogen fuel-cell vehicles. Science.

where residents do not have access to a personal vehicle. Further leveraging these options across the State, as is discussed in the next chapter, will reduce pollution-related death and illness, and improve health, especially for those who face disproportionate burdens from air pollution exposure. Active transportation such as walking and biking can enhance health benefits from increased physical activity. Most public transit is accompanied by other forms of transportation such as walking and/or biking. State and regional emissions will decline substantially since riding public transportation can significantly replace passenger car trips and in addition can increase individual's physical wellbeing from walking or biking to the public transportation. Even after considering exposure to air pollutants and potential traffic injury, the health benefits of active transportation and public transit can still be substantial.[80]

Active transportation and public transit will not only contribute to a reduction in fossil fuel burning vehicles, but also will improve various health outcomes such as mental illness, cardiovascular diseases, and cancer.[81] Additionally, walking, biking, and other variants of active transportation such as scooters will create a more social and cohesive environment, and improve an individual's quality of life and increased life expectancy.[82] The potential health benefits from replacing fossil fuels in the transportation sector with public transportation and active transport are substantial. More needs to be done to make sure that these critical transportation options are safe, accessible, and meet the needs of low-income and disadvantaged communities.

Role of Cleaner Combustion and Zero-Emission On-Road Heavy-Duty Vehicles

As we look forward, it is evident that there are certain areas where CARB, other State and local agencies, and other partners, will need to dedicate extra attention to fully analyze and determine the best path into the future. In order to meet our numerous standards, targets, and goals over the next thirty years, California will need to see a substantial transition of the mobile fleet, with zero-emission vehicles dominating the on-road fleet and certain off-road

[80] Maizlish et al. (2013). Health cobenefits and transportation-related reductions in greenhouse gas emissions in the San Francisco Bay area

[81] Furie, G. L., & Desai, M. M. (2012). Active Transportation and Cardiovascular Disease Risk Factors in U.S. Adults; Mueller et al. (2015). Health impact assessment of active transportation: A systematic review

[82] Sallis et al. (2004). Active transportation and physical activity: opportunities for collaboration on transportation and public health research

sectors, and penetrating into the remaining off-road sectors wherever possible, with cleaner combustion engine technologies and renewable fuels everywhere else.

All forms of cleaner heavy-duty trucks and buses will be critical to achieving ambient air quality standards, near-term risk reduction goals, and climate targets. CARB has a number of programs already in place or under development to require and otherwise encourage the adoption of clean on-road heavy-duty vehicles; these include the Truck and Bus Regulation, the Heavy-Duty Omnibus Regulation, the Advanced Clean Trucks Rule, the forthcoming Advanced Clean Fleets rule, and various incentive programs including the Moyer Program.

Trucks certified to CARB's previous optional low NOx standard are currently in-use, and as such, are highly important for achieving more near-term SIP deadlines including attainment of the 80 ppb ozone standard in the South Coast Air Basin in 2023, attainment of PM2.5 standards in the San Joaquin Valley in 2024 and 2025, and attainment of the 75 ppb ozone standard throughout the State by 2031. CARB's recently adopted Heavy-Duty Omnibus Regulation includes more stringent engine standards which will phase in statewide starting in 2024. It is expected that trucks manufactured to meet this standard or already certified to meet the pre-existing optional standard (0.02 grams per brake horsepower-hour) will contribute significant near-term NOx reductions for attainment, as well as to near-source risk reduction in and around disadvantaged communities.

That said, as emphasized by Governor Newsom's recent Executive Order, zero-emission trucks already play an important role in reducing emissions throughout the State and will be especially critical to meet long-term climate goals. In order to put California on track to meet climate goals in 2045 and 2050, 1.4 million medium- and heavy-duty ZEVs are necessary. An important first step to move the State in this direction is the Advanced Clean Trucks Rule, which was adopted by the Board in June 2020 and will implement manufacturer sales requirements beginning in 2024. CARB staff is also working to develop and bring to the Board the complementary Advanced Clean Fleets rule which will be brought to the Board for consideration by the end of 2021.

Furthermore, the State of California announced last year a Memorandum of Agreement with 14 other states and the District of Columbia to accelerate truck and bus electrification, with a goal of ensuring that 100 percent of all new medium- and heavy-duty vehicle sales are ZEV by 2050, and an interim target of 30 percent ZEV sales by 2030. While California will need to see 100 percent of on-road heavy-duty vehicle sales be ZEV by 2035, increased out-of-state sales of ZEV trucks will also be important for emissions reductions given that it's estimated that around 50 percent of heavy-duty vehicle miles travelled on California roads is driven by trucks first sold out-of-state.

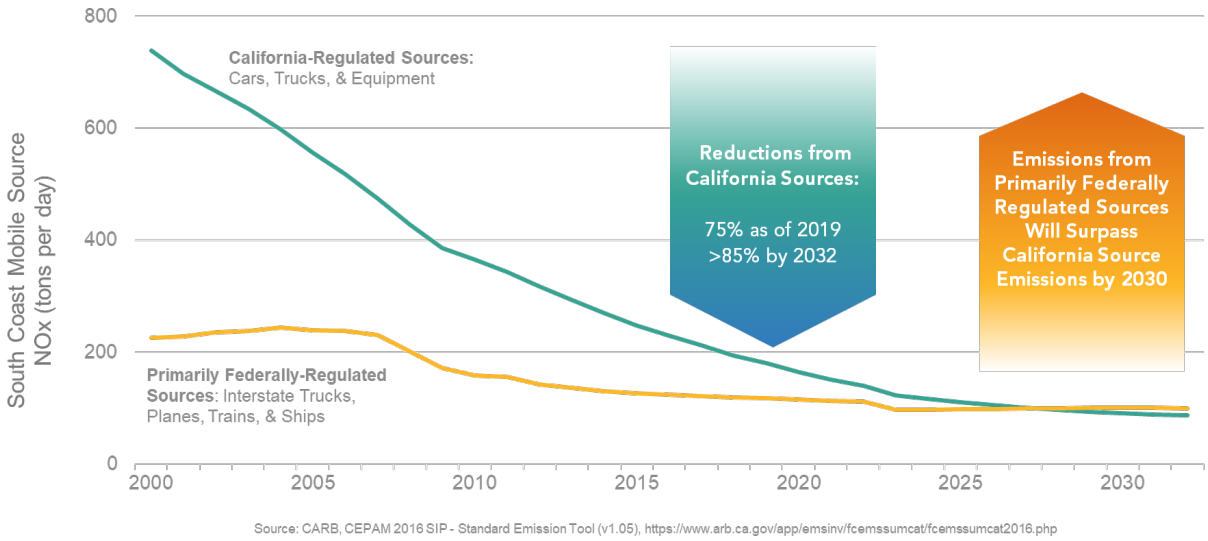
Addressing Emissions from Primarily-Federally Regulated Sources

In addition to reducing emissions from on-road vehicles and off-road equipment, another critical effort will be to ensure reductions in emissions from sources that are primarily

regulated at the federal and international level. In the 2016 Strategy, CARB discussed actions we could take at the State level and those that could be taken by U.S. EPA to achieve reductions from these sectors, which include ships, locomotives, aircraft, and certain off-road equipment. Since that time, 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, since the release of the 2016 Strategy and the subsequent petitions, action by U.S. EPA to limit emissions from these sources has yet to materialize, making it more challenging to meet federal air quality standards and reduce air pollution that harms public health in California and across the U.S.

As shown in Figure 8, NOx emissions from California-regulated mobile sources in the South Coast have declined by 75 percent since 2000 while emissions from primarily federally-regulated mobile sources have declined by half that amount over the same time period. More significantly, whereas California-regulated mobile sources accounted for more than three times the NOx emissions of federally-regulated mobile sources in the South Coast in 2000, by 2030 NOx emissions from federally-regulated sources in South Coast will exceed emissions from California-regulated sources. These trends highlight the need for aggressive and immediate federal action to address emissions from interstate trucks, aircraft, locomotives, and ships, ensuring that the costs of attaining federal air quality standards are borne by all sources of air pollution.

Figure 8 – Federal Action is Increasingly Critical



Source: CARB, CEPAM 2016 SIP - Standard Emission Tool (v1.05), https://www.arb.ca.gov/app/emsinv/fcemssumcat/fcemssumcat2016.php

While engine standards do exist at the federal and international level for new aircraft, locomotives, and ocean-going vessel engines and equipment, these standards do not reflect the current state of technology. In addition, equipment in these categories tends to remain in operation for long periods of time. As a result, emissions from these categories have not

decreased at the same pace as those for other mobile sources in California. Achieving the magnitude of emission reductions necessary from these categories will require strong action at the federal and international level, coupled with State and local advocacy and action to facilitate these efforts. It is critical to continue to reduce emissions from in-use equipment through new national emission standards for newly manufactured and remanufactured locomotives, adoption of more stringent emission standards for new ocean-going vessels and efficiency requirements for existing vessels, and by spurring the early implementation of clean technologies via mechanisms to incentivize the use of those technologies in California.

In addition to off-road sources that are primarily regulated at the federal level, heavy-duty trucks are another category where action at the federal level is essential to California's success. As mentioned previously, approximately half of heavy-duty VMT within California is driven by trucks first sold out-of-state. Without a more stringent federal engine standard, newer model year 2024+ vehicles certified or first sold outside of California will lack stringent standards. This will make it very challenging for California to meet federal air quality standards, particularly in areas with extreme air quality issues such as the South Coast Air Basin and the San Joaquin Valley. Currently, U.S. EPA is developing the Cleaner Trucks Initiative, which has many of the same elements as CARB's recently-adopted Heavy-Duty Omnibus Regulation and begins in 2027. On January 21, 2020, U.S. EPA released an Advanced Notice of Proposed Rulemaking for pre-proposal comments.

Regardless of the timing of federal action on emission standards, CARB is moving forward and will take action where possible to lower emissions now. As described earlier, CARB has identified strategies available to lower emissions from locomotives, aircraft, and ocean-going vessels. This includes partnerships with ports and engine manufacturers to incentivize the use of cleaner technologies in California and to encourage the production of cleaner, more efficient engine technologies.

Targeting Benefits in Low-Income and Disadvantaged Communities

CARB has long worked to reduce negative effects of air pollution in the State's most highly-impacted populations through programs to control emissions from freight transport and other significant sources affecting low-income and disadvantaged communities. In recent years, CARB and the State have been enabled through AB 617 programs, SB 350 equity efforts, and Low Carbon Transportation to renew our focus on and engagement with these communities. As discussed earlier, disadvantaged communities experience the highest levels of air pollution impacts in California. In addition, populations in these communities are generally more likely to be impacted by the COVID-19 health and economic crisis, in part due to already-high pollution exposure and impacts. As such, the need is greater than ever to reduce emissions and exposure in low-income and disadvantaged communities throughout the State, while also meeting community-identified clean transportation and mobility needs.

CARB's AB 617 CAPP is a first-of-its-kind statewide effort that includes community air monitoring and CERPs with the primary purpose of reducing exposure in communities most

impacted by air pollution. The program provides an opportunity to continue to enhance our air quality planning efforts and better integrate community, regional, and State level programs to provide clean air for all Californians, and is a complimentary mechanism through which CARB works to improve air quality in highly-impacted communities. Throughout the AB 617 process to date, many communities and their representatives have continually sought a transition of the dirtiest mobile sources in their communities to zero-emission technology as fast as possible.

There are also a number of Low Carbon Transportation projects designed to advance CARB's equity goals, including meaningful community engagement and inclusion in policy decisions, increasing access to critical goods and services, and improving connectivity to public transit and other clean options in communities, while reducing GHG emissions. And as previously described, the investment minimums for GGRF created under *Assembly Bill 1550*[83] also play a significant role in CARB's ability to target benefits in disadvantaged communities. CARB and other State agencies are continually striving to go beyond the requirements of AB 1550, with 57 percent of projects implemented using California Climate Investment funds to date benefiting California's disadvantaged communities and low-income communities and households.[84] Because mobile sources are such a significant source of emissions throughout the State, much of California Climate Investment funding allocated to CARB, including a considerable portion of CAPP funds, is used to incentivize development and deployment of cleaner mobile source technology.

Moving forward, CARB will continue to go above and beyond these various mandates to improve air quality and reduce exposure to criteria pollutants and toxics in low-income and disadvantaged communities. Many of the measures proposed in the 2016 Strategy have since been adopted by CARB as regulations and will provide substantial emissions and health benefits in these communities. In addition, programs under development and new concepts discussed here in the 2020 Strategy, including the Heavy-Duty Inspection and Maintenance Program and the Locomotive Emission Reduction Measure, have immense potential to provide additional benefits. More broadly, across all programs moving forward, CARB is working to factor in environmental justice and accelerate controls in communities of concern where feasible, and to engage more directly with community members throughout the regulatory development and implementation process.

Ramifications of the Current Health and Economic Crisis

The COVID-19 pandemic has already had extreme effects on lives and livelihoods, as well as on federal, State, and local budgets. In 2020, the State confronted a budget deficit of $54.3 billion, and the State Budget reflected estimated spending of $5.7 billion to respond

[83] Gomez, Chapter 369, Statutes of 2016
[84] 2020 California Climate Investments Annual Report
https://ww2.arb.ca.gov/sites/default/files/classic//cc/capandtrade/auctionproceeds/2020_cci_annual_report.pdf

directly to the COVID-19 pandemic. Despite the initial budget deficit last year, California has rebounded and proved resilient through the COVID-19 pandemic such that the fiscal outlook for 2021 is significantly better, as demonstrated by the Governor's 2021 State Budget proposal. Amongst other things, in the proposed 2021 State Budget, Governor Newsom included a $1.5 billion comprehensive strategy to achieve the state's zero-emission vehicle goals by 2035 and 2045, including securitizing up to $1 billion to accelerate the pace and scale of the infrastructure needed to support zero-emission vehicles. That said, with the deferral on GGRF appropriations handled through the Cap-and-Trade Expenditure Plan and funding levels for many incentives to achieve mobile source emissions reductions still uncertain, all efforts to reduce emissions and exposure are especially critical during this time. Air pollution can have a wide variety of negative effects on respiratory health, and COVID-19 has been shown to pose greater risk to individuals suffering from respiratory illnesses. In addition, both COVID-19 and air pollution are seen to have a disproportionate impact on disadvantaged communities and people of color.

Even prior to the current crisis, incentive funding was not yet at the levels needed to achieve the level of vehicle and equipment turnover necessary for attainment of near-term SIP deadlines. Given the reduced monetary resources available for incentives in the near-term due to COVID-19, increased emissions reductions from regulatory programs may be necessary.

Ongoing Need for Incentive Funding to Support Clean Technology

Regulations take considerable time to develop and in many instances, lead-time and transition periods are necessary for industry to feasibly comply; despite this challenge, significant emissions reductions are needed from mobile sources in California over the next 5, 10, and 30 years. In recent years, the Board has repeatedly directed staff to advance regulatory deadlines where feasible in order to reduce emissions earlier than previously planned. To the extent possible, CARB will continue to explore areas where it may be possible to achieve emissions reductions earlier than currently scheduled in a developing regulation or by amending an existing regulation.

While regulatory mechanisms have and will continue to achieve a majority of the necessary emissions reductions, incentive funding is of critical importance, especially in the near-term to advance technology development and deployment and accelerate the rate of fleet turnover to the levels needed to meet targets. Substantial funding and investment will be needed from all levels of government, and the private sector, to deploy clean technologies and the infrastructure to support them. Despite the delay in some funding appropriations specifically dedicated to incentive-based turnover of mobile source vehicles and equipment as a result of the COVID-19 pandemic, there is the potential to leverage other funding that may be available in this year's budget and in coming years to achieve emission reductions from the mobile fleet and from other sources of air pollution statewide. The $1.5 billion included in the Governor's proposed 2021 State Budget towards achieve the state's zero-emission vehicle goals by 2035 and 2045 could play a substantial role, and it is likely that funding from a

federal infrastructure would directly support the transition to clean and zero-emission vehicles as well.

Like California has shown for decades, clean technologies and the markets evolving around them are compatible with, and contribute to, a thriving State economy. As the State moves forward and works to revive California from the current economic crisis, it is imperative that we use the funds that are available to achieve the maximum benefit possible for all Californians, and this includes reducing mobile source emissions through a transition to zero-emission technologies, and otherwise supporting the green economy.

Chapter 6 - 2020 Mobile Source Strategy Scenario Concepts

In California, on-road and off-road mobile sources are the largest contributor to NOx and GHG emissions. In 2017, direct emissions from mobile sources were responsible for 80 percent of statewide NOx (Figure 9) and 40 percent of statewide GHG (Figure 10) emissions when excluding emissions from the production of fuels that power them.

Figure 9 – 2017 Statewide NOx Emissions by Sector

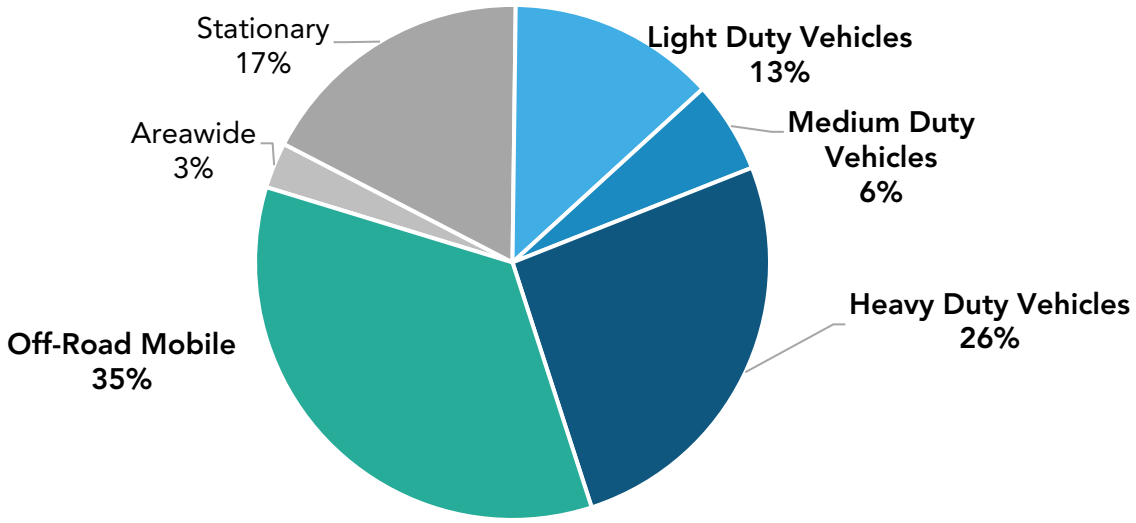
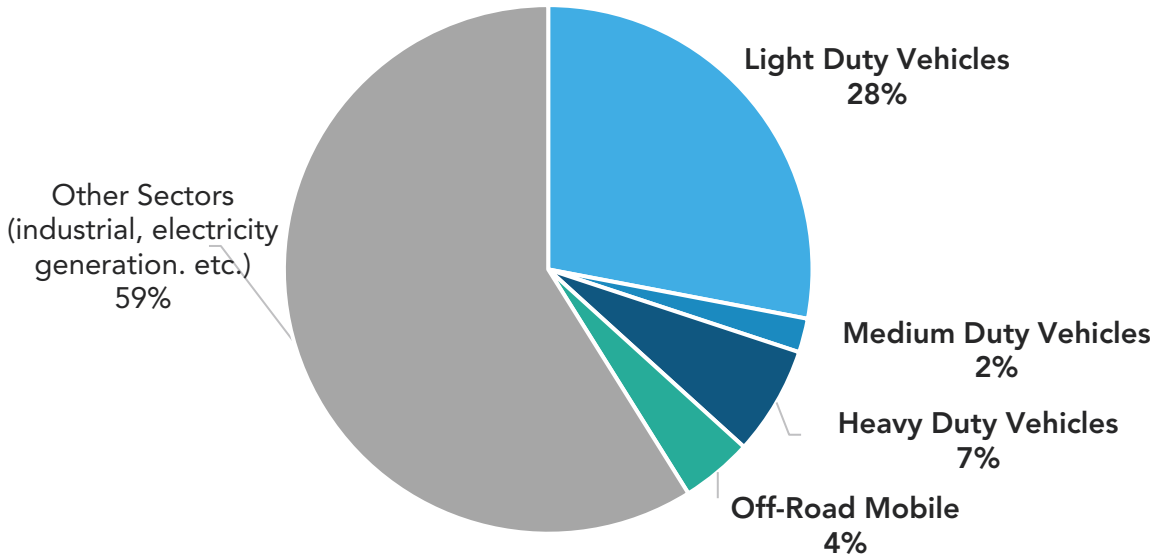


Figure 10 – 2017 Statewide GHG Emissions by Sector



As outlined earlier in the document, while significant progress has been made in reducing mobile source emissions in California, substantial additional emissions reductions from today's levels are required to meet air quality standards and California's climate goals. The 2020 MSS presents a top-down scenario modeling approach that defines the technology mixes needed to achieve these emissions reduction targets. These scenarios are also reflective of the scale of technology transformation that needs to happen within California's mobile source sector. While the scenarios define the technology mixes, they do not necessarily pinpoint the strategies and policy tools that could be used to achieve them. Such a level of transformation requires multiple policy tools as no one tool will achieve all of our goals. Potential policy tools could include, but are not limited to, the following:

- Manufacturer requirements to foster clean technology production and sales;
- In-use requirements to accelerate penetration of newer technology;
- Incentive programs to promote and accelerate the use of advanced clean technologies;
- Zero-emission vehicle fueling and charging infrastructure planning and development;
- Regional land use and transportation planning to enable more transit and mobility options, and to encourage less VMT for mobility needs;
- Transportation pricing to permanently signal to users the mobility options that are more sustainable;
- Enhanced enforcement strategies; and
- Outreach and education to bridge the knowledge gap and increase consumer acceptance of advanced vehicle technologies.

The scenarios developed for the 2020 MSS would require major changes to mobile source sectors, particularly a transformation to zero-emission technologies wherever feasible, and near zero-emission technologies with the cleanest, lowest-carbon fuels everywhere else.

Scenario Modeling Tools

Vision for Clean Air

CARB's *Vision for Clean Air Framework*, first released in 2012, was developed to enhance CARB's ability to conduct transportation policy, multi-pollutant analyses to inform air quality and climate planning. It allows for the evaluation of technology, energy, and transportation system policy evaluations across multiple sectors and pollutants. In support of the 2016 Strategy, CARB released the updated and expanded Vision 2.1. For the 2020 MSS, staff are using the same modeling framework, but with updated light-duty vehicle population and emission rates from EMFAC2017, [85] updated vehicle activity from California's metropolitan

[85] California Air Resources Board (CARB) (2017). EMFAC2017 Web Database (v1.0.2) (*https://arb.ca.gov/emfac/2017*)

planning organizations (MPOs), and refined technology adoption forecasts. Refined technology adoption rates for zero-emission vehicles were updated based on the preliminary ZEV market projection analysis presented in the July 30, 2020 EMFAC 202x workshop.[86] Scenario assumptions for the light-duty vehicle sector are described later in this chapter.

Mobile Emissions Toolkit for Analysis (META)

META was developed to facilitate the updates included in the 2020 MSS. It uses the most current emissions inventory data as the basic framework and incorporates major strategies to reduce criteria and GHG emissions, to present what-if scenarios of technology mix, fuel consumption, and emissions for the on-road heavy-duty and off-road sectors. The META tool provides the explicit technical details and spells out strategy assumptions of the scenario analyses. Most importantly, it provides transparency for the 2020 MSS development. Scenarios visualized through the META tool are used to understand how different combinations of concepts will transform the technology mix of the future vehicle fleet and associated emissions.

The on-road medium- and heavy-duty scenarios in META used population and emission outputs from EMFAC2017 with vehicle activities from MPO travel demand models. This version of EMFAC is used for SIP and transportation conformity purposes. EMFAC2017 incorporated emissions reductions from regulations that had been officially adopted before the end of 2017. The emission benefits of regulations adopted between now and then, such as ACT, are modeled off-line within the META tool. EMFAC2017 outputs served as a baseline for populations and tailpipe emissions, broken down by EMFAC categories. This tool applies the scenario assumptions outlined later in this chapter to the baseline, and then calculates scenario technology population mixes, emissions, and fuel consumption for the 2020 MSS. META on-road allows for scenario selection (for heavy-duty only) and output type, including pollutant and fuel type. There are also options to model what-if scenarios with different combinations of cleaner combustion application scope and ZEV phase-in schedules. This provides an opportunity for end users to compare results with 2020 MSS scenarios.

META-Off-road allows users to visualize the baseline and 2020 MSS scenario results and view assumptions for each off-road sector. Baseline inventories for each off-road sector in META are based on the most recent inventory results. In the Results pages, users may select outputs such as population, fuel use, NOx, PM2.5, and carbon dioxide (CO2) emissions for each off-road sector in the South Coast Air Basin, the San Joaquin Valley, and statewide domains. The "Results-Totals" page shows the comparison of annual totals between the baseline and MSS scenario. The "Results-Detailed" page provides detailed outputs broken down by either Tier group or fuel type for both scenarios. The "Scenario Description" page provides a summary of the data sources, inventory status, current rule concepts, 2020 MSS

[86] *https://ww2.arb.ca.gov/sites/default/files/2020-07/EMFAC202x_2nd_Workshop_07302020_ADA.pdf*

scenario details, and next step for CARB for each sector. The "Detailed Data" tab provides the detailed data behind each scenario.

On-Road Light-Duty Vehicles

Baseline and Existing Policies

In California, the light-duty vehicle sector contributes a sizeable proportion of current NOx and GHG emissions. Light-duty vehicles are defined as vehicles with a gross vehicle weight rating (GVWR) less than or equal to 8,500 lbs. As shown in Figure 9 above, light-duty vehicles contribute 13 percent of the total NOx emissions statewide in 2017. In the South Coast Air Basin specifically, light-duty vehicles comprised 18 percent of the 2017 NOx emissions inventory. This represents a smaller proportion of the inventory than in prior years as a result of the aggressive light-duty vehicles regulations and incentives in effect. Future emission baseline projections are shown later in this section.

As shown in Figure 10 above, light-duty vehicles comprise 28 percent of the GHG emissions in California, or about 70 percent of the direct emissions from vehicles or equipment. The indirect or upstream emissions from fuel production (for all transportation modes) are 7 percent for refineries, 4.1 percent for oil/gas extraction, 0.9 percent for pipelines, and 0.7 percent for agriculture fuel production.[87] When coupled with the direct emissions from all transportation sources, the total GHG emissions from mobile sources and their fuel production represent more than 50 percent of the total statewide GHG inventory. The light-duty vehicle portion of the upstream fuel emissions depend on the emission characteristics of producing gasoline, as opposed to diesel or other petroleum products, at refineries.

The sizable emission contribution of the light-duty vehicle sector is the primary reason that numerous existing policies have been adopted by CARB to control future year emissions, as shown in the next section. Taking into account currently adopted regulations and major CARB programs, emission inventory projections for the light-duty sector are provided below in Table 12.[88] Emission projections for future years provide a critical glimpse into whether current policies are sufficient for achieving emission targets, or if additional actions are necessary.

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[87] CARB GHG emissions inventory: *https://ww2.arb.ca.gov/ghg-inventory-data*

[88] To be consistent with SIP planning inventory, emissions in Table 12 are estimated based VMT provided by MPOs as custom VMT inputs to EMFAC2017. As a result, the GHG emissions for light-duty vehicles in 2017 is lower than the official GHG inventory

Table 12 - Baseline NOx and GHG Emission Projections for Light-Duty Vehicles

NOx Statewide	2017	2031	2037
Tailpipe, tons per day (tpd)	184.2	47.9	40.2
% Change from 2017	-	-74%	-78%
*GHG Statewide**	2017	2030	2045
Vehicle, MMT CO2e/yr	98.8	68.9	61.8
% Change (vehicle) from 2017	-	-30%	-37%
WTW, MMT CO2e/yr**	118.5	83.7	74.8
% Change (WTW) from 2017	-	-29%	-37%

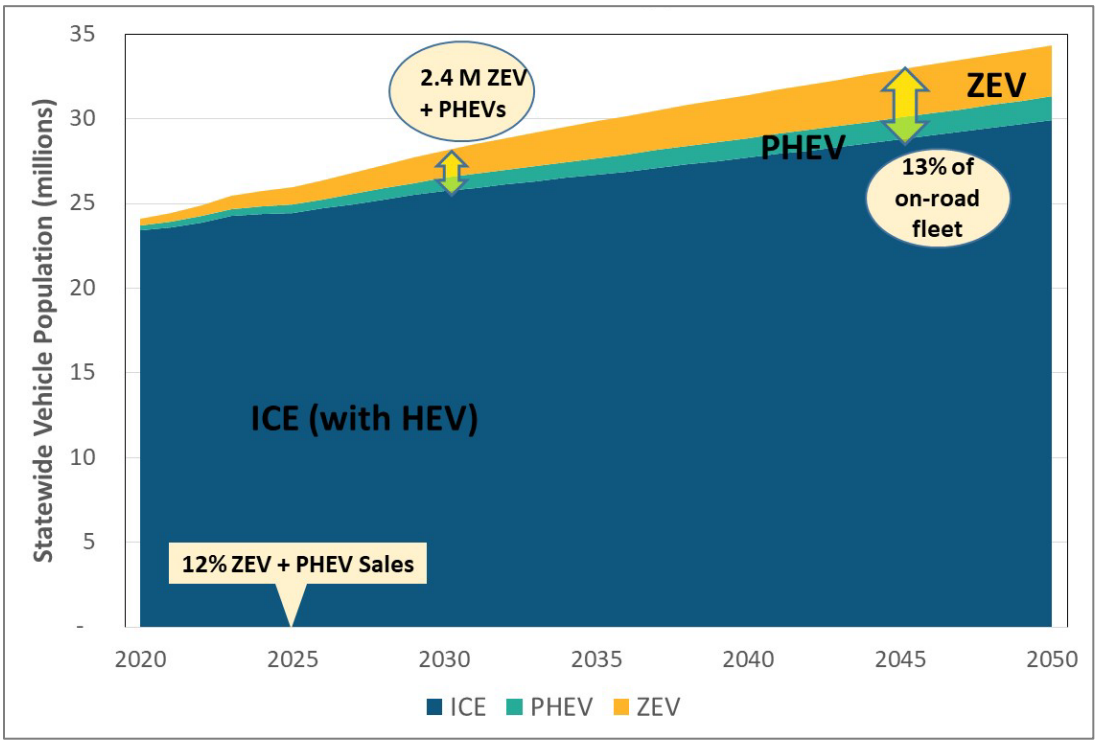
*Excludes biogenic sources
**WTW = Well-to-wheel emissions, including upstream fuel production and delivery

The table for statewide GHG emissions includes both vehicle emissions, and an inclusion of upstream fuel production emissions – this is known as "well-to-wheel" (WTW) when included with vehicle emissions. The analysis accounts for lower fuel lifecyle carbon content (both electricity and gasoline) over time. CARB staff estimated emissions from producing gasoline in 2020 and 2030, accounting for the anticipated lower carbon-intensity ethanol fuel blends in reformulated gasoline (E10 fuel) due to the 2018 *Low Carbon Fuel Standard* (LCFS) amendments. Emissions from producing electricity accounts for California's power generation mix under the *Senate Bill 100*[89] renewable requirements (a 60 percent renewable portfolio standard by 2030) and the phase-out of coal generation. These assumptions consider the unique conditions in California and show that driving an electric vehicle produces significantly lower emissions than a conventional gasoline vehicle.

Because of current programs, Table 12 shows that light-duty vehicle emissions are projected to decline significantly in the next several decades. However, this is still not sufficient to achieve future emission targets. For additional context, Figure 11 below shows the baseline projection of electric vehicles in the on-road fleet. This shows the State is likely to achieve the Governor Brown's target of 1.5 million zero-emission vehicles (including PHEVs) by 2025, as directed in Executive Order B-16-12 which guides State agencies to take actions to support the commercialization of ZEVs and launch the path to the 2050 climate targets, while providing air quality co-benefits. Figure 11, however, also shows that current programs across State agencies will only achieve approximately half of the 5 million ZEVs and PHEVs by 2030 directed in the Governor Brown's *Executive Order B-48-18*, signed in 2018 (noted as 2.4 million in the figure). This 5 million goal represents the path necessary for the 2030 SB 32 climate statutory requirements.

[89] De Léon, Chapter 312, Statutes of 2018

Figure 11 - Baseline Statewide Light-Duty Vehicle Technology Projections for the On-Road Fleet

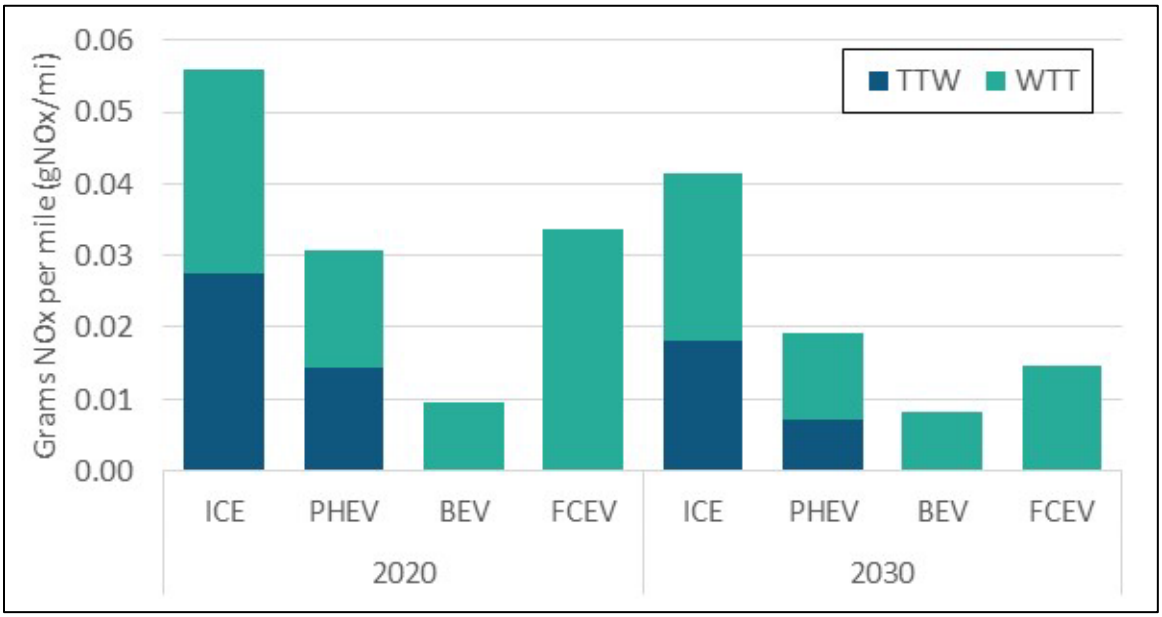


CARB staff have quantified the marginal difference in emissions between driving a mile with a new gasoline conventional vehicle compared to varying electric drive vehicles, coupled with California specific upstream fuel facility emission factors. [90] The figures below show the emissions per mile for a gasoline vehicle (ICE) compared to a PHEV, BEV, and FCEV in California. The data displays both the tailpipe emissions ("tank-to-wheel" or TTW) and upstream emissions associated with producing and delivering the fuel to the vehicles ("well-to-tank" or WTT). Combined, this is called a well-to-wheel emissions analysis comparing varying powertrain types. The analysis compares new passenger vehicles in two different years to account for improved vehicle fuel efficiency and fuel carbon content (electricity, hydrogen and gasoline) over time based on current vehicle and fuel regulations. The PHEVs are assumed to have a percent eVMT of 48 percent in 2020 and 70 percent in 2030. As noted earlier, staff estimated emissions from vehicles using the most current CARB on-road vehicle inventory using EMFAC2017.

[90] California Air Resources Board (CARB) (2019). Staff Report: Initial Statement of Reasons. Public Hearing to Consider Electric Vehicle Supply Equipment (EVSE) Standards. Release Date: May 7, 2019. (*https://ww3.arb.ca.gov/regact/2019/evse2019/isor.pdf*)

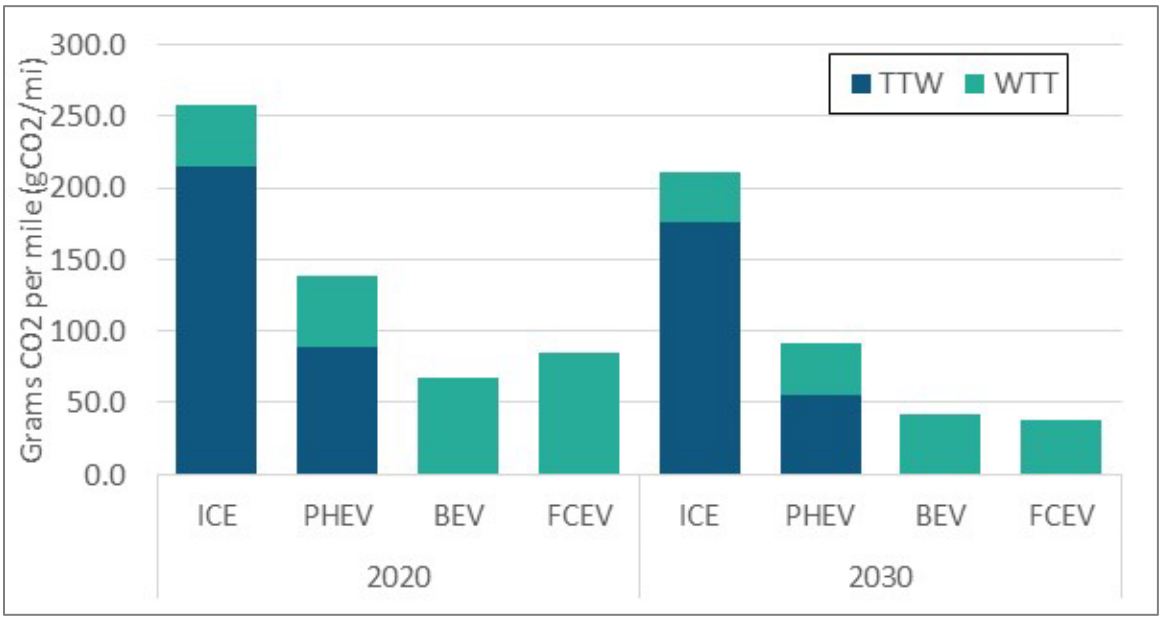
The results are presented below for NOx and GHG emissions assuming a passenger car classification. The accompanying model includes further results for light-duty trucks.[91] Figure 12 shows that CARB staff project the WTW NOx emissions for the BEV to be 83 percent lower in 2020 compared to a conventional vehicle, and slightly decreasing to 80 percent lower in 2030. Figure 13 shows that CARB staff project well-to-wheel GHG emissions from a new BEV to be about 74 percent lower than a new gasoline vehicle in 2020, and increases to 80 percent lower in 2030. This trend highlights that BEVs have much lower emissions, and that for GHG emissions the difference is growing over time as emissions from producing electricity are expected to become lower.

Figure 12 - NOx Emission Factors for Four Vehicle Technology Types in a Passenger Car (grams of NOx/mile)



[91] California Air Resources Board (CARB) Vision program model results for well-to-wheel emission factor comparison, *https://ww2.arb.ca.gov/resources/documents/vision-scenario-planning*

Figure 13 - GHG Emission Factors for Four Vehicle Technology Types in a Passenger Car (grams of CO2e/mile)



Current Light-Duty Vehicle Policies

CARB has been regulating light-duty vehicles for over 50 years. Some policies in place are described below. As discussed earlier, CARB's currently effective regulations to control emissions from passenger vehicles are collectively called the Advanced Clean Cars (ACC) program. This California program combined the control of smog-causing pollutants and GHG emissions into a single coordinated package of regulations: LEV III Criteria, LEV III GHG, and a technology-forcing mandate for ZEVs.

When CARB adopted ACC in 2012, the Board committed to conducting a comprehensive midterm review of three elements of the program: 1) the ZEV regulation, 2) the 1 milligram per mile particulate matter standard, and 3) the light-duty vehicle GHG standards for 2022 and later model years. Staff's review was conducted at the same time as a similar U.S. EPA and NHTSA midterm evaluation of the federal light-duty vehicle greenhouse gas and fuel economy standards for 2022 through 2025 model years at the national level. CARB concluded the following for its midterm review at its March 2017 hearing:

- Adopted GHG standards remain appropriate for 2022 through 2025 model years;
- Continue with existing technology-forcing ZEV requirements to develop the market;
- Direct staff to immediately begin rule development for 2026 and subsequent model years;
- Continue and expand complementary policies to help support an expanding ZEV market; and

- The particulate matter standard is feasible but further action is needed to ensure robust control.

On April 13, 2018, however, the previous federal administration took a significant step toward dismantling the harmonized national program for reducing light-duty vehicle greenhouse gas emissions when it issued a revised, abbreviated final determination that the federal GHG and fuel economy standards for model year 2022 through 2025 vehicles were no longer appropriate, revoking the previous, comprehensive determination that the standards were appropriate.[92] Over the course of the next year and a half, the previous federal administration revoked California's Clean Air Act waiver for its GHG and ZEV light-duty standards, issued a regulation that those standards are preempted by the Energy Policy and Conservation Act (EPCA), and significantly relaxed the federal light-duty vehicle GHG and fuel economy standards.[93] CARB challenged these actions and the litigation is pending.[94] Additionally, *CARB finalized a voluntary agreement with five automakers* to adhere to more aggressive emission reductions on a contractual basis than required by the relaxed federal standards. On January 20, 2021, President Biden ordered U.S. EPA and NHTSA to consider rescinding these actions.[95]

California and International Policy to Phase out ICEs

Most recently, on September 23, 2020, Governor Newsom signed Executive Order N-79-20 establishing a goal for 100 percent of in-state sales of new passenger cars and trucks to be zero-emission by 2035.[96] The Governor's order also directs CARB to develop and propose regulations towards reaching 100 percent zero-emission vehicle sales. Such an ambitious goal is the first in the United States, and complements what others are doing around the world. The specifics of each national target vary slightly in that some explicitly require 100 percent sales of electric vehicles while others require the opposite of 0 percent new gasoline, diesel, or fossil fuel vehicles. Timelines for these also vary widely with Norway, the most aggressive country targeting 100 percent electric vehicle sales by 2025, while Costa Rica and Germany are aiming for these levels by 2050 (see Table 13 for full listing of countries and target

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[92] 83 Fed. Reg. 16,077 (Apr. 13, 2018).

[93] *See* Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model Years 2021-2026 Passenger Cars and Light Trucks, 83 Fed. Reg. 42,986 (Aug. 24, 2018); SAFE Vehicles Rule Part One: One National Program, 84 Fed. Reg. 51,310 (Sept. 27, 2019); SAFE Vehicles Rule for Model Years 2021-2016 Passenger Cars and Light Trucks, 85 Fed. Reg. 24,174 (Apr. 30, 2020).

[94] *See California v. Wheeler, et al.* United States Court of Appeals, District of Columbia Circuit, Case No. 19-1239, consolidated under No. 19-1230 along with Nos. 19-1241, 19-1242, 19-1243, 19-1245, 19-1246, and 19-1249; *California v. Wheeler, et al.*, United States Court of Appeals, District of Columbia Circuit, Case No. 20-1167, consolidated with Nos. 20-1145, 20-1168, 20-1169, 20-1173, 20-1174, 20-1176, and 20-1177.

[95] Executive Order No. 13990 of January 20, 2021, Protecting Public Health and the Environment and Restoring Science To Tackle the Climate Crisis, § 2(a)(ii), 86 Fed. Reg. 7,037 (Jan. 25, 2021).

[96] Available at https://www.library.ca.gov/Content/pdf/GovernmentPublications/executive-order-proclamation/40-N-79-20.pdf.

dates[97]). Such targets send strong policy signals to the market. France and Spain have codified these targets as formal laws that would make these targets legally binding and enforceable requirements.

Table 13 - Countries with 100% ZEV Sales or Phase Outs of Gasoline, Diesel, or Fossil Fuels

Target Year	Country (target type)
2025	Norway (EV only)
2030	Iceland (no gasoline/diesel vehicles) Ireland (no fossil fuel vehicles) Israel (no gasoline/diesel vehicles) Netherlands (EV only) Sweden (no gasoline/diesel vehicles)
2032	Scotland (no gasoline/diesel vehicles)
2035	Denmark (no gasoline/diesel /PHEV) UK (no gasoline/diesel /PHEV)
2040	Canada (EV only) France (no fossil fuel vehicles) Portugal (no ICE vehicles) Singapore (no ICE vehicles) Sri Lanka (EV/HEV only) Spain (EV only)
2050	Costa Rica (EV only) Germany (EV only)

ZEV market support in partnership with California State Agencies

As described in CARB's *Senate Bill 498*[98] report,[99] California has a suite of regulatory, incentive, and supporting programs that accelerate the adoption of ZEVs (light-duty but also medium- and heavy-duty vehicles). The regulatory programs help ensure that vehicles are manufactured and supplied to the market (e.g., the ACC ZEV regulation) or procured for a certain usage (e.g., heavy-duty vehicle fleet requirements). Incentive programs help spur demand for these vehicles by encouraging consumers and fleet operators to purchase or lease ZEVs by offsetting some of the additional upfront costs of ZEVs compared to conventional vehicles (e.g., purchase rebates through the Clean Vehicle Rebate Project) or by developing and testing new technologies through demonstrations and pilots (e.g., the

[97] International Council for Clean Transportation (July 2020). Update on the global transition to electric vehicles through 2019. *https://theicct.org/sites/default/files/publications/update-global-EV-stats-sept2020-EN.pdf*
[98] Skinner, Chapter 628, Statutes of 2017
[99] California Air Resources Board (CARB) (2020). Assessment of CARB's Zero-Emission Vehicle Programs Per Senate Bill 498. July 2020. (*https://ww3.arb.ca.gov/programs/zev/SB-498-Report-072320.pdf*)

Advanced Technology Demonstration Project). The supporting programs also play a critical role in facilitating ZEV market growth by providing ZEV fuels and refueling infrastructure (e.g., the LCFS and the Clean Transportation Program), building ZEV awareness, and sharing best practices among different jurisdictions through collaboration. These three types of programs work together to accelerate the ZEV market by fostering supply and demand across all phases of ZEV technology commercialization and market development.

Assembly Bill 2127[100] requires the California Energy Commission (CEC) to conduct a statewide assessment of the electric vehicle charging infrastructure needs in support of the 5 million ZEV by 2030 target issued in Executive Order B-48-18. Developed through a collaboration between the CEC and National Renewable Energy Laboratory (NREL), the current version of Electric Vehicle Infrastructure Projection model (EVI-Pro 2), incorporates observed travel and charging data and evolving market and technology conditions to estimate the charging demand to meet the needs of future PEV drivers. EVI-Pro 2 designs the supply of charging infrastructure capable of meeting this demand, and quantifies the associated load impacts from charging. EVI-Pro 2 also leverages MSS county level projections to achieve more granular results and a higher degree of spatial resolution. More information on the CEC's electric vehicle charging infrastructure assessment is on the CEC's *AB 2127 webpage*.

The State also has a number of electric vehicle charging infrastructure programs. The *Clean Transportation Program*, administered by the CEC, provides funding to support PEV infrastructure through various grant solicitations. Additionally, CEC manages the *California Electric Vehicle Infrastructure Project* (CALeVIP) to provide streamlined incentives for electric vehicle charging infrastructure, and through 2019, CEC has allocated $71 million for charger rebates. The California Public Utilities Commission (CPUC) authorizes investor-owned electric utilities to undertake transportation electrification activities. In 2016, the CPUC approved charging infrastructure pilot programs for three large investor-owned utilities – Pacific Gas and Electric, Southern California Edison, and San Diego Gas and Electric – to install charging stations for a combined budget of up to $197 million.[101] In 2018, the CPUC approved additional investor-owned utility projects to deploy charging infrastructure pursuant to *Senate Bill 350*.[102] To date, CPUC has approved over $780 million for transportation electrification programs under SB 350.[103] Finally, *Volkswagen*, through its subsidiary Electrify America, has agreed to invest $800 million over a 10-year period for ZEV infrastructure,

[100] Ting, Chapter 365, Statutes of 2018
[101] California Public Utility Commission, 2019. Summary of CPUC Actions to Support Zero-Emission Vehicle Adoption. *https://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=6442459998*
[102] De León, Chapter 547, Statutes of 2015
[103] California Public Utility Commission, Approved SB350 Projects. Accessed July 27, 2020: *https://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=6442457944*

education, and access in California as part of a settlement with CARB. Electrify America will invest $200 million in four installments over the next 10 years.[104]

The State also has a few important programs to support the rollout of hydrogen fueling infrastructure for light-duty vehicles. CARB's LCFS *Hydrogen Refueling Infrastructure* credit provision has initiated the development of nine stations. Additionally, as part of the *Assembly Bill 8*[105] program aimed at establishing at least 100 stations (45 existing stations are open, with retail service today), the CEC released its latest Grant Funding Opportunity 19-602 to solicit applications to co-fund new hydrogen fueling stations, with awards expected to be announced soon. To facilitate opening of new hydrogen fueling stations, CARB staff assists light-duty vehicle manufacturers and retail station operators by conducting independent testing to verify compliance with SAE fueling protocols. These are necessary steps to move California's hydrogen fueling and fuel cell electric vehicle (FCEV) industries out of the current early adopter phase and into the broader mass-market.

Scenario Analysis – Targeting New Vehicle Technology

Targets

As noted earlier, the State has a number of emission reduction targets that apply either to all sectors in the economy, or to the transportation sector as a whole (all mobile sources, including on-road and off-road sectors). Given the size of the contribution from light-duty vehicles to the 2017 emissions inventory, this sub-sector will need to make strong contributions toward regional and Statewide emission targets. Therefore, for the purposes of creating a reference for these light-duty scenarios, the results are compared to an equal-share reduction of the broader targets. This includes a 62 percent NOx reduction in 2037 below the baseline 2037 NOx projections, citing preliminary estimates of the needed NOx reductions to meet the 70 ppb 8-hour ozone standard.[106] For GHG emissions, with an uncertainty of whether natural and working lands will not provide increased carbon sinks over time, this analysis assumes mobile sources will need to achieve zero carbon emissions by 2045 on a full well-to-wheel basis. CARB will be comprehensively evaluating strategies to achieve carbon neutrality through the 2022 Scoping Plan Update process, including renewable fuel supply constraints and unique challenges in varying sectors.

In principle, to achieve full carbon neutrality by 2045 with direct vehicle and fuel production emissions from the light-duty vehicle sector, the entire on-road light-duty vehicle fleet needs to be either some form of an electric vehicle using renewable electricity/hydrogen or an internal combustion engine using sustainable biofuels. When considering the additional

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[104] Volkswagen Group of America, 2017. California ZEV Investment Plan: Cycle 1. *https://www.electrifyamerica.com/our-plan*

[105] Perea, Chapter 401, Statutes of 2013

[106] *https://www.aqmd.gov/docs/default-source/clean-air-plans/air-quality-management-plans/2016-air-quality-management-plan/final-2016-aqmp/final2016aqmp.pdf?sfvrsn=15*

constraint of dramatically reducing the criteria emissions from the vehicles themselves, separate from the upstream fuel production, the necessity for ZEVs becomes even stronger.

The scenario described below is aggressive, as there are certain limitations that inhibit fully achieving carbon neutrality with direct vehicle and fuel production emissions. These limitations include the pace at which new ZEV sales can grow, the scrappage of legacy gasoline vehicles, and biomass supply limitations and competition from other sectors, among other factors. There are many combinations of strategies that can help to achieve these air quality and 2045 GHG light-duty vehicle equal-share emission targets, so the challenge is to identify the combination with the greatest chances for success, knowing that every individual strategy will need to be extremely aggressive. The following list describes key scenario considerations and assumptions that were considered.

Framework for Scenario Development

The strategies and scenarios described below do not reflect a market feasibility analysis, but rather were identified as strategies that are technically possible but most likely only under optimal policy and market conditions. The technology and fuel assumptions reflect staff's current understanding of the vehicle and fuel technologies that have been developed and are already entering the market. Staff then make assumptions about their future potential market growth.

Advanced vehicle technology and efficiency improvement form the foundation for the scenarios. Given the large incremental improvement in emissions per vehicle from electrification, the scenarios focus on aggressively moving to all-electric technologies, coupled with increases in conventional vehicle improvements. These strategies were assumed to have a correlation related to automaker investments – much of the industry will focus investments on electrification, but conventional vehicles will see a scaling up of existing efficiency strategies, such as hybrid powertrains (as compared to widespread investments in new innovations for conventional engine technology). Battery-electric vehicles were the dominant technology selected for the scenarios, but fuel cell electric vehicles are assumed to continue their growth in the market and are included in the scenarios.

Further, the scenarios rely solely on new light-duty vehicle sales as the mechanism to change the fleet's technology mix and did not assume any retrofit or accelerated scrappage policies. Finally, new mobility trends, namely ride-hailing services with high-mileage vehicles and connected, autonomous vehicles, create opportunities to substantially increase electric vehicle miles traveled (eVMT) by the fleet as a subset of vehicles are more intensively used and thus retired more quickly.

The fuel supply sector will need to transition to nearly all renewable sources to achieve the equal-share emission targets. However, partly because there are limits to renewable sources depending on the fuel type, the results shown here do not quite achieve the "equal share" targets used in this analysis. These scenarios will be revisited as CARB develops the renewable fuel assessments for the 2022 Scoping Plan Update. Transportation electricity will

leverage the same grid supply mix that is changing economy-wide in response to State statutes for an aggressive renewable portfolio standard. Hydrogen was assumed to transition to all renewable sources, though there is currently no statute requiring these high levels. To offset remaining liquid fuel usage in the light-duty fleet, the 2016 Strategy had assumed that renewable "drop-in" gasoline would emerge on the market by 2020. However, a review of fuel technology advancements and new expected fuels shows that renewable gasoline is not being seriously developed for California markets. This, coupled with the ongoing supply constraint of low carbon biofuels anticipated to be primarily used in heavier mobile sources, led to the assumption that biofuels beyond ethanol in E10 would not be used in these light-duty vehicle scenarios.

Reducing vehicle miles traveled is necessary to directly and immediately reduce mobile source emissions, and to bring the light-duty transportation sector within striking distance of carbon neutrality by 2045 and attainment of the 70 ppb 8-hour ozone standard in 2037. This scenario assumes a 15 percent reduction in statewide light-duty VMT by 2050 compared to business as usual assumption, the same as the 2016 Mobile Source Strategy and the 2017 Scoping Plan. Further, the VMT reduction strategy areas discussed in this document reflect the nature of the actions necessary to achieve the level of reductions in the scenario. In addition to providing congestion mitigation and improved community mobility, VMT reduction also reduces fuel demand, and therefore can reduce investments and land-use impacts from advanced fuel sources (e.g. biofuels, build out of solar and wind, etc.).

Scenario Input Assumptions

Multiple scenarios were created to evaluate the impacts of varying the pace of ZEV sales, with a particular focus on either 2035 or 2040 as dates at which conventional vehicle sales could end. In the scenarios, PHEV sales were included, but at a declining ratio to ZEV sales and also assuming greater all-electric driving range[107] than exhibited by PHEVs in the market today. The primary scenario selected assumed conventional vehicle sales end in 2035, with ZEV and PHEV sales reaching 100 percent by that date. Several specific technology and fuel assumptions are listed below, many of which would require new policy actions.

- The relative ratio of combined ZEV and PHEV sales start at 75 percent ZEV/25 percent PHEV in 2030 scaling to 90 percent/10 percent in 2045 (see Figure 14). The rationale for this assumption reflects a projection that as pure ZEV technology advances, PHEV costs will be relatively higher than BEVs given the complexity of two powertrains (combustion engines and electric systems), and this cost differential will affect market demand. Additionally, to achieve the emission targets, pure ZEV technology will need to be prioritized.

[107] Modeled as a larger "percent eVMT" which represents the proportion of a PHEV's annual driving that is solely from the electric drive system.

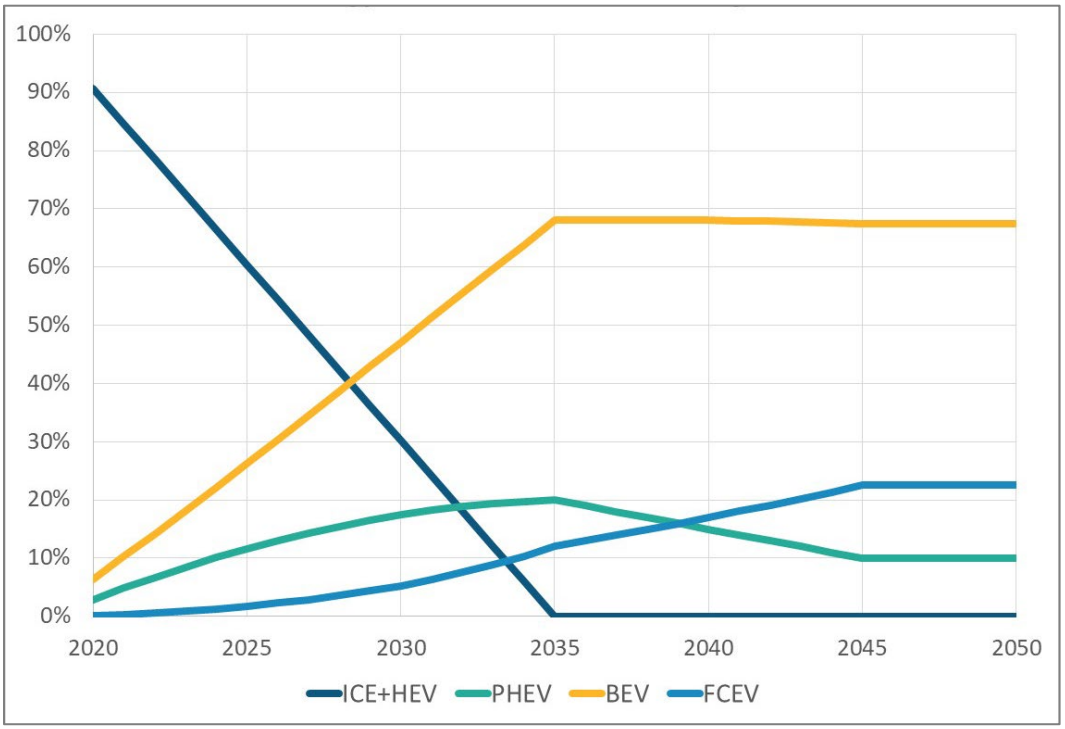
- The relative ratio of combined BEV and FCEV sales start at 90 percent BEV/10 percent FCEV in 2030 scaling to 75 percent/25 percent by 2045 (see Figure 14). The rationale for this assumption reflects increasing FCEV adoption as hydrogen fueling infrastructure expands and a subset of the vehicle market that will still require frequent fast refueling, particularly in larger vehicle classes.
- PHEV eVMT is fixed at 70 percent (or about 52 miles of all-electric range) for passenger cars and 50 percent (or about 28 miles of all-electric range) for light trucks for all years after 2030. Although technology will continue to improve beyond 2030, these values were kept constant in future years given that the technology will need to be used on a larger number of larger vehicle platforms as the market grows. The scenarios assume the technology improvements will be needed to maintain the eVMT performance on heavier vehicles, some of which will require towing capability.
- New gasoline-only vehicles, including hybrids (non-plugged vehicles), are assumed to have reduced GHG emissions by 2.0 percent per year from 2026 to 2035. This assumption reflects an investment by the automotive industry in ongoing conventional vehicle improvements while focusing most investments on ZEVs, and likely would require a regulatory change to California's vehicle standards.
- BEV and FCEV new vehicle efficiency is assumed to improve at 0.5 percent per year from 2026 to 2045. This assumption reflects greater emphasis on cost reduction of components and systems rather than on further improvements to efficiency.
- NOx emission factors do not change for new vehicles in any of the vehicle classes. This assumption reflects the need for vehicles to remain clean and to prevent a backslide on emission certification levels as a result of the increasing fraction of ZEVs. To accomplish this, light-duty vehicle regulations will need to change to protect against backsliding. The effect would be that as ZEV sales increase, the total light-duty new vehicle fleet average for NOx emissions will decline. It is possible to additionally assume conventional vehicle NOx emission levels will decline, in addition to ZEV sales. CARB staff are considering this as a regulatory option in addition to regulatory provisions to protect against emission certification backsliding.
- By 2045, approximately 90 percent of electricity and all hydrogen is assumed to be from renewable sources. Per SB 100, electricity must be 60 percent renewable by 2030 (when coupled with nuclear and large hydro, the grid is likely to be higher than 60 percent of zero carbon sources by 2030); the statute further requires 100 percent zero carbon on the grid retail sales by 2045.[108] It is assumed 100 percent electrolytic

[108] SB 100 requires that 100 percent of retails sales of electricity come from RPS-eligible and zero-carbon resources by 2045. SB 100 does not define zero-carbon resources. An interagency effort is underway to evaluate potential paths to achieving the 2045 goal, and this process evaluates electricity generation technologies that could be eligible zero-carbon resources and will model potential resource mix scenarios for 2045. Refer to *https://www.energy.ca.gov/sb100* for more information about this process. SB 100 allows for a small amount of electricity generated by natural gas in 2045 which could be replaced by renewably sourced bio-methane, but this scenario did not assume bio-methane was available for electricity production.

hydrogen will utilize growing curtailed renewable electricity as utilities procure more zero GHG generation to meet the Renewable Portfolio Standard (RPS).

- For remaining liquid fuel demand in 2045, all scenarios assume E10 ethanol blend in gasoline as the fuel.

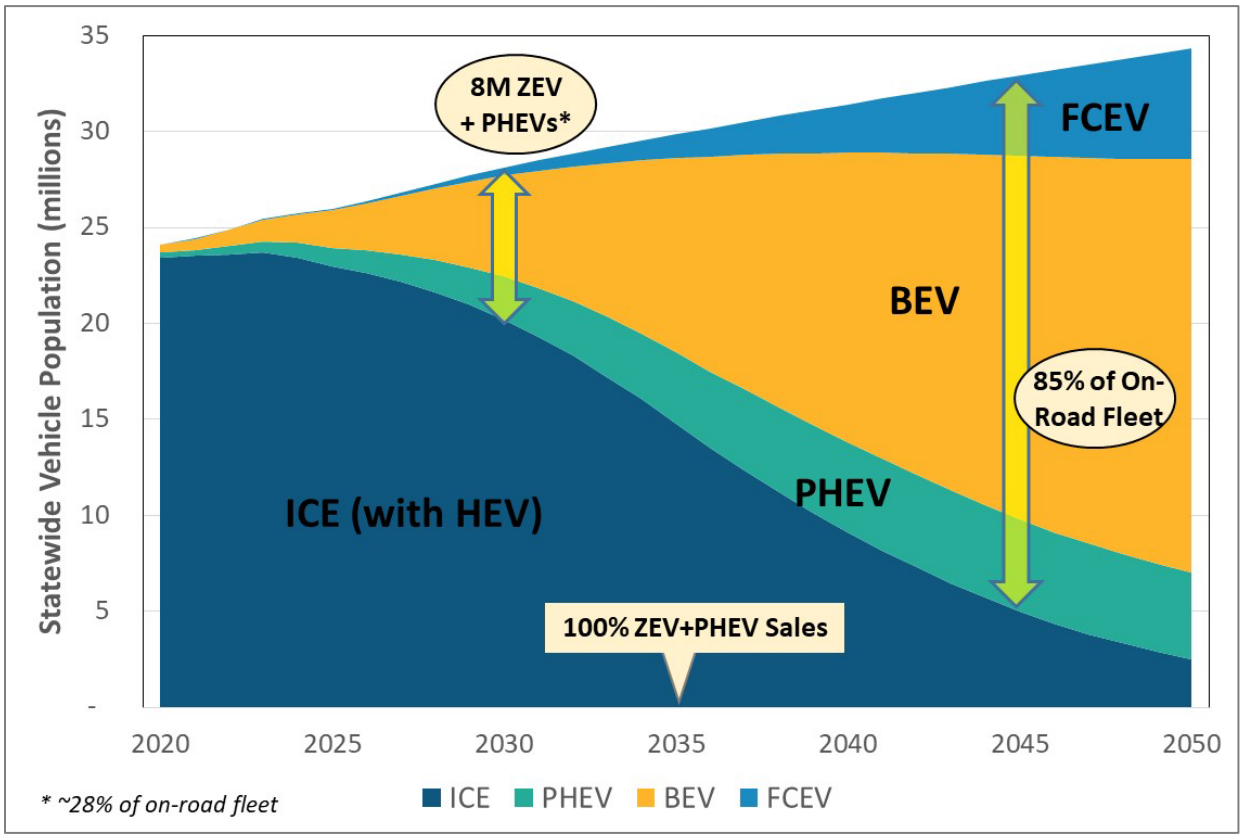
Figure 14 – Light-Duty Vehicle Sales Fractions by Technology Type



Scenario Results and Trends

In the primary scenario where new sales of ZEVs and PHEVs reach 100 percent in 2035, the on-road fleet still includes 15 percent conventional or hybrid vehicles in 2045, as shown in Figure 15. In 2045, 16 percent of total VMT is from conventional vehicles or PHEVs not using electricity. Given the aggressive nature of sales before 2035, up to 8 million ZEVs and PHEVs would be in the fleet by 2030, well above the Governor Brown's target of 5 million ZEVs by 2030. This modeled scenario reflects the more aggressive climate target being evaluated here compared to when Governor Brown established the 5 million ZEV target.

Figure 15 – Statewide Light-Duty Vehicle Technology Penetration in the On-Road Fleet



Under this fleet composition, combined with the fuel mix changes and VMT reduction assumptions, the primary scenario generates a 17 percent reduction in NOx emissions in 2031 and a 43 percent reduction in 2037 relative to baseline projections of tailpipe emissions Statewide for each of those years. GHG emissions in 2045 are 87 percent lower than 2020 levels.

Figure 16 - Statewide Light-Duty Vehicle NOx Emissions (Tailpipe)

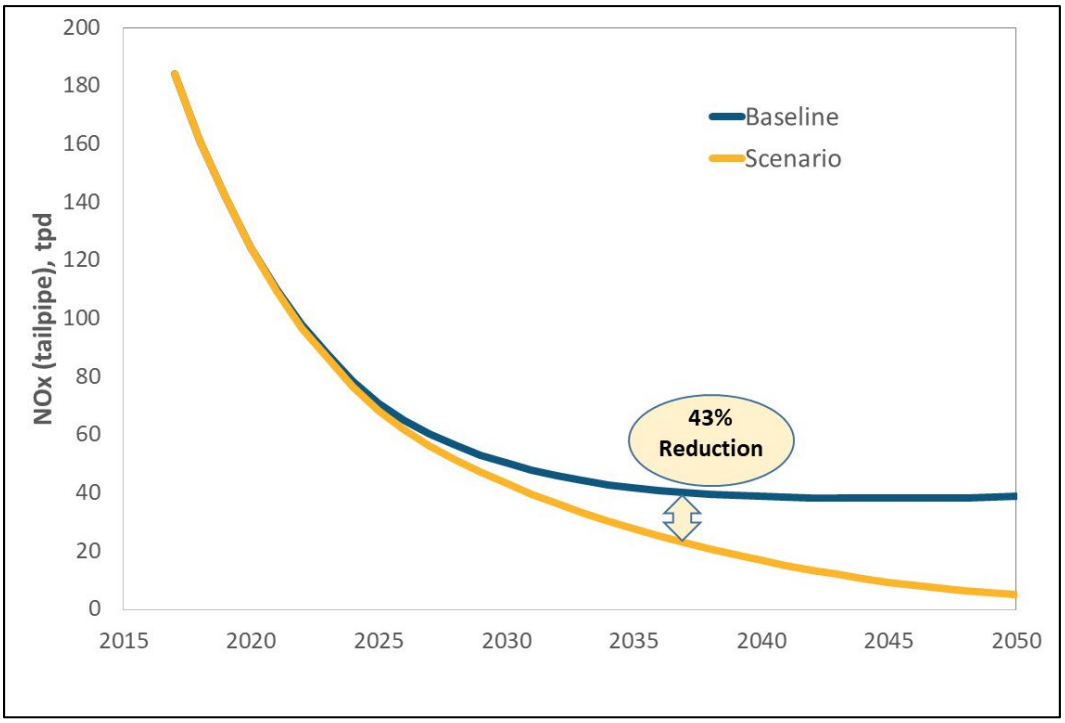


Figure 17 – Statewide Light-Duty Vehicle GHG Emissions (Well-to-Wheel)

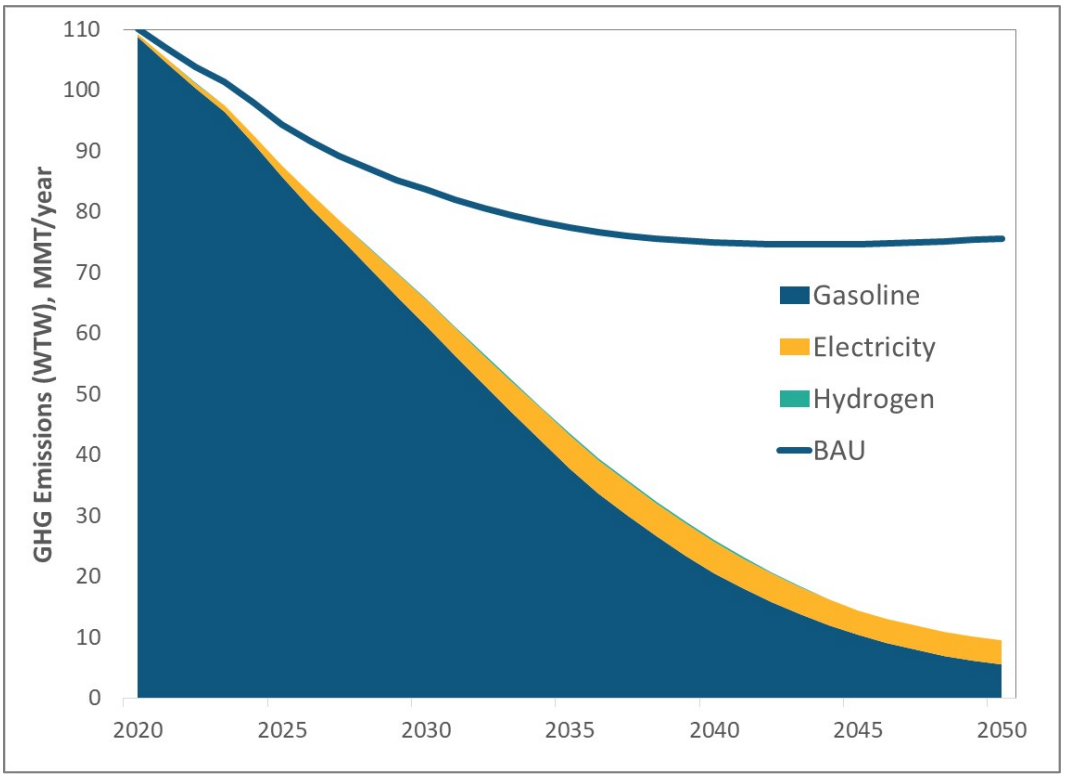
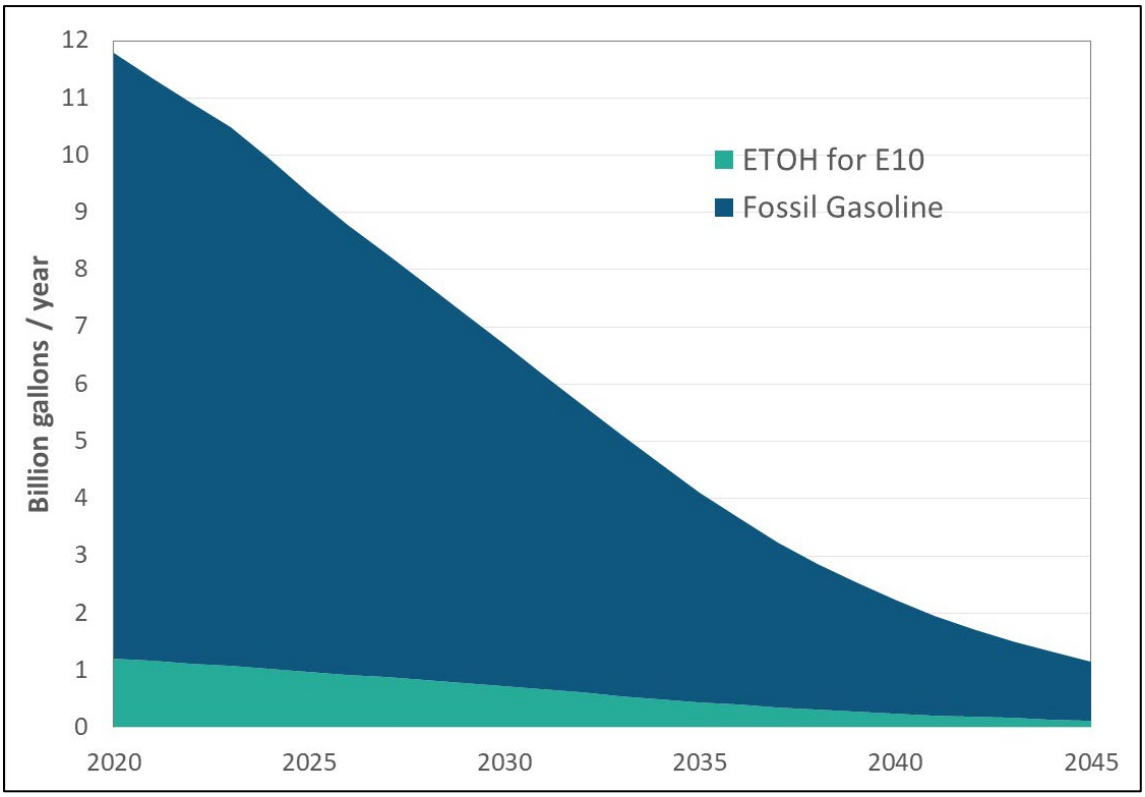


Figure 18 shows the total liquid fuel usage for the light-duty fleet over time. Although a relatively small portion of the on-road fleet in 2045, combustion vehicles would still consume 1.2 billion gallons of liquid fuel in 2045 – only 30 percent of which would be used by PHEVs – and contribute roughly three quarters of the fleet's GHG emissions (see Figure 17). Therefore, the quantity of liquid fuel demand that remains in 2045 has an oversized influence on achieving the light-duty equal share emission targets. Separately, GHG emissions from electricity usage in vehicles would not be zero due to some remaining fossil natural gas usage for electricity generation but will be a small impact.

Figure 18 – Light-Duty Vehicle Liquid Fuel Demand (fossil gasoline, ethanol for E10)



Discussion of Results

The light-duty vehicle scenarios reveal that even with extremely aggressive electrification, coupled with aggressive VMT reductions and fuel decarbonization,[109] the sector still cannot achieve its "equal share" of the reductions for NOx and GHG emissions in 2037 and 2045 respectively assumed for this analysis.[110] The emission reductions are sizeable, however, with a 43 percent reduction in 2037 of tailpipe NOx emissions below the 2037 baseline, and an 87 percent reduction of well-to-wheel GHG emission reductions in 2045 below 2020 levels.

The earliest possible date by which staff believe conventional vehicle sales possibly could end is 2035, and although automotive battery technology costs are rapidly declining, achieving this sales trajectory still faces broader market challenges of insufficient ZEV fueling infrastructure, electric drive manufacturing scale-up constraints, battery and fuel cell raw material supply constraints and uncertainty in consumer demand, particularly with lower income households. The next few years will be very telling in terms of new electric vehicle

[109] Fuel decarbonization refers to a group of strategies, including SB 100 electric grid requirements, liquid fuel carbon reductions through the Low Carbon Fuel Standard (LCFS), and other actions.
[110] As noted earlier, the "equal share" target for GHG emissions in this analysis is carbon neutrality for the light-duty sector by 2045.

models entering the market, and consumers seeing wider choices and fuel infrastructure advancements.

The scenarios also reveal that while the State needs to push as hard as possible on electrification, CARB also needs to continue taking action to reduce NOx and GHG emissions from new conventional vehicles. A sizeable fraction of the on-road fleet in the later years will still use combustion engines, so new emission standards in model years 2026 to 2035 will have important benefits. For NOx emissions, this includes the need to strongly consider "anti-back-sliding" actions on conventional vehicles in the light-duty fleet average standards as ZEV sales scale up (as simulated in these scenarios), and possibly going further to require the fleet average standard to be lower, thus requiring conventional vehicles to get cleaner (not simulated in this scenario). For GHG emissions, an additional reason to consider new conventional vehicle GHG emission reductions (as simulated in this scenario with efficiency improvement assumptions) is the cumulative climate change mitigation for the years before electrification becomes dominant. This is noted because the difference in the 2045 annual GHG emission results from the scenario, with and without the conventional vehicle GHG improvements is small. But cumulative GHG emissions over time for these conventional vehicles will not be trivial.

Further reductions from conventional vehicles would be possible with select actions not evaluated in these scenarios. For example, to further control NOx emissions, targeted policies (e.g. regulation changes) could focus on cold start emissions. For GHG emissions, advanced biofuels could be used, but were not considered here given the limitations on biomass supply.

Scenario Analysis – Accelerated Vehicle Retirement

As described above, phasing out new internal combustion engine light-duty vehicles by 2035 is not sufficient to achieve the needed NOx emission reductions to meet the 2031 ozone standard in the South Coast Air Basin or the 2045 Statewide climate neutrality goal, assuming an equal share emission target for light-duty vehicles. Further emission reductions in the light-duty sector could be achieved through a suite of actions including accelerated vehicle turnover programs.

This section focuses on an accelerated turnover scenario where the oldest light-duty vehicles registered in the South Coast Air Basin—those with the highest criteria emissions—are replaced with ZEVs or other alternative transportation options. California has several related incentive programs in place, but the scale of these would need to increase significantly to make up the gap to achieve the 2031 ozone standard in 2031 and the 2045 climate target.

Equity considerations, including the specific clean transportation and mobility needs of low-income and disadvantaged communities, must be foundational to the design and implementation of accelerated vehicle turnover programs, *in addition to* enabling more individuals to purchase new electric vehicles. This includes understanding and overcoming some of the biggest barriers to ZEV adoption—affordability, access, awareness, and utility—

as identified in CARB's SB 350 Barriers Report.[111] CARB's light-duty vehicle replacement and incentive programs, in addition to ongoing outreach and education efforts, play a large role in addressing these barriers and increasing adoption of ZEVs and use of other, more sustainable transportation modes.

Current Scrappage Programs

- *Vehicle Scrappage:* California's Bureau of Automotive Repair (BAR) administers the Consumer Assistance Program, [112] which provides either an incentive of $1,000 or $1,500 for the voluntary scrappage of an eligible operational vehicle, with the higher incentive amount provided to consumers having a household income of less than or equal to 225 percent of the Federal poverty level.[113,]
- *Vehicle Scrappage and Replacement*: Clean Cars 4 All[114] provides incentives to lower-income vehicle owners living in disadvantaged communities to retire a functioning, high-polluting vehicle and replace it with a new or used ZEV, PHEV, conventional hybrid vehicle, or an alternative mobility voucher. The average incentive amount is approximately $8,500, although this varies both by income level and vehicle technology of the replacement vehicle. An additional incentive of up to $2,000 is available for the installation of electric vehicle charging infrastructure. Clean Cars 4 All is administered through several air districts across the State. Some air districts run a similar vehicle retirement and replacement program but allow for the replacement vehicle to be a conventional internal combustion engine vehicle if it meets a minimum fuel economy standard.

Scenario – Vehicle Population Implications

- Retiring approximately 160,000 vehicles older than model year 2000 registered in the South Coast Air Basin by 2031 would yield emission reductions of approximately 3.1 tpd of tailpipe NOx and 0.3 MMT/yr of WTW GHG in the year 2031.
- Retiring an additional 125,000 vehicles older than model year 2006 by 2037 in the basin would result in emission reductions of 1.8 tpd of NOx and 0.4 MMT/yr of GHG in 2037.
- Assuming the 160,000 vehicles are turned over equally for the next decade between 2021 and 2031, the increased scale of vehicle turnover needed—16,000 vehicles every year—would be about a ten-fold increase compared to the annual number of vehicles retired in the South Coast Air District through Clean Cars 4 All.

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[111] *https://ww2.arb.ca.gov/sites/default/files/2018-08/sb350_final_guidance_document_022118.pdf*

[112] *https://www.bar.ca.gov/Consumer/Consumer_Assistance_Program/*

[113] In order to qualify for the program, the vehicle must fail a Smog Check inspection. However, low-income consumers are also eligible to participate in program if vehicle passes a Smog Check inspection within the last 180 days.

[114] Previously known as the Enhanced Fleet Modernization Program Plus-Up.

- In 2031, these 160,000 older vehicles would contribute approximately 22 percent of the total light-duty vehicle NOx tailpipe emissions in the South Coast Air Basin while only representing 1.5 percent of all light-duty vehicles expected to be registered in the basin, according to EMFAC.
- Retiring an additional 125,000 vehicles older than model year 2006 between 2031 and 2037 in the basin would result in emission reductions of 1.8 tpd of NOx and 0.4 MMT/yr of GHG in 2037.

Anticipated Regulatory Actions

Advanced Clean Cars II

The ACC regulations are responsible for setting criteria pollutant and GHG emission standards for light-duty and medium-duty vehicles and establishing a ZEV mandate (although CARB's authority for the GHG and ZEV light-duty vehicle regulations has been preempted by federal action in the SAFE Rules - which California is contesting and the federal agencies have been directed to reconsider). ACC II is currently in development to strengthen these standards beyond model year 2025, and the regulatory proposal is anticipated for Board consideration in late 2021. Staff provided an informational Board update in May 2020, outlining staff's preliminary thoughts on real-world emission reduction measures for combustion vehicles, cold-start emission reductions, improved emission control for plug-in hybrid vehicles, and new medium-duty requirements.

Staff are also considering potential changes to the ZEV regulation stringency and new ZEV assurance measures like vehicle warranty, durability, standardized data requirements, and battery state-of-health monitoring requirements to ensure emission benefits from ZEVs. These latter ZEV assurance measures will be necessary to support wide-scale adoption of ZEVs, not just in the new vehicle market but in the used vehicle market as well. As new vehicle buyers typically do not own their vehicles for the entirety of the vehicles' life, warranty and durability requirements are especially important to ensure that subsequent owners can experience the full utility of a ZEV powertrain in order to realize the expected emission reductions. Additionally, CARB is proposing that the battery's state of health be accessible to drivers without the use of any specialized equipment so that vehicle owners are able to understand the vehicle's need for repair and warranty qualifications or that used vehicle buyers will be able to evaluate the health of the battery. More detailed data would also be required to allow for repair technicians to assess the vehicle's need for repair or for those in the battery repair or reuse industry to better assess the remaining battery life and ideal second life application. Finally, CARB is considering proposing that ZEV powertrain service and repair information be available to independent technicians to allow for vehicle servicing by non-dealer technicians. This provision will help ensure independent repair shops can continue to participate in the market as more ZEVs are added to California's fleet and also provide consumers with more options for their vehicle servicing needs. All these measures are designed to ensure ZEVs fulfill their potential to reduce emissions.

Clean Miles Standard

Senate Bill 1014,[115] the Clean Miles Standard and Incentive Program, requires CARB to develop and the CPUC to implement a GHG reduction program for transportation network companies (TNC) such as Uber and Lyft. SB 1014 directs CARB to adopt GHG per-passenger-mile reduction and percent eVMT targets for TNCs by January 1, 2021. Staff anticipates achieving GHG goals through increased use of ZEVs and increased pooling, as well as use of transit and micro mobility modes of transportation facilitated by the TNCs. The program will begin in 2023 and increase in stringency through 2030. The *Clean Miles Standard* regulatory proposal is currently being developed; staff provided an informational Board update in January 2020 and the regulation is scheduled for Board consideration in early 2021. The Standardized Regulatory Impact Assessment has been made public, and the program expects to achieve at least 0.25 MMT CO2e/year of GHG emission reductions in 2030.

Additional Information

Sensitivity scenarios

In addition to the main scenario presented in this chapter, staff have evaluated a number of additional scenarios to gain an understanding of how certain assumptions influence the emissions results. This is important given that the main scenario does not yet achieve the light-duty equal share emission targets noted earlier. The first sensitivity scenario explored how influential the ZEV sales target was on the results of the main scenario. The sensitivity scenario explored a delayed date of 2040 for the end of conventional vehicle sales. As noted earlier, staff will revisit these scenarios as part of the 2022 Scoping Plan Update, and the fuel supply assumptions may change, affecting the emission results.

Scenario with conventional vehicle sales ending in 2040 instead of 2035

- +4 MMT/yr GHG emissions in 2045 compared to the 2035 scenario (83 percent reduction instead of 87 percent below 2020 baseline emissions)
- +3.4 tpd additional NOx tailpipe emissions in 2037 Statewide compared to the 2035 scenario (35 percent reduction instead of 43 percent below 2037 baseline emissions)
- 1.6 billion gallons liquid fuel demand (instead of 1.2 billion gallons in the 2035 scenario)

Scenario with aggressive growth in ride hailing vehicles

- Assumes growth in high-mileage ride hailing services, including driverless automated ride-hailing in later years

[115] Skinner, Chapter 369, Statutes of 2018

- Slightly lower vehicle population for same mobility needs as vehicle age requirements force older vehicles out of the ride hailing fleets
- Overall increase in light-duty VMT as increased "deadhead miles" over compensate for increased pooling assumptions in the scenario. In 2045, the ride-hailing scenario results in 944 million miles per day statewide compared to 905 million miles in the main scenario,
- Increased deadhead VMT over-compensates for slightly higher fraction of the fleet as electric, creating a small increase in the sector's GHG emissions. In 2045, well-to-wheel GHG emissions rise by +0.5 MMT/yr. However, had electrification not been prioritized on the ride-hailing vehicles in this scenario, the rise in GHG emissions would have been larger.

Additional details on equity considerations

A cornerstone to addressing mobility equity is to focus on meeting the clean transportation needs and utility of low-income and disadvantaged community households. Previously identified barriers must be overcome in order to advance transportation equity:

- *Affordability*: Advanced technology vehicles currently have higher upfront costs than conventional vehicles. There is less ability to leverage traditional financing options.
- *Access*: There is a lack of new and used ZEV options at dealerships, used car lots, and infrastructure available in their communities. Home charging is frequently not a viable option for those who rent or live in multi-unit dwellings. Information on ZEVs, their benefits, and low-cost financing options is not widely available.
- *Awareness*: Communities do not have as much information on advanced technologies and how they can meet their needs. There is often a lack of transparency of the risks associated with new or used ZEV battery life.
- *Utility*: ZEVs need to meet unique community needs, including longer battery range for those living farther from destinations, sufficient space to transport tools and materials or family members, and ability to charge in public spaces. Alternative mobility options need to be safe, convenient, and affordable.

Providing a variety of solutions to address these barriers is essential in meeting the unique clean transportation needs of underserved communities. Some examples include:

- Incentives provided through the Clean Vehicle Rebate Project and Clean Cars 4 All Program provide low-income consumers with affordable financing and more options when purchasing or leasing new and used ZEVs.
- The Clean Vehicle Assistance Program helps low-income Californians access grants and loans for new and used ZEVs.
- The Zero-Emission Assurance Project, once launched, will help address concerns regarding ZEV battery life and mitigate the risk of buying used ZEVs by providing a rebate for the purchase of a replacement battery.

- Assurance measures being considered through the ZEV regulation—such as requiring a battery state-of-health indicator and adding a useful life and minimum warranty requirements—will reduce the risk of owning future new and used ZEVs and benefit the secondary ZEV market, which is crucial to increasing access among low-income consumers.
- The One Stop Shop Pilot Project provides a multi-pronged approach of expanding, prioritizing, and tailoring ZEV and clean mobility outreach and education in underserved communities, including how advanced technologies can meet their needs.

Beyond ZEVs: The Need to Reduce VMT

Governor Newsom's Executive Order N-79-20 to phase out the sale of internal combustion engine (ICE) vehicles by 2035 will result in substantial emission reductions from light-duty passenger vehicles, but ZEVs alone will not be sufficient to achieve the State's climate and air quality goals. Even with phasing out the sale of new ICE vehicles, 30 percent of light-duty vehicles will still be gas-powered in 2045, by which time California must achieve carbon neutrality to help prevent the worst impacts of climate change. Reducing vehicle miles traveled (VMT) is necessary to directly and immediately reduce mobile source emissions, and to bring the light-duty transportation sector within striking distance of carbon neutrality by 2045 and attainment of the 70 ppb 8-hour ozone standard in 2037.

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CARB's previous *2016 Mobile Source Strategy* and *2017 Climate Change Scoping Plan* emphasized the critical role VMT reductions play in attaining 8-hour ozone standards, and meeting California's 2030 climate goals. This update to the Mobile Source Strategy uses the same targets for reducing VMT as these previous plans, which aim to reduce light-duty VMT by 15 percent by 2050 compared to business as usual. The intent of this section of the 2020 Mobile Source Strategy is to identify strategies CARB can undertake to assist in achieving additional reductions and support implementation of regional SCSs. In addition to needing to substantially reduce emissions, our growing dependence on cars also threatens our ability to achieve California's critical health and equity goals. Historic decision-making favoring single-occupancy vehicle travel has shaped many communities. Where and how communities plan and build housing also imposes and often reinforces long-standing racial and economic injustices that leave residents with little choice but to spend significant time and money commuting long distances in search of an affordable place to live. This places a disproportionate burden on low-income Californians, who end up paying the highest proportion of their wages for housing and transportation.[116] Meanwhile, growth in VMT, where it involves or incentivizes land conversion, impedes California's ability to store carbon and maintain resilient ecosystems and the life-sustaining resources they provide, including clean air and water, food, and fiber.

[116] CARB's 2018 Progress Report showed that as housing is becoming less affordable, California's low-income residents are relocating at greater rates than the rest of the population. Low-income residents are moving at greater rates to inland parts of Southern California and to the San Joaquin Valley, especially near the boundary of the Bay Area. Few are moving into the coastal areas of Southern California and the Bay Area, the latter of which has the highest displacement risk in the state.

Moreover, auto ownership is expensive. Low- and moderate-income households spent over half their yearly income to acquire their last vehicle,[117] and it costs on average $9,000 per year to own, maintain, and operate a private vehicle, which represents about 16 percent of average US household expenditures.[118] Rural and suburban households report about 25 percent more VMT than urban households, and thus, incur higher cost burdens.[119] Finally, building and maintaining roads is expensive - roadway maintenance costs alone have ballooned to over $1.4 billion per year in California.[120] California's roads have some of the worst congestion in the nation, and 10 million more vehicles are projected to be on the road by 2050.

Without additional policy intervention, VMT may continue to rise. California needs to re-envision its built environment in a way that reduces the number and length of trips people make, as well as make walking, biking, transit, and other mobility options become more viable. Along with reducing GHG emissions and air pollution,[121,122] lowering transportation expenses by driving less helps people meet other critical household needs, accumulate wealth, buy homes closer to key destinations, and increase discretionary income. Less driving will reduce congestion, save the State money by not having to build expensive new transportation infrastructure, and reduce overall costs to maintain the road system.

Reducing VMT is difficult. Many factors influence an individual's travel choices, and they interact with one another in a complex manner that is not always well understood. Investments in viable travel alternatives such as transit, cycling, and walking, as well as regional growth patterns all play a role in influencing personal travel behavior. It is also important to acknowledge that other factors determined at a macro-level, such as gas prices and employment, play a significant role in influencing personal travel behavior.[123] When

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[117] Pierce, G. DeShazo, J.R., et al. 2019. Designing Light-Duty Vehicle Incentives for Low- and Moderate-Income Households. *https://ww3.arb.ca.gov/research/single-project.php?row_id=65259*

[118] Handy, S. 2020. Reducing Car Dependence Has Economic, Environmental, and Social Benefits. UC Davis: National Center for Sustainable Transportation. http://dx.doi.org/10.7922/G2J101FV Retrieved from *https://escholarship.org/uc/item/7js9s5jk*

[119] Pierce, G. DeShazo, J.R., et al. 2019. Designing Light-Duty Vehicle Incentives for Low- and Moderate-Income Households. https://ww3.arb.ca.gov/research/single-project.php?row_id=65259

[120] Bureau of Transportation Statistics. 2015. Highway Statistics 2015. Table SF-12. *https://www.fhwa.dot.gov/policyinformation/statistics/2015/sf12.cfm*

[121] Ewing, R., Hamidi S. 2016. Urban sprawl as a risk factor in motor vehicle crashes. *https://doi.org/10.1177/0042098014562331*

[122] Busch, B., Lew, E., & Distefano, J. 2015. Moving California Forward: How Smart Growth Can Help California Reach Its 2030 Climate Target While Creating Economic and Environmental CoBenefits. Joint report by Energy Innovation Policy and Technology LLC, and Calthorpe Analytics. Available: *https://energyinnovation.org/wp-content/uploads/2015/11/Moving-California-Forward-Full-Report.pdf*

[123] Travel behavior is influenced by a number of factors including income, the costs of owning and operating a vehicle, other travel options, the time cost of travel, urbanization, and highway capacity. During the last SB 375 Target Setting Update MPOs cited a rebound effect of increased overall driving due to increasing vehicle fuel

CARB released its *2018 Progress Report to the Legislature on SB 375 Implementation* (SB 375 Progress Report), the report day-lighted several issues that impede California's success in reducing VMT and that despite our collective efforts to put in place transportation plans with more coordinated land use plans and policies that would reduce transportation emissions, implementation of those plans is not occurring as envisioned. These shortcomings do not rest fully on any particular entity, but fixing them will require greater leadership across all levels of government. The report identified a number of key areas for future action and additional collaboration, including: aligning certain State funding sources with environmental, equity, and other priorities; increasing affordable travel and housing choices in under-served communities; developing sustainable and equitable methods of funding the transportation system; deploying new mobility options that complement environmental and equity priorities; piloting innovative approaches to speed adoption of clean transportation options; improving access to data; and updating and strengthening SB 375. This document is intended to identify actions that CARB, for its part, can undertake to begin to advance implementation of those recommendations.

The recipe for success in reducing VMT requires many ingredients, but two essential ones include a focus on equity and partnerships.

Addressing Equity

Historically, many transportation and land use policies in California created, exacerbated, and perpetuated systems through which white, middle- and high-income populations advanced their privilege at the expense and detriment of Black, Indigenous and People of Color (BIPOC) communities, people of low-income, and other under-served communities. In turn, those systems contributed to the stark disparities Californians observe today across race and levels of income in relation to access to quality housing, educational attainment, employment rates, and general health and life expectancy, among others.[124] CARB is committed to dismantling embedded systems of disenfranchisement and discrimination, and to prioritizing the needs of historically under-served communities in our work. The 2020 Strategy aims to mark a decisive step by CARB on a much longer path to develop the knowhow and frameworks for collaboration to combat longstanding inequities through California's transportation and land use policies and programs.

State transportation agencies have reviewed their past policies and impacts, and acknowledged their contributions to structural inequities. In June 2020, CalSTA Secretary David S. Kim made an official statement recognizing that the expansion and improvement of

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efficiency, as a significant factor making it difficult to achieving their targets. As part of the Advanced Clean Car II Rulemaking, CARB will analyze the rebound effect

[124] For example, life expectancy varies by as much as 21 years in the San Joaquin Valley depending on zip code; zip codes with the lowest life expectancy tend to have a higher percentage of Hispanic and low-income residents. (Joint Center for Political and Economic Studies; Fresno State's Central Valley Health Policy Institute. 2012. Place Matters for Health in the San Joaquin Valley: Ensuring Opportunities for Good Health for All)

California's transportation system disproportionately benefitted some population groups and burdened others, and that "far too often, past transportation decisions quite literally put up barriers, divided communities, and amplified racial inequalities, particularly in our Black and Brown neighborhoods."[125] In December 2020, the California Department of Transportation (Caltrans) issued its own Equity Statement affirming that "communities of color and under-served communities experienced fewer benefits and a greater share of negative impacts associated with our state's transportation system."[126] Finally, in January 2021, the California Transportation Commission (CTC) declared that "new highways were frequently constructed through predominately Black, Latino, Asian, and low-income neighborhoods to meet the needs of primarily white suburban commuters, and through tribal lands" while other "racist policies and decisions also influenced the siting of other types of transportation infrastructure, such as commuter railways, and the delivery of transit services."[127]

Land use policy has been another structural pillar for socioeconomic and environmental inequity in California. The current makeup of our cities – their patterns of racial and social segregation, investment and underinvestment, and residents' varying rates of income, education and health – is heavily rooted in legacy federal urban renewal, housing, and mortgage insurance programs that codified and advanced racial discrimination dating back to the 1930s.[128] Local governments in California acted to protect these federal programs through zoning decisions that "drove new industrial facilities to or near redlined communities, while at the same time upholding race restrictions through local covenants."[129]

Last fall, CARB adopted *Resolution 20-33* acknowledging that "impacts from air pollutants and greenhouse gases disproportionally affect communities of color … condemn(ing) racism and racial bias in all forms and in all spaces, and welcom(ing) the opportunity to establish and enhance proactive measures to ensure racial equity permeates all of CARB's activities both internal and external."[130] Upholding that commitment will require introspection on our potential role effecting inequitable outcomes (intentionally or unintentionally) through decades of work focused on reducing air pollution and greenhouse gas emissions. It will also require that, moving forward, CARB center equity in all its efforts by prioritizing the needs of those most and worst affected by air pollution and the impacts of climate change, such as BIPOC communities, low-income communities, and other under-served communities. CARB

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[125] CalSTA, Secretary David S. Kim Issues Statement on Racial Equity, Justice and Inclusion in Transportation, 2020.
https://calsta.ca.gov/press-releases/2020-06-12-statement-on-racial-equity
[126] Caltrans, Caltrans Equity Statement, 2020. *https://dot.ca.gov/about-caltrans/equity-statement*
[127] CTC, Racial Equity Statement, 2021. *https://catc.ca.gov/about/racial-equity-statement*
[128] Richard Rothstein, The Color of Law: A Forgotten History of How Our Government Segregated America. 2017.
[129] CalEPA. Pollution and Prejudice: Redlining and Environmental Injustice in California. 2021.
https://storymaps.arcgis.com/stories/f167b251809c43778a2f9f040f43d2f5
[130] CARB. Resolution 20-33: A Commitment to Racial Equity and Social Justice. 2020.
https://ww3.arb.ca.gov/board/res/2020/res20-33.pdf

believes that true changes will not come from just investing in these communities, but also from ensuring that these communities have a more active role in needs assessment, solutions design, and planning processes that lead to such investments and other strategic policy decisions.

CARB is taking key steps in that direction with the 2020 Strategy. In developing the strategies and actions to reduce VMT included here, equity outcomes have been a key consideration. CARB is making commitments to expand our collaboration with under-served communities in transportation needs assessments to identify clean mobility projects for funding; to studying and providing recommendations to develop equitable road pricing programs; and to crafting a strategy of State policy solutions that increase the development of equitable infill housing projects. However, CARB is cognizant that centering equity in our work also requires considering how an action engages within the historic and ongoing context of systemic racism. For example, there is a potential for road pricing and infill housing programs to work against equity if agencies do not appropriately design and implement them. Recent decades have been marked by a significant in-migration of white and middle- and high-income households and businesses to the core of California's most populous cities, a steep increase in core city rents and real estate values, and the relocation of BIPOC and low-income communities to peripheral areas further away from employment hubs, key services, and good transit service. Strategies that increase infill and transit-oriented development have brought up concerns around displacement of existing residents due to increasing land values. In addition, as the housing cost burden is rising in every region, for all income-levels, pricing strategies raise serious concerns. Pricing can put a greater burden on low-income Californians, who also experience greater cost burdens from vehicle ownership than wealthier Californians or who have no alternatives to driving. CARB and its partners will need to confront these realities head on when developing solutions.

Integral to CARB's push to center equity in its VMT reduction work will be building new structures for engagement, co-creation, implementation, and program evaluation with BIPOC, low-income, and under-served communities. Over the years, CARB's various programs and agency-wide perspectives on equity have benefitted greatly from the participation, ideas and activism of local communities, community-based organizations (CBO) and non-governmental organizations (NGOs) concerned with equity issues. As CARB moves to further develop and implement the VMT reduction strategies and actions identified in the 2020 Strategy, it is committed to elevating and empowering under-served communities' voices in the decision-making process; identifying who will benefit or be burdened by a given decision (including examining potential unintended consequences of a decision); designing strategies to advance equity and mitigate unintended negative consequences; and, to structuring mechanisms for successful implementation and evaluation of impacts. CARB will intentionally lead these efforts with a racial justice perspective to confront the impacts of a long history of systemic racial inequity and the intersectionality of race with low-income and other under-served communities. CARB will also closely monitor its efforts to collaborate with BIPOC communities across multiple geographies and fields of policy intervention so that it can continue to learn and improve over time.

CARB does not hold all the answers, but it is committed to the work of building out robust structures to center equity in its work and to prioritizing the needs of under-served communities. The great urgency of racial and other inequities today demands that we take actions now, learn by doing, and improve our approach iteratively. Ahead of the 2020 Strategy lies the development of the 2022 Scoping Plan Update, where we will be working closely with State agency partners like CalSTA, Caltrans, and the CTC who are similarly committed to prioritizing transportation equity in State policy. Let this be an invitation to all stakeholders, and particularly local communities and CBOs, to reach out to CARB and engage in shaping how the agency advances equity moving forward through the 2020 Strategy, the Scoping Plan update, and CARB's work at-large.

Partnerships

Growth in VMT is governed by a host of interconnected factors that are not confined by political boundaries or addressed through singular policy domains; successful VMT reduction policy relies on reinforcement across all levels of government using multiple policy levers. Meeting the magnitude and complexity of the challenge will require improved alignment across multiple agencies and systems that address the interconnected relationship of land use, housing, economic and workforce development, transportation investments, and travel choices.

An important State effort that reflects, and seeks to address, this complexity is the Climate Action Plan for Transportation Infrastructure (CAPTI) that CalSTA is developing in collaboration with CARB and other State agency partners, pursuant to Executive Order N-19-19. Executive Order N-19-19 directs CalSTA to leverage the State's $5 billion transportation funding portfolio in a manner to help achieve the goals in the 2017 Climate Change Scoping Plan. Over the course of the last year, CalSTA and partner agencies have identified a number of actions to better align transportation investment priorities with State climate goals. Actions that involve CARB and aim to reduce VMT are included in this document.

Another key partnership opportunity is the reconvening of the State Agency-Metropolitan Planning Organization (MPO) Working Group. Through this Working Group, CARB staff are working with the Governor's Office of Planning and Research (OPR), MPOs, and other State agencies to support improvements to regional planning and SB 375. As part of this effort, CARB staff are working with MPOs to discuss principles for establishing an evaluation framework that can help prioritize State funding in a manner with the greatest potential to advance SCS implementation.

CARB is also:

- Participating in the State's Housing and Transportation Coordination Working Group, which facilitates cross-disciplinary learning and collaboration, including funding program guideline changes to better incentivize coordinated housing and transportation projects with State funds.

- Holding joint meetings with the CTC and Department of Housing and Community Development (HCD) twice a year to help better align state transportation, housing, climate, and air quality programs and policies.
- Collaborating with State and regional partners to enhance our understanding of travel behavior. For example, a partnership between CARB, Caltrans and the Sacramento Area Council of Governments (SACOG) is leading to new approaches to use "big data" to assess regional travel patterns in the Sacramento region and enhance planning.[131]
- Participating in the interagency Transportation Research Roundup Group to ensure that State-funded transportation research is well-coordinated, and to identify cross-agency research collaboration opportunities.

Continuing to build on and expand partnership opportunities will be an important and necessary component of CARB's work to achieve greater VMT reductions and meet our collective emissions reduction goals. The actions identified in this chapter are examples of this view, all of which will require collaboration and partnerships across multiple State agencies, regional and local government, tribal governments, transit operators, air districts, private companies, and environmental and community-based organizations.

Process to Develop VMT Actions in the Mobile Source Strategy

The 2020 Strategy represents a waypoint in a broader interagency and stakeholder process that lies ahead to identify actions to reduce passenger VMT. Specifically, while the 2020 Strategy identifies a suite of actions CARB could take under its authority, the 2022 Scoping Plan Update will identify a broader set of actions across State government to reduce VMT to meet State climate goals. This process will be outlined in more detail at the end of this section.

The scope of this chapter in the 2020 Strategy includes concepts organized around eight strategy areas that build from or support related, ongoing efforts, or would be new actions that CARB could initiate under its existing authority within the next several years. These eight strategy areas represent often mentioned types of strategies for reducing VMT and are aligned with the challenge and opportunity areas explored in CARB's *SB 375 Progress Report*, which relied on input from MPOs; academics; builders; environmental, public health, and equity advocates; State and local government practitioners; and public stakeholders.

The strategy areas are:

1. Increase Transportation Choices and Improve Access
2. Authorize and Implement Equitable Pricing of Transportation

[131] *www.sacog.org/post/big-data-pilot-project-transportation-planning-replica*

3. Align State Funding Programs to Reduce Vehicle Travel and Achieve the State's Greenhouse Gas Emissions Reduction Goals
4. Shape the Deployment of New Mobility Options in Ways That Reduce VMT
5. Better Align Land Use Planning with the Scoping Plan's Goals
6. Accelerate Infill Housing Production
7. Support Local and Regional Partners to Implement VMT Reduction Measures
8. Elevate the State of Science to Inform the Development and Implementation of Sustainable Community and Transportation Policies

In the next section, CARB staff provides additional detail on the importance of each strategy area in reducing VMT, current challenges and opportunities, and a description of the concepts CARB could undertake. Because CARB's existing authority is limited when it comes to VMT-reducing actions, staff have identified areas where new resources and legislation would be necessary. Above all, strong partnerships, alignment, and close collaboration across State agencies, MPOs, and affected stakeholders will be critical to maximize impact.

In each of the following strategy areas, CARB staff identify why the strategy is important for VMT reduction, known challenges and opportunities, and actions it could pursue in the near-term to advance the strategy.

Strategy Area 1: Increase Transportation Choices and Improve Access

Increasing viable options other than a personal vehicle, such as walking, bicycling, transit, or other emerging mobility options to get people where they need to go more conveniently and frequently is a necessary step to VMT reduction. However, decades of transportation and land use planning practices have created car-dependent communities in which driving is a virtual necessity to access most destinations. In addition, residents and visitors face a disaggregated public transportation network that is often not as friendly to use as it might be, is costly to operate, and faces new competition for ridership in many places. Transit ridership has fallen across California and there continues to be a relatively small percentage of people who walk and bike to work, approximately 4.5 percent.[132] COVID-19 has taken a particularly devastating toll on transit, with several agencies dealing with public perceptions about contagion, record-low ridership and resulting revenue losses, and detrimental service cuts that affect vulnerable groups and essential workers in the greatest need of transit services.

Overall, the need for greater investments in all modes is needed to advance transportation choices to help slow VMT growth. Important strides to increase funding for transportation choices have been made, including increasing public transit, road maintenance, and active transportation spending, but as CARB's SB 375 Progress Report shows, more must be done to shift transportation investments and accelerate progress on climate, accessibility, health

[132] CARB. 2018. 2018 Progress Report: California's Sustainable Communities and Climate Protection Act. Available: *https://ww2.arb.ca.gov/sites/default/files/2018-11/Final2018Report_SB150_112618_02_Report.pdf*

and equity benefits. Caltrans' *California Transportation Plan 2050* (CTP 2050) offers some insight into the substantial magnitude of funding needed to implement this transformation and uses a compilation of the MPO regional transportation plans (RTP) and SCSs to estimate the lower bound cost, of more than $1 trillion over the next 20 years. While CARB acknowledges the substantial need for increased investment, this document highlights and focuses on actions CARB could immediately undertake within its authority to help advance these broader objectives.

Recently, CARB has invested efforts in identifying and overcoming barriers to clean transportation access for low-income residents. As discussed previously, CARB published the SB 350 Barriers Report in February 2018. Through the statewide public process to develop recommendations for this study, residents and stakeholders stressed that transportation and mobility needs vary widely across communities and across demographic groups within communities. Residents of low-income and disadvantaged communities stated their interests and needs were not being adequately considered during transportation planning efforts that affected their communities. And yet, in order for clean transportation projects to successfully reduce GHG emissions and VMT, residents have to buy into and utilize the implemented clean transportation services. Consequently, the SB 350 Barriers Report recommends expanding assessments of community residents' transportation needs to identify barriers to accessing and adopting clean, transportation and mobility options for low-income communities and communities most burdened by air pollution. The study also recommends involving those community residents in transportation planning and project implementation.

CARB has piloted this approach in two funding programs - the Clean Mobility Options (CMO) Voucher Pilot and the Sustainable Transportation Equity Project (STEP). So far, CARB is funding 24 small-scale community transportation needs assessments (totaling $1.15 million) through CMO and eight larger-scale community transportation needs assessments and planning projects (totaling $1.75 million) through STEP. Based on the proposals received in the STEP solicitation and the CMO voucher application window, there is significant demand for transportation needs assessments. STEP received 20 Planning and Capacity Building Grant proposals requesting $7.2 million in total and was oversubscribed by more than four times the available funding, while CMO received 44 needs assessment voucher applications requesting $2 million in total and was oversubscribed by twice the available funding.

CARB is also funding clean transportation projects selected to fulfill unmet transportation needs identified by community residents. In STEP, CARB is investing $17.8 million in VMT-reducing projects in three communities that have conducted and plan to continue extensive community engagement through the grant's duration. Through CMO, CARB is investing $20 million in shared mobility project vouchers in communities statewide. Based on demand for these pilots, it is also clear that more funding is needed to implement clean mobility projects identified by community residents.

The impacts of COVID-19 on transit agencies have been immense, but also present an opportunity to implement changes to increase transportation choices. Monterey-Salinas

Transit, in a first-of-its kind partnership with Caltrans and Visa to implement contactless payments in public transit buses, is already discovering that during the COVID-19 pandemic, customers prefer this form of payment over cash.[133] Contactless payments may provide an opportunity to renew transit ridership after the pandemic. London, for example, in its first year accepting contactless payments, saw a four to five percent growth in ridership.[134] Contactless payments will also lower the cost for transit providers, as it is expensive to operate and maintain cash collection systems. These savings can be passed on to riders.[135] Washington D.C, for example, spends 10 cents per dollar collecting cash fares, but just 4 cents per dollar on credit/debit card fares.[136]

Having so many different transit systems also makes it harder for riders to understand and use the services available to them. Opportunities to align services include the California Integrated Travel Project (Cal-ITP), which aims to implement a statewide contactless integrated fare payment and data reporting system that allows for seamless fare payment and collection across transit agencies and mobility service providers. Cal-ITP would not require a unique card, app, ticket, or account for each transit service, increasing the accessibility and usability of diverse transportation options. Cal-ITP would standardize contactless payments allowing transit riders to pay from bank cards (such as credit, debit, and prepaid cards) and smart devices equipped with mobile wallets. This simplifies the payment process across modes and service providers, and provides real-time data services for trip planning. Importantly, as part of this effort, Cal-ITP is working to address solutions for California's most underserved communities and un- and underbanked transit users by offering a unique verification system for individuals to receive free or reduced fares across all California transit providers without having to prove eligibility to each transit agency, thereby making it easier to use transit.

In light of these challenges and opportunities, CARB could expand work to identify community needs, fund an array of transportation choices to meet those needs, and reduce barriers to the use of transit.

Strategy Area 2: Authorize and Implement Equitable Pricing of Transportation

Adjusting price signals in ways that make it advantageous to travel via carpool, public transit, and active transportation than to drive alone can provide a powerful incentive to shift travel

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[133] MST. 2020. MST Announces A New Partnership with Caltrans, Visa Introducing Contactless Fare Payment Demonstration. Available https://mst.org/news_items/mst-announces-a-new-partnership-with-caltrans-visa-introducing-contactless-fare-payment-demonstration/

[134] Transport for London. 2016. Commissioner's Report. Available: http://content.tfl.gov.uk/board-160203-item05-commissioners-report-v2.pdf

[135] Caltrans. 2021. CAL-ITP. Available: https://www.calitp.org/

[136] Caltrans. 2021. CAL-ITP. Available: https://www.calitp.org/

patterns and reduce congestion while also providing revenue that may be reinvested to expand travel choices. Research and analysis show that pricing – whether through congestion pricing, tolling, parking pricing, or cordon pricing-is one of the most effective strategies for reducing statewide VMT and GHG emissions when paired with effective alternatives to driving alone.[137,138]

Pricing transportation can take many forms. It can be a charge to motorists for use of the roadway network based on how many miles they drive, instead of how many gallons of gas they use, under a "user pays" principle. Pricing can also take the form of behavioral pricing policies that are meant to incentivize users to prioritize or avoid certain trips, or to switch to other modes. These can include instituting pricing for operating vehicles in certain lanes at peak times, driving into certain designated areas, parking in prime locations, as well as instituting lower-cost transit passes, and pricing structures that encourage carpooling or avoiding unnecessary trips.

Pricing, however, raises serious equity concerns, especially for those Californians already paying a significant portion of their income on housing and transportation. This is made even worse as the housing cost burden is rising in every region, for all income levels.[139] As housing prices have soared in job centers, commutes can lengthen if people have to drive further to find a home they can afford. Pricing can also put a greater burden on low-income Californians, whose household transportation cost burden is already higher than wealthier Californians due in part to these households driving older and less efficient cars. Thus, any strategies developed will need to consider these equity concerns and ensure that they do not place an additional burden on those already struggling with rising housing and transportation costs, and those who have no alternatives to driving.

While further progress on pricing strategies would require State action, five regions in California report they have already adopted or are beginning to consider pricing, including some rural regions with heavy tourist traffic or heavy traffic passing through their region.[140] They include implementing congestion-based bridge tolls that vary the cost of the toll based on whether or not the driving occurs during peak commute hours; creating networks of express lanes that are free to transit, carpools, vanpools, and motorcycles and that are available to single-occupant vehicles for a toll; educating the public about the high costs of traffic congestion and the possibility of creating mobility zones via congestion pricing; and valuating means-based pricing strategies for public transit.

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[137] https://dot.ca.gov/-/media/dot-media/programs/transportation-planning/documents/ctp-2050-v3-a11y.pdf
[138] *Carbon Neutrality Studies: Vehicle Emissions and Fossil Fuel Demand and Supply | CalEPA*
[139] CARB. 2018. 2018 Progress Report: California's Sustainable Communities and Climate Protection Act. Available: *https://ww2.arb.ca.gov/sites/default/files/2018-11/Final2018Report_SB150_112618_02_Report.pdf*

[140] CARB. 2018. 2018 Progress Report: California's Sustainable Communities and Climate Protection Act. Available: *https://ww2.arb.ca.gov/sites/default/files/2018-11/Final2018Report_SB150_112618_02_Report.pdf*

These pricing strategies also help regions overcome significant losses in revenue from State and federal gas taxes as a result of more fuel-efficient vehicles and ZEVs.[141] The Southern California Association of Governments (SCAG), for example, assumes increases in federal gas taxes, revenue from a yet-to-be implemented mileage-based user fee that replaces the gas tax, local pricing policies (e.g., congestion and parking) and fees placed on transportation network companies (TNCs). These new revenue sources amount to $128 billion – nearly 20 percent of the RTP's budget - and are important to implementing the SCS.

Equitable pricing can also achieve other important benefits aside from VMT and GHG reductions. As analyzed in Caltrans' CTP 2050, the impacts of increasing the cost of driving in California's most congested counties (exempting the lowest income quintile) and implementing cordon pricing in California's ten most populous downtowns results in a positive economic impact. As travelers shift from driving to other modes, reduced congestion allows for faster and more efficient travel for those who rely on roadways, including freight vehicles.

Changing the structure of costs people incur to access the transportation system provides an opportunity to more equitably and sustainably reduce congestion, increase transportation choices, and fund the transportation system as a whole. Any transportation system pricing program, regional or state, will need to be implemented in conjunction with requirements to use the resulting revenue to invest in alternatives to driving alone, with a particular focus on ensuring low-income residents have affordable access to jobs and other key destinations. Revenues from pricing could be used to fund shuttles, enhance transit service, facilitate pooling by ride-hailing, install protected bike lanes, implement bike-and scooter-sharing, as well as provide financial incentives, including low-and no-cost transit passes.

In light of these challenges and opportunities, CARB could collaborate with other agencies in developing an equitable pricing strategy. (This action supports implementation of the CAPTI.)

Strategy Area 3: Align State Funding Programs to Reduce Vehicle Travel and Achieve the State's Greenhouse Gas Emissions Reduction Goals

A critical test of progress on VMT reduction is whether investments have shifted in ways that improve transportation choices, especially those that make it easy for people to drive less. Improving the alignment of funding, especially funding for transportation infrastructure, with State and regional goals is a necessary strategy for success. Yet, few funding sources exist that prioritize climate mitigation or VMT reduction, and the overall ratio of dollars planned to be spent on roads versus on infrastructure supporting other transportation modes in the largest regions of California has shown remarkably little shift since SB 375 became law in

[141] See Figure 17 showing the decline in total liquid fuel usage for the light-duty fleet over time under the primary scenario.

2008.[142] Structural factors also make it difficult to align SCS planning and transportation funding allocations, in part because many funding decisions are not controlled by the MPOs who develop the regional SCS plans.[143]

New opportunities have made it possible for State agencies to improve collaboration on reducing passenger VMT, while simultaneously advancing crucial climate, health, housing, equity, and conservation goals. For example, the Road Repair and Accountability Act of 2017 (SB 1)[144] made significant and supportive shifts away from past transportation packages, provided essential funding for fixing existing infrastructure, and increased investment in multi-modal programs. In addition, Governor Newsom issued two EOs that provide direction for State transportation spending, including support for VMT reduction projects. *Executive Order N-19-19* directs CalSTA to leverage $5 billion in annual discretionary State transportation funds to reduce GHG emissions in the transportation sector and align transportation spending with the State's Climate Change Scoping Plan, where feasible. It also calls for actions from multiple State agencies to reduce GHG emissions and mitigate the impacts of climate change (e.g., direct investments to support smart growth to increase infill housing production; reduce congestion through strategies that encourage a reduction in driving and invest further in walking, biking, and transit). As discussed earlier, *Executive Order N-79-20* explicitly points to the critical role of transit, passenger rail, active transportation, complete streets, and micro-mobility as tools to expand mobility options, encourage mode shift, and reduce overall VMT, and further directs CalSTA to identify near-term actions and investment strategies by July 15, 2021 to improve clean transportation and sustainable freight and transit options. The draft *Investment Framework* for the Climate Action Plan for Transportation Infrastructure developed in response to the EO identifies guiding principles for investments that will help achieve VMT reductions, such as "Investing in networks of safe and accessible bicycle and pedestrian infrastructure," "Promoting projects that do not increase passenger vehicle travel," and "Promoting compact infill development while protecting residents and businesses from displacement."

One action in CAPTI that CARB proposes to lead is a collaborative process with state and regional partners to develop a framework for identifying projects that best advance the objectives of the RTP/SCSs and the Scoping Plan. In a time of constrained resources, the framework is intended to both help prioritize projects that do the best job of advancing SCS implementation and to send clear and consistent signals about what types of transportation and land use projects will bring the State important SCS benefits. These benefits include improvements in public health, especially in communities that are already the most burdened by pollution, as well as conservation of natural and working lands, expanded access to homes

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[142] CARB. 2018. 2018 Progress Report: California's Sustainable Communities and Climate Protection Act. Available: https://ww2.arb.ca.gov/sites/default/files/2018-11/Final2018Report_SB150_112618_02_Report.pdf
[143] CARB. 2018. 2018 Progress Report: California's Sustainable Communities and Climate Protection Act. Available: https://ww2.arb.ca.gov/sites/default/files/2018-11/Final2018Report_SB150_112618_02_Report.pdf
[144] Beall, Chapter 5, Statutes of 2017

that are affordable to households at a range of income levels, reduced traffic congestion and road maintenance burden, improved transportation choices for people of all incomes, and planning for attainment of air quality standards.

In light of these challenges and opportunities, CARB could explore collaboratively developing tools that help advance project selection and transportation planning to better align with climate and equity goals. (This action supports implementation of the CAPTI.)

Strategy Area 4: Shape the Deployment of New Mobility Options in Ways That Reduce VMT

New mobility brings together technology, transportation services, as well as public and private business models into a new transportation landscape providing new options for travelers such as public and private bike and scooter share, carsharing, ride-hailing, on-demand delivery, on-demand transit, and automated vehicles. These services offer the opportunity to transform our transportation system in ways that help reduce VMT by providing options for riders that need them and slowing growth in auto ownership, optimizing linkages with public transit, as well as helping to facilitate carpooling.

However, without additional State policy, these services could also increase VMT and GHG emissions, result in safety concerns, and exacerbate equity issues related to service gaps and costs by disrupting and competing with existing services. For example, VMT by ride-hailing services offered by transportation network companies (TNCs) grew 24-fold between 2014 and 2018, with a 2018 TNC share of total light-duty VMT in California of 1.2 percent.[145] TNC growth is expected to continue growing until market saturation. The share of trips from TNCs is still small compared to trips overall, but is rapidly increasing and contributing to congestion, especially in urban areas.[146] With dead-head miles (one-way trips without a passenger), VMT from TNCs is greater than the equivalent would be if driven in personal vehicles.[147,148]

Additionally, changes in transportation behavior resulting from the COVID-19 pandemic are also contributing to the changing transportation landscape. In particular, the pandemic has accelerated the growth of on-demand delivery services even further.[149] The share of VMT

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[145] CPUC. 2014-2018 Transportation Network Companies historical data provided to CARB.

[146] San Francisco County Transportation Authority. 2018. TNCs and Congestion: Final Report. Available: *https://www.sfcta.org/sites/default/files/2019-05/TNCs_Congestion_Report_181015_Finals.pdf*

[147] CARB. 2019. Clean Miles Standard 2018 Base Year Emissions Inventory Report. Available: *https://ww2.arb.ca.gov/sites/default/files/2019-12/SB%201014%20-%20Base%20year%20Emissions%20Inventory_December_2019.pdf*

[148] Henao, A., Marshall, W.E. The impact of ride-hailing on vehicle miles traveled. Transportation 46, 2173–2194 (2019). *https://doi.org/10.1007/s11116-018-9923-2*

[149] Matson G. et al. Longitudinal Analysis of COVID-19 Impacts on Mobility: An Early Snapshot of the Emerging Changes in Travel Behavior" (2021). https://escholarship.org/uc/item/2pg7k2gt

coming from new mobility services will increase rapidly as the use of these delivery services continues growing, especially without any policies in place to help make these services more efficient and sustainable.

In light of these challenges and opportunities, CARB could continue and expand regulations around new mobility services to help support an expanding ZEV market and an efficient transportation system.

Strategy Area 5: Better Align Land Use Planning and Development with the Scoping Plan's Goals

Integrated planning that aligns land use and housing development with transportation options that are accessible to and near daily needs reduces the number and length of vehicle trips. Densifying development through infill, making sure growth occurs in walkable or transit-oriented areas, and disallowing leapfrog development out in natural or agricultural areas are known land use strategies for supporting VMT reduction. While land use decision-making in California is under the control of cities and counties, myriad state polices in California affect land use development patterns. In recent years, California has adopted new laws to support growth through infill and transit-oriented development through the CEQA and housing planning processes, as well as put in place competitive funding programs to support these objectives through State transportation, housing, and climate investment programs.

Most prominently, SB 375 was adopted in 2008 and intended to be the State's primary mechanism to achieve significant emissions reductions from changed land use patterns and improved transportation. The law set forth new requirements for California's MPOs to include sustainable communities strategies within their RTP, and was intended to set forth a long-range vision for the region's land use allocation. However, as described in more detail in *CARB's SB 375 Progress Report*, many of the forecasted results of this State policy, including achievement of more compact growth and per capita VMT reduction, have been slow to occur.

Stakeholders interviewed by CARB staff during preparation of the SB 375 Progress Report pointed out that the regional SCSs' impact on local development decisions to date are minor. Interviewees cited fundamental challenges to achieving greater consistency between local plans and the SCS. These challenges included issues with the clarity of SCS plans and not being able to easily distinguish whether a potential local action supports or interferes with implementing the region's SCS, as well as lack of direct, ongoing and predictable incentives or penalties to localities that support conformance with SB 375 goals. Interviewees also cited the elimination of key tools for land use change, specifically, the loss of redevelopment revenue in 2012 as continuing to have a major impact.

In addition to identifying challenges pertaining to local alignment with regional plans, interviewees identified opportunities to strengthen local and regional plan alignment with State VMT reduction goals. In particular, interviewees pointed out that the SB 375 law itself

could be changed to require State and regional alignment on VMT reduction targets out to 2050, so that regional and local planning efforts focus on identifying needed long-term land use and transportation systems strategies, as opposed to vehicle technology strategies that advance GHG emissions reductions only.

A combination of changes to law are needed to help address these challenges and increase delivery of the current SB 375 program's targeted VMT reductions from land use change. To address the issue of clarifying VMT reduction goals and timelines between government agencies, the legislature would need to add authority for CARB to set regional VMT-based targets for 2035, 2045, and 2050, aligned with key State climate planning milestones. To help with the issue of clarity of SCS plans and local implementation of them, SB 375 would need to be modified to direct MPOs to identify what transportation, housing, and land use project investments and supporting local implementation actions are most critical to achieving its SCS VMT reduction strategies and targets, and to monitor whether its local agencies are implementing land use decisions that conform. In cases where a local agency is taking action that will interfere with its regional SCS's VMT reduction goal, the legislature could direct MPOs to issue a formal warning to the local agency and report on outcomes to State partner agencies. Requiring these SCS plan clarifications could help increase likelihood of delivering SB 375 VMT reductions by providing clear and consistent signals to local agencies on the amount, type, accessibility characteristics of growth needed in its communities to achieve California's SB 375 goals so that the agency can more easily operationalize that information in its planning, funding, and permitting processes. State agencies would also be able to use identified local priority investments and actions to help better align and prioritize State funding decisions toward VMT reduction.

In light of these challenges and opportunities, CARB could update SB 375 to provide actions and incentives that help advance SCS implementation.

Aligning land use planning to meet California's VMT reduction needs also means providing a counterbalance and complement to urban development strategies through strategies like land conservation. Conservation is an effective method to reduce VMT and provides extensive co-benefits beyond reducing transportation emissions. When natural and agricultural lands are lost to more intensive uses, the carbon stored in the soil and plant biomass on the land is degraded or lost as carbon dioxide.[150] In addition, the construction of roads and sprawl-style development leads to the parcelization and fragmentation of natural and working lands. This fragmentation can make it more difficult and costly to implement effective conservation and restoration management strategies. Protecting agricultural lands from conversion to developed lands also helps protect natural lands by limiting the relocation

[150] California loses, on average, approximately 50,000 acres of farmland per year, mostly due to urbanization. Strategic Growth Council. 2019. Annual Report to the Legislature: 2018-2019 Fiscal year. California Department of Conservation. Division of Land Resource Protections Farmland Mapping and Monitoring Program. https://www.conservation.ca.gov/dlrp/fmmp

of agricultural production.[151,152,153] As agricultural production relocates, it is likely to move farther from existing support infrastructure such as markets, processors, and farm worker housing. Directing new growth to existing communities without displacing current residents can prevent the conversion of natural and working lands, and the associated impacts to climate, water, and air, while fostering compact development that reduces VMT. And, as highlighted during the pandemic, there is significant demand for outdoor recreational opportunities. Creating and maintaining walkable and bikeable outdoor recreation within cities can provide a multitude of other benefits, including improved public health, economic vitality, wildlife habitat conservation, and community cohesiveness.

Further, as we chart a path towards carbon neutrality, direct GHG emission reductions alone are not enough to reach our ambitious goals. Carbon sequestration is also necessary to achieve carbon neutrality, and investments in the conservation and restoration of natural and working lands are essential for storing carbon in ways that are resilient to the effects of climate change. In accordance with Governor Newsom's *Executive Order N-82-20*, agencies are required to analyze and project the impact of climate change and other stressors on California's biodiversity, advance multi-benefit and cooperative approaches to steward natural and working lands, and CARB is expanding efforts to understand the relationship and synergies of taking an integrated cross-sector approach.

In light of these challenges and opportunities, CARB could update State planning guidance to better connect State climate, transportation, and conservation goals with regional planning. (This action supports implementation of the CAPTI.)

Strategy Area 6: Accelerate Infill Housing Production

Policies that will result in higher densities have often been mentioned in the suite of land use tools that might reduce VMT. These policies include direct changes to land use, such as encouraging urban infill through combinations of infrastructure, zoning, or public finance policies that, for example, focus development around transportation nodes (including transit stations) and job centers.

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[151] From 1973 to 2000, 2,014 km^2 of agricultural lands were converted to urban land use in California. However, overall agricultural land use declined by only 473 km^2 because of conversion of natural lands (predominantly grasslands and shrublands) to agriculture. Sleeter, B. M., Wilson, T. S., Soulard, C. E., & Liu, J. (2011). Estimation of late twentieth century land-cover change in California. Environmental Monitoring and Assessment, 173(1-4), 251-266.

[152] Broadly, as prime farmland near cities is converted to development, rangelands are converted to croplands. Greene, R. P., & Stager, J. (2001). Rangeland to cropland conversions as replacement land for prime farmland lost to urban development. The Social Science Journal, 38(4), 543-555.

[153] From 1984 to 2008, 40 percent of the loss of rangelands in California was due to conversion to more intensive agricultural use. Cameron, D. R., Marty, J., & Holland, R. F. (2014). Whither the rangeland?: Protection and conversion in California's rangeland ecosystems. PLoS One, 9(8), e103468.

Accelerating infill housing production will need to be a key strategy in the context of California's severe housing shortage. To meet current demand, keep pace with future growth, and provide a safe, decent, and affordable home for all Californians, State estimates suggest that we need to build over 2 million new homes and more than double the pre-2020 pace of development over the next decade. The housing shortage contributes to increased VMT, and hinders our ability to meet GHG reduction goals. The dearth of available and affordable housing – particularly in high market demand areas with a diversity of viable, low-carbon transportation choices – forces households to live farther from their destinations and drive greater distances to meet their basic needs, contributing to the rise in per capita VMT, as reported in CARB's SB 375 Progress Report.

Additionally, in virtually all regions of the state, and at all but the highest income levels, the shortage of available and affordable homes also affects quality of life, economic prosperity, and resilience to climate impacts, and exacerbates widening social and racial equity gaps. It means as California housing prices soar to some of the highest in the nation, households pay ever greater shares of their income on rent or mortgage payments, not only hurting household finances but potentially constraining their expenditures at local businesses. Californians then also have fewer options to choose the neighborhood or even the region in which they live, and have limited access to employment, schools, and economic mobility. Importantly, all of these impacts disproportionately affect low-income households and communities of color, which are already disadvantaged by historic and present-day discrimination in housing law and practice, and broader patterns of systemic and institutionalized racism.

The causes of these issues are intertwined; so are the solutions. As VMT rises, equity gaps widen rather than narrow, and the basic costs of living grow more unattainable for Californians, it is ever more imperative to address the nexus of housing, climate and equity objectives holistically, rather than as separate policy goals. For these reasons, *where* and *how* we build new housing matters – and will shape our ability to meet GHG reduction goals and advance social and racial equity. Building housing in types and locations that reduce long commutes and dependence on cars – e.g. places that are higher-density, location-efficient, and well-served by low-carbon transportation options – helps reduce VMT and GHG emissions, enhance climate resilience, improve quality of life, and increase access to economic opportunity.

The current imbalance of housing supply can be attributed to many factors. CARB's SB 375 Progress Report summarizes key challenge areas cited during interviews with builders, regional, and local agencies. These include: State and local regulatory and taxation structures, whether MPO RHNA allocations support local jobs-housing balance, as well as the higher cost and lack of funding opportunities for infill development compared to greenfield development. Political dynamics in many parts of the state pose further hurdles for infill housing as much-needed new housing is often halted or prohibited altogether by extensive and costly local review processes. Additionally, a dearth of financing tools and resources for

infill-supportive infrastructure presents a significant hurdle to infill housing development in many parts of the state.

The challenges and solutions to California's housing crisis are numerous, complex, and a topic of extensive scholarship and debate. Fundamentally, however, future growth that aligns California's housing, climate, and equity goals will require broad, systemic changes and significant, multi-sector collaboration and innovation. This includes technological, financial, regulatory, political, and public education measures to deliver new housing faster, cheaper, and with greater efficiency in ways that also advance climate and equity goals – and avoid unintended consequences like gentrification and displacement.

Since 2017, the Legislature has passed a series of housing bills designed to address California's housing shortage and affordability crisis. It is too soon to know what net effect these tools will have on the backlog of affordable housing need. However, given the magnitude of current housing shortfalls, as well as CARB's findings on the importance of accelerating infill to further implementation of SCS plans, it is clear that more tools to directly address California's biggest housing challenges will almost certainly be needed.

Fortunately, the dynamic current state of California and the nation - on the brink of a slow but inevitable recovery from the impacts of COVID-19, in an era of renewed commitment to social and racial justice, and at the outset of a new federal administration – is ripe with possibility. And, CARB is well-positioned to play a strategic role in supporting collaborative efforts to achieve innovation and systemic change in where and how we grow.

To accelerate infill housing production that advances CARB's VMT reduction goals, CARB has recently expanded its work on policy development at the intersection of housing, climate, and equity – in collaboration with State agency partners and many others. CARB's objectives in taking on this work are to advance housing production, GHG/VMT reduction, social and racial equity, and health and safety – including climate resilience. By working to achieve overlapping benefits for housing, climate, equity, resilience *and* health and safety outcomes, CARB's goal is to demonstrate it is not only possible but also mutually beneficial to pursue multiple policy objectives holistically to achieve a better California for all.

In light of these challenges and opportunities, CARB could study and explore infill housing development barriers and potential state solutions. CARB could also develop tools to increase outreach to stakeholders and alignment of housing, transportation and climate goals.

Strategy Area 7: Support Local and Regional Partners to Implement VMT Reduction Measures

Slower growth in VMT from more efficient land use development patterns is necessary to achieve deeper reductions in the transportation sector, and regional and local agencies are uniquely positioned to influence the future of the built environment and its associated GHG emissions. These agencies are tackling a multitude of issues that aim to increase housing and

mitigate the impacts of expanding freight sectors and other changes in land use and transportation systems.

SB 743[154] went into effect statewide on July 1, 2020 and fundamentally changes the way public agencies assess the impacts of land use and infrastructure projects. Specifically, public agencies will no longer identify localized traffic congestion as a significant impact on the environment under the CEQA, and will focus on the impact driving and auto dependence have on our environment. OPR and Caltrans both recognize VMT as a useful measure of this impact. To that end, land use development projects approved by local governments and capacity-increasing projects on the State Highway System where Caltrans is the lead agency (or when Caltrans designates another entity as the lead agency) will be evaluated based on the project's propensity to increase VMT. This important structural and philosophical shift presents opportunities to streamline and lower the costs for infill development projects in low-VMT areas, and to identify and mitigate the environmental impacts from VMT where they occur.

When a lead agency identifies a significant impact, it must identify feasible mitigation measures that could avoid or substantially reduce that impact.[155] Under the new SB 743 paradigm, transportation impacts extend well beyond the localized conditions around the project site. Opportunities to mitigate VMT outside of the project site (e.g., elsewhere in the region) may be an appropriate form of mitigation[156], if all feasible on-site mitigation has been exhausted. However, there is currently no administrative mechanism to transfer funding and responsibility from a lead agency approving a project (e.g., local jurisdiction) to a responsible party that could implement off-site VMT mitigation measures (e.g., transit agency, mobility service provider). To overcome this barrier to implementing off-site VMT mitigation, individual jurisdictions are currently exploring the feasibility of VMT mitigation banking at different geographies, and stakeholders believe there may be a role for the State to make it easier for local governments to find local projects that mitigate VMT, deliver multiple community benefits, and prioritize equity considerations. Importantly, because CEQA requires impacts to be mitigated to the extent feasible, having options to simultaneously mitigate GHG emissions, criteria air pollutants, and VMT would benefit developers of projects and ensure impacts are, in fact, mitigated.

In light of these challenges and opportunities, CARB could work with other state and regional agencies to support the development of a statewide VMT mitigation bank. (This action supports implementation of the CAPTI.)

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154 Steinberg, Chapter 386, Statutes of 2013

155 Public Resources Code, § 21002.1, subd. (a)

156 OPR. 2018 (December). Technical Advisory on Evaluating Transportation Impacts in CEQA http://opr.ca.gov/docs/20190122-743_Technical_Advisory.pdf

Strategy Area 8: Elevate the State of Science to Inform the Development and Implementation of Sustainable Community and Transportation Policies

CARB has identified important data and research gaps that stand in the way of our ability to develop and implement more effective VMT reduction policies. For example, the development of the SB 375 Progress Report highlighted that there is not a standardized way to measure passenger VMT, and reliable passenger VMT data are not available at the regional level. In addition, rapidly evolving emerging mobility services generate significant amounts of data that could provide key insights into their diverse VMT impacts and potential strategies to manage them, but government agencies have very limited access to that data due to concerns around the disclosure of private and proprietary business information. Telework, telemedicine, remote learning, and other remote activities also offer interesting opportunities for trip reduction and curbing peak demands on the transportation system, while also presenting new challenges in terms of the equity impact of these policies and their potential impacts promoting different travel patterns.[157]

Moreover, the COVID-19 pandemic has brought about additional challenges related to tracking VMT and assessing the impact of specific policies on VMT. Everyday practices that framed VMT patterns like going to work, school, shopping, the doctor, and visiting friends and family, among others, were all severely impacted by COVID-19. Numerous households and businesses have taken concrete steps (such as relocating homes or downsizing offices) to respond to these new conditions, and what they expect the world will look like after the COVID-19 pandemic. Attitudes towards commuting in public transit or densely populated workplaces seem to be shifting, and their long-term impact is a major concern.

In response to these challenges, CARB has several research projects and partnerships underway to improve the planning and monitoring of policies to meet transportation, housing, health, and environmental goals. Those projects and partnerships are described in more detailed in the actions listed below. CARB is also seeking to establish a more collaborative relationship between State agencies, MPOs, and local governments to jointly solve shared issues and to better measure progress toward regional targets. Another body of work worth highlighting is CalEPA's research around the State's goal of achieving carbon neutrality by 2045 (in partnership with CARB and other State agency partners). This effort will help inform the upcoming 2022 Scoping Plan Update by identifying scenarios, related strategies, tradeoffs and benefits for areas where action can be taken now, as well as additional actions, targets, policies, research and technology development needed in the medium- and longer-term.

In light of these challenges and opportunities, CARB could develop a Sustainable Transportation and Communities Research Roadmap to identify research that is needed to

[157] Zhu, P., Mason, S.G.. 2014. The impact of telecommuting on personal vehicle usage and environmental sustainability. Int. J. Environ. Sci. Technol. 11, 2185–2200 (2014). https://doi.org/10.1007/s13762-014-0556-5

support CARB and other agencies' efforts related to transportation, housing, land use, and buildings.

Next Steps

The 2020 Strategy represents a waypoint, an early marker, in a larger interagency and stakeholder process that kicks into higher gear this spring to broaden the scope of State-led actions to reduce passenger VMT. Specifically, while the 2020 Strategy identifies a suite of concepts CARB could take under its existing authority within the next several years, the 2022 Scoping Plan Update will define a more complete set of strategies, actions and commitments across State government to further reduce VMT and to also support successful implementation of the regions' SCSs in order to meet air quality standards and the State's climate goals.

CARB will also launch an external engagement process as part of the 2022 Scoping Plan Update this spring to collaborate with regional and local government agencies, community organizations and community leaders, NGOs, academia, and other interested stakeholder partners, to assess proposed actions and identify new actions. Over time, the workshop process is expected to yield an overall strategy of priority short- and long-term actions that would be included in the 2022 Scoping Plan Update. As a result of these efforts, it is possible the actions identified in the 2020 Strategy will evolve.

A draft of the 2022 Scoping Plan Update will be published in Early 2022. This draft will include, at minimum, the overall framework and list of proposed actions to reduce VMT and meet the State's GHG reduction goals. The draft will also document the process to date, including stakeholder and community engagement and input. The final 2022 Scoping Plan Update will be published in late summer 2022, incorporating the feedback received on the draft, and fleshing out in more detail each activity, their expected impact, and their proposed implementation strategies. To stay up-to-date about opportunities for input on passenger VMT reduction strategies, please *subscribe* to CARB's "SB 375 Implementation" email distribution list.

On-road Motorcycles

CARB administers a program for reducing emissions from On-Road Motorcycles (ONMC). Current emissions limits for ONMCs are given in California Code of Regulations (CCR), title 13, sections 1958 (exhaust) and 1976 (evaporative). Requirements for ONMC certification include provisions for demonstrating compliance with the applicable emission standards using specific test procedures, as well as emission labeling and warranty obligations. On-road motorcycles emission standards were last updated in 1998.

There are currently 680,000 on-road motorcycles in the fleet growing slowly to approximately 700,000 vehicles by 2050. CARB's current mobile source emissions inventory demonstrates that as emissions from cars and trucks are reducing at a rapid rate – due to stringent regulation adopted by CARB – the relative emissions contribution from motorcycles will be increasing in future years. Therefore, similar to other mobile source categories, it is important that CARB seek the most cost effective emissions reductions from this sector as well.

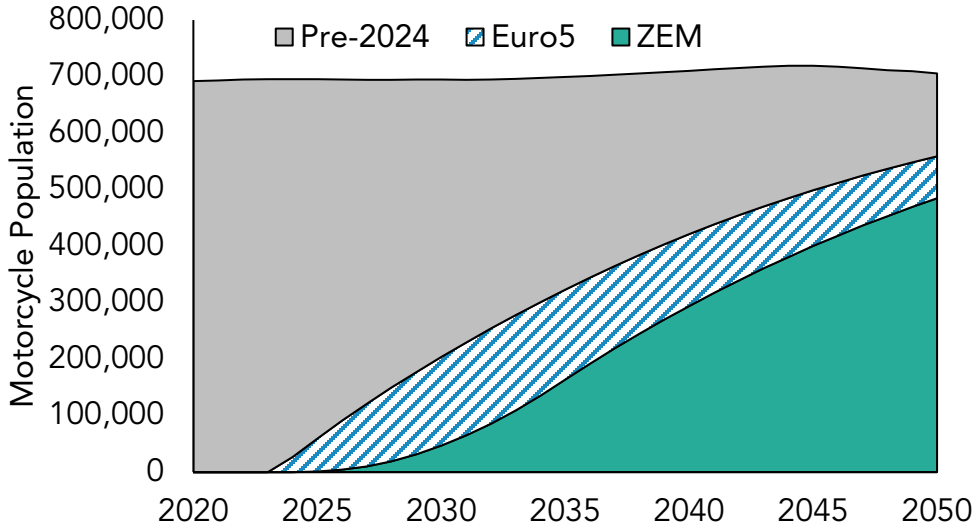
CARB staff are currently in the preliminary stages of developing new regulations for ONMC. An ONMC workshop was held in April 2018 to discuss potential harmonization with the recently adopted European Union (EU) standards for motorcycles. Technical Working Groups with CARB staff and a broad representation of industry stakeholders began meeting in June 2018 to work through challenges related to harmonization, with the goal of developing new emissions for exhaust and evaporative standards for ONMC starting with the 2024 model year. Updates to the on-road motorcycle certification test procedures is scheduled to be presented to the Board in 2021.

From a technological perspective, it is quite feasible to meet the Euro 5 standards. Several models currently being sold in California are actually certified to the Euro 5 standards. In fact, staff analysis of U.S. EPA's motorcycle certification database found that 38.6 percent (117 of 306) of the engine families certified in 2020 have emissions levels that meet, or nearly meet, the Euro 5 standards. In addition, CARB's evaporative testing has shown that there is a need to require more robust evaporative controls on motorcycles similar to what has been in place on passenger cars for decades.

Zero-Emission Motorcycles (ZEMs) will play a role in reducing overall emissions by displacing emissions from internal combustion engines. Historically, some of the challenges facing ZEM adoption have included vehicle cost, limited range, availability of charging stations, and long charging time. With advancements in battery technology and an increase in the number of electric vehicle (EV) charging stations, ZEMs are becoming a more attractive option for motorcyclists.

For the 2020 Strategy, staff have considered a scenario where starting with model year 2024, all new motorcycle sales will meet the Euro 5 standards. Also staff assumed a ZEM sales requirement that will start at 5 percent in 2025 and increases up to 100 percent by 2035 (i.e., model year 2035 and newer motorcycles will be all ZEM). Figure 19 illustrates the number of Euro 5 certified as well as ZEM under this scenario.

Figure 19 – Statewide Projected Motorcycle Populations – MSS Scenario



Staff assessment has shown that this scenario reduces the motorcycle statewide ROG + NOx emissions by approximately 3.1 tpd in 2031, and 7.7 tpd in 2037. Additional ROG reductions will be achieved through more stringent evaporative controls, although these have not been accounted for in staff's assessment. In addition, electrification of motorcycles is projected to reduce fuel consumption by 28 million gallons per year by 2045. These results are shown in Figure 20 and Figure 21.

Figure 20 - Statewide Smog-Forming Projections for On-Road Motorcycles – MSS Scenario

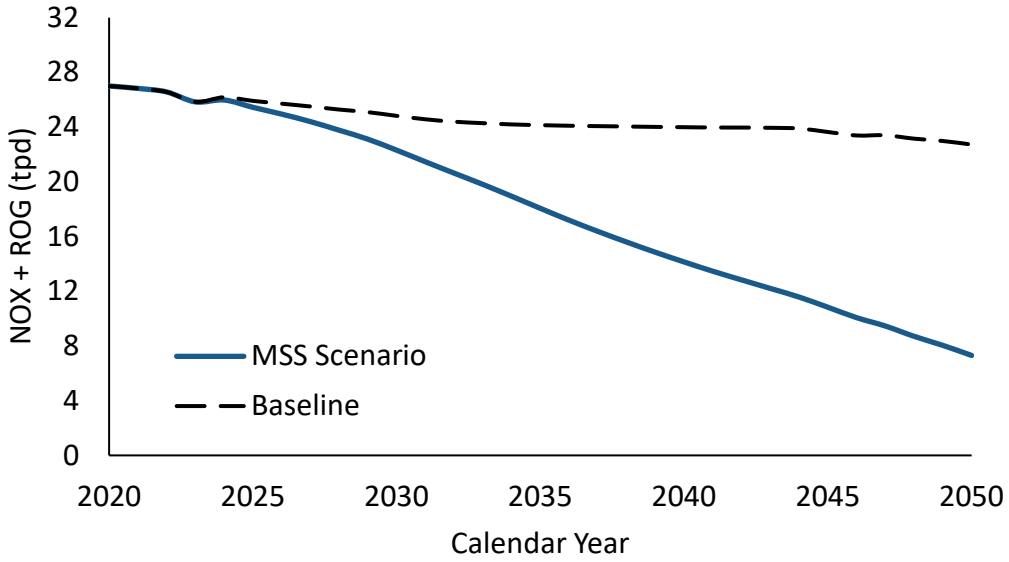
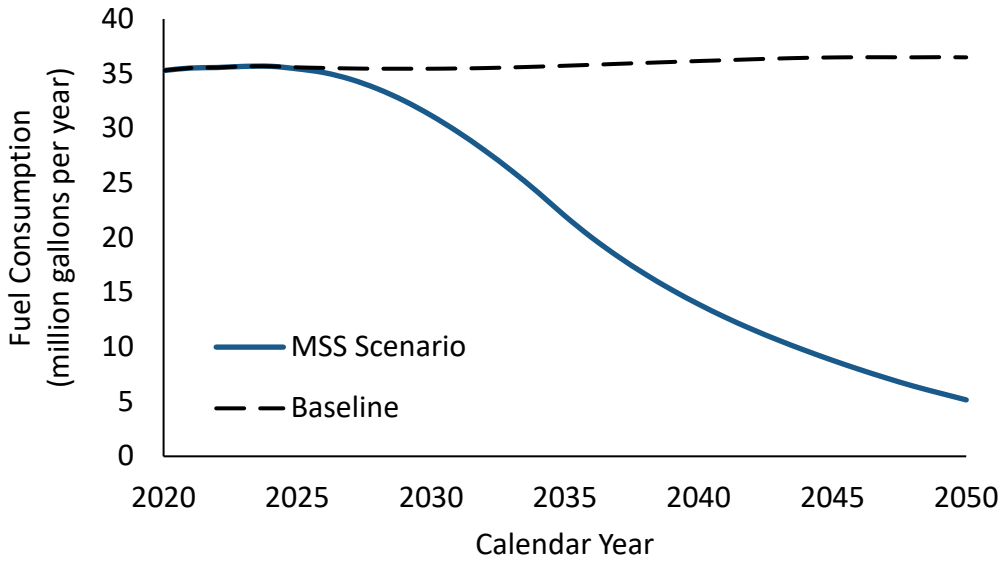


Figure 21 - Statewide Fuel Consumption for On-Road Motorcycles – MSS Scenario



On-Road Medium- and Heavy-Duty Vehicles

In California, medium and heavy-duty vehicles are defined as vehicles with gross vehicle weight rating (GVWR) greater than 8,500 lbs. Emissions from on-road medium and heavy-duty vehicles are major contributors to poor air quality in California. In particular, these vehicles produce emissions in amounts highly disproportionate to the total population of these vehicles, accounting for only 6 percent of the on-road vehicle population, but 72 percent of NOx emissions. The problem is complicated by the large number of heavy-duty vehicles, like long-haul trucks, registered in other states that travel on California's highways and roads, while bringing goods and commerce into and out of our state. For more than a decade, CARB has been working closely with the U.S. EPA, engine and vehicle manufacturers, and other interested parties to address this issue and reduce heavy-duty vehicle emissions in California.

The on-road medium-duty vehicle (MDV) sector includes gasoline and diesel-fueled vehicles with GVWR greater than 8,500 lbs. and less than or equal to 14,001 lbs. This sector contributes approximately 7 percent of statewide mobile source NOx emissions and 5 percent of statewide mobile source GHG emissions. Examples include heavy-duty pick-up trucks and walk-in vans. MDVs currently have a suite of requirements for controlling GHG and criteria pollutant emissions. These include criteria pollutant control through the LEV III standards that are part of the ACC program and GHG emission control through Phase 1 GHG standards for medium- and heavy-duty engines and vehicles starting in 2014. In June 2020, CARB's Board adopted California's pioneering Advanced Clean Trucks (ACT) regulation,[158] which pushes zero-emission technology penetration with sales requirements for medium- and heavy-duty truck manufacturers.

The on-road heavy-duty sector consists of vehicles that have GVWR greater than 14,000 lbs. and are responsible for 33 percent of statewide mobile source NOx and 16 percent of statewide mobile source GHG emissions. This sector is unique from light- or medium-duty on-road sectors because close to half of VMT from the on-road heavy-duty sector is contributed by vehicles sold outside of California, or so called federal-certified vehicles. These federal-certified vehicles fall into two categories: 1) vehicles that were first sold out-of-state and then registered as used vehicles in California, and 2) vehicles that are sold out-of-state and continue to be registered outside of California. In the absence of federal regulation or a fleet rule, a California standard or mandated sales requirement will only impact vehicles that are sold in California but not those that are originally sold outside of California and are then brought into the state as used vehicles.

CARB has made significant strides in reducing both criteria and greenhouse gas pollutants from heavy-duty vehicles through technology-forcing regulations. CARB's *Truck and Bus*

[158] CARB (2019). Proposed Advanced Clean Trucks Regulation *https://ww2.arb.ca.gov/rulemaking/2019/advancedcleantrucks*

Regulation requires all fleets, registered in- and out-of-state, that operate in California to meet stricter NOx standards and have a diesel particulate filter (DPF) by 2023 (i.e. 2010-certified technology).[159] Also, the aforementioned Phase 1 greenhouse gas regulations for heavy-duty trucks and engines, as well as CARB's *Tractor-Trailer Greenhouse Gas (TTGHG) Regulation*, have resulted in fuel efficiency improvements for the heavy-duty sector.[160]

CARB's newly adopted regulations on zero-emission trucks and buses will contribute to achieving both the State's criteria pollutant and GHG reduction goals. The ICT regulation was adopted in December 2018 and requires all public transit agencies to gradually transition to a 100 percent zero-emission bus (ZEB) (either battery-electric or fuel cell) fleet.[161] In addition, as mentioned previously, CARB adopted the ACT regulation in 2020, which requires the sale of heavy-duty ZEVs. To reduce NOx emissions from new on-road heavy-duty engines and ensure these emissions reductions are maintained as engines and vehicles are operated, CARB also adopted the Heavy-Duty Omnibus Regulation in 2020. This regulation includes certification of all combustion vehicles to a stricter standard on the Federal Test Procedure (FTP) cycle and a certification standard on a new low load cycle for 2024 and subsequent model year. Taken together, these requirements ensure lower NOx emissions over a more comprehensive range of vehicle operation. Additionally, this regulation includes in-use performance requirements such as more stringent in-use performance standards, lengthened engine useful life, warranty and durability requirements. Besides, in past few years, CARB adopted multiple regulations, which aimed at improving in-use performance including the Heavy-Duty Vehicle Inspection Program and the Periodic Smoke Inspection Program (PSIP) amendments starting in 2019,[162] and Heavy-Duty Warranty Phase 1 starting in 2022.[163]

As noted in the 2017 Climate Change Scoping Plan,[164] as well as 2016 Mobile Source Strategy, meeting our climate and air quality goals requires sustainable passenger and freight transportation powered by zero-emission technologies everywhere feasible, and cleaner combustion with renewable fuels everywhere else. In addition, the Governor's Executive Order N-79-20 established zero-emission targets for short-haul and drayage truck fleets by 2035 and also for zero-emission bus and long-haul truck fleets where feasible by 2045. To

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[159] CARB (2019). Truck and Bus Regulation Compliance Requirement Overview. *https://ww3.arb.ca.gov/msprog/onrdiesel/documents/fsregsum.pdf*

[160] CARB (2018). Proposed California Greenhouse Gas Emissions Standards for Medium- And Heavy-Duty Engines and Vehicles (Phase 2) And Proposed Amendments To The Tractor-Trailer GHG Regulation. *https://ww2.arb.ca.gov/rulemaking/2018/phase-2-and-tractor-trailer-amendments-regulation*

[161] CARB (2018). Proposed Innovative Clean Transit Regulation, a Replacement of the Fleet Rule for Transit Agencies. *https://ww2.arb.ca.gov/our-work/programs/innovative-clean-transit*

[162] *https://ww2.arb.ca.gov/our-work/programs/heavy-duty-diesel-inspection-periodic-smoke-inspection-program/hdvip-psip*

[163] *https://ww2.arb.ca.gov/rulemaking/2018/hd-warranty-2018*

[164] *https://ww2.arb.ca.gov/sites/default/files/classic//cc/scopingplan/scoping_plan_2017.pdf*

start on that path, CARB has conducted comprehensive technology and infrastructure assessments for the on-road heavy-duty sector as part of the annual *Funding Plan for Clean Transportation Incentives for Low Carbon Transportation Investments and the Air Quality Improvement Program* (see Long-Term Heavy-Duty Investment Strategy),[165] as well as the ACT regulation.[166] According to these documents, significant progress has been made in the readiness of zero-emission technology for on-road heavy-duty vehicles. Note that technology readiness generally assesses a technology's technical ability to reliably perform in a majority of its typical duty cycles. It can be described as a continuum, progressing from early research and development, through low-volume demonstration and pilot phases, to full technical readiness where it might be considered commercialized. Technically-ready technologies may still face other barriers to market transformation. There have been thousands of successful deployments of battery-electric and fuel cell heavy-duty vehicles that operate locally (i.e. return-to-base operation), including zero-emission transit buses and large-scale purchases of electric delivery vans and trucks. Additionally, drayage and regional-haul applications and refuse trucks are in the demonstration phase with some now commercially available, as shown on HVIP eligibility list.[167]

Heavy-duty ZEVs market and their applications are expanding. According to CALSTART's Zero-Emission Technology Inventory (ZETI) tool,[168,169] currently there are close to 100 different models of zero-emission vans, trucks and buses that are already commercially available from approximately 26 manufacturers globally. The ZETI tool also estimates that by 2023, the number of vehicle models available will grow to more than 200 models from approximately 49 manufacturers based on industry input and market analysis. Note that commercial availability is defined as availability for immediate production based on placed orders. Of the models announced to be available in 2023, 67 of them are planned to be on medium-duty vehicle platforms, and 19 of them will be deployed on heavy-duty platforms. These heavy-duty vehicles will potentially have all-electric ranges from 75 miles (e.g., Volvo VNR Electric) all the way up to 500 to 650 miles (e.g., Nikola Two FC and Tesla Semi) which makes them suitable for long-haul operation. There are also a number of models that are suitable for drayage trucks such as BYD 8TT model, Peterbilt 520EV/579EV, Mercedes Benz

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[165] CARB (2019). Fiscal Year 2019-20 Funding Plan on Clean Transportation Incentives - Appendix D: Heavy-Duty Investment Strategy. *https://ww2.arb.ca.gov/sites/default/files/2019-09/fy1920fundingplan-appd.pdf*

[166] CARB (2019). Staff Report: Initial Statement of Reasons. Public Hearing to Consider the Proposed Advanced Clean Trucks Regulation. Appendix E: Zero-Emission Truck Market Assessment. *https://ww3.arb.ca.gov/regact/2019/act2019/appe.pdf*

[167] CARB (2020). HVIP Eligible Vehicle Catalog (web link: *https://www.californiahvip.org/how-to-participate/#Eligible-Vehicle-Catalog*).

[168] CALSTART is a nonprofit organization working nationally and internationally with businesses and governments to develop clean, efficient transportation solutions.

[169] CALSTART (2020): Drive to Zero's Zero-emission Technology Inventory (ZETI) Tool Version 5.5. *https://globaldrivetozero.org/tools/zero-emission-technology-inventory/*

eActros, and *Freightliner eCascadia Battery Electric Truck*. These are just some examples of the zero-emission technologies that are already or planned to be commercially available in the next 2 to 3 years.

Also in collaboration with the CALSTART, CARB developed a "beachhead" strategy that targets investments on beachhead or first success analysis, identifying the segments of the commercial vehicle market where zero-emission and near clean combustion technology is most likely to succeed first and transfer that success to other applications for different technology pathways. This analysis considered several key identifying factors such as technology readiness, duty cycle and use, industrial activity and capacity, and user economics. For every technology pathway (e.g. zero-emissions), this process starts with one beachhead application and then the success of that first application transfers or spreads to additional applications through, for example, adoption of similar drive trains or expansion of fueling infrastructure. For the zero-emission pathway, the first on-road beachhead application was battery-electric transit buses, which served as a "launch point" for shuttle vans, package and delivery vans and trucks, terminal tractors, class 8 drayage trucks, and regional distribution (freight) trucks. In a similar effort, the Institute of Transportation Studies at the University of California, Davis published a report titled "Zero-Emission Medium- and Heavy-Duty Truck Technology, Markets, and Policy Assessments for California"[170] that assesses zero-emission medium- and heavy-duty vehicle technologies, their associated costs, as well as their projected market share. Several heavy-duty ZEV applications, such as battery-electric transit buses, yard trucks, and city delivery trucks, are already economically favorable despite higher purchase prices. Thanks largely to lower operational costs, the total cost of ownership for these vehicles is often less than their conventionally-fueled counterparts. Similar ZEVs using fuel cells are also attractive assuming a hydrogen cost of five dollars per kilogram.

Additionally, CARB efforts towards heavy-duty decarbonization are consistent with the ongoing efforts across the globe in other jurisdictions. For example, Amsterdam, Netherland, Bergen, Oslo, Norway, British Columbia, and Canada all have set clear timelines to eliminate fossil fuel heavy-duty traffic in their region;[171] the C40 Cities Climate Leadership Group have committed to ensure major areas in the cities are zero-emission by 2030;[172] and multiple local authorities in different counties have released plans to electrify public transportation including buses and coaches in the next decades.[173] In addition to local efforts, a number of

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[170] *https://escholarship.org/uc/item/7n68r0q8*

[171] ICCT Briefing (2020), Update on the global transition to electric vehicles through 2019
ICCT Briefing (2020), The end of the road? An overview of combustion engine car phase-out announcements across Europe

[172] C40 Cities, Green and Healthy Streets: The C40 Fossil Fuel Free Streets Declaration (web link: https://www.c40knowledgehub.org/s/article/Green-and-Healthy-Streets-The-C40-Fossil-Fuel-Free-Streets-Declaration?language=en_US)

[173] ICCT Briefing (2020), Update on the global transition to electric vehicles through 2019

countries have proposed national plans to move towards the zero-emission heavy-duty goal. For instance, Norway has limited that 75 percent of new long-distance coaches and 50 percent of new trucks sold in the country shall be zero-emission vehicles by 2030[174] and Israel plans to ban the sales of diesel and gasoline buses and trucks starting from 2030.[175]

Despite substantial progress made in technology development, there still remain significant barriers to zero-emission transition for the on-road heavy-duty sector, which are outlined in more detail in CARB's Funding Plan for Clean Transportation Incentives for Low Carbon Transportation Investments and the Air Quality Improvement Program.[176] For example, the biggest challenge identified for heavy-duty battery-electric technology is infrastructure availability and cost, which is key for scaling up from a small number of vehicles to larger deployments. CARB staff recognizes that the approaches and design of a heavy-duty vehicle infrastructure system will differ from the infrastructure network for LD vehicles, and may require sector or fleet-specific approaches.

Transition to zero-emission technologies calls for actions and collaboration by multiple agencies. CARB is working collaboratively with other California State agencies to ensure these efforts are well aligned, bring the state into compliance with federal air quality standards, and reduce GHG emissions from mobile sources. Currently, the CEC is developing the Infrastructure Development Strategy with charging infrastructure assessments in response to *Assembly Bill 2127*.[177] This bill requires a statewide assessment of the electric vehicle charging infrastructure needed to support the levels of electric vehicle adoption required for the state to meet its goals of putting at least 5 million zero-emission vehicles on California roads by 2030 and of reducing emissions of greenhouse gases to 40 percent below 1990 levels by 2030.

As part of their analysis for AB 2127, CEC is collaborating with Lawrence Berkeley National Laboratory (LBNL) to determine the number, locations, and types of charger deployments for MDV and heavy-duty electric vehicle infrastructure ("HEVI-Pro") in California in 2030. HEVI-Pro aims to develop regional charging infrastructure needs for public, shared-private, and private charging, where charging is selected from suitable power levels from overnight charging (<50 kW) to public fast charging (multi-MW), for the range of medium and heavy-duty vehicle applications envisioned in California's transition to ZEVs. The preliminary findings show that 134,000 battery electric MDV and heavy-duty vehicles deployed statewide in 2030 would require approximately 67,000 of 50 kW chargers and 11,000 of 350 kW

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[174] Ibid.

[175] P.K. Senecal et al. (2019), Diversity in transportation: Why a mix of propulsion technologies is the way forward for the future fleet, Results in Engineering **4** *100060* (DOI: 10.1016/j.rineng.2019.100060)

[176] *https://ww2.arb.ca.gov/sites/default/files/2019-09/fy1920fundingplan.pdf*

[177] Ting, Chapter 365, Statutes of 2018 (web link: https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201720180AB2127)

chargers to complete their trips.[178] CEC plans on releasing the first projections in conjunction with the 2020 Integrated Energy Policy Report, likely in late 2020.

The Transportation Electrification Framework, released by the CPUC in February 2020, directs future investor-owned utility (IOU) investments and programs and ensures these investments are in accord with key State goals and policies. Since 2016, the CPUC authorized IOUs to direct over a billion dollars of funds to transportation electrification infrastructure. Additionally, California Governor's Office of Business and Economic Development (GO-Biz) has been developing Zero-Emission Medium- and Heavy-Duty Vehicle Deployment and Market Acceleration Strategy (Big ZEV Strategy) as part of their ZEV Market Development Strategy. This report will identify State actions and areas where more can be done to overcome barriers to achieve market success and scale.

In addition to infrastructure, the high upfront capital cost relative to conventional ICE vehicles is another challenge. Today and for the near future, battery-electric and fuel cell electric trucks and buses are expected have higher upfront costs when compared to their diesel or gasoline counterparts. This is due to a combination of low volume production and more expensive components, including batteries and fuel cell systems. The incremental upfront cost difference between ZEV and ICE vehicles is expected to decline over time. As with any new technology, there could also be additional upfront costs associated with ZEV deployment, such as professional services for site assessment and infrastructure buildout and planning, additional procurement processes, as well as operator and technician training. As described in detail within the ACT staff report,[179] while BEVs cost more than conventional combustion vehicles initially due to their large upfront investments, they often pay back over time due to their lower operating costs resulting in a favorable total cost of ownership. Financing the vehicles and infrastructure can spread out the payments to be offset with ongoing reductions in operating costs. Additionally, incentive programs for vehicles or infrastructure may allow fleets to lower or eliminate these higher upfront costs. Educating fleets about the lifecycle costs and payback opportunities will be an important part of accelerating the ZEV market.

Mobile Source Strategy Scenarios

Medium-Duty Vehicles

Starting with MDVs (8,501 – 14,000 lbs. GVWR), CARB is developing strategies for reducing criteria pollutants and GHG emissions from this sector, some of which may overlap with

[178] Preliminary findings from the first scenario of the Medium and Heavy-Duty Electric Vehicle Infrastructure Projections (HEVI-Pro) Tool illustrates the wide variation in the on-road vehicle duties and the potential for gigawatt-scale daytime and evening charging requirements. Credit: Lawrence Berkeley National Laboratory: *https://efiling.energy.ca.gov/getdocument.aspx?tn=234209*

[179] CARB (2019). Staff Report: Initial Statement of Reasons. Public Hearing to Consider the Proposed Advanced Clean Trucks Regulation. *https://ww3.arb.ca.gov/regact/2019/act2019/isor.pdf*

light-duty vehicle strategies, and some of which have overlap with heavy-duty vehicle strategies. Looking towards the future with the 2020 MSS scenarios, an important concept for MDV includes zero-emission transformation starting in 2024. One critical piece of this transition is CARB's ACT regulation mentioned earlier. Besides, CARB is developing an Advanced Clean Fleet rule to accelerate the number of medium and heavy-duty ZEV purchases to achieve a full transition to zero-emission vehicles in California as soon as possible. Other concepts include enhanced LEV IV regulations through ACC II and continued energy efficiency improvements and GHG emission reduction through Phase 3 GHG standards, which is a continuation of the Phase 2 GHG standards.[180]

Driven by California's mid-century climate goals as well as the Governor's executive order N-79-20, staff proposed a scenario to fully transform the medium-duty vehicle sector to zero-emission technologies. Built upon the recently adopted ACT regulation, this scenario further extends the ZEV phase-in schedule and assumes 100 percent of model year 2035 and newer MDVs being sold in California to be zero-emission. As mentioned above, achieving this level of ZEVs will require multiple concepts and tools in addition to CARB's currently adopted rules.

Figure 22 shows the technology for medium-duty vehicle population under this 2020 MSS scenario, which results in approximately 580,000 zero-emission MDVs driving on California roadways by 2045. As shown in Figure 25, the scenario will also translate to statewide NOx reductions of 0.25 tpd and 1.11 tpd in 2031 and 2037, respectively. This scale of fleet transformation will result in a fuel saving of about 0.15 billion gallons of diesel per year and 0.26 billion gallons of gasoline per year in 2045 (Figure 23), which translates to a WTW GHG reductions of approximately 3.5 million metric tons (MMT) per year (Figure 24). Also by 2050, the WTW GHG emissions from MDVs will be 86 percent below the 2020 baseline. The WTW analysis presented in this document is only for informational purposes and the assumptions (e.g., renewable and bio-fuel mix) are further described in Appendix A.

[180] CARB (2018). Proposed California Greenhouse Gas Emissions Standards for Medium- And Heavy-Duty Engines and Vehicles (Phase 2) And Proposed Amendments To The Tractor-Trailer GHG Regulation. *https://ww2.arb.ca.gov/rulemaking/2018/phase-2-and-tractor-trailer-amendments-regulation*

Figure 22 – Statewide Medium-Duty Sector Vehicle Population

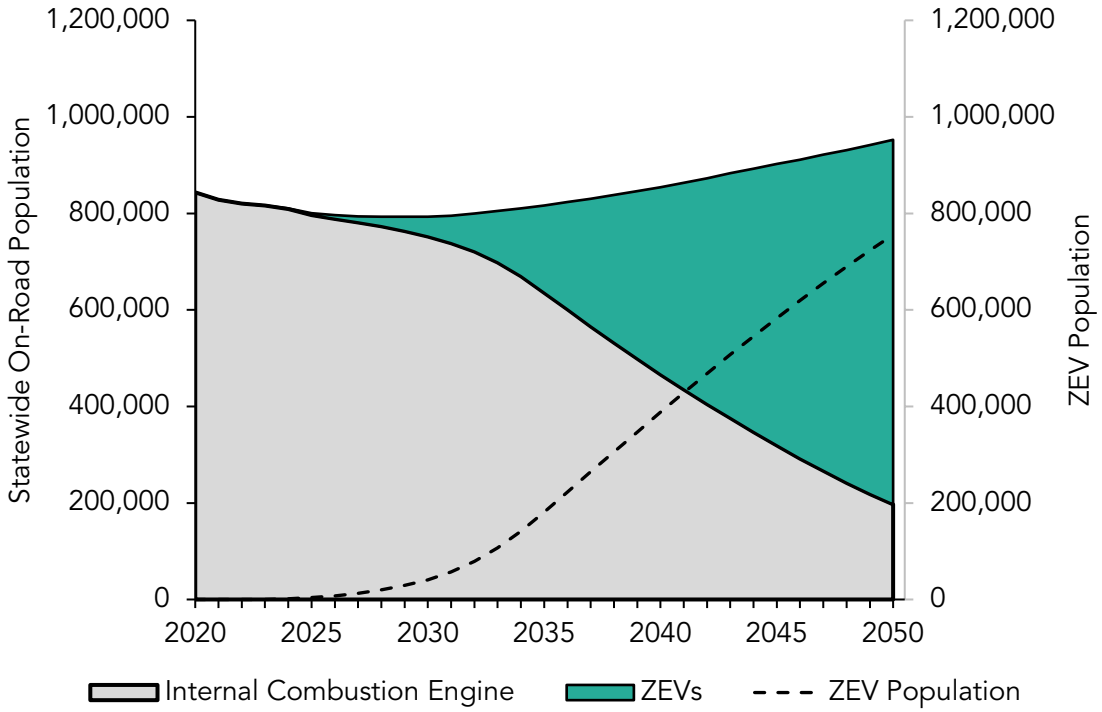


Figure 23 - Statewide Fuel Consumption by Medium-Duty Vehicles

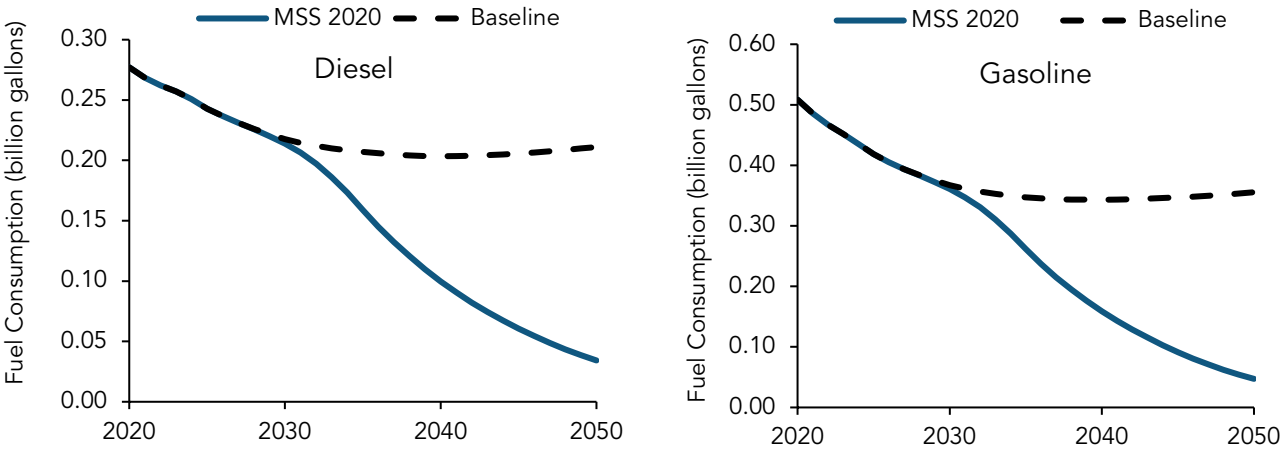


Figure 24 - Statewide Well-to-Wheel GHG Emissions from Medium-Duty Vehicles

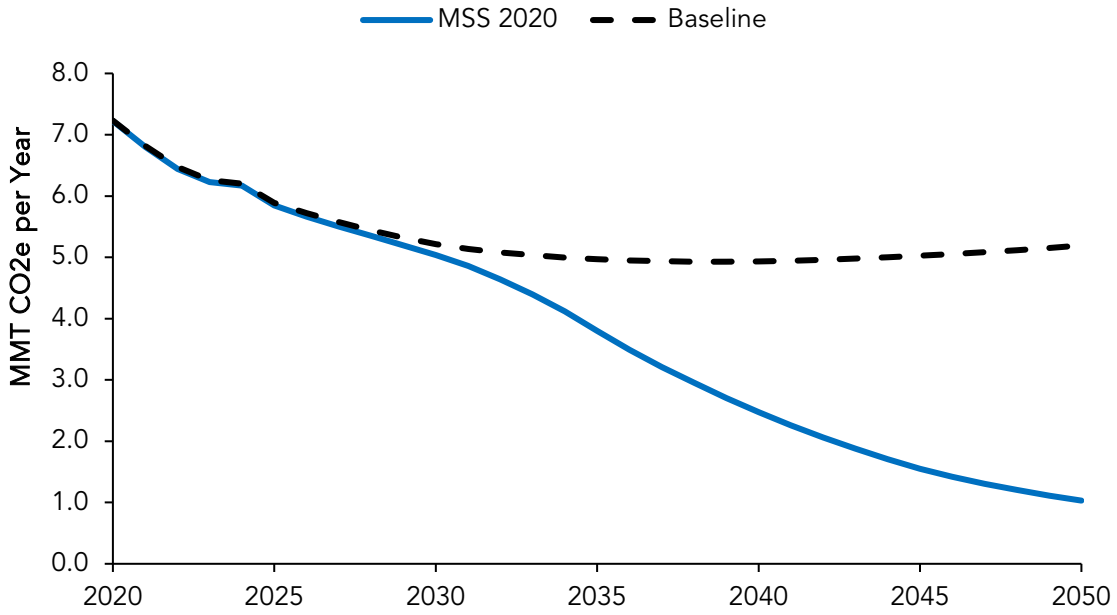
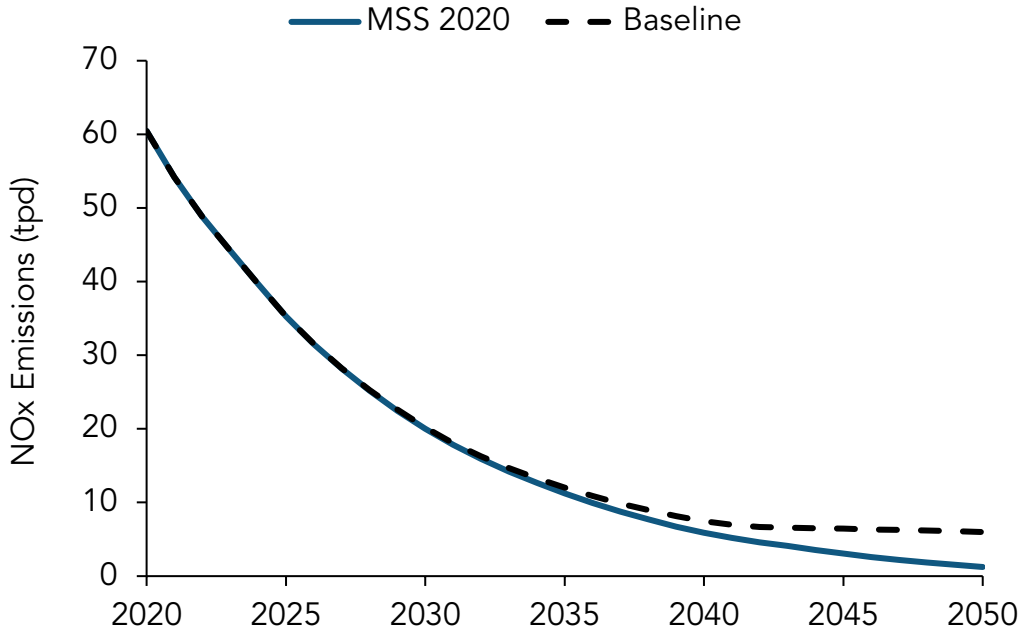


Figure 25 - Statewide NOx Emissions from Medium-Duty Vehicles



Heavy-Duty Vehicles

Moving on to heavy-duty vehicles (above 14,000 lbs. GVWR), the 2020 MSS charts the course for the heavy-duty sector in the future through a range of concepts, the most important of which is the transition to ZEVs. An ambitious ZEV phase-in for newer vehicles and accelerated turnover of older and high emitting vehicles to ZEV ensures that this sector meets both near- and mid-term air quality goals, while simultaneously achieving long-term climate goals. Currently, there are heavy-duty ZEVs on the market that meet both local and regional trucking needs. Many of CARB's incentive programs, such as the Low Carbon Transportation Investments and the Air Quality Improvement Program, have supported introduction of heavy-duty ZEV technology. The recently adopted ACT regulation requires manufactures to produce and sell ZEVs starting from 2024 and the potential advanced clean fleet rule will ensure the purchase and deployment of ZEVs across the fleet.

In addition to ZEVs, cleaner and more efficient ICE technology will also be essential for meeting air quality targets, especially in applications where ZEVs may not yet be capable of serving all duty cycles. As mentioned previously, one example of CARB's effort towards cleaner ICE technology is the Heavy-Duty Omnibus Regulation.

Another critical piece of CARB's heavy-duty concepts includes the Heavy-Duty Inspection and Maintenance (Heavy-Duty I/M) program, which will ensure that the engines and after-treatment systems of heavy-duty vehicles are well-maintained throughout their lifetime. The Heavy-Duty I/M program will require all heavy-duty vehicles operating in California have properly functioning emissions controls systems. This program will be implemented beginning in 2023. On August 12, 2020, CARB staff conducted public workshops to discuss draft concepts for California's future Heavy-Duty I/M program.[181]

OBD systems are going play a critical role in implementation of the Heavy-Duty I/M program. Beginning with the 2022 model year, OBD requirements include Real Emissions Assessment Logging (REAL) requirements for the collection and on-board storage of NOx and CO2 emission data, but there are currently no requirements to report REAL data to CARB. The opportunity exists to make better use of the REAL data, potentially via regular reporting requirements. OBD requirements also need to evolve to account for the much lower emission standards included in the Heavy-Duty Omnibus Regulation.

Considering the above mentioned regulatory activities, staff developed a scenario that strives for zero-emission transformation consistent with governor's Executive Order N-79-20, while emphasizing cleaner combustion technologies for ICE vehicles, utilization of renewable fuels, continued fuel efficiency improvements, as well as enhanced in-use performance. Taking into account those heavy-duty truck market segments that are suitable for transitioning to ZEVs in

[181] *https://ww2.arb.ca.gov/our-work/programs/heavy-duty-inspection-and-maintenance-program*

the near-term and implementation of the ACT regulation to accelerate ZEV sales, the major assumptions for the phase-in of heavy-duty vehicles includes:

- Delivery and drayage fleets are assumed to have 100 percent ZEV sales starting with model year 2024;
- Vehicle categories with low annual mileage or return-to-base operation, which have similar duty cycle to transit buses, assumed ZEV phase-in that matches the ICT[182] regulation phase-in schedule;
- Other vocational and tractor vehicle categories are assumed to follow the ZEV sales schedule as required by the ACT rule for Class 4-8 and Class 7-8 tractors until model year 2030, after which ZEV sales assumptions ramp up to 100 percent sales in 2035;
- All California registered fleets, whether California certified or not, assumed to follow the same ZEV phase-in schedule. As noted above, there are heavy-duty vehicles that were originally sold out-of-state and then registered in California as used vehicles. This assumption ensures that California fleets (not just those first sold in California) reflect the ambitious ZEV phase-in schedule; and
- For model years 2035 and newer, 100 percent ZEV sales assumed for all vehicle categories.

The remainder of model year 2024 and newer heavy-duty vehicles are cleaned up by more stringent engine standards, either through California's Heavy-Duty Omnibus Regulation for vehicles only first sold (or certified) in California, or through the future federal Cleaner Trucks Initiative[183] for all heavy-duty vehicles operating in California.

While ZEV phase-in and cleaner technologies for ICE vehicles will reduce NOx emissions significantly, meeting CARB's air quality targets in 2031 and 2037 requires additional reductions through accelerated scrappage of older and high-emitting vehicles and replacement with zero-emission technologies before the end of vehicles useful lifetime. With Omnibus and ZEV requirements applying to post-2024 model year vehicles, older pre-2024 model year vehicles will contribute disproportionately to overall NOx emissions. According to the 2016 State SIP Strategy,[184] there is a need for an additional 11 tpd of NOx reductions in the South Coast Air Basin by 2031 to meet the 2015 ozone standards of 75 ppb. To achieve the needed 11 tpd NOx reductions, staff determined that approximately, 31,000 heavy-duty model year 2023 and older vehicles would need to be turned over before their end of lifetime. At the statewide level, this translates to approximately 94,000 heavy-duty vehicles that would need to be scrapped and replaced with zero-emission technologies. Note that this scenario does not specify the exact mechanism of accelerated turnover, but rather

[182] CARB (2018). Proposed Innovative Clean Transit Regulation, a Replacement of the Fleet Rule for Transit Agencies. (*https://ww2.arb.ca.gov/our-work/programs/innovative-clean-transit*)

[183] *https://www.epa.gov/regulations-emissions-vehicles-and-engines/cleaner-trucks-initiative*

[184] https://ww2.arb.ca.gov/resources/documents/2016-state-strategy-state-implementation-plan-federal-ozone-and-pm25-standards

defines the number of vehicles that are needed to meet air quality goals. It is also worth noting that turnover through a future regulation is currently limited by "useful life" provisions of the Road Repair and Accountability Act of 2017 (SB1). According to SB 1, should a future in-use regulations be adopted, trucks will not be required to turnover until they have reached 13 years from the model year the engine and emission control systems are certified or until they reach 800,000 vehicle miles traveled (but no longer than 18 years from the model year the engine and emission control systems are certified for use), whichever is later.[185]

Figure 26 shows the technology mix resulting from the heavy-duty scenario developed as part of the 2020 MSS. The scenario results in approximately 830,000 heavy-duty ZEVs in 2045. This equates to about 1.9 billion gallons per year in diesel fuel savings (Figure 27), 0.2 billion gallons per year in gasoline fuel savings, and WTW GHG emissions reductions of 20 MMT per year (Figure 28). Also by 2050, the WTW GHG emissions from heavy-duty vehicles will be 66 percent below the 2020 baseline. As shown in Figure 29, the scenario also provides statewide NOx reductions of 141 tpd and 195 tpd in 2031 and 2037, respectively, which are equivalent to 67 and 86 percent reduction below the current baseline.

Collectively, the 2020 MSS scenarios call for deployment of approximately 1.4 million medium- and heavy-duty ZEVs in California by 2045. This transition to ZEVs will results in a fuel savings of 2.1 billion gallons of diesel and 0.46 billion gallons of gasoline. By 2050, the WTW GHG emissions from MDV and heavy-duty vehicles will be approximately 71 percent below the 2020 baseline (assumptions in Appendix A).

[185] *https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201720180SB1*

Figure 26 – Statewide Heavy-Duty Population by Technology Type

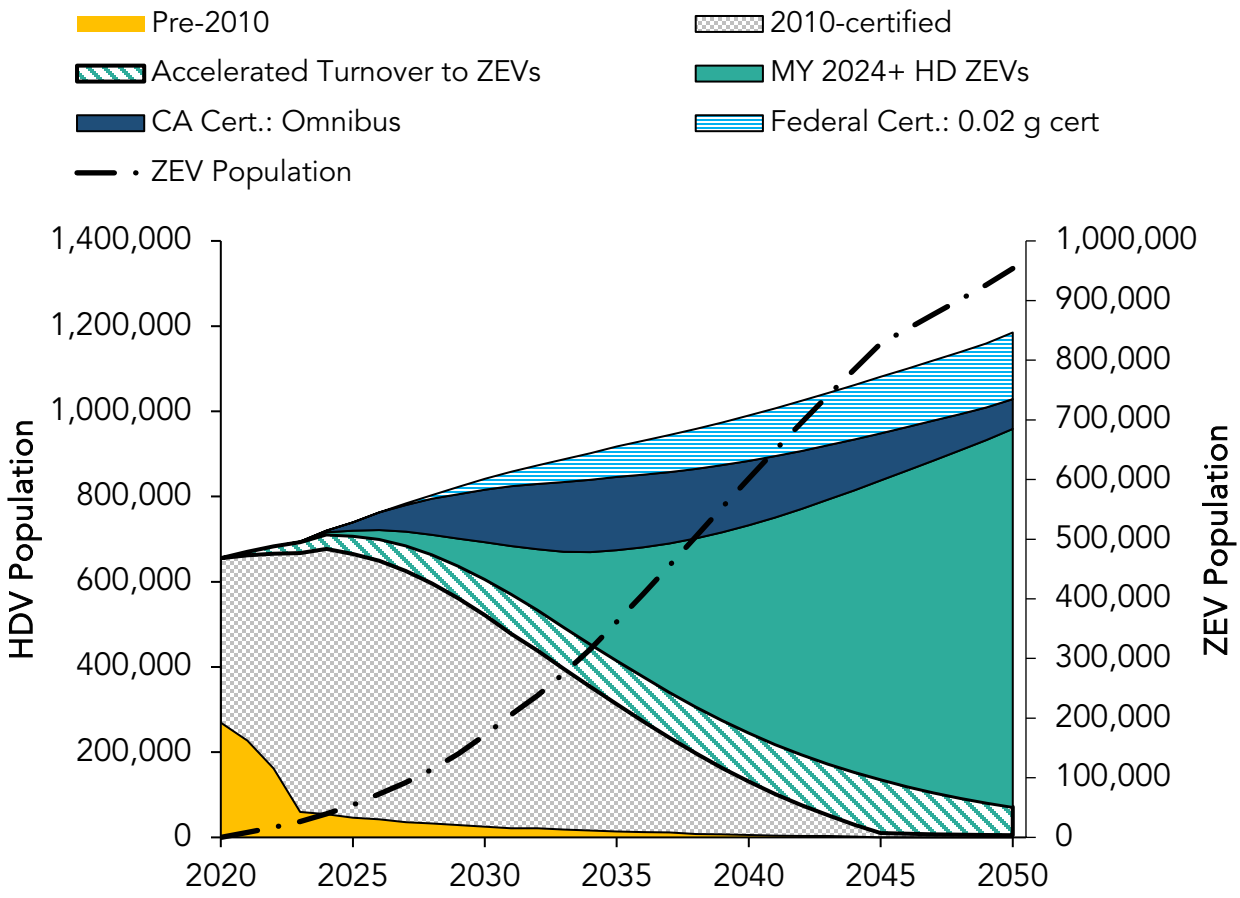


Figure 27 - Statewide Fuel Consumption by Heavy-Duty Vehicles

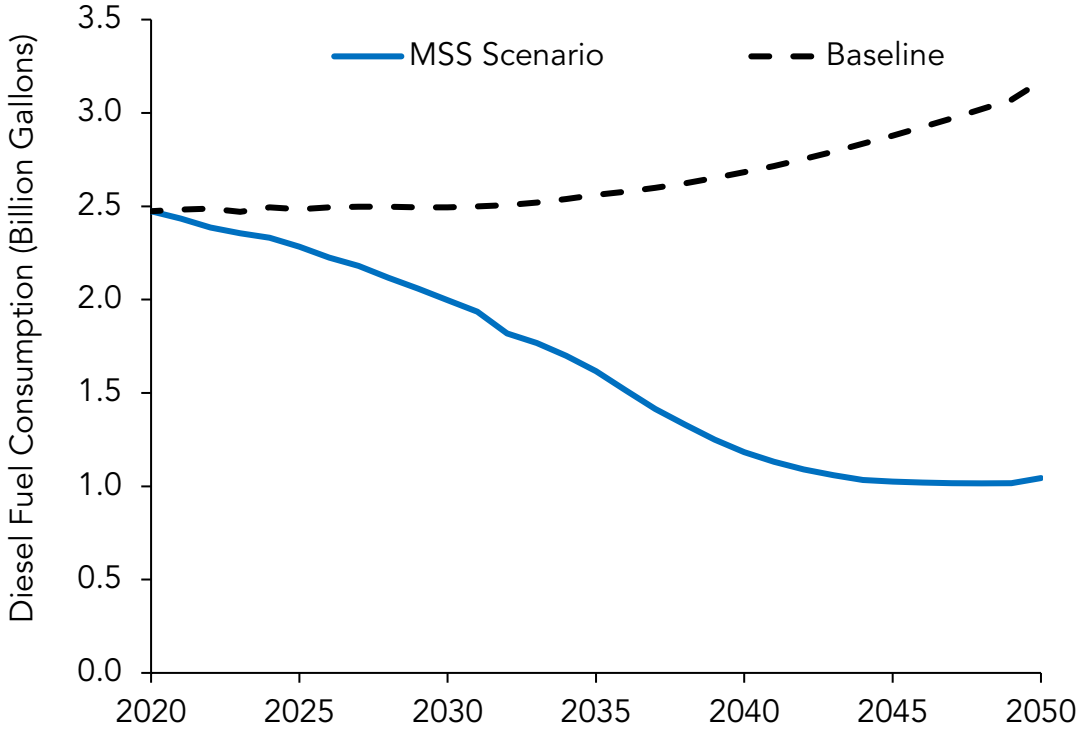
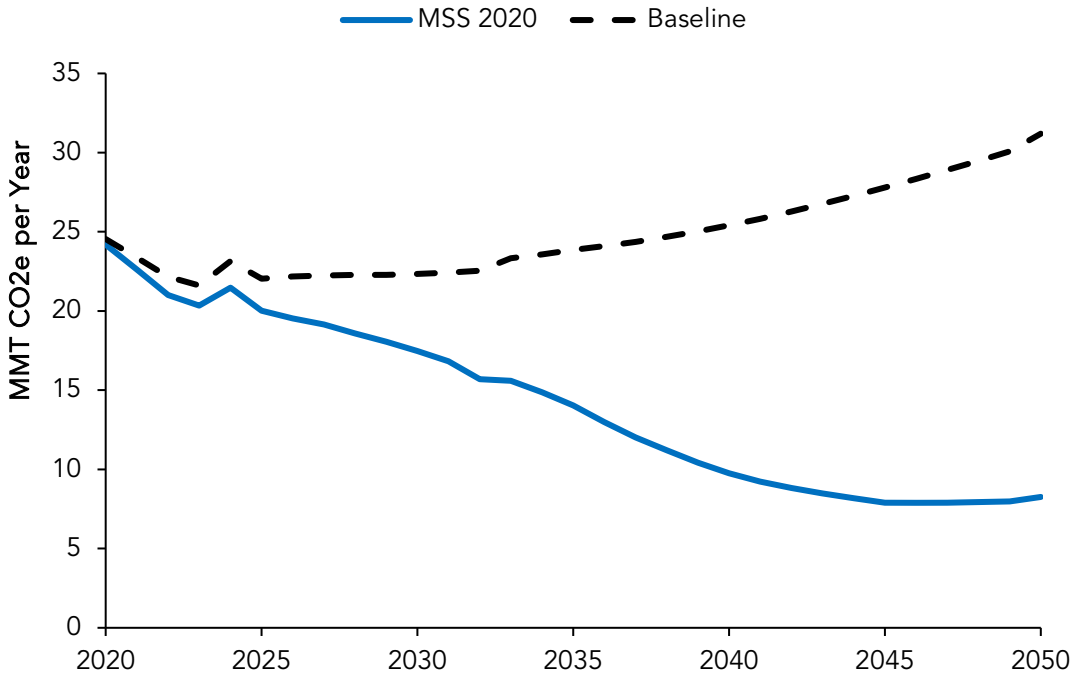
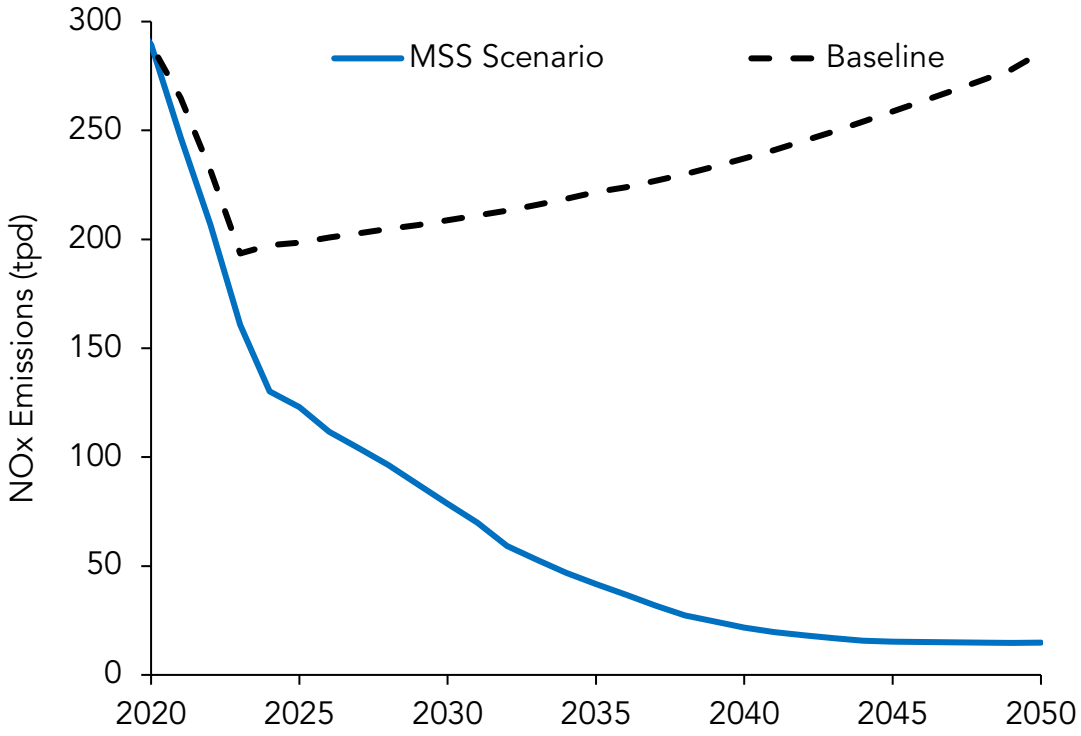


Figure 28 - Statewide Well-To-Wheel GHG Emissions from Heavy-Duty Vehicles[186]



[186] These calculations include the use of a dairy biogas methane emissions factor that differs from the convention in our inventory as it includes avoided methane emissions; this was done to reflect some of the potential systems effects from choices in the MSS. The estimated benefits for the use of dairy biogas do not reflect the accounting convention in the GHG inventory (https://ww2.arb.ca.gov/ghg-inventory-data) and therefore over-estimate the contribution of GHG benefits from the use of RNG in the transportation sector when compared to the accounting framework used in the GHG inventory, which is our primary data set to track progress towards achieving our statewide targets. Avoided methane emissions would occur from this fuel even if used in other sources, so there is no necessary link between those emissions reductions and the transportation system; what is shown here is one of many possible policy scenarios. The use of avoided methane emissions from dairy biogas in this scenario accounts for approximately 0.25% of the cumulative WTW GHG benefits from 2020 to 2045.

Figure 29 - Statewide NOx Emissions from Heavy-Duty Vehicles

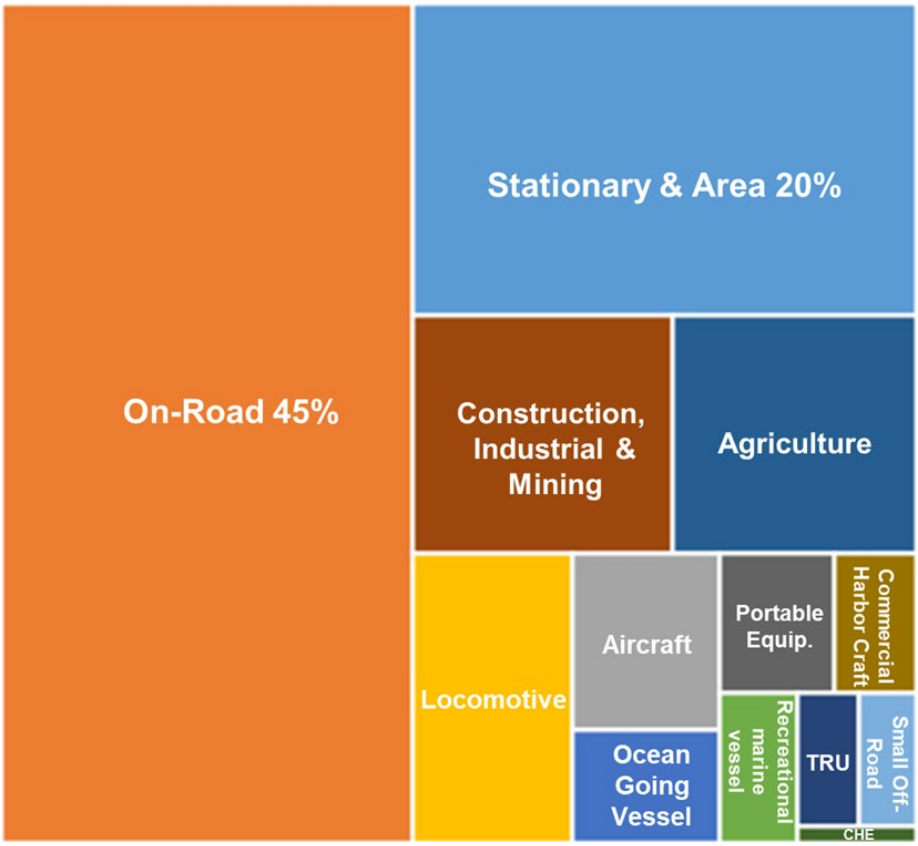


Off-Road Vehicles and Equipment

Off-road equipment covers a wide range of sectors including locomotives, ocean-going vessels, commercial harbor craft, pleasure craft, portable generators, agricultural equipment, construction, mining, oil drilling, lawn and garden, aircrafts, recreational watercraft and many other industries. Off-road engines are significant sources of air pollutants such as NOx, reactive organic gases (ROG), and PM. Figure 30 shows statewide NOx emissions by sector in 2017.[186] Off-road equipment contributes about 35 percent of total statewide NOx emissions in 2017. As the regulations for off-road equipment tend to follow those for on-road vehicles by a few years, the relative contribution of emissions from off-road equipment is expected to continue to grow, absent additional controls. By 2022, off-road equipment will replace on-road vehicles as the largest source of NOx emissions at the statewide level. In addition, off-road equipment consumed 1.5 billion gallons of diesel and more than 400 million gallons of gasoline in 2017 and contributes to about 4 percent of the GHG emissions statewide. Without further progress in improving internal engine efficiency or transitioning to electrification, off-road diesel and gasoline consumption is expected to increase to 2.1 billion and 580 million gallons per year, respectively,[187] by 2045.

[186] CEPAM: California 2019 ozone sip baseline emission projection - version 1.01 planning inventory tool
[187] OFFROAD2017 – ORION, *https://www.arb.ca.gov/orion/*

Figure 30 - 2017 Statewide NOx Emissions by Sector[188]



The mobile source scenarios and concepts to reduce air pollutants and GHG emissions in the off-road sector are developed based on the following guiding principles:

- *Push for zero-emission technologies wherever feasible*: Commercial deployment of zero-emission technologies is still at an early stage for some off-road sectors due to barriers in technology and cost. CARB is working closely to identify those off-road sectors with the most potential for near-term transitions to zero-emissions.
- *Introduction of cleaner combustion technology*: Where electrification is not currently feasible, introduce more stringent emission standards such as Tier 5 to reduce emissions from new internal combustion engines, and OBD standards to ensure emissions from those engines continue to meet expected levels throughout their entire service lives.
- *Accelerated turnover*: Early turnover of older equipment to cleanest available technologies including Tier 4 or 5 engines, hybridization, and retrofit engines with after-treatment technologies such as DPF and selective catalytic reduction (SCR).

[188] OGV 3 nm includes OGV emissions occurring within 3 nautical miles of the California coastline.

- *Renewable fuel:* Use renewable fuels where electrification is not available to reduce GHG emissions.

Given the diversity of equipment and duty cycles that comprises the off-road sector, each sector includes a more detailed description of the specific strategies. Table 14 provides a short summary of the conceptual strategies for each off-road sector.

Table 14 - Summary of Conceptual Off-Road Strategies

Sector	Summary of Strategy
▪ Locomotives	• Significantly accelerate the turnover of all locomotives operating in California to Tier 4 or cleaner • Adopt Tier 5 locomotive standards with U.S. EPA • Accelerate the adoption of zero-emissions locomotives and infrastructure • Replace the oldest switchers at railyards near communities with Tier 4 or cleaner by 2030
▪ Ocean-Going Vessels	• Increase at-berth requirements for auxiliary engines and boilers, while moving towards vessels visits with Tier 3 engines • Adopt Tier 4 marine standards with U.S. EPA and IMO • Work towards zero-emission OGV demonstrations
▪ Construction, Mining, Industrial	• Accelerate turnover and require remaining Tier 0 through Tier 2 engines be turned over by 2033 • Develop Tier 5 standards, including efficiency and hybridization requirements to reduce GHG emissions, as well as first ever requirements for OBD for off-road engines
▪ Agriculture	• Target cost effective reductive reductions in Tier 0 through Tier 2 equipment (tractors and non-tractors) by 2024, and maintain incentive programs to accomplish additional reductions by 2031 • Develop Tier 5 standards, including efficiency and hybridization requirements to reduce GHG emissions
▪ Commercial Harbor Craft	• Increase applicability of Tier 4 marine standards for commercial harbor craft to apply to all vessel types, require DPFs and develop Tier 5 marine standards • Require new and in-use excursion vessels to be plug-in hybrid, new tugboats diesel-electric, and 20 percent of all ferries to be zero-emission by 2030

Sector	Summary of Strategy
▪ Cargo Handling Equipment ▪ Airport Ground Support ▪ Small Off-Road Engines ▪ Transport Refrigeration Units ▪ Forklifts ▪ Spark Ignited Marine Engines	• Accelerate adoption of full zero-emission operation, with 100 percent zero-emission saturation by mid 2030s • Where exceptions apply to a zero-emission mandate, cleaner emissions standards and hybrid electric units would apply
▪ Aircraft	• Improvement in the current Air Traffic Operation (ATO) as well as transitioning to zero-emission technologies such as zero-emission APUs

Off-Road Federal and International Sources

Locomotives

A locomotive is a self-propelled vehicle used to push or pull trains; the combination of one or more locomotives and the attached freight or passenger railcars forms a train. Higher horsepower line-haul locomotives and lower horsepower switcher locomotives operate in California. A typical freight and passenger locomotive in the United States is powered by a diesel engine that drives an electrical generator or alternator. Locomotives and the railway system are an essential part of California's freight and passenger movement network, but also significant contributors to diesel PM, NOx and GHG emissions in California. These emissions often occur in or near densely populated areas and neighborhoods, exposing nearby residents to harmful levels of diesel PM and ground-level ozone.

In the past, CARB has developed and implemented a number of measures to understand and reduce locomotive and railyard emissions, including studies, enforceable agreements, and funding of clean technology. More recently, CARB has been working closely with the railroad industries to develop more representative and up-to-date emission inventories and to identify emission control strategies. CARB's locomotive emission inventory covers four main sectors: Class I line-haul locomotives, Class III (short-line) locomotives, Class I switch locomotives (switchers), and passenger locomotives. Class I railroads, which are defined as those operations that gross over $450 million per year,[189] carry the most freight and are responsible for about 80 percent of NOx and 79 percent of PM produced by all locomotives in California.[190] Union Pacific Railroad (UP) and BNSF Railway (BSNF) are the two Class I freight railroads operating in California. Class III railroads move goods regionally, have lower revenues, and generally have older locomotives, but much lower overall emissions simply due

[189] Association of American Railroads, Rail Statistics of Class 1 Freight Railroads *https://www.aar.org/Documents/Railroad-Statistics.pdf*, accessed December 12, 2016.
[190] CARB locomotive emission inventories, *https://ww2.arb.ca.gov/our-work/programs/mobile-source-emissions-inventory/road-documentation/msei-documentation-road*

to their lower population and usage of locomotives. Switcher locomotives move railcars and sections of trains in and around railyards (but should not be confused with rubber-tired railcar movers, smaller off-road vehicles than move individual railcars in yards, but are not considered switchers). CARB released updated line-haul and short-line emissions inventories in 2017 and is currently developing a new line-haul and switcher inventory based on the 1998 Memoranda of Understanding (MOU) reporting data[191] from the railroads.

According to the latest MOU data, in 2018, Tier 4 line-hauls account for only 4 percent of total line-haul energy use in the South Coast Air Basin, which suggests that rail companies are not purchasing new Tier 4 locomotives, instead relying on older tier locomotives that are being remanufactured and used for the next few decades.[192] In the absence of federal action to address harmful emissions from locomotives and railyards, CARB is developing a regulation[193] to reduce criteria pollutants, toxic air contaminants, and GHG emissions for locomotive in-use, idling, and maintenance activities. This regulation include actions originally presented to CARB's Board in March 2018, as well as new concepts to further reduce locomotive and railyard emissions. This regulation could be implemented at the State and/or air district level, and provide an opportunity for the railroads to further reduce emissions from rail operations and address long-standing environmental justice concerns voiced by communities near railyards. Regulation concepts for locomotives include:

- Establish a locomotive emissions reduction spending account (conceptually this is an account that railroads pay into when using older, dirtier tiers of locomotives, and can use the account funds to purchase newer, cleaner locomotives);
- Adopt an in-use useful life limit;
- Adopt a 30-minute idling limit based on U.S. EPA requirements.

As discussed earlier, in 2017, CARB also petitioned U.S. EPA to exercise its authority[194] to adopt more stringent emission standards for locomotives to help states meet federal air quality standards and climate goals, and address issues affecting public health and welfare.[195] CARB has recommended the NOx and PM emission factor for Tier 5 locomotives to be set at 0.2 grams per brake horsepower-hour (g/bhp-hr) and 0.01 g/bhp-hr, respectively. Tier 5 locomotives also offer 25 percent energy efficiency improvement over the current technology (i.e., Tier 4).

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[191] Summary data can be found at: *https://ww2.arb.ca.gov/1998-mou-summay-data-archive*

[192] More details can be found at: https://ww2.arb.ca.gov/sites/default/files/2020-09/CARBlocoinvwebinar2020.pdf

[193] *https://www.aqmd.gov/docs/default-source/planning/fbmsm-docs/railworkshop_11-20-19_english.pdf?sfvrsn=6*

[194] 42 U.S.C. § 7547(a)(5). Nonroad engines and vehicles

[195] Petition for rulemaking: seeking the amendment of the locomotive emission standards, *https://ww2.arb.ca.gov/resources/documents/petition-rulemaking-seeking-amendment-locomotive-emission-standards*, April 2017

CARB is also participating in demonstration projects with the rail industry on battery electric locomotives, with delivery and testing possible near the beginning of 2021. These efforts may offer additional emission reduction options and in the near future, but are not yet reflected in the criteria emission reduction strategies, pending a successful demonstration.

Mobile Source Strategy Scenario

While CARB continues to work closely with stakeholders including rail companies, environmental groups, and communities on expanding the concepts to reduce emissions from locomotives and railyards, staff has also laid out more ambitious and longer-term strategies that are needed to achieve California's near- and mid-term air quality and longer-term climate goals. These strategies aim for a complete phase out of Tier 0 through Tier 2 line-hauls by 2030, coupled with a significant penetration of Tier 4 locomotives, as well as Tier 5 and zero-emissions locomotives once they are available. Following this strategy, almost 90 percent of all line-hauls will become Tier 4 or Tier 5 by 2031. Additionally, the strategy assumes locomotives that are remanufactured twice or more will be prohibited from California operations. The scenario assumes that beginning in 2023, all pre-Tier 0, Tier 0, and Tier 0+ switchers will be replaced with Tier 3 and Tier 4 locomotives by 2030.

Based on the assumptions described above, Figure 31 shows projected NOx emissions by Tier group in the South Coast Air Basin for line-haul locomotives. The dashed line shows the updated baseline emissions. The new baseline is higher than the emissions estimated previously in the 2016 State SIP Strategy. As shown, the scenario will result in almost 12 tpd of NOx reduction in 2031. This reduction is equivalent to 2 tpd of NOx emissions below the emissions estimated in the South Coast 2016 Air Quality Management Plan, which is needed to meet the NOx reduction commitment from mobile sources in 2031.

Figure 31 - South Coast Air Basin NOx Emissions from Locomotives: MSS Scenario

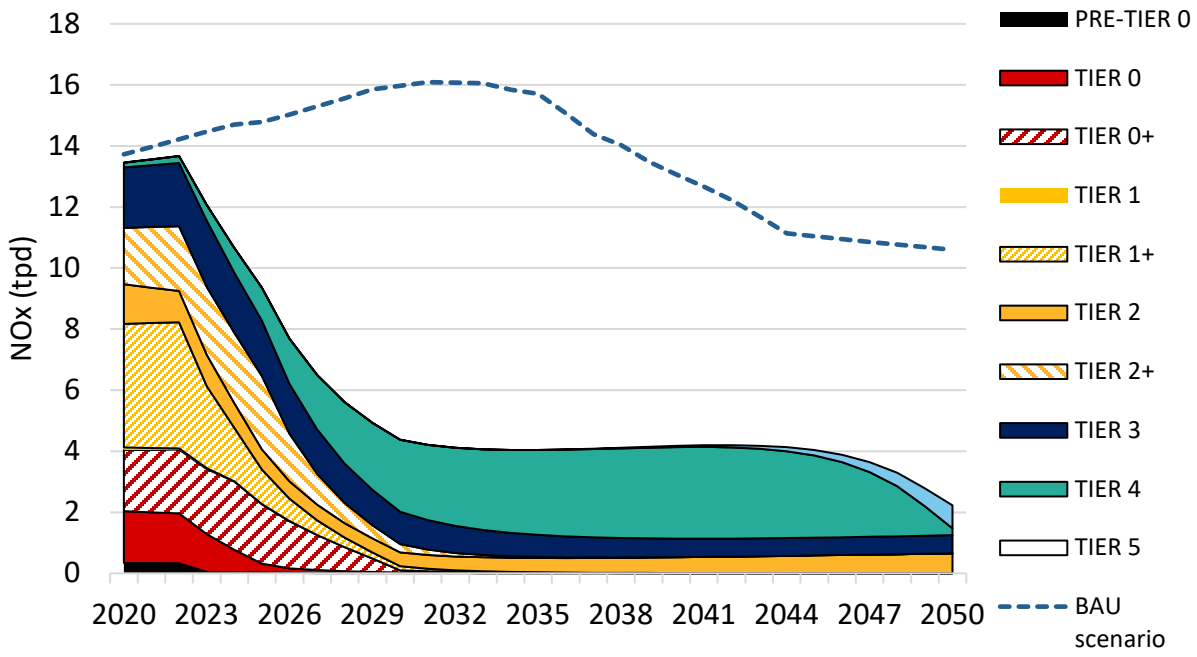
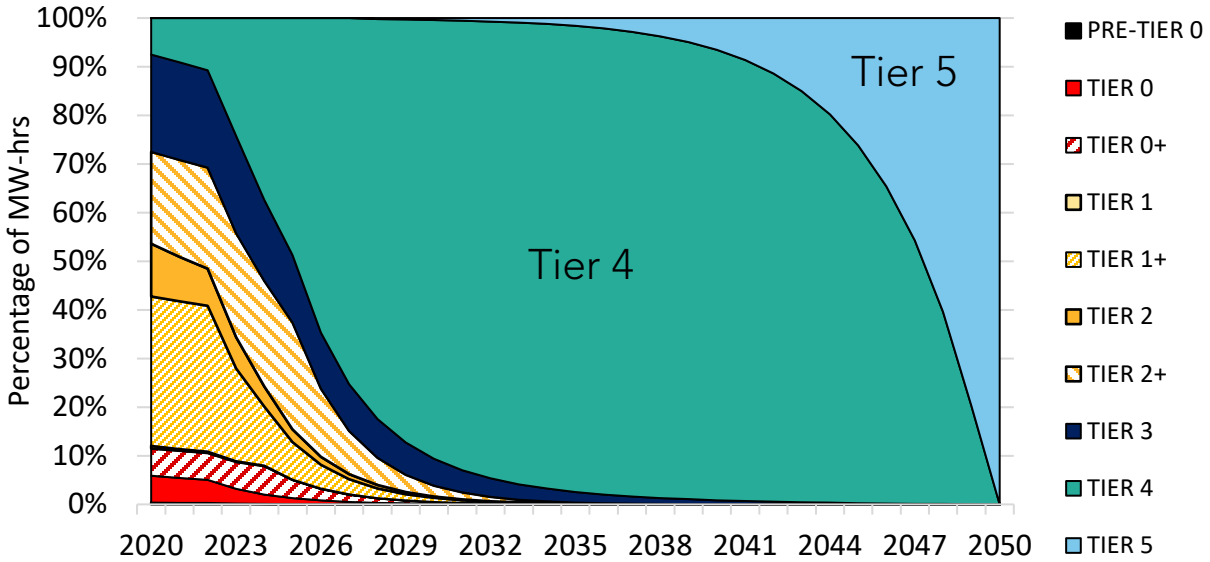


Figure 32 shows the relative energy use by different locomotive Tier groups assuming the technology penetration shown in Figure 31. As described earlier, following the 2020 MSS scenario, Tier 4 and 5 locomotives will make up over 90 percent of the total line-haul activities in 2031.

Figure 32 - South Coast Air Basin Locomotive Energy Use: MSS Scenario



Ocean-Going Vessels

Ocean-Going Vessels (OGV) are large vessels designed for deep water navigation, defined as commercial vessels greater than or equal to 400 feet in length, with a carrying capacity of 10,000 gross tons or more, or propelled by a diesel marine compression ignition engine with a displacement of greater than or equal to 30 liters per cylinder. OGVs include large cargo vessels such as container vessels, tankers, bulk carriers, and car carriers (or "ro-ro" vessels), as well as passenger cruise vessels. These vessels transport containerized cargo; bulk items such as vehicles, cement, and coke; liquids such as oil and petrochemicals; and passengers. OGVs are an important part of California's trade economy, but are also a significant source of GHG emissions, criteria pollutants, and toxic air contaminants especially in areas near ports and marine terminals.

The International Maritime Organization (IMO), under Annex VI ("Regulations for the Prevention of Air Pollution from Ships"), specifies new marine engine NOx standards and sets fuel sulfur limits. CARB has the authority to regulate emissions from auxiliary engines on vessels docked at California ports. CARB set the first OGV At-Berth Regulation in 2007 with compliance requirements that began in 2014.[196] The At-Berth Regulation requires container ships, cruise vessels and refrigerated cargo vessels to turn off their auxiliary engines and utilize shore power for a certain percent of time while at berth. The rule is limited to fleets of vessels making 25 or more visits (five or more for passenger ships) that operate in six California ports: Los Angeles, Long Beach, Oakland, San Diego, San Francisco, and Hueneme. This regulation will result in an 80 percent NOx emission reduction from auxiliary engines from applicable vessel types by 2020.

In August 2020, CARB expanded the At Berth Regulation to cover new vessel types (such as roll-on/roll-off vehicle carriers and tankers), small fleets, new ports and terminals, and increase the usage of shore power. The action will continue to reduce vessel emissions at berth from auxiliary engines, and reduce toxic pollutant exposure in disadvantaged communities near the ports.

Mobile Source Strategy Scenario

While the recent actions target at berth auxiliary engine emissions, emissions from main engines and auxiliary engines during transit, anchorage, and maneuvering must also be addressed in order to achieve NOx reductions needed to meet California's near- and mid-term air quality goals. Currently, very few vessels with Tier 3 main engines visit California ports, even though the Tier 3 engine standard applied to new marine engines beginning in 2016. Tier 2 vessels emit three times higher NOx than Tier 3 vessels; thus, phasing out of older Tier vessels is key to reducing criteria and toxics emissions from OGVs. Under this scenario staff assumed:

[196] *https://ww2.arb.ca.gov/our-work/programs/ocean-going-vessels-berth-regulation*

1. *Incentivizing vessels visits from cleaner OGVs:* Starting in 2023, replace all Tier 0, Tier 1, and Tier 2 vessel visits in California with visits made by Tier 3 or cleaner vessels by 2031. Current Tier 3 vessel manufacturing data suggest that there may not be sufficient Tier 3 to meet the vessel visits in California, even if California were to receive a large majority of the worldwide Tier 3 vessels. However, these reductions may be achieved by incentivizing visits from Tier 2 vessels that have been retrofitted to reduce NOx emissions. Current retrofit technologies for marine engines include water-in-fuel emulsion, exhaust gas recirculation (EGR) and selective catalytic reduction (SCR). Both EGR and SCR have shown potential to reduce emissions by up to 80 percent. Water-in-fuel emulsion strategies have shown up to 40 percent reduction in NOx emissions, and may provide significant and cost-effective reductions options (particularly at near-port and low load conditions where Tier 3 and other retrofit options may not operate at full potential). All options will be considered to achieve the needed emissions reductions.
2. *Cleaner marine standards:* While marine Tier 3 is considerably cleaner than Tier 2, the Tier 3 NOx standard is still 5 to 10 times higher than the standards for other diesel equipment sectors, and does not include a PM standard. CARB will work with U.S. EPA, U.S. Coast Guard, and other partners to urge IMO to adopt more stringent Tier 4 marine standard by 2028, and establish efficiency requirements for existing vessels. In the 2020 MSS scenario, Tier 4 NOx and PM emission factors are set at 1 g/kw-hr and 0.1 g/kw-hr, respectively.

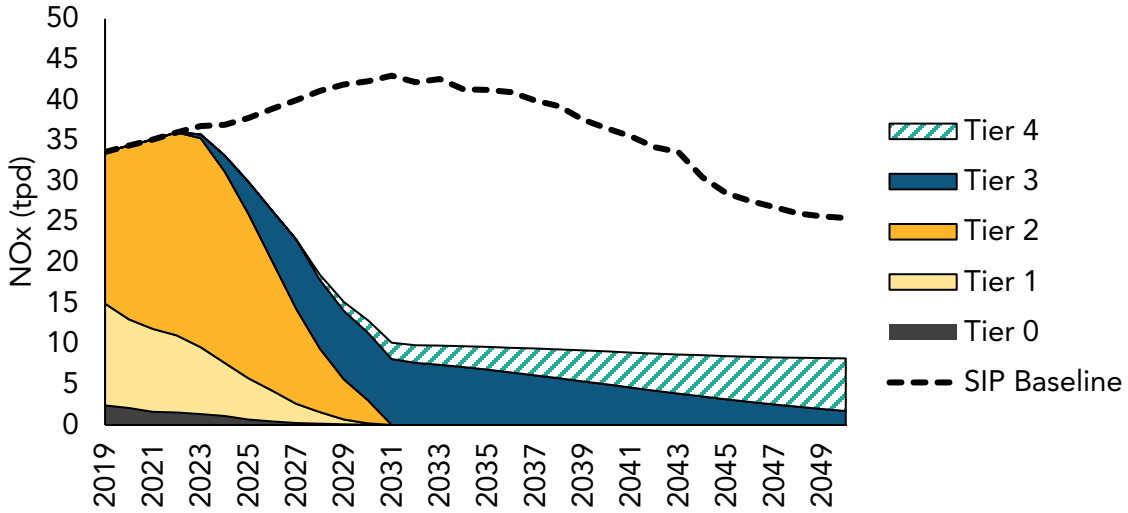
Figure 33 shows the OGV NOx emission projection in the South Coast Air Basin under the MSS scenario. The emissions here include all OGV modes and cover up to 100 nautical miles of operation off the coast of California. The dashed line shows baseline emissions from main and auxiliary engines. The 2020 MSS scenario can reduce NOx emissions by 33 tpd in South Coast by 2031 (a portion of the reductions could also be achieved through Tier 2 retrofits noted above), still short of the target of 38 tpd reduction as identified in the 2016 MSS[197] which relied on earlier Tier 4 engine adoption.

Several major shipping companies are working towards zero-emission vessels. For example, Maersk, the world's largest container shipper, aims to be carbon neutral by 2050 and to have carbon neutral vessels commercially available by 2030.[198] Biofuels, renewable hydrogen and other hydrogen-derived fuels such as ammonia, methanol, batteries and fuel cells are being considered as potential fuel choices for zero-emission vessels. As the zero-emission technologies for marine vessels are still at an early stage and technological feasibility needs to be proven, CARB did not incorporate these strategies in the current 2020 MSS scenario. CARB will consider these strategies in future updates to the MSS as more information becomes available.

[197] Under further deployment of cleaner technologies

[198] *https://www.maersk.com/news/articles/2019/06/26/towards-a-zero-carbon-future*

Figure 33 - South Coast NOx Emissions from All OGV Modes: MSS Scenario



Aircraft

Currently, CARB's official emissions inventory[199] has emissions data for five different aircraft categories that contribute significantly to NOx emissions; these are piston aircraft (civil), agricultural aircraft (crop dusting), jet aircraft (military), jet aircraft (commercial), and jet aircraft (civil). The jet aircraft (commercial) contribute to about 90 percent of NOx emissions from aircraft in California, whereas jet aircraft (military) and jet aircraft (civil) each contribute about 4.5 percent of NOx. Together, the piston aircraft (civil) and agricultural aircraft (crop dusting) produce less than 1 percent of NOx emissions. As significant progress has been made to reduce NOx emissions from on-road, off-road, and area sources in recent years, the NOx emissions from aircraft are becoming increasingly important. For the South Coast Air Basin, about 16.2 tpd of NOx emissions comes from the aircraft in 2020; and by 2031, NOx emissions from the aircraft will increase to about 20.5 tpd by 2031.

The International Civil Aviation Organization (ICAO) is a United Nations intergovernmental body responsible for worldwide planning, implementation, and coordination of civil aviation and emissions. The Committee on Aviation Environmental Protection (CAEP) within ICAO coordinates the development of ICAO emission standards and recommended practices. ICAO standards incorporate a definition of "technological feasibility" that considers in-production and in-development aircraft, resulting in standards that are "technology-following" and do not tend to result in emissions reductions beyond business as usual. The ICAO standards have been the basis of Federal Aviation Administration's aircraft engine performance certification standards, established through U.S. EPA regulations. While U.S.

[199] CEPAM: California 2019 ozone sip baseline emission projection - version 1.01 planning inventory tool

EPA historically has codified the aircraft emission standards adopted by ICAO for harmonization with global airline industry, individual ICAO member states may adopt more stringent standards if desired.

The first NOx standard, adopted in 1981, applied to engines starting in 1986. The standard established a ceiling on NOx emissions at 100 g/kN at rated engine thrust for engine pressure ratio (EPR) of 30. Table 15 shows the progression of NOx emission standards at 30 EPR and Figure 34 shows the comparison between different NOx standards at various EPRs.

Table 15 - Aircraft engine emission standards relevant to NOx

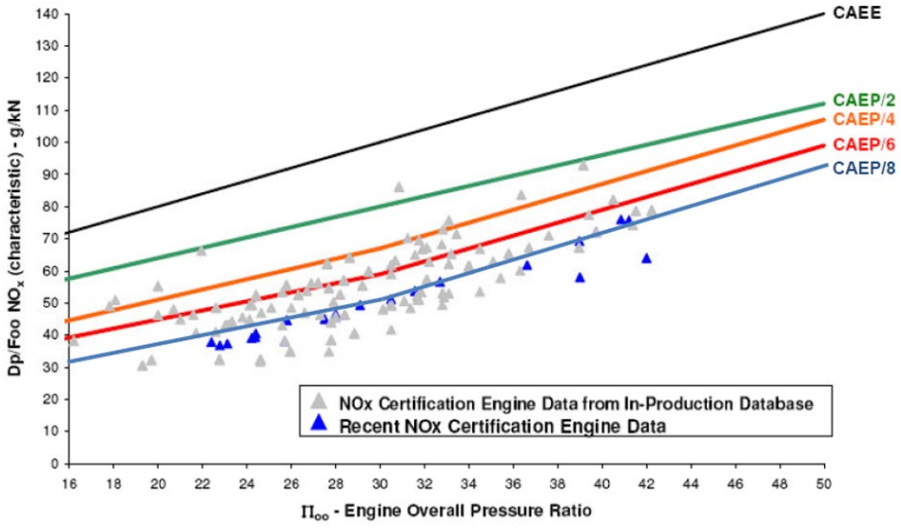
Regulation	Adoption year	NOx @ EPR 30	% NOx below CAEP/1	Newly certified engine
CAEP/1	1981	100 g/kN	0%	1986
CAEP/2	1993	80 g/kN	20%	1996
CAEP/4	1999	67 g/kN	33%	2003
CAEP/6	2005	59 g/kN	41%	2007
CAEP/8	2011	50 g/kN	50%	2013
CAEP/10*	2017	NA	NA	2020

* Note: Focusing on fuel efficiency and CO2 reduction

In January 2021, U.S. EPA adopted GHG emission standards for certain classes of engines used by certain civil subsonic jet airplanes (those with a maximum takeoff mass greater than 5,700 kilograms), as well as larger subsonic propeller-driven airplanes (those powered by turboprop engines with a maximum takeoff mass greater than 8,618 kilograms). These standards are equivalent to the Airplane CO2 Emission Standards adopted by the ICAO in 2017, and therefore reflect only technologies available for in-production and in-development airplanes as of 2017 (expected to be in production by about 2020).[200] Although there are a variety of aircraft and engine technologies under development which show tremendous promise in reducing GHG emissions, the standard does not require a technology response from manufacturers. Furthermore, U.S. EPA did not consider standards for in-use aircraft, more advanced technology under development by the industry (i.e., hybrid and zero-emission technology), or other emission-reduction mechanisms like sustainable aviation fuels or operational measures. CARB urges U.S. EPA to strengthen the standard in terms of stringency, applicability, and time.

[200] Control of Air Pollution from Airplanes and Airplane Engines: GHG Emission Standards and Test Procedures: Final Rule, 86 Fed. Reg. 2136, 2145 (Jan. 11, 2021).

Figure 34 - Comparison of CAEP NOx standards and engine NOx emissions[201]



[201] Jahangir, Ebad. *ICAO Technology Goals Process for Aviation Environmental Protection.* May 12, 2010. http://www.icao.int/Meetings/EnvironmentalColloquium/Documents/2010-Colloquium/3_Jahangir_Icao.pdf

Landing and Take-off (LTO) Cycle

The CAEP is responsible for setting emission measurement procedures and standards for ICAO. These standards and procedures are based on a standardized landing and take-off (LTO) cycle developed to address ground-level air quality issues. The LTO cycle is comprised of six modes; namely, taxi-out, take-off, climb-out, approach, landing, and taxi-in modes (Figure 35 and Figure 36); climb, cruise, and descent operation for aircraft above 3,000 feet are not included in the LTO cycle.

Figure 35- Typical aircraft flight path including the LTO cycle[202]

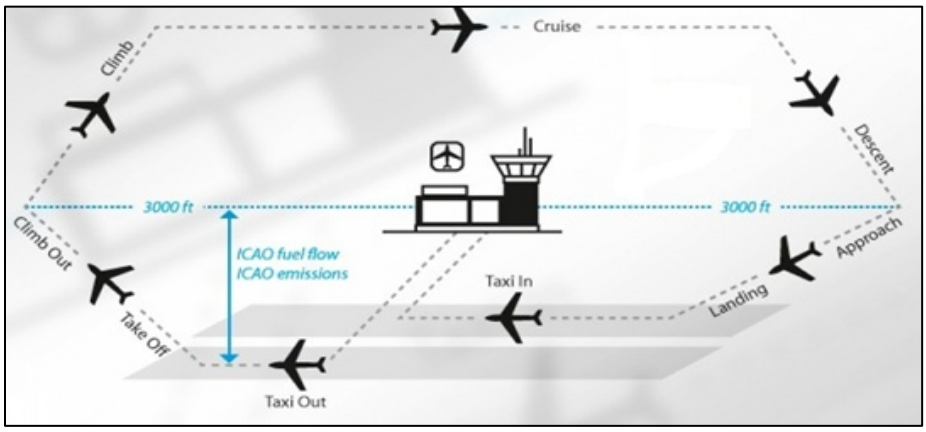
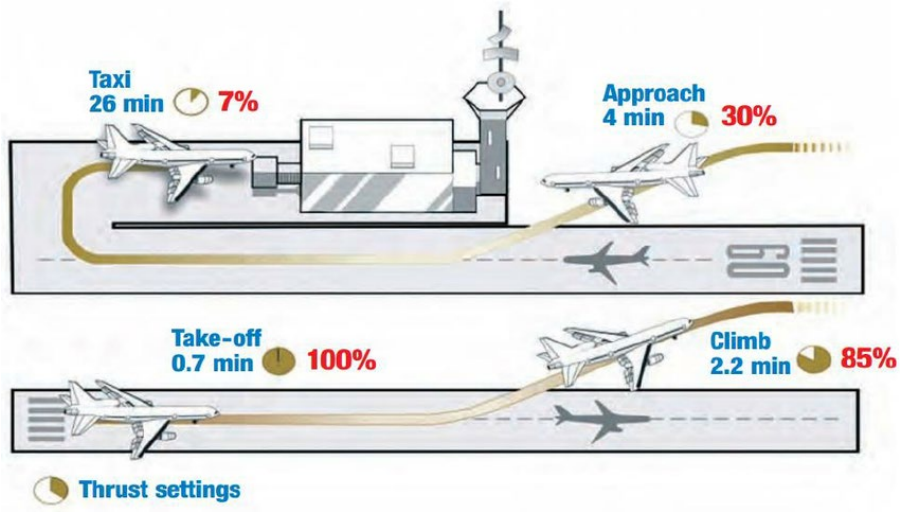


Figure 36- Duration and Thrust Settings within each Segment of the LTO Cycle



[202] Advanced Emission Model. "European Organisation for the Safety of Air Navigation." 2015. https://www.eurocontrol.int/services/advanced-emission-model-aem.

Mobile Source Strategy Scenario

Under the 2020 MSS, staff proposed a scenario focusing on four strategies: (1) improving the current air traffic operation, (2) transitioning toward zero-emission auxiliary power unit (APU), (3) accelerating the turnover of old aircraft, and (4) technology advancement for future aircraft. The following provides additional details for each strategy:

Improve the Current Air Traffic Operation (ATO) during LTO cycle

a) *De-Rated Take Off:* Aircraft are designed to take off safely without full thrust. By not applying full thrust during take-off, aircraft would reduce NOx emissions as well as the level of noise. According to a study conducted by MIT in 2005,[203] each 1 percent of derate can approximately reduce NOx emissions by 0.7 percent below 3000 feet while slightly increasing the fuel burn. A more recent study by Koudis et. al. (2017)[204] has shown that using reduced thrust takeoff reduces fuel consumption, NOx, and black carbon (BC) emissions by 1.0–23.2 percent, 10.7–47.7 percent, and 49.0–71.7 percent respectively, depending on aircraft-engine combinations relative to 100 percent thrust takeoff. Additionally, a study by Electronic Navigation Research Institute of Japan has indicated that reduced thrust near the top of the climb can result in fuel saving[205]. The engine derate can also extend engine life and reduce maintenance cost.[206]
b) *Reduce Power during Taxiing:* Most commercial aircraft are equipped with two to four engines. Aircraft engines, even at idle or minimal power settings, are used to taxi the aircraft while on the ground. Because of this, taxi-in, idle and even taxi-out can be completed with one or more of those engines not operating. If an engine can be shut down during the taxi-in until the aircraft is in an advanced stage of the taxi-out for takeoff, then such a procedure has the potential to reduce fuel burn and criteria emissions such as NOx.[207]
c) *Improved Taxi Time:* Prolonged taxi time for aircraft causes unnecessary waste of fuel and an increase in emissions. By minimizing the taxi time when the aircraft is taxi-in or taxi-out, less fuel will be consumed leading to less NOx emissions. Such a control measure would require real-time optimization of air traffic with constant feedback from all associated airports.

[203] King, M., Waitz, I., 2005. Assessment of the Effects of Operational Procedures and Derated Thrust on American Airlines B777 Emissions from London's Heathrow and Gatwick Airports. Partner, Cambridge, MA.

[204] Koudis, G. S., Hu, S. J., Majumdar, A., Jones, R., & Stettler, M. E. (2017). Airport emissions reductions from reduced thrust takeoff operations. Transportation Research Part D: Transport and Environment, 52, 15-28.

[205] Mori, R., 2020. Fuel-Saving Climb Procedure by Reduced Thrust near Top of Climb. Journal of Aircraft, pp.1-7.

[206] Donaldson, R., Fischer, D., Gough, J., Rysz, M. (2007). Economic Impact of Derated Climb on Large Commercial Engines. Proceedings of the Performance and Flight Operations Engineering Conference.

[207] Sustainable Aviation, Aircraft on the Ground CO2 Reduction Programme, UK's Airport Operators Association

Reduce the Usage for Auxiliary Power Unit

The typical aircraft APU is a small turbine engine that starts the aircraft main engines and powers the electrical systems on the aircraft when the main engines are off. By switching to the on-board rechargeable batteries as the power supply, it would reduce the usage of the gas turbine APU and hence the NOx emissions.

Accelerated Turnover

Similar to other off-road mobile source categories, replacing old aircraft that are powered by the CAEP/1 to CAEP/4 engines with the newer engines (CAEP/8 or newer) can reduce NOx emissions and improve safety, as well as fuel efficiency.

Technology Advancement

The NOx formation correlates with the high temperature and pressure during the combustion process. With innovative research and advanced optimization of engine design, it has been demonstrated that NOx emissions can be further reduced beyond the CAEP/8 standards. For example, under the FAA's Continuous Lower Energy, Emissions, and Noise Phase II (CLEEN II) Program, FAA awarded five-year agreements to Aurora Flight Sciences, Boeing, Collins Aerospace, Delta Tech Ops/MDS Coating Technologies, General Electric, Honeywell, Pratt & Whitney, and Rolls-Royce to accelerate the development of new aircraft and engine technologies. The goal of the program is to achieve 70 percent NOx and 40 percent fuel burn reduction below the CAEP/8 standards. In 2016, GE's Twin Annular Premixing Swirler (TAPS) II combustor matured under CLEEN I and entered into service as part of CFM International's TAPS Leading Edge Aviation Propulsion (LEAP) engine, currently onboard Airbus 320neo, Boeing 737 MAX, and COMAC C919 aircraft. Under CLEEN I, GE engine emissions tests of TAPS II had results that were more than 60 percent below the 2004 ICAO CAEP NOX standards. The FAA anticipates that more of these technologies could go into service in the next several years.[208]

With all of these technology advancements in mind, for the 2020 MSS, staff developed a scenario assuming a phase-in requirement for improving ATO efficiency starting in 2023. Staff assumed that by 2030:

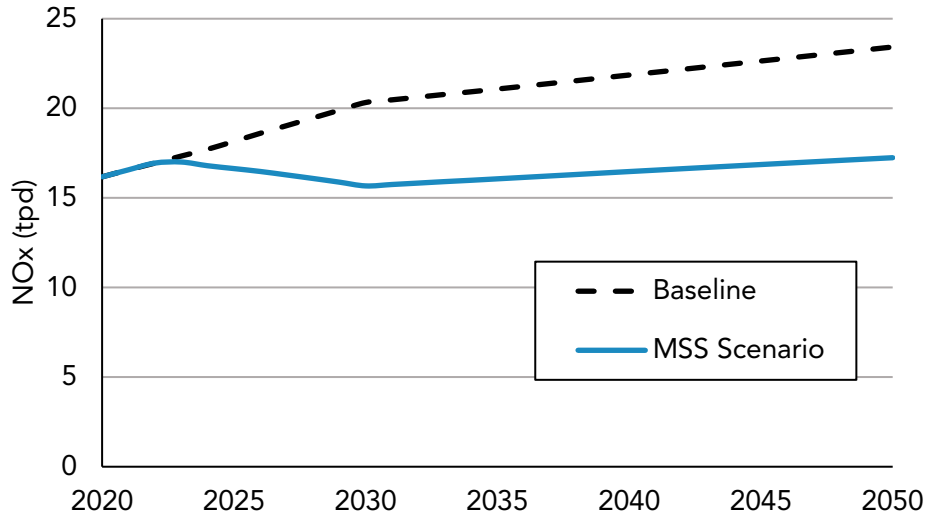
- 90 percent of take offs in California will be 25 percent de-rated (95 percent of take offs by 2050);
- 90 percent of aircrafts will have single engine taxiing (95 percent by 2050);
- 40 percent reduction in taxi time (50 percent by 2050);
- 40 percent reduction in APU usage (95 percent by 2050)

With these assumptions, Figure 37 presents the resultant NOx emissions reductions for the South Coast Air Basin. Without any control, the NOx emissions would increase from 16.2 tpd

[208] *https://www.faa.gov/about/office_org/headquarters_offices/apl/research/aircraft_technology/*

in 2020 to about 20.5 tpd by 2031. However, with improved air traffic operation, and reduced APU usage, NOx emissions will be reduced by 4.7 tpd and 5.2 tpd in 2031 and 2037 respectively. Please note that these estimates do not account for further deployment of cleaner technologies and accelerated turnover of older aircrafts.

Figure 37 - South Coast NOx Emissions from Aircraft: MSS Scenario



It is noteworthy to also mention that as a result of the COVID-19 pandemic, the domestic and worldwide air traffic volume has declined significantly. It is estimated that almost 62 percent of the worldwide passenger jets were grounded right after the COVID-19 pandemic. To save the cost of fuel, most airlines started operating newer aircraft that were most fuel-efficient. Therefore, the airline industry is already accelerating the turnover of the older aircraft based on sound business solutions. Moreover, the COVID-19 pandemic has forced all business sectors and government agencies to reduce travel by encouraging more online meetings. Such new business practice is likely to continue after the COVID-19 pandemic is over.

FAA has recently released its latest Terminal Area Forecast[209] (TAF) report which is the official FAA forecast of aviation activity for U.S. airports. The report contains active airports in the National Plan of Integrated Airport Systems (NPIAS) including FAA-towered airports, Federal contract-towered airports, non-federal towered airports, and non-towered airports. According to the latest report, a total of 924.1 million passengers were enplaned at U.S. airports in 2019. This figure decreased by 44.4 percent in 2020 to 514.0 million enplanements as a result of the COVID-19 pandemic. Total enplanements at U.S. airports are forecast to recover in aggregate to their 2019 level by 2025. The latest aircraft emissions

[209] *https://www.faa.gov/data_research/aviation/taf/*

analysis in South Coast air basin utilizing the 2020 TAF report was presented at the 2022 South Coast AQMP mobile source working group meeting in August 2021.[210]

[210] *http://www.aqmd.gov/docs/default-source/clean-air-plans/air-quality-management-plans/2022-air-quality-management-plan/2022-AQMP-Mobile-Source-Presentations-Aircraft-8-18-21.pdf?sfvrsn=17*

Off-Road Sectors: Zero-Emission

Cargo Handling Equipment

Cargo handling equipment (CHE) includes any motorized vehicles used to handle cargo or perform routine maintenance activities at California's ports and intermodal rail yards. CHE includes yard tractors, rubber-tired gantry (RTG) cranes, container handlers, forklifts, etc. CHE can be a significant source of diesel PM emissions in communities near the ports and intermodal rail facilities.

CARB initially adopted the CHE regulation on December 8, 2005, and it became effective on December 31, 2006. This regulation was fully implemented by the end of 2017 and has resulted in reductions of diesel PM and NOx at ports and intermodal rail yards throughout California. CARB staff are currently assessing the availability and performance of zero-emission and hybrid technologies to reduce emissions from a fleet predominantly powered by internal combustion engines and evaluating additional solutions that may include efficiency improvements.

Mobile Source Strategy Scenario

As part of the 2020 MSS, CARB staff has developed a scenario where CHE will start transitioning to full electric in 2026, with over 90 percent penetration of electric equipment by 2036. This assumption about aggressive electrification is supported by the fact that currently some electric RTG cranes, electric forklifts, and electric yard tractors are already commercially available. Other technologies are in early production or demonstration phases. Figure 38 shows the technology mix as a result of this scenario. As shown, the zero-emission CHE population share will reach 90 percent by 2036. Figure 39 shows statewide NOx emission from CHE. Statewide NOx emission reductions from CHE in 2031 and 2037 will be 1.1 tpd and 1.5 tpd, respectively. Under this scenario, CHE electrification will reduce diesel fuel use by 115 million gallons in 2045.

Figure 38 - Statewide CHE Population: MSS Scenario

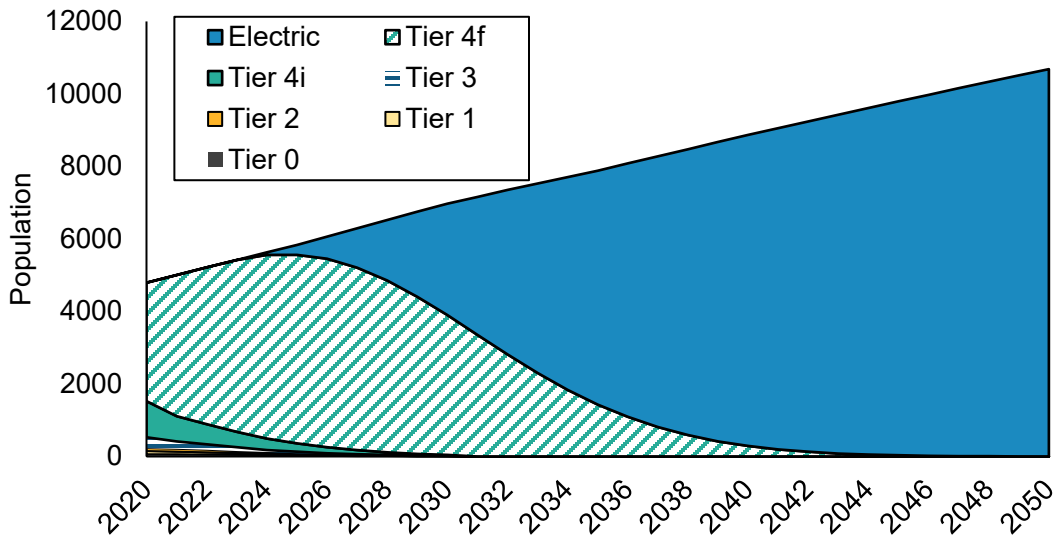
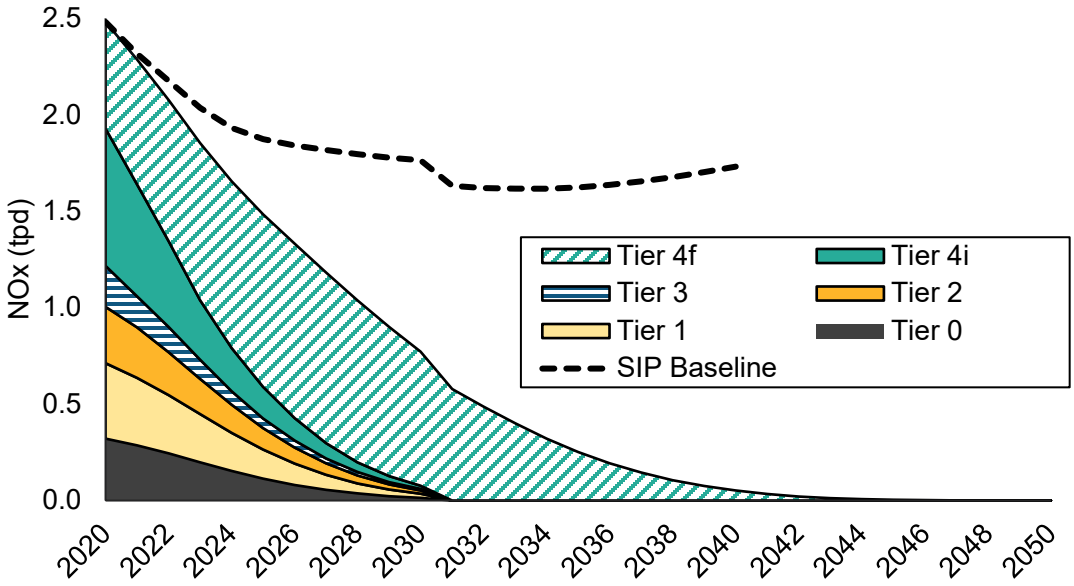


Figure 39 - Statewide CHE NOx Emissions: MSS Scenario



Small Off-Road Engines

Small off-road engines (SORE) are spark-ignition engines rated at or below 19 kilowatts (i.e., 25 horsepower). Engines in this category are primarily used in lawn and garden equipment as well as other small off-road equipment and specialty vehicles. Currently there are

14 million gasoline-powered SORE in California, equivalent to the number of light-duty passenger cars[211] driving on California roadways.

SORE are significant contributors to ROG and NOx, which are ozone precursors. CARB adopted emission standards for SORE in 1990 and was the first agency in the world to control emissions from these engines. While SORE are 40-80 percent cleaner today than they were before CARB's control program began, they are still significantly dirtier than cars. Total smog-forming emissions from SORE will exceed the emissions from light-duty passenger cars in California in 2021 and, without additional regulation, will be almost twice those from California's light-duty passenger vehicle fleet by 2031. Currently, nearly 50 percent of the lawn and garden equipment and 70 percent of the light commercial equipment (such as generators, air compressors, and pressure washers) are electric, based on the survey by California State University, Fullerton.

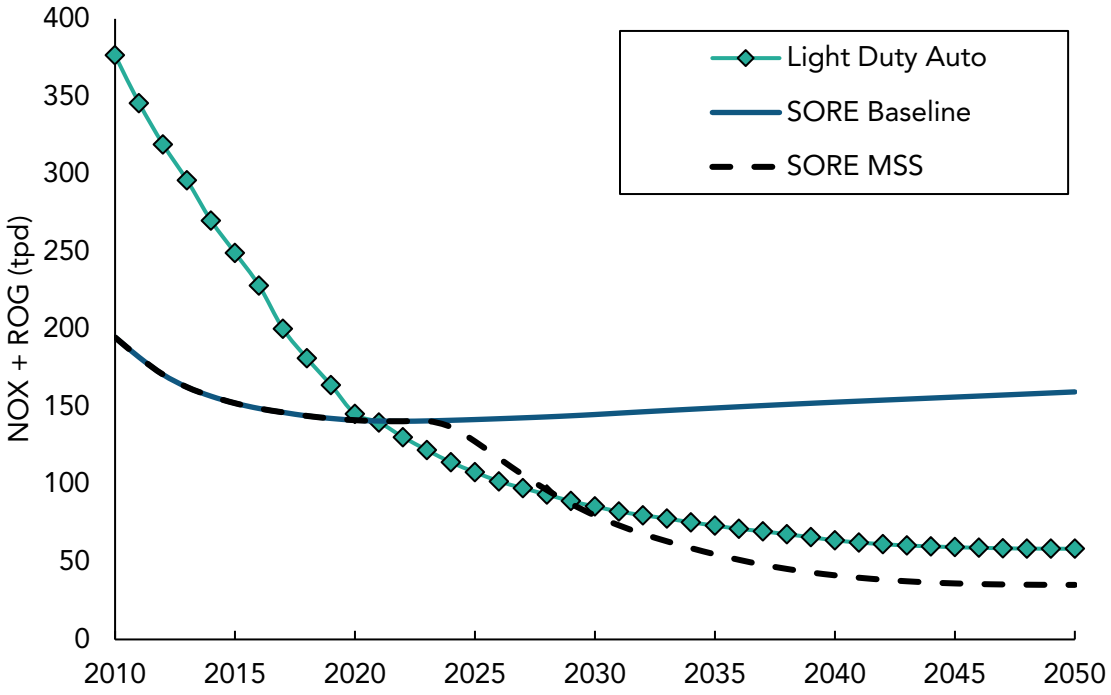
Driven by the State SIP Strategy, Governor Newsom's Executive Order N-79-20, and needs for further reductions of ozone and particulate matter, CARB is currently developing a proposal to implement significantly tightened exhaust and evaporative emission standards for generator engines and emission standards of zero for other engines for model year 2024. Starting in model year 2024,[212] the new emission standards will accelerate a transition of all SORE regulated by CARB – or about 90 percent of all SORE in the state – to zero-emission. The remaining 10 percent of SORE includes new engines which are used in construction equipment or vehicles used in farm equipment or vehicles which are smaller than 175 horsepower that fall under section 209, subsection (e)(1)(A) of the Clean Air Act. The Clean Air Act does not grant CARB the authority to regulate the emissions from engines used in these equipment.

Considering that staff's current proposal would largely transform SORE to zero-emission technology by 2040, no additional 2020 MSS scenarios were modeled for this sector. Figure 40 shows statewide NOx and ROG emission projections from SORE. NOx emission reductions under the 2020 MSS scenario in 2031 and 2037 are 7.9 tpd and 11.8 tpd, respectively. As noted earlier, federally preempt engines account for the majority of remaining emissions after 2031, making up almost 90 percent of the total remaining NOx emissions from SORE by 2040. This again emphasizes the need for federal actions to reduce emissions from preempt equipment. As shown, the current proposal will reduce emissions from SORE in California such that overall emissions will be lower than those from California's light-duty passenger car fleet starting in 2029. Transitioning SORE to zero-emission equipment is estimated to reduce gasoline fuel use by 237 million gallons in 2045.

[211] Referring to LDA category in the EMFAC model

[212] Emission standards of zero would be implemented for model year 2028 and later generator engines

Figure 40 - Statewide Smog-Forming Emission Projections from SORE



Airport Ground Support Equipment

Airport Ground Support Equipment (GSE) are diesel, gasoline, natural gas and electric equipment used at airports. Common equipment includes aircraft tugs, baggage tugs, passenger stairs, and similar equipment. This category is well suited to electrification due to the equipment generally being captive at one location (allowing for the development of charging infrastructure), and the relatively stable power requirements (compared to large mining or construction equipment). Currently, approximately 34 percent of GSE reported to CARB is electric, with 38 percent being diesel, 17 percent gasoline, and 11 percent being natural gas. This proportion of equipment sales in each fuel type does not appear to have changed significantly in the last decade (based on data reported in the DOORS program), meaning that higher penetration of zero-emission equipment may not occur naturally.

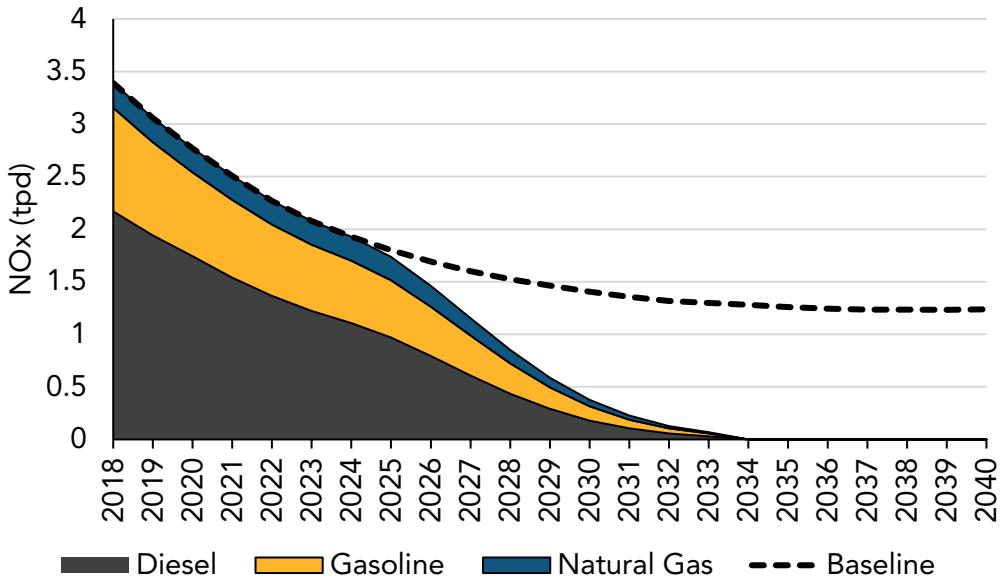
This equipment, although not a relatively large contributor to statewide emissions compared to other categories, is significant source of air pollution and toxic air contaminants to communities located near airports. The use of GSE is clustered and confined to a small area near other sources (such as cars and mass transit to airports, aircraft emissions, and other sources in or near the communities that surround many of the airports in the state). Currently, the diesel portion of this equipment is subject to the In-Use Off-Road Diesel Regulation, which requires these fleets meet approximately a Tier 3 average by 2023.

Mobile Source Strategy Scenario

Under the 2020 MSS, staff assumes full electrification of the remaining diesel, gasoline and LNG equipment, phased in over 10 years from 2025 to 2034. This technology trajectory will require additional electrification infrastructure installed at airports and ground support terminals. As shown in Figure 41, this effort will reduce statewide NOx emissions by about 1 tpd in 2031.

This effort is supported by incentives currently, and may be accomplished with an MOU between the South Coast Air Quality Management District for specific airports in impacted communities.

Figure 41 - Statewide NOx Emissions from GSE: MSS Scenario



Forklifts (Spark Ignition and Diesel)

Forklifts are off-road equipment with a mix of diesel, gasoline, natural gas and electric engines. Forklifts with moderate to low lift capacity are an excellent candidate for full electrification, as they are often captive to facilities, used in urban or industrial areas, and already have electric options available commercially. Larger forklifts may be less suitable to full electrification, due to a mix of available technology and power requirements. A threshold for full electrification will be developed by CARB staff in further developing this strategy, but it is likely to be between 6,000 to 10,000 pound capacity which broadly means full electrification for all forklifts under 50 or 80 horsepower.

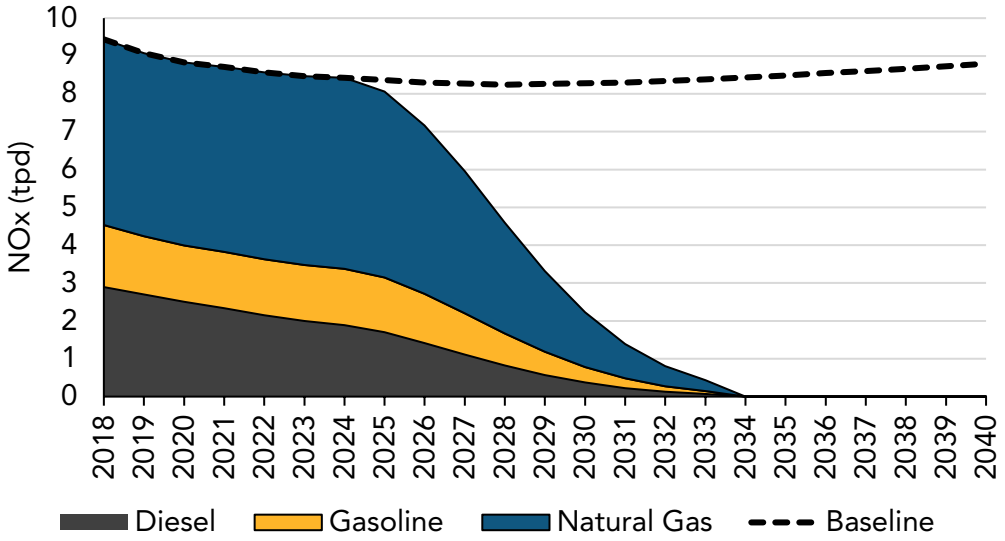
Diesel forklifts over 25 horsepower are currently subject to the *In-Use Off-Road Regulation*, meeting an increasingly stringent fleet average target with a final target in 2023. Gasoline

and CNG forklifts have been subject to the *Large Spark Ignition Regulation*, and completed their final emissions requirements in 2013.

Mobile Source Strategy Scenario

Under this 2020 MSS scenario, staff developed a scenario where forklifts will transition to zero-emission technology starting in 2025, with a possible measure coming to the Board in 2022. Diesel forklifts would need to be pulled from the In-Use Off-Road Regulation and included with forklifts from other fuels in this strategy. As shown in Figure 42, this strategy would result in 6.9 tpd of statewide NOx reduction in 2031.[213]

Figure 42 - Statewide NOx Emissions from Forklifts: MSS Scenario



Transport Refrigeration Units

Transport refrigeration units (TRUs) are diesel-powered refrigeration units installed on vehicles such as trucks, trailers, shipping containers, and rail cars. The CARB TRU emissions inventory also includes TRU generator sets (gensets), which are designed to provide electricity to electrically driven refrigeration units (including systems for semi-trailers, vans, and shipping containers). TRUs are responsible for the safe transportation of refrigerated goods, including meats, produce, dairy, and certain medicine and chemical products. TRUs operate in large numbers at distribution centers, food manufacturing facilities, packing houses, and intermodal facilities.

[213] Although this figure shows the reduction from all forklifts, CARB will assess the impact from smaller fleets, rental equipment (due to the infrastructure required for the end user to charge the forklift), and determine if there is a need for an upward limit on forklift capacity due to technology limitations.

TRUs are a significant source of various pollutants, but are of particular concern due to their PM2.5 emissions at locations and facilities where a large number of TRUs operate simultaneously, concentrating their emissions impact in the surrounding communities. CARB adopted the *TRU Airborne Toxic Control Measure* (ATCM) on February 26, 2004, with amendments in 2010 and 2011, to reduce diesel PM emissions. This regulation requires TRU diesel engines to meet in-use diesel PM emission standards by the end of the seventh year after manufacture.

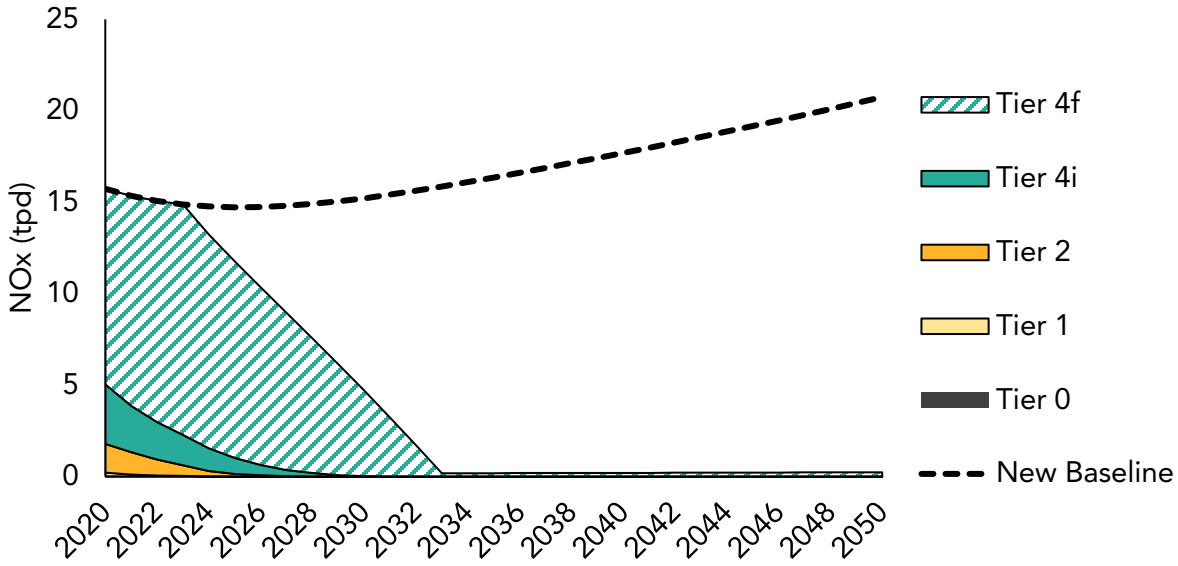
Currently, CARB is pursuing regulatory actions to further reduce emissions from this sector. The current regulatory concepts go beyond the current TRU ATCM by transitioning to zero-emission wherever feasible, as well as increasing the earlier penetration of infrastructure that will be needed for those technologies. The current regulatory proposal requires the following:

- Starting December 31, 2023, all truck TRUs must turnover at least 15 percent each year (for 7 years) to full zero-emission technology. All truck TRUs must be full zero-emission by 2029; and
- Starting December 31, 2023, newly manufactured diesel engines in trailer TRUs, domestic shipping container TRUs, railcar TRUs, and TRU gensets that operate in California, regardless of horsepower, must meet the U.S. EPA Tier 4 final emission standard for 25-50 hp engines. This requirement applies to all diesel engines in trailer TRUs, domestic shipping container TRUs, railcar TRUs, and TRU gensets starting December 31, 2030. The current emission standards for TRU engines below 25 horsepower are significantly higher than those for over 25 horsepower engines. As a result, many TRU engines are between 23 and 25 horsepower. This measure can reduce PM emissions from these engines by 90 percent, and NOx emissions by 71 percent.

Mobile Source Strategy Scenario

As part of the 2020 MSS, staff developed a rapid electrification scenario for TRUs, featuring the share of zero-emission TRUs increasing from 10 percent in 2024 to 100 percent in 2034. Statewide NOx emissions from TRUs will be reduced by 12 tpd in 2031 under the MSS scenario.

Figure 43 - Statewide NOx Emissions from TRU: MSS Scenario



Recreational Marine Vessels

Recreational marine vessels (RMVs) include gasoline powered spark-ignition marine watercraft (SIMW), spark-ignition marine engines (SIMEs), and diesel-powered marine watercraft. A significant ROG emission source in California is the exhaust and evaporative emissions produced by SIMW and SIMEs. In 2015, the Board set standards for evaporative emissions from SIMW, however, the exhaust emissions standards for these watercraft have not been changed since 2009.

Mobile Source Strategy Scenario

Under the 2020 MSS, staff developed a scenario which assumes that from 2029 to 2033, the THC+NOx emission standards for outboard and personal watercraft will be gradually reduced to 40 and 70 percent below current levels for less than 40 kW and above 40 kW engines, respectively.

In addition to these standards changes, which would apply to internal combustion outboard and personal watercraft marine engines only, staff is evaluating the potential for electrification of marine engines in certain applications. Specifically, small outboard engines less than 19 kW, which are not typically operated aggressively or for extended periods, could be replaced with electric motors within a seven-year phase-in period (i.e., from 2029 through 2036). Additionally, 50 percent of existing PWC applications could be powered with electric motors over that same seven-year time period. The inherently lighter mass typical of PWCs is better suited to electric propulsion systems than are other types of marine vessels. Not only would this replacement of internal combustion engines with electric propulsion motors eliminate exhaust emissions, it would also eliminate evaporative emissions, helping to

achieve attainment with ambient air quality standards in the South Coast Air Basin and other areas of the State.

Figure 44 provides potential NOx and ROG emissions reductions under this scenario. As shown, the scenario will achieve a total of 1.4 and 9.2 tpd of ROG + NOx emissions in 2031 and 2037, respectively. In addition to criteria emissions benefit, the proposed scenario will result in reductions in gasoline consumption of about 20 million gallons by 2045 (Figure 45).

Figure 44 - Statewide Smog-Forming Emissions from Recreational Marine Vessels

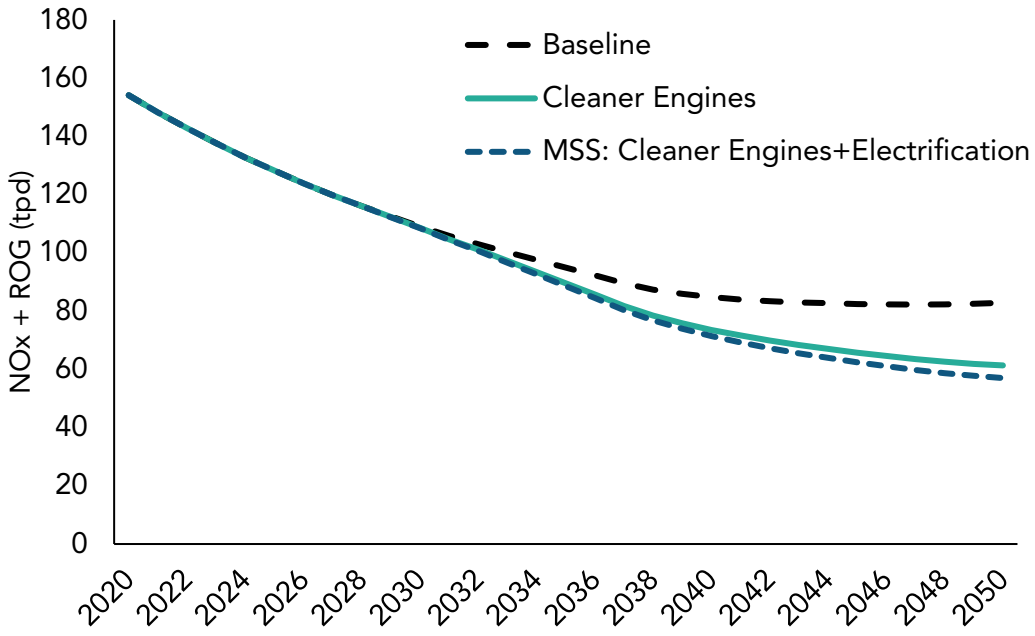
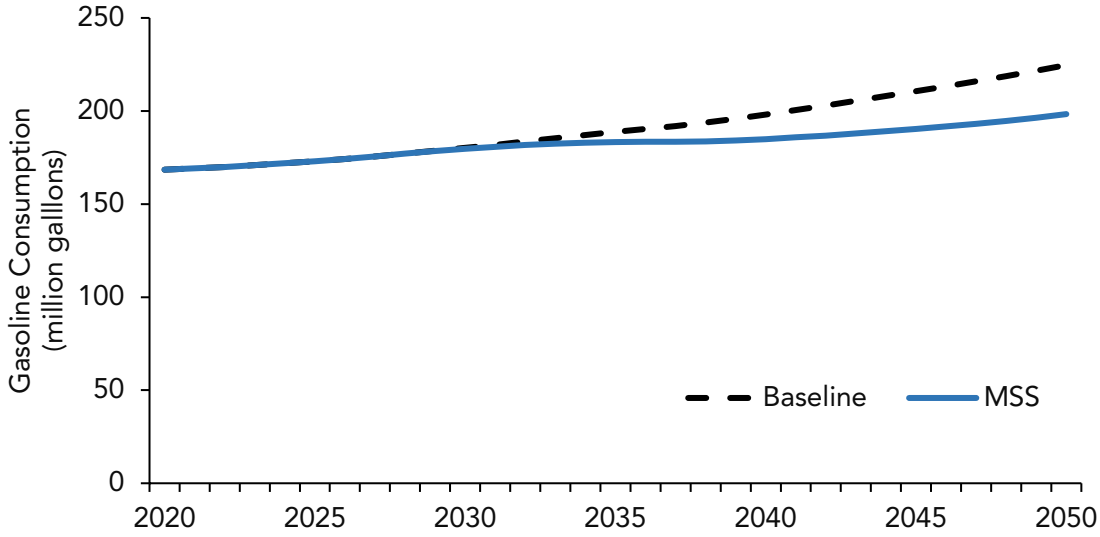


Figure 45 - Statewide Gasoline Fuel Consumption from Recreational Marine Vessels



Off-Road Sectors: Accelerated Turnover and Zero-Emission

Construction and Earthmoving Equipment (In-Use Off-Road)

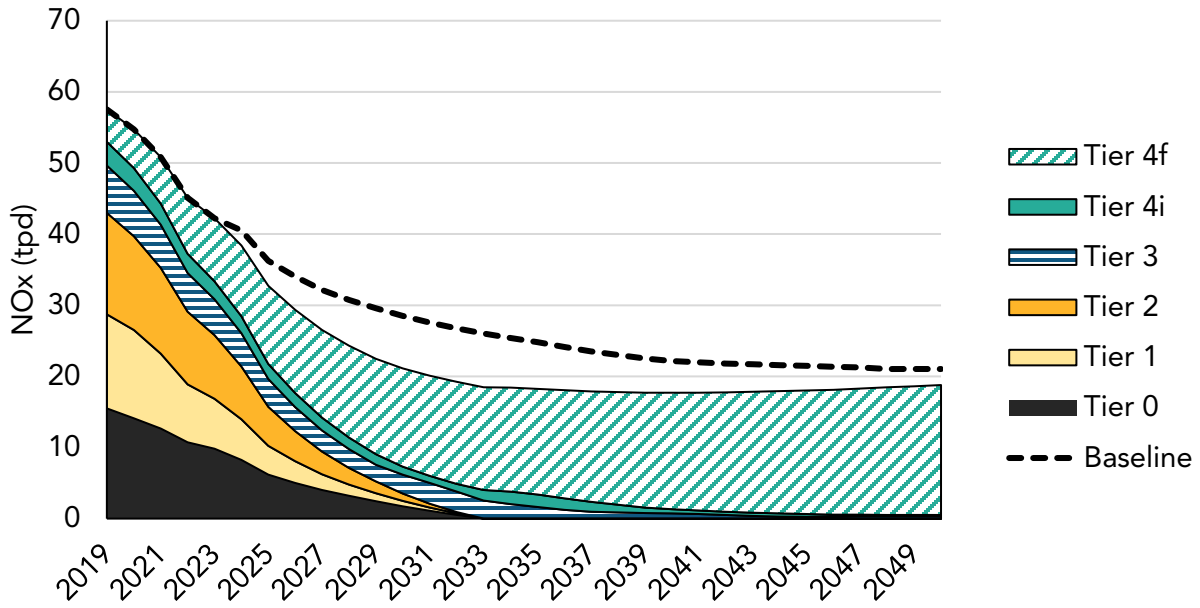
The in-use off-road equipment sector includes equipment used in industries such as construction, mining, industrial, oil drilling, and similar industries, and covers mobile diesel vehicles over 25 horsepower. Common examples are loaders, backhoes, excavators, forklifts, oil rigs, and other off-road equipment.

The diesel equipment in this category is currently subject to CARB's In-Use Off-Road Regulation, passed by the Board in 2008. The existing rule requires that fleets meet an increasingly stringent set of fleet average targets, culminating in 2023 for large fleets (large fleets represent about 73 percent of vehicle ownership). The most stringent fleet average target generally corresponds to roughly a 2012 model year, or a Tier 3 average standard. While this regulation has resulted in significant emissions reductions from the sector, the regulation does allow Tier 0, 1 and 2 equipment to continue operating indefinitely with no activity restrictions (dependent on the mix of other equipment owned by the fleet). For comparison, a single Tier 0 off-road engine in the 100-175 horsepower bin has 80 times higher NOx emissions than a Tier 4 Final off-road engine. By 2031, this Tier 0 equipment will be 32 years old or more, Tier 1 will be 28 to 31 years old, and Tier 2 will be 24 to 27 years old. This equipment, already having provided a long useful life, can continue to operate hundreds or thousands of hours per year with no restrictions under the current rule, with no end date.

Mobile Source Strategy Scenario

For the 2020 MSS, staff developed a scenario where the current In-Use Off-Road Regulation will be extended with the goal of full turnover of Tier 0, 1 and 2 engines between 2024 and 2033. This scenario will allow a 10 year phase out of these engines to cleaner Tier 4 final engines. As illustrated in Figure 46, this scenario will result in a statewide NOx emissions reduction of 7.5 tpd by 2031, with 2.4 tpd in South Coast and 1.7 tpd in the San Joaquin Valley. Diesel PM will be reduced in the sector by 47 percent over the same period.

Figure 46 - Statewide NOx Emissions from In-Use Off-Road: MSS Scenario



Agricultural Equipment

California is the nation's leader in agricultural production, producing over 400 different commodities that generate over $40 billion in annual sales and over 400,000 jobs statewide. Agricultural equipment is used in agricultural goods production and supply, and is a significant contributor to California's air quality issues. The San Joaquin Valley contains over 50 percent of the state's agricultural equipment, and diesel agricultural equipment contributed 18 percent of the NOx emissions in the San Joaquin Valley in 2019.[214]

Since 2009, over $400 million dollars in private and public funding have been invested in the San Joaquin Valley to replace older agricultural tractors with newer and cleaner models. Through 2016, the Natural Resources Conservation Service (NRCS) grant program by U.S. Department of Agriculture, in combination with the San Joaquin Valley Air Pollution Control District's program, has provided over $129 million that helped replace over 5,000 Tier 0 and Tier 1 tractors, plus other agricultural equipment. In 2018, CARB developed the Funding Agricultural Replacement Measures for Emission Reductions (FARMER) Program,[215] which facilitates distribution of State funds allocated by the California Legislature to incentivize turnover of agricultural equipment. The 2017-18 fiscal year allocated $108 million for San Joaquin Valley agricultural equipment replacement projects. The 2018-19 fiscal year included $132 million statewide for the FARMER program, with approximately 80 percent of

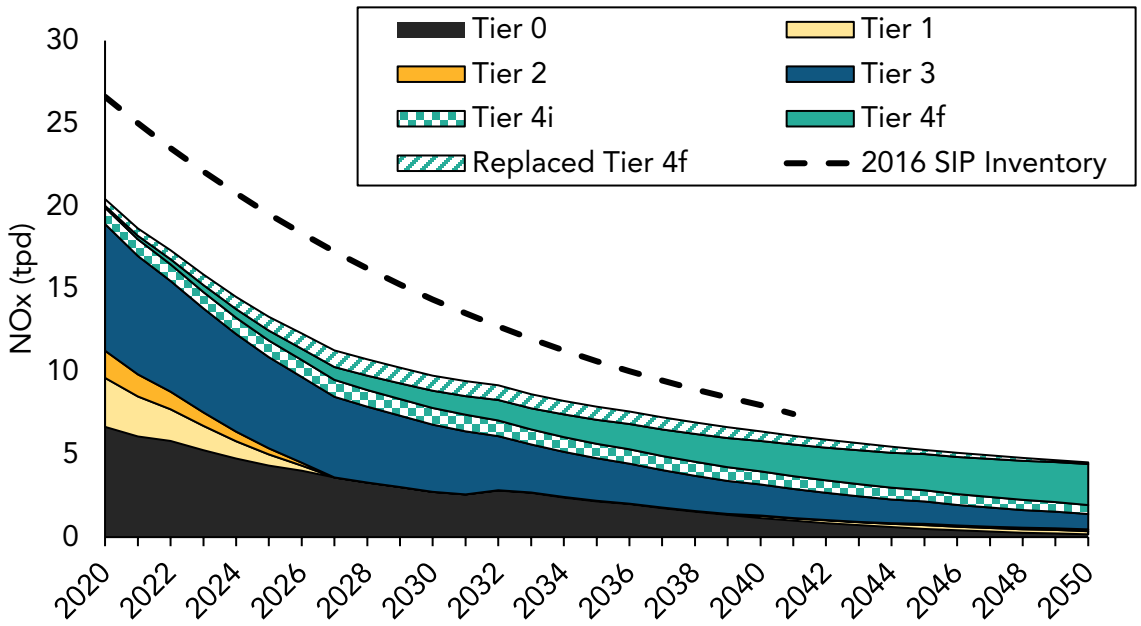
[214] https://www.arb.ca.gov/app/emsinv/fcemssumcat/fcemssumcat2016.php
[215] CARB FARMER Program, *https://ww2.arb.ca.gov/our-work/programs/farmer-program*

the funds allocated to the SJV. The current goal for emissions reductions is 11 tpd of NOx from agricultural equipment in the San Joaquin Valley by 2024; this is roughly equivalent to replacing all Tier 0, Tier 1 and Tier 2 tractors that are used over 200 hours per year with Tier 4 engines and equipment.

Mobile Source Strategy Scenario

Under this 2020 MSS, staff developed a scenario that assumed continued incentive funding opportunities in the sector through 2031. Figure 47 shows the NOx emissions from farm tractors in the San Joaquin Valley under the baseline (i.e., 2016 SIP inventory) as well as the proposed MSS scenarios. At the average levels of funding over the past 4 years, continued funding through 2031 could replace Tier 0, 1 and 2 equipment in the remaining categories of equipment such as harvesters, bale wagons, tillers, etc. that are used over 100 hours per year, and the remaining Tier 0, 1 and 2 tractors used from 100 to 200 hours per year, with a total reduction of an additional 4 tpd of NOx in the San Joaquin Valley in 2031.

Figure 47 - San Joaquin Valley NOx Emissions from Farm Tractors



Commercial Harbor Craft

Commercial harbor craft (CHC) include any private, commercial, government, or military marine vessels including, but not limited to ferries, excursion vessels, tugboats (including ocean-going tugboats), towboats, crew and supply vessels, work boats, pilot vessels, barges, dredges, and commercial and charter fishing boats. The majority of CHC have diesel engines, which are significant emitters of PM and NOx. CHC emissions are concentrated near the ports, and pose significant health risks to nearby communities.

CARB's CHC Regulation was adopted in 2007 to reduce toxic and criteria emissions to protect public health. It was then amended in 2010 and will be fully implemented by the end of 2022. CARB is currently developing a new emission inventory and rule concept for CHC. The current regulatory concepts establish expanded and more stringent in-use requirements to cover more vessel categories. The concepts also mandate accelerated deployment of zero-emission and advanced technologies in vessel categories where technology feasibility has been demonstrated. For example, based on regulatory concepts released March 2020:

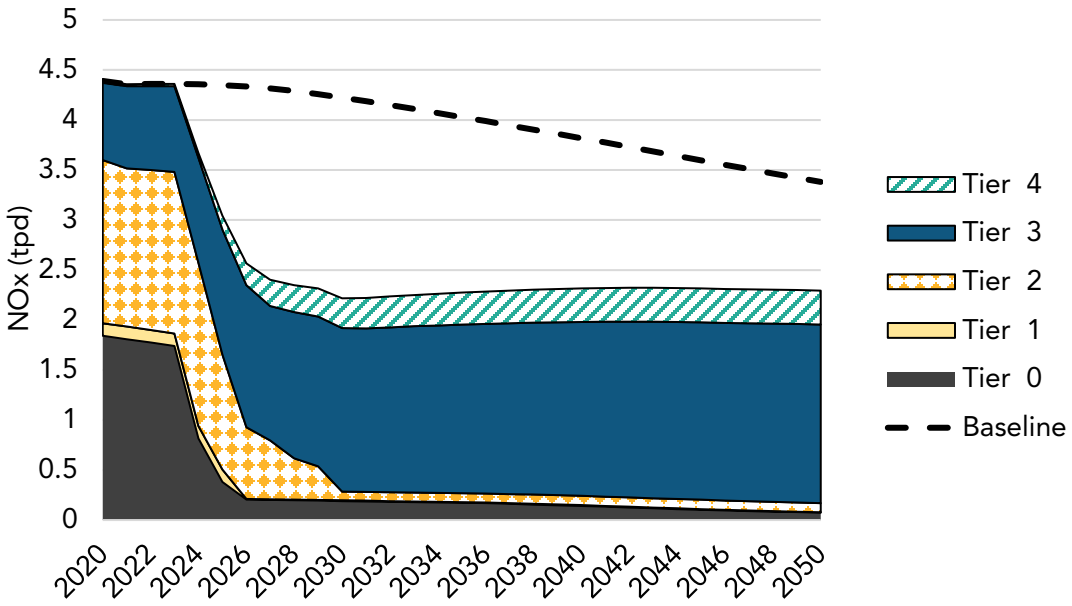
- Starting in 2023, all CHC except for commercial fishing vessels are required to meet the cleanest possible standard and retrofit with DPF based on a compliance schedule. The current regulated CHC categories are ferries, excursion, crew and supply, tug/tow boats, barges, and dredges. The concept will impose in-use requirements on the rest of vessel categories except for commercial fishing vessels, including workboats, pilot vessels, commercial passenger fishing, and all barges over 400 feet in length or otherwise meeting the definition of an ocean-going vessel. The concept also removes the current exemption for engines less than 50 horsepower;
- Starting in 2025, all new tugboats are required to be diesel-electric vessels. Diesel-electric vessels can deliver power to propellers through multiple pathways, such as diesel electro-mechanical propulsion systems, to reduce fuel by eliminating the need to run large main engines when vessel power demand is low (standby or low speed transit modes).[216] Diesel-electric tugboats could achieve about 15 percent fuel efficiency enhancement over their conventional counterparts;
- Starting in 2026, all new excursion vessels are required to be plug-in hybrid vessels that are capable of deriving 30 percent or more of combined propulsion and auxiliary power from a zero-emission tailpipe emission source;
- Starting in 2028, all new and in-use short run ferries are required to be zero-emission.

Figure 48 shows NOx emissions from CHC under the current regulatory concepts.[217] As noted in CARB's March 5, 2020 workshop, emissions under the new baseline emissions inventory are much higher than those estimated previously for the 2016 State SIP Strategy. As a result, the NOx emission reductions from the 2016 SIP baseline under the rule concepts are minimal and therefore more aggressive actions need to be taken in order to achieve the NOx reductions needed to meet the State's air quality goals.

[216] Enhanced Efficiency Diesel-Electric Vessels have been built today in the tugboat sector. By design, the vessels augment mechanical propulsion with auxiliary diesel electric generators using a power take-in (PTI) system to maximize the time diesel engines are operating in their most efficient load range (e.g. typically 80 to 90 percent of maximum rated power).

[217] *https://ww2.arb.ca.gov/resources/documents/public-webinar-notice-march-5-2020*

Figure 48 - South Coast NOx Emissions from CHC: Regulatory Proposal

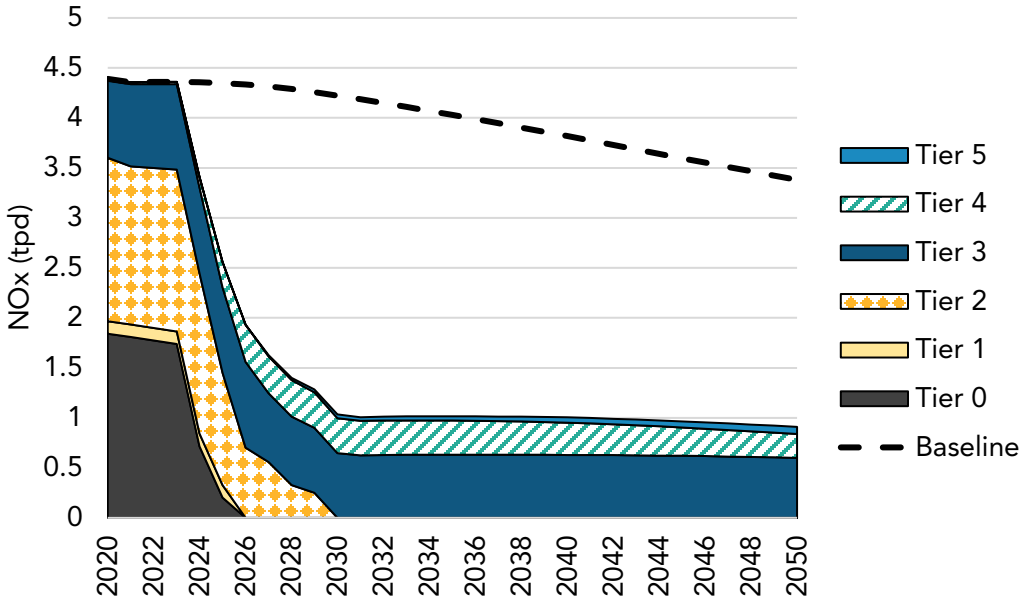


Mobile Source Strategy Scenario

For the 2020 MSS, staff developed a scenario which assumes introduction of Tier 4 and Tier 5 standards with DPF requirements for all CHC in 2024 and 2027, respectively. The scenario also assumes that commercial fishing vessels would no longer be exempted from the emission performance requirements. Current Tier 4 standard only applies to new vessels over 600 kW. This scenario would require Tier 4 engines for all vessel types. Under this scenario, staff assumed a Tier 4 standard which would impose a NOx emission standard of 1.04 g/bhp-hr (three to four times lower than the current Tier 3 levels); and a PM emission standard of 0.027 g/bhp-hr (two to seven times lower than current Tier 3 levels). Also, staff assumed a Tier 5 standard with NOx emissions of 0.20 g/bhp-hr and PM emissions of 0.010 g/bhp-hr. In this scenario, staff assumed that by 2030, all new and in-use excursion vessels would be plug-in hybrid, all new tugboats would be diesel-electric, and 20 percent of all ferries would be zero-emission.

Figure 49 shows NOx emission projections from CHC in the South Coast Air Basin under the 2020 MSS Scenario. As shown, the scenario can achieve over 3 tpd of NOx emissions reduction in 2031, significantly more than is estimated under the current regulatory concept.

Figure 49 - South Coast NOx Emissions from CHC: MSS Scenario

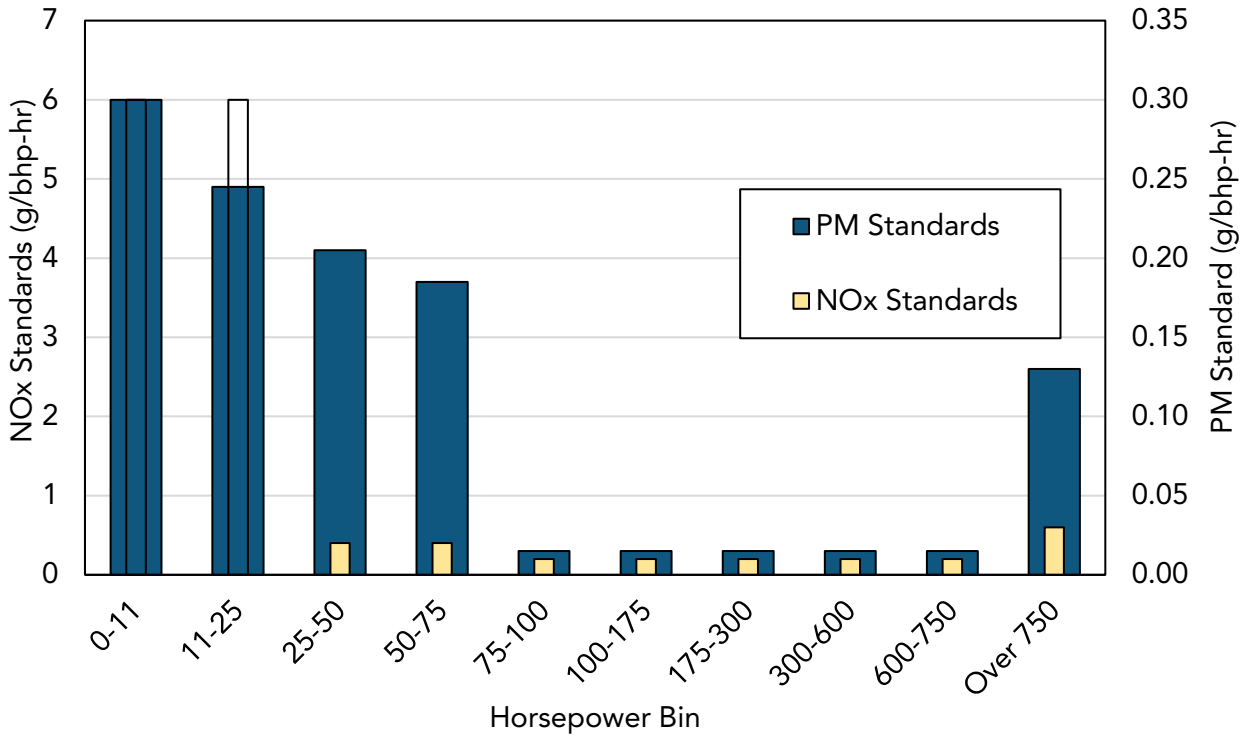


Cleaner and More-Efficient Off-Road Diesel Technology

Cleaner Diesel Technology

The last emissions standards for off-road diesel equipment (Tier 4 Interim and Final standards) were established in May 2004 by U.S. EPA, and took effect starting in 2008 with full implementation in 2015. These standards are shown below in Figure 50. From 75 to 750 horsepower, the standards are approximately equivalent to the 2010 on-road heavy-duty truck emission standards. However, technical challenges in lower and higher horsepower applications created barriers to SCR and DPF requirements, leaving NOx emissions standards in these horsepower bins only slightly below Tier 1 standards in the 50 to 75 horsepower bin, and exactly the same for the 0 to 50 horsepower groups.

Figure 50 - Tier 4 Final Off-Road Diesel Standards for NOx and PM[218]

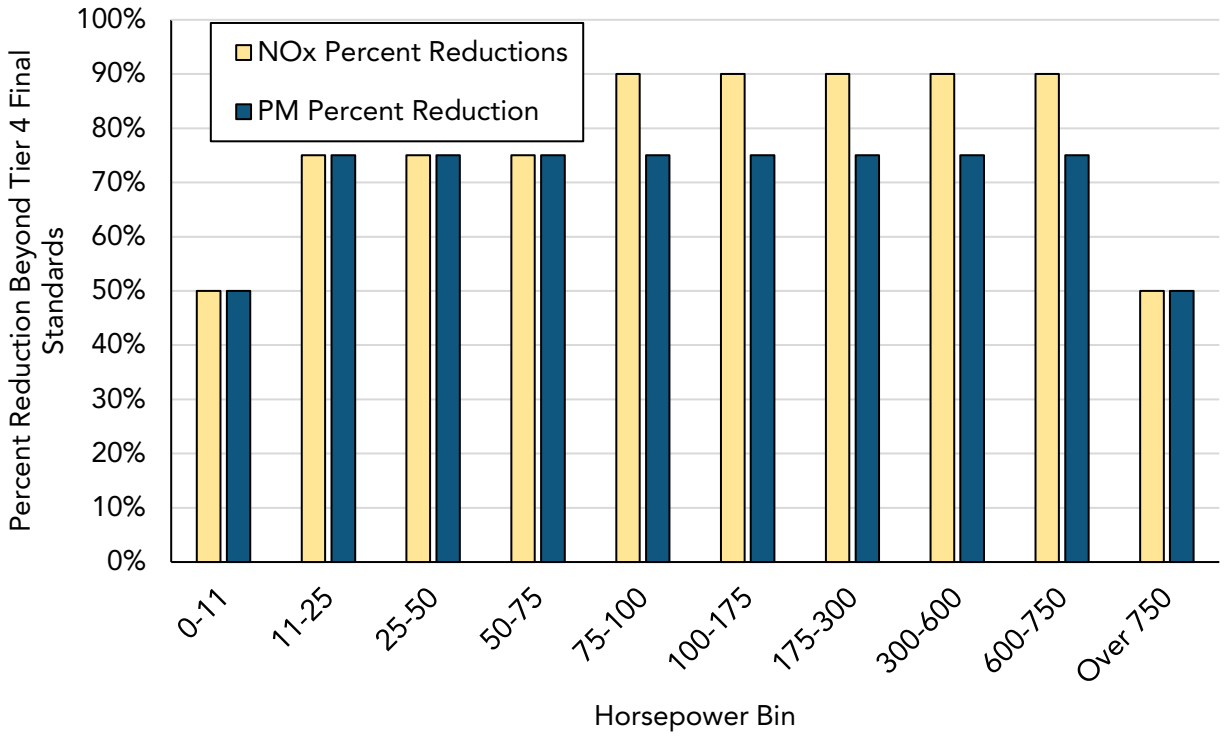


Technology demonstrations for SCR and DPF systems in the last 16 years (in particular the last three years) have shown that significant additional reductions are feasible for off-road engines. Again, the 75 to 750 horsepower groups show the greatest potential for reductions with up to 90 percent NOx reductions below Tier 4 Final as potentially feasible. However,

[218] The less stringent PM standard for <11 hp engines was effective until 2010. Tier 4 HC and NOx are a combined standard for < 75 hp engines.

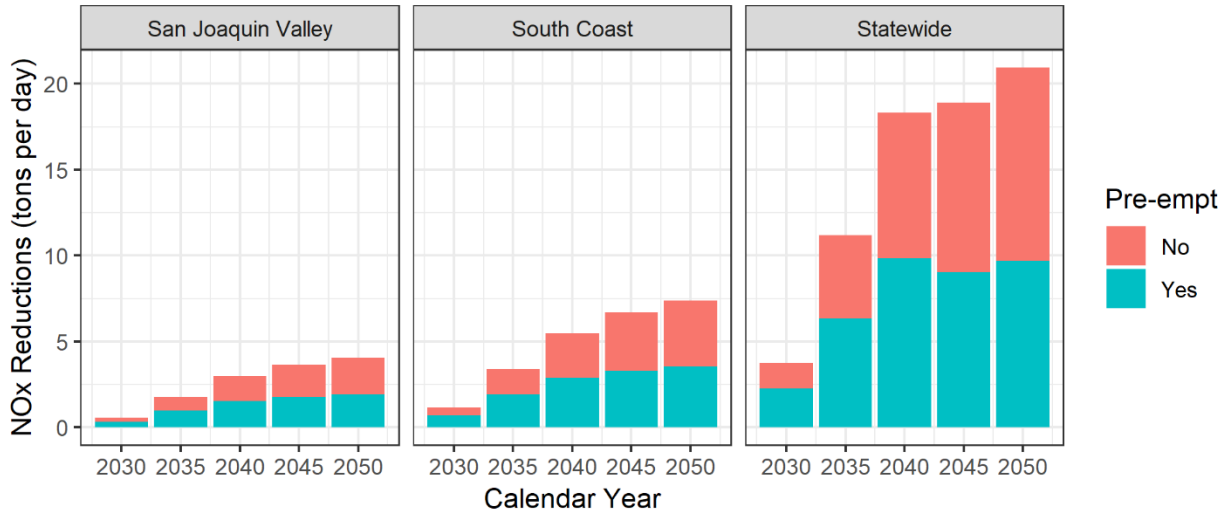
under 75 horsepower, there seems to be significant potential for 50 to 75 percent NOx and PM reductions. This would effectively be the first real NOx reduction requirements for equipment under 25 horsepower, and the most significant PM reduction requirements for equipment under 75 horsepower of all off-road engine standards. The reduction beyond the Tier 4 Final standards is shown below in Figure 51, as the percent reduction from the existing standards.

Figure 51 - Potential NOx and PM Emission Standard Reductions from Tier V Standards



The Tier 5 standards could be implemented as early as 2028 for non-federally preempt equipment, and possibly in 2030 for preempt equipment. While these standards would improve benefits seen from incentive and regulations that accelerate turnover, they would also have a significant positive impact solely due to natural turnover of equipment as shown below in Figure 52, providing up to 18 tpd NOx benefits statewide in 2040.

Figure 52 - Off-Road NOx Emissions Benefits from Tier 5



On-board diagnostics for Off-road

OBD systems are self-diagnostic systems incorporated into a vehicle's on-board computer. They are comprised mainly of software designed to detect emission-control system malfunctions as they occur. This is done by monitoring virtually every component and system that can cause increases in emissions. The OBD system continuously works in the background during vehicle operation to monitor emission-related components and alerts the vehicle operator of detected malfunctions by illuminating the malfunction indicator light (MIL) on the vehicle's instrument panel. Additionally, the OBD system stores important information, including identification of the faulty component or system and the nature of the fault, which allows for quicker diagnosis and proper repair of the problem by technicians. This helps vehicle owners experience less expensive repairs, and promotes repairs being done correctly the first time. OBD systems have also become the basis for emission inspection programs in California and throughout the nation. For light-duty vehicles, all 2000 and newer model year vehicles are inspected nearly exclusively by accessing the OBD system to verify that no emission-related faults are present. For heavy-duty, research is still ongoing to develop such a program, but it is likely that OBD information will play a vital role in the inspection process.

The first generation of OBD systems intended for light- and medium-duty vehicles with three way catalysts and feedback control (referred to as OBD I) was implemented by CARB in 1988, and required monitoring of only a few of the emission-related components on the vehicle (CARB, 1985). In 1989, CARB adopted regulations requiring a second generation of OBD systems (referred to as OBD II) that standardized the system and addressed the shortcomings of the OBD I requirements. OBD II required all 1996 and newer passenger cars, light-duty trucks, and medium-duty vehicles and engines to be equipped with OBD II systems (CARB, 1989).

In 2004, CARB adopted regulations requiring diagnostic systems for heavy-duty vehicles and engines (i.e., vehicles with a GVWR greater than 14,000 pounds). CARB first adopted the Engine Manufacturer Diagnostic (EMD) regulation, which required manufacturers of heavy-duty engines and vehicles to implement diagnostic systems on all 2007 and subsequent MY on-road heavy-duty engines. The EMD regulations were much less comprehensive than the OBD II regulations and were intended for heavy-duty manufacturers to achieve a minimum level of diagnostic capability (CARB, 2004). In 2005, CARB adopted heavy-duty OBD requirements for 2010 and subsequent MY heavy-duty engines and vehicles, which phased in with full implementation required for the 2013 MY (CARB, 2005a).

The OBD system is required to monitor components that can cause emission increases and detect a fault when emissions exceed the emission standards by a certain amount. Emission "thresholds" for these faults are typically either a multiple of the exhaust emission standard (e.g., 2.0 times the applicable standard) or an additive value above the standards (e.g., 0.2 g/bhp-hr above the applicable standards).

OBD systems have been instrumental in reducing emissions for on-road light-, medium-, and heavy-duty vehicles and engines, and the opportunity now exists to expand this benefit to off-road equipment and engines. Concurrent with consideration of Tier 5 emission standards, CARB staff would consider proposing initial off-road OBD requirements, including standardized engine control unit communications and interfaces, threshold monitoring, and recording of emissions history information from on-board NOx sensors (as is done for on-road vehicles via the REAL requirements).

Efficiency Improvement

Off-road diesel equipment is becoming an increasingly important contributor to statewide GHG emissions. By 2045, off-road diesel equipment in California will consume approximately 2.1 billion gallons of diesel fuel, which is equivalent to the annual diesel consumption of approximately 490,000 heavy-duty trucks in California. While the recent state and federal regulatory actions such as national Phase 2 greenhouse gas emissions standards for medium and heavy-duty trucks as well as California's ACT regulation will significantly improve the efficiency of the on-road heavy-duty sector, off-road equipment sectors have generally lagged in hybridization and electrification. In part, this is due to technology and infrastructure hurdles, and in part due to the difficulty of creating targets for fuel efficiency in off-road sectors that lack a universal, objective metric such as miles per gallon. Despite these difficulties, there are already numerous commercial hybrid vehicles available in the construction, mining, and industrial equipment sectors. It is notable that these equipment types were produced with no emissions requirements and demonstrate that hybridization technology is viable for many types of off-road equipment and desirable for end users in many applications. Currently, commercial and demonstration off-road hybrid projects show a range of 14 to 60 percent fuel savings over traditional diesel engines, with an average of 25 percent.

Separately, marine and locomotive sectors do not yet have many commercial applications available but have made significant progress in demonstration projects. Marine engines used in auxiliary engines for ocean going vessels, as well as main engines for some commercial harbor craft have shown potential for hydrogen as a fuel source. Locomotives have shown significant progress in demonstration projects including battery-electric assist, with up to 70 percent fuel savings. In terms of electrification, San Bernardino County Transit Authority is planning to begin revenue service with a single fuel cell multiple unit (MU) in early 2020 and other passenger rail operators have been progressive in adopting the cleanest locomotives, and initiated various efforts to transition to ZE locomotives. Additionally, BNSF will demo a battery-electric locomotive (BEL) from Stockton to Barstow in early 2021. Potentially, large percentage of passenger locomotives can be converted to fuel cell or electrified, but the overall fuel consumption of passenger locomotives is much smaller than freight locomotives. BEL increases efficiency by 10 to 15 percent, but stores little energy, so fuel use converted from diesel to electric will be small. Switchers that account for about 10 percent of freight diesel use could also be converted to electric, but it is unlikely any significant portion of freight line-haul locomotives will be converted to electric (connected to the grid). The current cleanest locomotive (Tier 4) does not have efficiency benefits compared to older locomotives. Tier 5 locomotives, if the standards are adopted, are expected to have 10 to 25 percent efficiency improvement. BELs are expected to provide 10 to 15 percent efficiency improvement to the diesel locomotives, but Tier 5 and BEL improvements will not be accumulative. If freight railroads begin using Tier 5 or hybridized locomotives in 2030, 25 percent efficiency improvement could be achieved.

In this 2020 MSS, staff assumed a scenario where there will be a significant efficiency improvement in off-road diesel engines sold in California beginning in 2028, with some early-action incentive-based penetration in 2025. The overall goal would be a 12 percent reduction in GHG emissions by 2030, and a 30 percent reduction by 2040. Detailed modeling assumptions (e.g., GHG emission benefits and target population of the off-road diesel engine sectors) are described in Table 16. Zero-emission and hybridization requirements could be incorporated into off-road Tier 5 standards for off-road equipment. For Locomotives and marine vessels, such requirements could be incorporated with locomotive Tier 5 standards and marine Tier 4 standards, which requires coordination with U.S. EPA and the IMO. Technology penetration rates for each off-road category will vary depending on their suitability for hybridization or electrification, as well as the rate of equipment turnover – including natural and accelerated turnover by incentives and/or regulatory actions.

Figure 53 demonstrates the potential fuel saving resulting from this scenario. As shown, the scenario will reduce GHG emissions by 25 and 26 percent from the baseline in 2040 and 2050, respectively.

The wide-scale electrification and hybridization transformation will result in a fuel saving of about 0.78 billion gallons of diesel and 0.23 billion gallons of gasoline per year in 2045, which translates to a WTW GHG reductions of approximately 10.45 MMT per year (Figure 54). Also by 2050, the WTW GHG emissions from off-road will be 44 percent below the baseline.

Table 16 – Modeling Parameters for Off-Road Diesel Engine Efficiency Improvement

Sector	Percent fuel savings	Target population of the sector	Penetration Rate Modeled
OGV	▪ 25% on average ▪ Renewable H2 production shows a 99% WTW NOx reduction & 51% reduction with non-renewable method	▪ Hybrid auxiliary engines and boilers → 32% of total fuel consumption ▪ Including car carrier and Roro types also → 35%	▪ Market share increases at 2% annually from 2028
Locomotive	▪ Approx. 25% efficiency improvement	▪ Class I Line-haul, Switcher, Passenger locomotives → 98% of total fuel consumption	▪ Market share increases at 2% annually from 2028
Construction & Mining & Industrial	▪ Approx. 25% on average (up to 70% depending on application type)	▪ 66% of the sector fuel consumption defined by the horsepower range 75 ~ 600hp	▪ Market share increases at 10% annually from 2024 to 2033
Agriculture	▪ Approx. 25% efficiency improvement	▪ 41% of the sector fuel consumption defined by the horsepower range 75 ~ 600hp	▪ Market share increases at 7% annually from 2028
Portable Equipment (PE)	▪ Requires additional demonstrations, but hydrogen has significant potential	-	-
Commercial Harbor Craft (CHC)	▪ Approx. 25% on average	▪ Tug, Ferry, and Excursion populations → 53% of the total sector fuel consumption	▪ Market share increases at 10% annually from 2028 to 2037
Transportation Refrigerator Unit (TRU)	▪ Zero-emission (MSS Scenario)	▪ 100% of the total sector fuel consumption	▪ Market share of E-TRU increases from 10% in 2024 to 100% in 2034
Cargo Handling Equipment (CHE)	▪ Zero-emission (MSS Scenario)	▪ 100% of the total sector fuel consumption	▪ Market share of E-CHE increases from 8% in 2026 to 100% by 2037

Figure 53 - Technology Shifts in Diesel Fuel Use by Sector

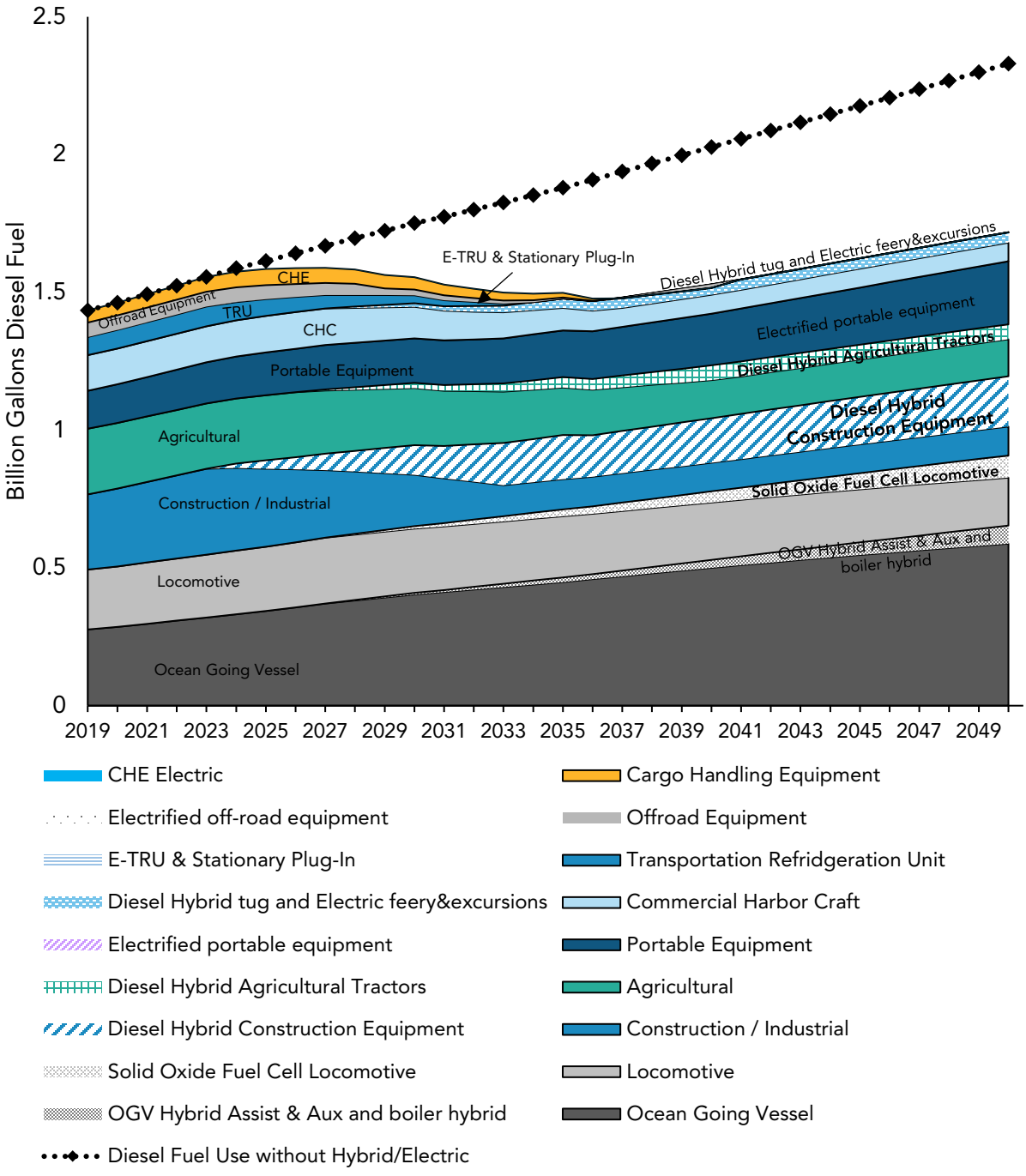
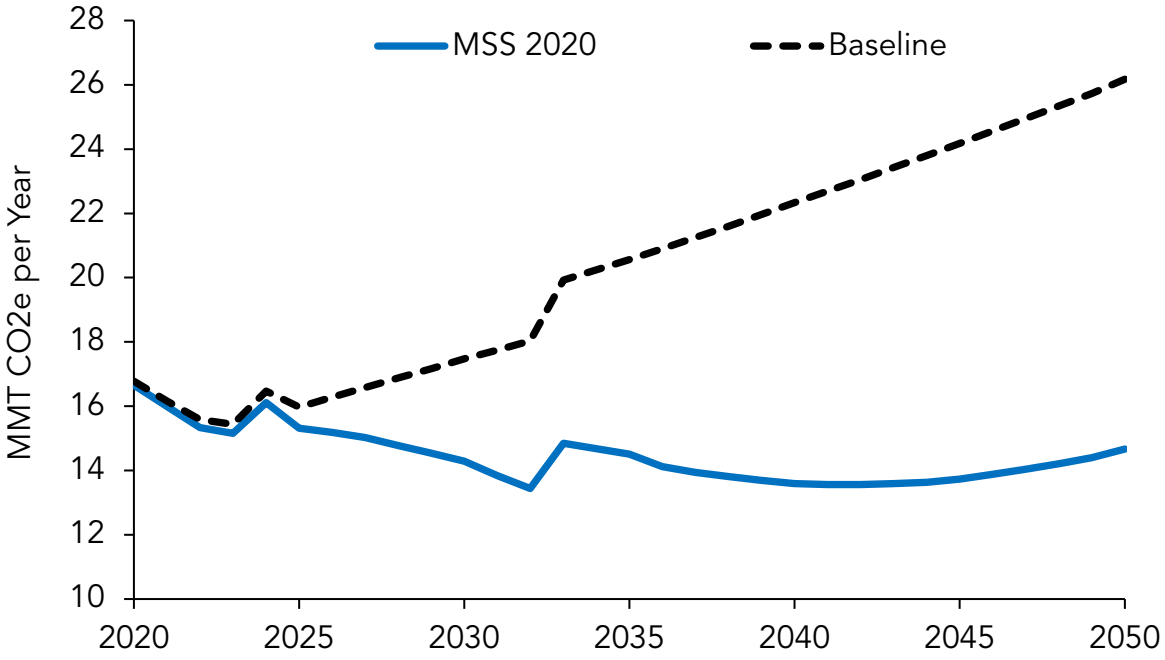


Figure 54 - Statewide Well-to-Wheel GHG Emissions from Off-road Sector[220]



[220] The use of avoided methane emissions from dairy biogas in this scenario accounts for approximately 0.44% of the cumulative WTW GHG benefits from 2020 to 2045.

Summary of Mobile Source Scenarios

A summary of statewide fuel use and NOx emissions reductions from the 2020 Mobile Source Strategy scenarios is provided in Table 17. As shown, the scenarios in the 2020 MSS would achieve an overall statewide NOx emissions reduction of 531 tpd and 592 tpd in 2031 and 2037, respectively, which are equivalent to 48 and 55 percent reduction from projected baseline NOx emissions in those years.[219] In addition, because of these strategies, mobile source NOx emissions in 2031 and 2037 will be 75 and 82 percent below the 2017 baseline. The scenarios will also reduce mobile source fuel consumption by 9.5 billion gallons of gasoline equivalent (GGE) and 3.0 billion gallons of diesel equivalent (DGE) in 2045. This equates to a WTW GHG emissions reduction of approximately 94 MMT CO2e in 2045. In terms of on-road transportation (i.e., on-road light- and heavy-duty vehicles), by 2045, the scenarios would achieve a WTW GHG emissions reductions of approximately 83 percent from the 2020 baseline.

Table 17 - Statewide NOx Emissions Reductions and Fuel Use from the 2020 MSS Scenarios

Category		Scenario Assumptions	Statewide NOx Reduction (tpd) 2031	2037	Statewide Fuel Use Reduction 2045
On Road	Light-Duty Vehicles	• 70% ZEV + PHEV sales in 2030 • 100% ZEV + PHEV sales in 2035 • 7.9 M ZEV by 2030 • 27.9 M ZEV+PHEV by 2045	4.2	13.8	8.8 B GGE 0.1 B DGE
	VMT	• ~15% reduction in statewide light-duty VMT by 2050 compared to business as usual			
	On-Road Motorcycles	• Alignment with EU5 standard for MY2024+ motorcycles • 100% ZEM sales in 2035 and onward	0.73	1.32	0.028 B GGE
	Medium-Duty Vehicles	• 100% ZEV sales starting 2035	0.25	1.11	0.15 B DGE 0.26 B GGE

[219] According to 2016 South Coast AQMP, the preliminary projections, based upon ozone "isopleths" developed for the 2031 emission scenarios indicate that 2037 Basin NOx carrying capacity to meet the 70 ppb standard could be as low as 75 tpd. This is additional 62 percent NOx reduction beyond the projected 2037 baseline and 25 tpd of additional NOx emission reductions between 2031 and 2037.

Category		Scenario Assumptions	Statewide NOx Reduction (tpd) 2031	2037	Statewide Fuel Use Reduction 2045
On-Road	Heavy-Duty Vehicles	• Reflect Heavy-Duty Omnibus, ACT, and Heavy-Duty I/M starting in 2024, and federal 0.02 g/bhp-hr starting in 2027 • 100% of model year 2035 and newer vehicles registered in California will be ZEV • Accelerated turnover of older trucks	141	195	1.9 B DGE 0.2 B GGE
Off Road	Off-Road Efficiency Improvement[220]	• Zero-emissions and hybridization where feasible with the goal of 12 percent reduction in GHG by 2030, and 30 percent by 2040	N/A	N/A	0.54 B DGE
	Off-Road Tier V Standard	• Tier 5 being introduced starting in 2028-2030 • 50 – 90% NOx reduction from current Tier 4f standard	4.7	14.1	N/A
	Rail	• 100% of replaced locomotive will be Tier 4 • Remanufacturing limit • Tier 5 being introduced in 2028	65	52	N/A
	Ocean Going Vessels *(out to 100 nm)*	• 100% of Tier 0/1/2 visits are phased out by 2031 • Tier 3 visits begin in 2025 (begin replacing all Tier 0-2) • Tier 4 visits begin in 2028 (no additional Tier 3 visits)	263	258	N/A
	Construction	• Full turnover of Tier 0/1/2 to Tier 4f by 2033	7.5	5.4	N/A
	SORE	• All non-federally preempt SORE sales except for generators will be zero-emission by 2024 (2028 for generators)	7.9	11.8	0.24 B GGE

[220] Excluding categories such as CHE and TRU that are going to zero-emission in other scenarios. This is done to avoid double counting

Category		Scenario Assumptions	Statewide NOx Reduction (tpd) 2031	2037	Statewide Fuel Use Reduction 2045
Off-Road	Aircraft	• 25 percent derate during take-off • 40 percent reduction in Taxi time • Single engine taxiing • 40 percent reduction in APU usage	12.5	13.3	N/A
	Transport Refrigeration Units	• Accelerated penetration of electric TRU (from 10% in 2024 to 100% in 2034)	12.2	16.7	0.11 B DGE
	Commercial Harbor Craft	• All vessels (including commercial fishing) being Tier 4/5 by 2031 • Introduction of Plug-in hybrid for excursions and diesel-electric for tugs by 2030	11.6	10.8	0.027 B DGE
	Cargo Handling Equipment	• Begin transition to full electric operation beginning in 2026 (accelerated turnover)	1.1	1.6	0.12 B DGE
	Agriculture	• An incentive based concept consistent with the 2018 SJV SIP	N/A	N/A	NYQ
	Airport Ground Support Equipment	• Full electrification transition from 2024-2034	1.1	1.2	0.035 B DGE
	Forklifts	• Transition to zero-emission technology starting in 2025 with fully electric fleet by 2034	6.9	8.6	0.016 B DGE
	Recreational Watercraft	• New THC + NOx standards of 40 and 70 percent below current levels • Electrification of small outboard and PWC engines	0.3	2.2	0.02 B GGE
Total Statewide Emissions/Fuel Use Reductions			**531**	**592**	**9.5 B GGE 3.0 B DGE**

DGE: Diesel Gallons Equivalent
GGE: Gasoline Gallons Equivalent

The 2020 MSS scenarios illustrate that even with extremely aggressive electrification, accelerated turnover, coupled with aggressive VMT reductions and fuel decarbonization,[221] the mobile source sector alone cannot become carbon neutral by 2045. This emphasized the importance of CDR strategies such as mechanical and land-based sequestration. This

[221] Fuel decarbonization refers to a group of strategies, including SB 100 electric grid requirements, liquid fuel carbon reductions through the Low Carbon Fuel Standard (LCFS), and other actions.

economy-wide approach that includes consideration of CDR is introduced in a recent report by Energy and Environmental Economics (E3). [222] The E3 report provides insights into the types of economy-wide transformation that will be necessary to achieve carbon neutrality by mid-century.

CARB staff will continue to develop the concepts described in Table 17 in order to translate them into measures that will be included in the State SIP Strategy being developed for the 70 ppb 8-hour ozone standard, along with the 2022 Scoping Plan Update, and other CARB planning documents to be released in the coming years.

[222] Achieving Carbon Neutrality in California: PATHWAYS Scenarios Developed for the California Air Resources Board *https://ww2.arb.ca.gov/sites/default/files/2020-08/e3_cn_draft_report_aug2020.pdf*

Appendix A - Upstream Energy Emission Factors for Scenario Modeling

Background

As part of the Mobile Source Strategy (MSS) both the emissions associated with the operation of the vehicles (i.e. tank-to-wheel emissions, TTW) and upstream energy production (i.e. well-to-tank emissions, WTT) are assessed. Well-to-tank (WTT) emissions include direct emissions resulting from the processes required for producing, refining and delivering energy. In order to estimate WTT emissions, staff developed WTT emission factors for each of the five transportation fuel types in the MSS, including gasoline, diesel, electricity, hydrogen, and compressed natural gas (CNG). The materials developed in this document are for informational purposes. Assumptions and forecasts for transportation fuels will be revisited in the 2022 Scoping Plan Update.

This technical appendix provides an overview of the methods and data used to estimate upstream emission factors. You can find a more detailed description of these methods on the Vision Scenario Planning webpage.[223]

Scope and Boundary

For the purposes of the 2020 Mobile Source strategy, the scope of the upstream emissions analysis is consistent with current emissions inventory methodologies.[224] For greenhouse gas (GHG) emissions, system scope refers to upstream life-cycle phases of fuel production. AB 32 defines statewide GHG emissions as the total annual emissions of greenhouse gases occurring in California, including all emissions of greenhouse gases from the generation of electricity delivered to and consumed in California.[225] For criteria emissions, only in-state emissions are included. Table 18 lists the system scope and the geographic boundary of the WTT emissions covered in the analysis. The system scope for most of the fuel blendstocks include feedstock and fuel production. For electricity, system loss from transmission and electric vehicle charging is also considered.

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[223] CARB, Vision Scenario Planning webpage. Available: *https://ww2.arb.ca.gov/resources/documents/vision-scenario-planning*

[224] CARB GHG emissions inventory: *https://ww2.arb.ca.gov/ghg-inventory-data*

[225] Nunez, Chapter 488, Statutes of 2006. *https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=200520060AB32*

Table 18 – System Scope and Geographic Boundary by Fuel Type

Fuel Type	Blendstocks	System Scope	Geographic Boundary
GAS	California Reformulated Gasoline Blendstock for Oxygenate Blending (CARBOB)	Crude extraction and transportation (tanker truck and ocean-going-vessel), refinery, fuel transportation (heavy-duty trucks), and evaporative losses of fuel marketing	GHG/Criteria Emission: in-state only
	Conventional ETOH	Feedstock and fuel production	GHG/Criteria Emission: in-state only
	Cellulosic ETOH	Feedstock and fuel production	GHG/Criteria Emission: in-state only
DSL	CARBOB-Diesel	Crude extraction and transportation, refinery, fuel transportation, and market loss	GHG/Criteria Emission: in-state only
	Biodiesel (BD)	Feedstock and fuel production	GHG/Criteria Emission: in-state only
	Renewable Diesel (RD)	Feedstock and fuel production	GHG/Criteria Emission: in-state only
ELE	CA-Grid Electricity	Feedstock production (natural gas recovery), power generation, and system loss for transmission (7%) and charging (15%)	GHG: emissions for in-state generation and import Criteria emission: in-state emission only
HYD	Hydrogen via steam methane reforming process (SMR)	Feedstock and fuel production	GHG/Criteria Emission: in-state only
	Renewable Hydrogen (via Electrolysis)	Feedstock and fuel production	GHG/Criteria Emission: in-state only
CNG	Renewable natural gas (RNG) from landfill gas (LFG)	Feedstock and fuel production	GHG/Criteria Emission: in-state only

Fuel Type	Blendstocks	System Scope	Geographic Boundary
	RNG from dairy biogas	Feedstock and fuel production	GHG/Criteria Emission: in-state only

Methodology

Upstream WTT emission factors for each fuel type (EF_f^{WTT}) are determined by the mix of blendstocks, the blendstock WTT emission factor, and the in-state production ratio, as follows:

$$EF_f^{WTT} = \sum_b (M_{fb} \times EF_{fb} \times R_{fb}) \text{(Equation 1)}$$

where:

EF_f^{WTT} represents the WTT emission factor for each fuel type (*f*)

M_{fb} is the mix (%) for the blendstock (*b*) in the *f* fuel type

EF_{fb} is the WTT emission factor for the blendstock or fuel pathway (b) in the *f* fuel type

R_{fb} is the in-state production ratio[226] of emissions for the blendstock (b) in the *f* fuel type

Blendstock Mix

Each fuel type is comprised of different blendstocks, and it is these blendstocks that determine the emissions intensity of a given fuel. For example, the blendstocks for diesel fuel consumed in California (e.g. B5, B20…etc.) include fossil ultra-low sulfur diesel (ULSD), biodiesel (BD), and renewable diesel (RD). Blendstock mix (M_{fb}) is critical to formulate the WTT emission factor of a fuel type and may vary given changes in supply and demand.

The following assumptions are used for determining blendstock mix.

Liquid Fuels (DSL and GAS)

- LCFS compliance scenario (low demand and low ZEV with 20 percent CI reduction)[227] is used for biofuel supply including ethanol, biodiesel, and renewable diesel through

[226] Please refer to Table 19 for the emissions scope by fuel type. In most cases only the in-state contribution of a fuel's upstream emissions are counted, with the exception of electricity.
[227] CARB, 2018. 2018 Amendments to the LCFS and ADF Regulations, Illustrative Compliance Scenario Calculator. https://www.arb.ca.gov/fuels/lcfs/2018-0815_illustrative_compliance_scenario_calc.xlsx?_ga=2.155021808.917945968.1597354480-1389483658.1577128071

2030. After 2030, BD and RD volumes are assumed to be constant at 500 mm gallon and 1.1 billion gallons annually respectively.
- The supply of cellulosic ethanol (ETOH) after 2030 is held constant at 2030 levels (i.e. 125 mm gallon/yr). The ethanol fraction in California reformulated gasoline (CaRFG) (i.e. E10) is consistent with the LCFS compliance scenario.

Electricity (ELE)

- Only grid electricity is considered, while behind-the-meter renewable power for EV chargers is excluded.
- Generation mix (including contracted imports) and unspecified import information is obtained from the 2019 Renewable Energy Solutions (RESOLVE)[228] model outputs for the preliminary scenario run, "46MMT base 20191001 2045", which is constrained by the SB100 target in 2045.[229]

Hydrogen (HYD)

- The renewable hydrogen supply in the BAU scenario is assumed to be fixed at 35 percent after 2025 based on SB1505.[230]
- The hydrogen supply in the scenario is assumed to be 60 percent by 2030 and 100 percent by 2045 according to the proposed SB662.[231]
- It is also assumed 100 percent electrolytic hydrogen in California will utilize curtailed renewable electricity as utilities procure more zero GHG generation to meet the Renewable Portfolio Standard (RPS).

Compressed Natural Gas (CNG)

- CNG is assumed to be 100 percent RNG starting in 2022, which is projected based on historical LCFS reporting data.[232] The supply of RNG from dairy biogas in the California transportation fuel market reflects the LCFS compliance scenario (low demand and low ZEV with 20 percent CI reduction), which is 24 percent of NG demand in 2030,

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[228] California Public Utilities Commission (CPUC), 2019. RESOLVE Model and Preliminary Results used for 2019 IRP Portfolio Development. *https://www.cpuc.ca.gov/General.aspx?id=6442462824*

[229] SB 100 requires that 100 percent of retails sales of electricity come from Renewables Portfolio Standard-eligible and zero-carbon resources by 2045. SB 100 does not define zero-carbon resources. An interagency effort is underway to evaluate potential paths to achieving the 2045 goal, and this process evaluates electricity generation technologies that could be eligible zero-carbon resources and will model potential resource mix scenarios for 2045. Refer to https://www.energy.ca.gov/sb100 for more information about this process.

[230] Lowenthal, Chapter 877, Statutes of 2006.
https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=200520060SB1505

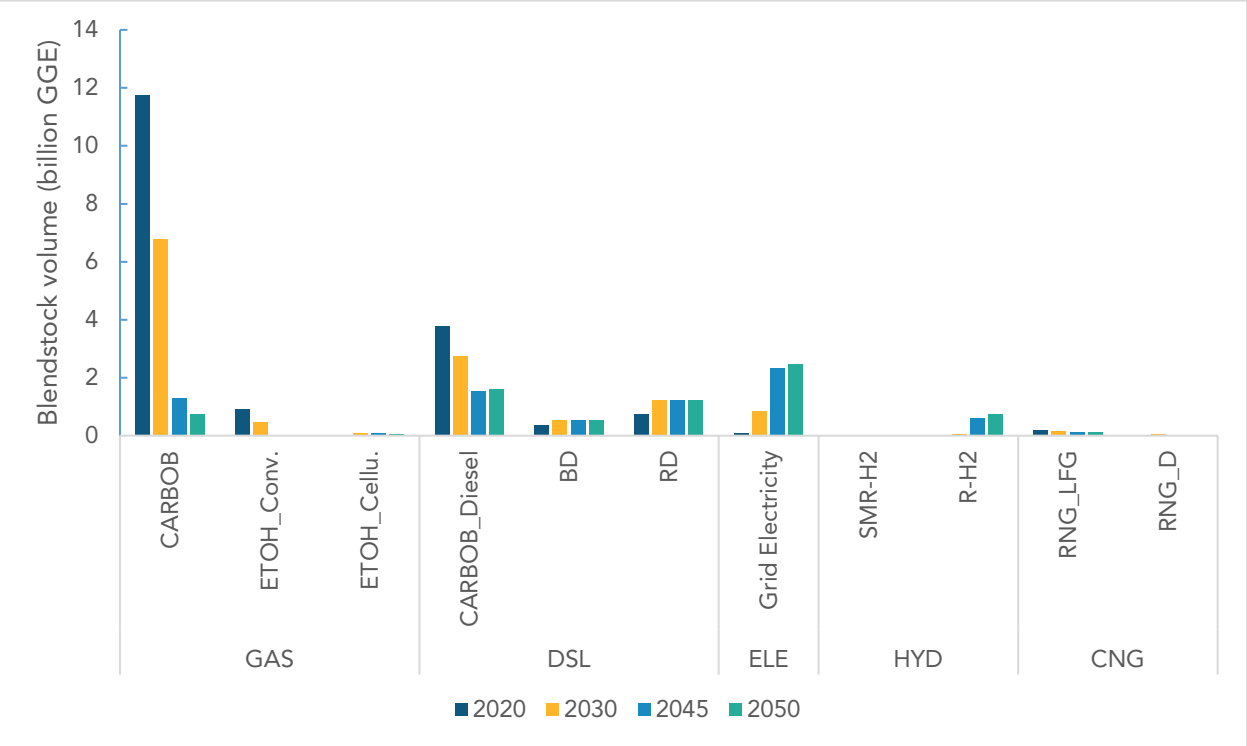
[231] Archuleta, SB-662 Energy: transportation sector: hydrogen.(2019-2020).
http://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201920200SB662

[232] CARB, LCFS Quarterly Data Spreadsheet.
https://ww3.arb.ca.gov/fuels/lcfs/dashboard/quarterlysummary/quarterlysummary_103020.xlsx

(76.56 mm DGE). Other feedstock supplying RNG, including landfill gas (LFG) and organic waste diversion are also considered in this analysis.

Figure 55 below provides the resulting blendstock volumes for the five fuel types in the MSS Scenario.

Figure 55 - Blendstock Volume by Fuel Type



In-State Production Ratio

As discussed earlier, AB 32 defines statewide GHG emissions as the total annual GHG emissions in the state, including all GHG emissions from the generation of electricity delivered to and consumed in California.[233] Therefore, a necessary step for estimating WTT emissions is identifying the in-state production ratio for each blendstock.

The in-state production ratio for any given blendstock is calculated by dividing the in-state supply by the fuel demand and blend-mix. For example, while almost finished fuel products consumed in California are blended in-state, the majority of blendstocks or feedstock are produced and imported from other places.

[233] Nunez, Chapter 488, Statutes of 2006.
https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=200520060AB32

CaRFG is blended by ethanol and CARBOB, with 100 percent of CARBOB refined in-state from mostly imported crude oil, and nearly 87 percent of ethanol coming from outside California.[234]

For crude oil, ethanol, and biodiesel the future in-state supply capacity is assumed to be set to 2019 levels, with 2019 capacity data from LCFS reporting data[235] and US Energy Information Administration (US EIA).[236] For RD, 100 percent in-state supply is assumed.[237] Electricity, when used as a transportation fuel, is assumed to be produced in California, while half of hydrogen demand is assumed to be produced in California starting in 2025.[238] CNG is assumed to be 100 percent RNG by 2022 from various feedstocks including dairy manure, landfill gas, and organic waste diversion with a significant portion produced within California.[239] It is also assumed that 10 percent of fossil natural gas produced in the State. Table 19 summarizes the assumptions for blendstocks or fuel pathways applied to all scenarios including BAU.

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[234] CARB, LCFS Dashboard: Share of Liquid Biofuels Produced In-State by Volume 2019. *http://ww3.arb.ca.gov/fuels/lcfs/dashboard/figure10_053120.xlsx;*

[235] CARB, LCFS Dashboard: Major Sources of Crude Supplied to California 2019. *http://ww3.arb.ca.gov/fuels/lcfs/dashboard/crude.xlsx;* CARB, LCFS Dashboard: Share of Liquid Biofuels Produced In-State by Volume 2019. *http://ww3.arb.ca.gov/fuels/lcfs/dashboard/figure10_053120.xlsx.*

[236] US EIA, 2019. U.S. Fuel Ethanol Plant Production Capacity. *https://www.eia.gov/petroleum/ethanolcapacity/index.php;* US EIA, 2020. Monthly Biodiesel Production Report. *https://www.eia.gov/biofuels/biodiesel/production/*

[237] Three refineries in California recently announced their plans for RD production/expansion. *https://adi-analytics.com/2020/02/10/regulations-to-drive-u-s-renewable-diesel-capacity-growth-through-2025/ https://www.mercurynews.com/2020/08/08/marathon-refinery-closure-could-signal-big-transition-for-area-refineries/#:~:text=Meanwhile%2C%20Marathon%20is%20exploring%20a,per%2Dday%20renewable%20diesel%20operation. https://www.mercurynews.com/2020/08/08/marathon-refinery-closure-could-signal-big-transition-for-area-refineries/#:~:text=Meanwhile%2C%20Marathon%20is%20exploring%20a,per%2Dday%20renewable%20diesel%20operation.*

[238] Air Liquide, 2019. Air Liquide committed to producing renewable hydrogen for the West Coast mobility market with new liquid hydrogen plant. *https://www.airliquide.com/united-states-america/air-liquide-committed-producing-renewable-hydrogen-west-coast-mobility-market*.

[239] In-state RNG production capacity considers a recent study. According to the study there will be 160 facilities in California which are capable of producing nearly 119 mm DGE RNG annually (including 43.56 mm DGE from dairy biogas) by January 1, 2024. Cliff Gladstein and Patrick Couch, Gladstein Neandross & Associates (GNA) (2020) An Assessment: California's In-state RNG Supply for Transportation 2020-2024. https://cdn.gladstein.org/pdfs/whitepapers/report-assesment-california-in-state-rng.pdf

Table 19 - In-State Production Ratios by Fuel Type and Blendstock

Fuel Type	Blendstocks/ Pathways	Assumptions	Data source
GAS	CARBOB	Import fraction of crude oil fixed at 2019 level (73%) and 100% CARBOB produced in-state	LCFS
	Conventional ETOH	Capped at 2019 level of CA supply from EIA (230 mm gallon/yr)	EIA
	Cellulosic ETOH	Capped at maximum in-state supply from LCFS data (1.4 mm gallon/yr)	LCFS
DSL	CARBOB-Diesel	Import fraction of crude oil fixed at 2019 level (73%) and 100% CARBOB produced in-state	LCFS
	Biodiesel (BD)	Capped at 2019 level of CA supply from EIA (85 mm gallon/yr)	EIA
	Renewable Diesel (RD)	100% RD produced in-state	Industrial News
ELE	CA-Grid Electricity	100% (AB 32 boundary)	AB 32[240]
HYD	Fossil SMR Hydrogen	50% produced in CA. The feedstock, fossil NG, is assumed 10% in-state produced.	Assumption
	Renewable Hydrogen (via Electrolysis)	50% produced via renewable power in CA	Assumption
CNG	RNG (LFG)	Capped at 2024 level of CA in-state capacity (75.44 mm DGE)	Study[241]
	RNG (Dairy biogas)	Capped at 2024 level of CA in-state capacity (43.56 mm DGE)	Study
	Fossil NG	10% fossil NG produced in State	Assumption

[240] *https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=200520060AB32*

[241] Air Liquide, 2019. Air Liquide committed to producing renewable hydrogen for the West Coast mobility market with new liquid hydrogen plant. *https://www.airliquide.com/united-states-america/air-liquide-committed-producing-renewable-hydrogen-west-coast-mobility-market*.

WTT EF for each Blendstock

WTT emission factors for each blendstock (EF_{fb}) are synthesized from a variety of sources and studies[242,243] as shown in Table 20 below. In general, the WTT GHG emission factors for each blendstock comes from the LCFS compliance scenario tool or average CI of current certified pathways, with the exception of CARBOB, electricity, and renewable hydrogen.

Upstream emissions for electricity are determined by generation mix and imports to the grid supplying California from the RESOLVE model. This annual generation mix data is then imported to CAGREET 3.0 to calculate the annual average emission factors, including emissions at power plants, natural gas extraction, processing, and delivery. Criteria emission factors for electricity generation are developed based on California Emission Inventory Development and Reporting System (CEIDARS), and applied to the total mix of generators located in California.

Hydrogen is assumed to be supplied from two sources, fossil hydrogen through SMR with fossil natural gas and electrolytic hydrogen using renewable power. The WTT GHG emission factor for SMR hydrogen includes emissions from hydrogen production processes and feedstock production (recovery of fossil natural gas). Criteria emission factors for SMR were developed based on CARB's CEIDARS database. Electrolytic hydrogen from renewable power is assumed to have an emission rate of zero.

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[242] Sun et al (2019) Criteria Air Pollutant and Greenhouse Gases Emissions from U.S. Refineries Allocated to Refinery Products, Environ. Sci. Technol. 2019, 53, 11, 6556–6569, DOI: *10.1021/acs.est.8b05870*

[243] D. L. Jones (2010) Potential Air Emission Impacts of Cellulosic Ethanol Production at Seven Demonstration Refineries in the United States, Journal of the Air & Waste Management Association, 60:9, 1118-1143, DOI: 10.3155/1047-3289.60.9.1118

Table 20 - Data Sources for Determining WTT EFs of Blendstocks

Fuel Type	Blendstocks/ Pathways	GHG EFs	Criteria EFs
GAS	CARBOB	*Crude Oil:* Oil Production Greenhouse gas Emissions Estimator (OPGEE) model data[244] *Refinery:* Argonne National Laboratory (ANL) update[245] *T/D:* Emission FACtors model (EMFAC) 2017[246]	*Crude Oil:* CAGREET3.0[247] Refinery: ANL update *T/D and marketing:* California Emission Projections and Analysis Model (CEPAM) database[248]
	Conventional ETOH	Compliance scenarios from LCFS rulemaking documents[249]	*Feedstock*: CAGREET3.0 *Fuel production:* CEIDARS
GAS	Cellulosic ETOH	Compliance scenarios from LCFS rulemaking documents[250]	*Feedstock*: CAGREET3.0 Fuel production: Literature[251]
DSL	CARBOB-Diesel	*Crude Oil:* OPGEE model *Refinery*: ANL update *T/D:* EMFAC	*Crude Oil:* CAGREET3.0 Refinery: ANL update T/D and marketing: CEPAM
	Biodiesel (BD)	Compliance scenario from LCFS rulemaking documents	*Feedstock:* CAGREET3.0 *Fuel production:* CAGREET3.0
	Renewable Diesel (RD)	Compliance scenario from LCFS rulemaking documents	*Feedstock*: CAGREET3.0 *Fuel production:* CAGREET3.0

[244] CARB, 2019. Calculation of 2019 Crude Average Carbon Intensity Value. *https://ww2.arb.ca.gov/sites/default/files/classic//fuels/lcfs/crude-oil/2019_crude_average_ci_value_final.pdf*

[245] ibid. footnote 242

[246] CARB, 2017. EMission FACtor (EMFAC). *https://arb.ca.gov/emfac/*

[247] CARB, 2019. CA-GREET3.0 Model. Available: https://www.arb.ca.gov/fuels/lcfs/ca-greet/ca-greet30-corrected.xlsm?_ga=2.247817287.1944131420.1600710547-1389483658.1577128071

[248] CARB, 2018. CEPAM: 2016 SIP - Standard Emission Tool. https://arb.ca.gov/app/emsinv/fcemssumcat/fcemssumcat2016.php

[249] CARB, 2019. Low Carbon Fuel Standard Amendments 2019. *https://ww2.arb.ca.gov/rulemaking/2019/lcfs2019*

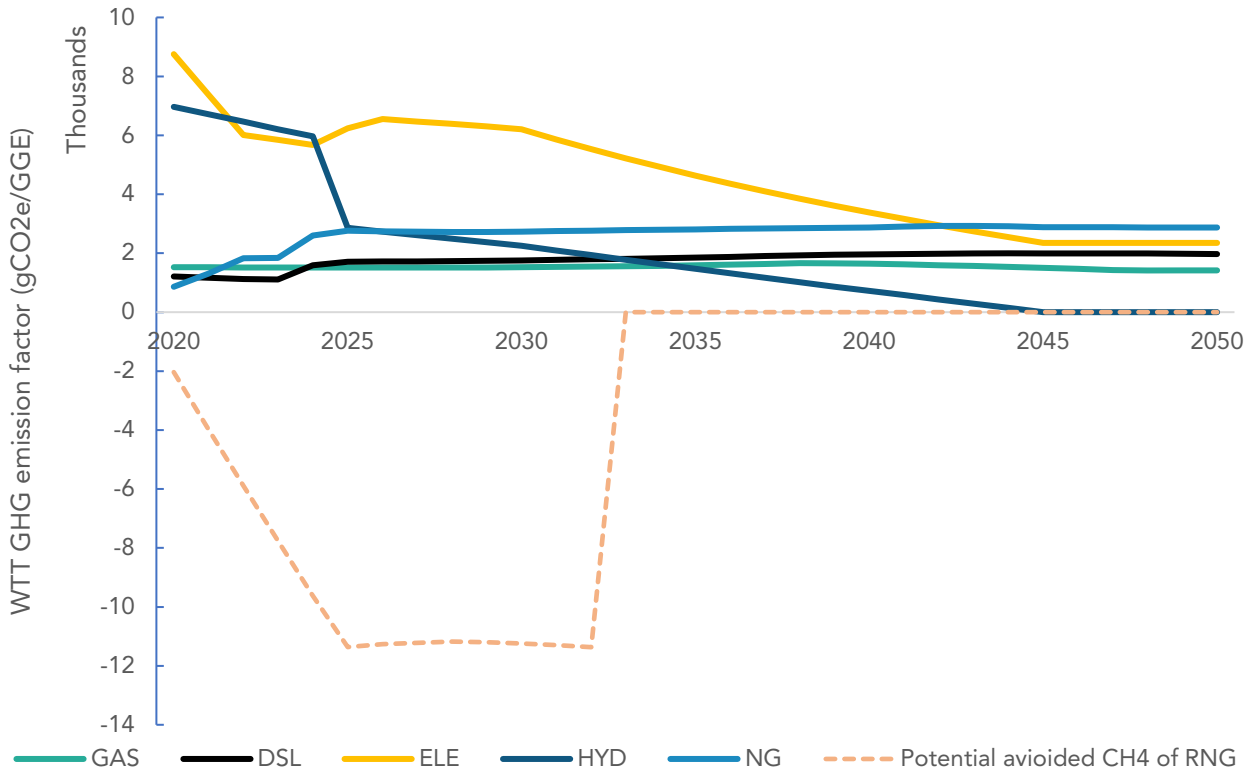
[250] The CI values for ethanol in the Illustrative Compliance Scenario assumed that eventually all ethanol consumed in California is produced with CCS. For a conservative estimate, we use the CI value without CCS credits as we assume all CCS projects located outside of California.

[251] ibid. footnote 243

Fuel Type	Blendstocks/ Pathways	GHG EFs	Criteria EFs
ELE	CA-Grid Electricity	RESOLVE's outputs with CAGREET3.0 EFs	RESOLVE's outputs with EFs developed based on CEIDARS
HYD	Fossil SMR Hydrogen	*Feedstock*: CAGREET3.0 *Fuel production*: CAGREET3.0	*Feedstock*: CAGREET3.0 *Fuel production*: CEIDARS
CNG	RNG (LFG and Others)	Weighted average CI of pathways with LFG, high solids anaerobic digestion (HSAD), and wastewater sludge as feedstock (29 gCO2e/MJ)	USEPA biogas study[252] (assuming 70% recovery)
	RNG (Dairy biogas)	Average CI of pathways in CA with dairy manure as feedstock (-331 gCO2e/MJ)	USEPA biogas study (assuming 85% recovery)
	Fossil NG	Average CI of certified pathway with North American NG as feedstock (80 g CO2e/MJ)	*Feedstock*: CAGREET3.0 *Fuel production:* CAGREET3.0

[252]Williams, R., C. Ely, T. Martynowicz, AND Mike Kosusko. Evaluating the Air Quality, Climate and Economic Impacts of Biogas Management Technologies. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-16/099, 2016. *https://nepis.epa.gov/Exe/ZyPDF.cgi/P100QCXZ.PDF?Dockey=P100QCXZ.PDF*

Figure 56 - WTT GHG EFs by Fuel Type[255]



[255]The previous figure and associated footnote utilized an accounting method for dairy biogas that included avoided methane emissions and spoke to potential changes to the treatment of avoided dairy methane emissions in the middle of this decade. Any changes would be speculative and are not currently proposed to happen. For better comparability with our GHG inventory, we have clarified the figure with a dotted line showing the effect of avoided methane emissions in this accounting and separately showing the emission factor from natural gas development and distribution, thereby providing better comparability with our primary data set to track progress towards achieving our statewide targets. In our GHG inventory, there is no accounting for avoided methane emissions for any source.