

Appendix I

Amendments to the Small Off-Road Engine Exhaust and
Evaporative Emission Regulations: Standardized Regulatory
Impact Assessment (SRIA)

State of California
Air Resources Board

Amendments to the Small Off-Road Engine Exhaust and Evaporative Emission Regulations

Standardized Regulatory Impact Assessment (SRIA)

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Foreword: Summary of Changes to Standard Regulatory Impact Assessment

California Air Resources Board (CARB or Board) staff proposes amendments to the Small Off-Road Engine (SORE) Exhaust and Evaporative Emission Regulations (Proposed Amendments) to accelerate the transition to zero-emission equipment (ZEE). On September 9, 2020, Department of Finance (DOF) published the Standardized Regulatory Impact Assessment (SRIA) for an earlier draft of the Proposed Amendments along with its comments on the document to its website. Since then, staff has updated the Proposed Amendments and the SRIA. This foreword identifies the changes in the economic impact analysis that are incorporated in the updated SRIA that follows.

First, the updated SRIA addresses the comments made by DOF staff. Specifically, the following changes were made:

- In response to DOF's request that annual benefits such as avoided health costs and emission reductions be added, staff has added tables delineating the annual reduction in emissions, reduction in negative health outcomes, and associated cost-benefits for both the Proposed Amendments and considered alternatives.
- In response to DOF's comment that the SRIA should include a cost and benefit breakdown analysis for each of the nine regulated product categories identified by CARB to identify impacts on representative individuals and businesses that use the equipment, staff has added more discussion of specific equipment types. The reasons for and impacts of the large upfront costs of switching to zero emission generators and pressure washers are now discussed. Furthermore, staff has added a table that shows the length of time it would take a typical owner of a piece of ZEE to experience cost-savings compared to SORE for each equipment type. This table shows that owners of some equipment types are expected to break even nearly immediately, and owners of other equipment types may not break even within the median lifetime of the equipment. Finally, staff has added more discussion of the differential impacts on residential versus professional users.

Second, staff updated the cost analysis to align with changes made to the Proposed Amendments since the originally-submitted SRIA was written and released. The Proposed Amendments now set the emission standards to zero for all new SORE produced starting in model year 2024, with the exception of those used in generators. Emission standards of zero for generator engines would be implemented starting with model year 2028. The analysis, including the considered regulatory alternatives, was adjusted to account for this change.

Third, CARB staff identified a transcription error in the modeled new sales of equipment. The correction resulted in a substantial increase in modeled new sales each year across all equipment types. Because the change was only to new sales, the emission and health benefits were largely unaffected. While this did affect the economic analysis and results, net benefits of the Proposed Amendments still exceed net costs.

Fourth, staff refined some assumptions made in the direct cost analysis. The analysis now includes updated purchase prices of some equipment types to be more reflective of what a typical consumer would be expected to purchase. The updated purchase price of each type of equipment, both professional and residential-grade, is based on the mean purchase price of a sample of popular models that includes models released in 2020. Some purchase prices

changed more substantially than others. For ZEE with a significantly higher purchase price than their SORE counterparts, or for which few models are available from which to calculate a mean, staff added a discussion of the price used for the calculations. Additionally, for all cordless ZEE, staff has accounted for the projected decrease in battery costs over time. The price decrease was applied conservatively, and projected prices in 2043 are 2.2 to 7.1 percent lower than prices in 2021.

Fifth, staff refined the estimates of maintenance costs for gasoline-powered equipment. In the originally-submitted SRIA, minimal maintenance costs were included. In the update, maintenance costs are based on results from the survey of equipment and use time conducted by California State University, Fullerton.

Finally, staff changed other minor assumptions that impact the economic modeling. Staff updated the regulatory horizon to 2023 through 2043. This updated modeled period represents 20 years of the Proposed Amendments' impact, the amount of time necessary for 99 percent of the small off-road equipment fleet to be ZEE. An assumption about all future ZEE being cordless was changed to exclude professional-grade pressure washers. As described in the updated SRIA, staff now assume that 75 percent of new ZEE pressure washers will be corded, and 25 percent will be cordless over the regulatory horizon. In addition, the analysis now considers updated emission credit banks and accounts for them in both the economic and emission analyses.

Given these updates, resultant total costs and benefits have changed. Overall, the Proposed Amendments have a net direct cost of \$4.08 billion through 2043. Residential users are expected to experience a total net direct cost accrued through 2043 of \$2.79 billion, while professional users are expected to experience a net direct cost of \$1.29 billion. When the valuation of health impacts is considered, through 2043, the Proposed Amendments are estimated to have a net benefit of \$4.27 billion and a benefit-cost ratio of 1.30. Table Foreword-1 shows the costs and benefits of the updated SRIA and the originally-submitted SRIA through 2040 in 2019 dollars (2019\$). When the valuation of health impacts is considered, through 2040, the Proposed Amendments are estimated to have a net benefit of \$2.25 billion and a benefit-cost ratio of 1.18. Staff added a discussion of the particular equipment types for which equipment owners would incur the greatest costs and cost-savings.

Table Foreword-1. Cost-benefit comparison of the updated SRIA and the originally-submitted SRIA through 2040 (billion 2019\$).

Document	Total direct costs	Health benefits	Total cost-savings (benefit)	Tax & fee revenue	Total benefit	Net benefit
Updated SRIA	\$12.19	\$6.80	\$7.89	-\$0.26	\$14.43	\$2.25
Originally-Submitted SRIA	\$9.86	\$7.82	\$13.57	-\$1.63	\$19.76	\$9.89

A. Introduction

The California Air Resources Board (CARB or Board) proposes to amend the Small Off-Road Engine (SORE) Regulations (Proposed Amendments), included in the California Code of Regulations.¹ SORE are small spark-ignition engines rated at or below 19 kilowatts (kW) (25.5 horsepower). SORE are predominantly used in lawn and garden equipment such as lawn mowers, string trimmers, and leaf blowers, as well as in other small off-road equipment such as generators and pressure washers. For the purpose of this document, the term “small off-road equipment” is defined as any off-road equipment powered by a small off-road engine, or comparable electric motor or other power source, consistent with § 2401(a) of the SORE regulations.

The population of SORE equipment in California, 15.4 million units, is greater than the population of light-duty passenger cars—14.0 million.^{2,3} The vast majority of SORE are fueled by gasoline, but SORE may also be powered by compressed natural gas, propane, liquefied petroleum gas, or liquefied natural gas. The use of small off-road equipment leads to significant emissions of air pollutants, including oxides of nitrogen (NO_x), reactive organic gases (ROG), and particulate matter (PM). Hydrocarbons (HC) are among ROG emitted by SORE and contribute to PM and ozone formation in California.

Operating a professional lawn mower for one hour emits as much ozone-forming pollution as driving a new passenger car about 300 miles – approximately the distance from Los Angeles to Las Vegas, more than 4 hours of drive time. Operating a professional backpack leaf blower for one hour emits ozone-forming pollution comparable to driving the same passenger car about 1,100 miles – approximately the distance from Los Angeles to Denver, more than 15 hours of drive time. Zero-emission small off-road equipment, or zero-emission equipment (ZEE), are available in the market now. ZEE do not directly emit exhaust or evaporative emissions and help protect public health, reduce petroleum use, and meet sustainability objectives.

The Proposed Amendments would accelerate the transition to ZEE by setting the evaporative and exhaust emission standards to zero for new SORE produced starting in model year (MY) 2024. Generator engines covered under the Proposed Amendments would be subject to stricter emission standards starting in MY 2024 and emission standards of zero starting in MY 2028. Emission reduction credits may be used to offset emissions from SORE

¹ CCR Title 13 §§ 2400 through 2409 and 2750 through 2774, and by reference, the following CARB certification procedures (CP) and test procedures (TP): TP-901, Test Procedure for Determining Permeation Emissions from Small Off-Road Engine Fuel Tanks, TP-902, Test Procedure for Determining Diurnal Emissions from Small Off-Road Engines, CP-902, Certification Procedure for Evaporative Emission Control Systems on Engines with Displacement Greater than 80 Cubic Centimeters, California Exhaust Emission Standards and Test Procedures for New 2013 and Later Small Off-Road Engines; Engine-Testing Procedures (Part 1054), and California Exhaust Emission Standards and Test Procedures For New 2013 and Later Small Off-Road Engines; Engine-Testing Procedures (Part 1065).

² CARB. 2020. 2020 Emissions Model for Small Off-Road Engines – SORE2020. Report prepared by staff of the CARB Air Quality Planning and Science Division. September 2020.

³ CARB. 2021. EMFAC2021 Volume III Technical Document. Version 1.0.1. Report prepared by staff of the CARB Air Quality Planning and Science Division. April 2021.

subject to stricter emissions standards or emission standards of zero. The Proposed Amendments also include changes to existing emission reduction credit programs and changes to clarify the certification and test procedures. The Proposed Amendments would repeal the section in the evaporative regulations that provides for a manufacturer who cannot meet the requirements of the regulations due to extraordinary reasons beyond the manufacturer's reasonable control to apply for a variance. The switch to ZEE will help achieve emission reductions required by the Revised Proposed 2016 State Strategy for the State Implementation Plan (2016 State SIP Strategy)⁴ and will be part of a portfolio of Strategies, in coordination with other State agencies, U.S. Environmental Protection Agency (U.S. EPA) and local air districts, to achieve 100 percent zero-emission from off-road vehicles and equipment operations in the State by 2035 as ordered in Governor Newsom's recent Executive Order N-79-20 (EO N-79-20).⁵

1. Regulatory History

CARB adopted SORE regulations in 1990 when setting the first exhaust emission standards. Since that time, the exhaust standards have been made more stringent. CARB adopted the first evaporative emission standards for SORE in 2003. Evaporative emissions occur both when the engine is operating and when it is not. Both the exhaust and evaporative emission regulations include emission reduction credit programs, which allow manufacturers to produce engines that emit at levels higher than the emission standards if they offset those emissions with credits from engines that emit at levels lower than the emission standards. The exhaust emission reduction credit program also allows for credit generation for ZEE. Most recently, CARB adopted the amendments to the evaporative emission regulations for SORE in 2016.

SORE emissions include regulated pollutants such as NO_x and ROG. The 2016 State SIP Strategy, which describes the control measures that will be implemented to achieve federal ambient air quality standards required under the Clean Air Act, includes a measure to reduce emissions of NO_x and ROG from SORE by 4 and 36 tons per day (tpd), respectively, in 2031. An additional measure would reduce NO_x and ROG emissions from off-road equipment – a category that includes SORE – by 18 and 20 tpd, respectively, in 2031, through “further deployment of cleaner technologies.” The Proposed Amendments would achieve the emission reductions in the SORE measure and a portion of those in the “further deployment of cleaner technologies” measure. The Revised Draft 2020 Mobile Source Strategy was released in April 2021 and calls for 7.9 tpd of NO_x and 64.5 tpd of ROG emission reductions from SORE in 2031.⁶

To better understand the small off-road equipment population in California, CARB contracted with the Social Science Research Center (SSRC) at California State University, Fullerton (CSUF) to conduct an intensive survey between 2017 and 2019 of households,

⁴ CARB. 2016. Revised Proposed 2016 State Strategy for the State Implementation Plan. Report prepared by staff of the Air Quality Planning and Science Division (AQPSD), California Air Resources Board (CARB). March 7, 2017.

⁵ Office of Governor Gavin Newsom. Executive Order N-79-20. September 23, 2020.

⁶ CARB. 2021. Revised Draft 2020 Mobile Source Strategy. Report prepared by staff of the Air Quality Planning and Science Division (AQPSD), California Air Resources Board (CARB). April 2021.

businesses, and landscape vendors (landscapers) on their ownership and use of small off-road equipment, and other related topics (CSUF survey).⁷ Staff developed the survey questions in close collaboration with SSRC, and other interested stakeholders, including manufacturers, trade associations, government agencies, individuals, and environmental organizations, through a series of working group meetings. At each stage of the survey, all parties were invited to give feedback on the questions asked, and the survey questionnaires were improved as a result. The main goal of the survey was to calculate a more accurate inventory of small off-road equipment in California for emissions modeling. The survey reached over 1,100 households, 1,300 businesses and 600 landscaping vendors throughout the state. Topics included ownership, use rates, knowledge of ZEE, and maintenance practices. The final report estimates the total small off-road equipment population and the populations of several equipment types.

2. Proposed Amendments

a. Emission Standards

The main goal of the Proposed Amendments is to transition all new equipment that uses SORE produced for sale or lease for operation in California to ZEE. ZEE, by definition, do not directly produce any emissions. This would be achieved by setting SORE emission standards to zero. Currently, nearly all ZEE are either battery-powered or corded, but fuel cells could also be used in place of engines subject to the SORE regulations. Zero-emission alternatives to SORE are available, and the number and breadth of models is expected to continue increasing as it has in recent years. The Proposed Amendments would reduce emission standards in two phases. First, for MY 2024, exhaust and evaporative emission standards would be zero (0.00 grams per kilowatt-hour or $\text{g}\cdot\text{kWh}^{-1}$ exhaust emissions, 0.00 grams per test or $\text{g}\cdot\text{test}^{-1}$ evaporative emissions) for engines used in all equipment types produced for sale or lease for operation in California, except generators. Generator engine emission standards would be more stringent starting in MY 2024 but not zero. The second phase would be implemented starting in MY 2028, when the emission standards for generators would be zero.

The Proposed Amendments allow a longer transition period for generators for two reasons. First, one of the main uses of generators is back-up power supply. In some regions of the state, public safety power shutoffs (PSPS) have become an occasional occurrence due to periods of increased fire danger. Second, there is still a need for innovation and growth in the zero-emission generator market. The fraction of all generators that are zero-emission lags significantly behind that for lawn and garden equipment, such as lawn mowers and trimmers. While there are some options for residential zero-emission generators, there are few zero-emission generators widely available for professional use, and they have a markedly higher purchase price than their SORE counterparts. Furthermore, per discussion with generator manufacturers, professional generator needs vary widely, and models currently on the market may not be able to meet all the needs of different industries. Including generators in this

⁷ CSUF SSRC. 2019. Survey of Small Off-Road Engines (SORE) Operating within California: Results from Surveys with Four Statewide Populations. May 15, 2019. Prepared by the Social Science Research Center (SSRC) at California State University, Fullerton (CSUF), for CARB and the California Environmental Protection Agency, under CARB Agreement 16MLD011.

rulemaking, while allowing their transition to zero-emissions to occur on a more gradual timeline, sends a market signal to manufacturers that demand for zero-emission generators will be growing in the coming years.

Under the Proposed Amendments, beginning in MY 2024, the evaporative emission standards would cover a greater portion of an engine's evaporative emissions, including both the "hot soak" and "diurnal cycle."⁸ Currently, only the emissions from the 24-hour diurnal cycle must meet the evaporative emission standards, while under the Proposed Amendments, the emissions from both the hot soak period and the 24-hour diurnal cycle must meet the evaporative emission standards. As manufacturers are already required to measure and report hot soak emissions when testing a complete engine, this change would not add testing burden or cost beyond that which is already required under the current SORE regulations. Hot soak emissions are typically small in relation to diurnal emissions. However, some engines tested by CARB have met the 24-hour diurnal emission standard, but had hot soak emissions several times higher than the diurnal emission standards. This change would more accurately account for real-world emissions from SORE by including emissions from the hot soak period and therefore ensure California is realizing the benefits of the tightened emission standards.

The proposed hot soak plus diurnal evaporative emission standards for MYs 2024-2027 generators are approximately 50 percent lower than the current diurnal emission standards. Some engines currently certified in the state of California already meet these emission standards, including the hot soak emissions. CARB staff proposes to expand applicability of these emission standards to engines with displacement⁹ less than or equal to 80 cubic centimeters (≤ 80 cc), for which only components of the evaporative emission control systems are currently subject to emission standards. CARB tests of currently available engines confirm that some products meet the proposed 0.50 grams per test standard in this category.

Tables A-1 and A-2 compare the current and proposed emission standards for exhaust and evaporative emissions, respectively. The proposed emission standard for the engines with displacement greater than 825 cc (> 825 cc) is aligned with the current emission standard for similar large spark-ignition engines, i.e., those rated greater than 19 kW and with displacement > 825 cc.

The Proposed Amendments also sunset the voluntary "Blue Sky Standards" for engines produced after MY 2023. The Blue Sky Standards were developed to allow manufacturers to receive recognition for certifying to more stringent exhaust and evaporative emission standards, but CARB has no record of any manufacturer taking advantage of the program for engines.

⁸ The evaporative emission test procedure for complete engines consists of several steps, including running the equipment and putting it into a sealed housing for evaporative determination (SHED), where emissions are collected and measured. Under the current regulations, the SHED is first held at 95 °F for one hour. This "hot soak" period represents placing a hot engine in storage after use on a hot summer day. This is followed by a period of cooling and the "diurnal cycle," a 24-hour period during which the engine is exposed to a temperature cycle akin to a typical summer day, including typical overnight cooling.

⁹ Displacement is the total swept volume of all the cylinders in an engine, usually expressed in cubic centimeters or liters, and is an expression of an engine's size.

Table A-1. Current SORE exhaust emission standards and exhaust emission standards under the Proposed Amendments.

Displacement category	Current HC + NO _x emission standard ¹⁰ (g·kWh ⁻¹)	Proposed HC + NO _x emission standard ¹¹ for MYs 2024-2027 generators (g·kWh ⁻¹)	Proposed HC + NO _x emission standard for all other SORE for MY 2024 and later (g·kWh ⁻¹)
< 50 cc	50	6.0	0.00
50-80 cc, inclusive	72	6.0	0.00
> 80 cc - < 225 cc	10.0	6.0	0.00
225-825 cc, inclusive	8.0	3.0	0.00
> 825 cc	8.0	0.80	0.00

Table A-2. Current SORE evaporative emission standards and evaporative emission standards under the Proposed Amendments.

Displacement category	Current diurnal emission standard (g organic material hydrocarbon equivalent·day ⁻¹)	Proposed hot soak plus diurnal emission standard ¹² for MYs 2024-2027 generators (g·test ⁻¹)	Proposed hot soak plus diurnal emission standard for all other SORE for MY 2024 and later (g·test ⁻¹)
≤ 80 cc	N/A	0.50	0.00
> 80 cc - < 225 cc except walk-behind mowers	0.95 + 0.056 × nominal capacity (liters)	0.60	0.00
> 80 cc - < 225 cc walk-behind mowers	1.0	N/A	0.00
≥ 225 cc	1.20 + 0.056 × nominal capacity (liters)	0.70	0.00

b. Emission Reduction Credit Programs

Under the Proposed Amendments, manufacturers may continue to use emission reduction credits through the averaging, banking, and trading (ABT) programs. The ABT programs allow manufacturers to earn credits when they certify SORE that emit at levels lower than the current emission standards. These credits may be 1) used to offset emissions from SORE that emit at higher levels (referred to as averaging); 2) banked for future years; or 3) traded with other manufacturers. Credits expire after five years if they have not been used. Staff expects that, overall, generator engines would use more credits than they earn after MY 2023. The sales- and power-weighted average HC + NO_x emission rates for MY 2018 generators exceed the proposed MY 2024 emission standards. No credits could be earned once emission standards of zero took effect for generator engines. Therefore, only remaining banked credits could be used for MY 2028 and subsequent model year engines.

The Proposed Amendments would lower the maximum family emission levels (FEL) for engines. An FEL is defined as an emission level that is declared by the manufacturer to serve

¹⁰ g·kWh⁻¹: grams (g) of emissions per kilowatt-hour (kWh). A kilowatt-hour is a unit of energy equal to one kilowatt of power sustained for one hour.

¹¹ For MY 2028 and later, the proposed HC + NO_x exhaust emission standards for generators are 0.00 g·kWh⁻¹.

¹² For MY 2028 and later, the proposed evaporative emission standards for generators are 0.00 g·test⁻¹.

for the ABT program and in lieu of an emission standard for certification. The reduced maximum FELs would be equivalent to the current HC + NO_x exhaust emission standards, shown in Table A-1. These lowered maximum FELs for HC + NO_x would ensure that no MY 2024 or subsequent model year engines are introduced for sale or lease for use or operation in California with excessive exhaust emissions, while still allowing manufacturers flexibility to use the credits they have generated to sell engines with emissions above the proposed, more stringent emission standards. This will ensure the highest-emitting engines, which have the greatest impact on air quality and expose operators to the greatest amounts of pollutants, are replaced with ZEE the earliest. These maximum FELs would also maintain flexibility for manufacturers to shift their focus to ZEE. By setting the maximum FELs to the current emission standards, manufacturers could continue using credits they have banked or earn in future years on engines already in production today, without having to develop new technology.

The Proposed Amendments would also allow manufacturers of alternative fuel-powered equipment to earn evaporative emission credits. This includes engines powered with compressed natural gas, propane, liquefied petroleum gas, or liquefied natural gas. These engines are not subject to the evaporative regulations, but if manufacturers wish to earn emissions credits, they may follow the test procedure to do so. This would allow more flexibility in production and give credits to manufacturers of low-emitting engines.

Currently, the emission reduction credit program for evaporative emissions only has provisions for averaging and banking. The Proposed Amendments would add trading to the program to align with the exhaust emission regulations. This would allow more flexibility in the program. Manufacturers who earn credits could trade them to other manufacturers, encouraging production of the lowest-emitting engines possible.

To send another market signal to manufacturers to increase development and production of zero-emission generators, the Proposed Amendments also include a new, generator-specific emission reduction credit program. This voluntary program would allow manufacturers to offset emissions from generators with emission levels above the proposed emission standards by using credits earned from certifying zero-emission generators. The program is tiered, granting more emission reduction credits for zero-emission generators with greater energy storage and power delivery than for those with less energy storage and power delivery. This tier system would enable the greatest credit benefits to manufacturers who develop zero-emission generators in the least developed sector of the market (i.e., zero-emission generators with the greatest energy storage and highest power output). The zero-emission generator credits would be subject to similar provisions to those in the existing emission reduction credit programs, including a five-year limit on banking credits.

In summary, the Proposed Amendments would expand the current emission reduction credit programs to increase flexibility for manufacturers. These amendments are intended to lessen the initial cost impacts for manufacturers (and those purchasing equipment) that could result when SORE equipment is replaced with ZEE. The credit programs spread out the cost impact over a longer period. Throughout the economic analysis, staff assumed that emission reduction credit banks would be completely used before the credits expire, as described in each regulatory scenario in Chapter C.1 and Chapter F.

c. Emissions Durability Periods

The exhaust emissions durability period is the period that represents the engine's useful life. Under California Part 1054.107, useful life is described as the period during which engines are required to comply with all applicable emission standards. The Proposed Amendments would change the emissions durability periods to more accurately reflect the actual lifetime of SORE equipment. Tables A-3 and A-4 describe the current and proposed exhaust emissions durability periods for SORE. The current regulations allow applicants for certification to select a durability period for their engines from a range of choices that generally reflect "moderate," "intermediate," or "extended," use. The proposed durability period for all SORE with displacement less than or equal to 80 cc other than generator engines is 300 hours. The proposed durability period for generator engines with displacement less than or equal to 80 cc is 500 hours. The proposed durability period for engines with displacement greater than 80 cc and less than 225 cc is 500 hours. The proposed durability period for engines with displacement greater than or equal to 225 cc is 1,000 hours. The durability periods in the Proposed Amendments are the longest of the current durability periods for each displacement category for engines other than generator engines with displacement less than or equal to 80 cc.

These changes would enable the durability periods to more accurately reflect the actual lifetime use of SORE equipment. For example, the 75th percentile age of in-use residential generators is 15 years.¹³ A generator used at the average residential activity level of 62 hours per year would be used for 930 hours in 15 years.¹⁴ The average professional activity rate is 146 hours per year and the 75th percentile age is 15 years. Those generators would be used for 2,190 hours in 15 years. The longer emissions durability periods would help ensure products meet emission standards over their full lifetimes.

Generators are not handheld equipment and do not have the same limitations of space and weight as handheld equipment. Among generators that use engines with displacement less than or equal to 80 cc, most have 80 cc engines. The design of many 80 cc engines is closer to that of an engine with displacement greater than 80 cc than it is to that of engines used in handheld equipment. The example in this section illustrates that a residential generator with an engine with displacement less than or equal to 80 cc used at the average residential activity level may be used well in excess of its current 50- to 300-hour durability period. A 500-hour durability period assures more residential generators using engines with displacement less than 225 cc will meet the emission standard for their lifetime. For all displacement categories except greater than 825 cc, there are currently engines certified below the proposed emission standards at the longest current durability periods. The proposed emission standards and emissions durability period for engines with displacement greater than 825 cc are aligned with the current emission standards and emissions durability period for similar large spark-ignition engines, i.e., those rated greater than 19 kW and with

¹³ CSUF SSRC. 2019. Survey of Small Off-Road Engines (SORE) Operating within California: Results from Surveys with Four Statewide Populations. May 15, 2019. Prepared by the Social Science Research Center (SSRC) at California State University, Fullerton (CSUF), for CARB and the California Environmental Protection Agency, under CARB Agreement 16MLD011.

¹⁴ CARB. 2020. 2020 Emissions Model for Small Off-Road Engines – SORE2020. Report prepared by staff of the CARB Air Quality Planning and Science Division. September 2020.

displacement greater than 825 cc. Therefore, these durability periods are technologically feasible for SORE.

Table A-3. Current SORE emissions durability periods and emissions durability periods for generator engines under the Proposed Amendments.

Displacement category	Current emissions durability period ¹⁵ (hours)	Proposed emissions durability period for MY 2024 and later (hours)
< 50 cc	50/125/300	500
50-80 cc, inclusive	50/125/300	500
> 80 cc - < 225 cc	125/250/500	500
225-825 cc, inclusive	125/250/500/1,000	1,000
> 825 cc	125/250/500/1,000	1,000

Table A-4. Current SORE emissions durability periods and emissions durability periods for SORE other than generator engines under the Proposed Amendments.

Displacement category	Current emissions durability period ¹⁶ (hours)	Proposed emissions durability period for MY 2024 and later (hours)
< 50 cc	50/125/300	300
50-80 cc, inclusive	50/125/300	300
> 80 cc - < 225 cc	125/250/500	500
225-825 cc, inclusive	125/250/500/1,000	1,000
> 825 cc	125/250/500/1,000	1,000

d. Variances

The Proposed Amendments would repeal the section in the evaporative emission regulations that provides for a manufacturer who cannot meet the requirements due to extraordinary reasons beyond the manufacturer’s reasonable control to apply for a variance. For the economic modeling, staff assumed that no manufacturer would be unable to meet the requirements of the regulations due to extraordinary reasons beyond the manufacturer’s reasonable control and that no manufacturer would need to apply for a variance. Repealing the variance section is therefore not expected to have an economic impact given this assumption.

e. Test Procedures

The Proposed Amendments include two main changes to the exhaust and evaporative emissions test procedures: reducing the number of engines required to be tested for exhaust

¹⁵ Manufacturers choose the emissions durability period which matches the expected useful life of an engine family. These categories are generally taken to reflect “moderate,” “intermediate,” and “extended” use.

¹⁶ Manufacturers choose the emissions durability period which matches the expected useful life of an engine family. These categories are generally taken to reflect “moderate,” “intermediate,” and “extended” use.

emission compliance determinations, and adding a tilt test to more accurately reflect real world equipment use when conducting evaporative emission testing.

First, the Proposed Amendments reduce CARB's compliance testing burden by changing the requirements to test "a reasonable number" of engines to "one or more," and eliminating the requirement that engines be tested in groups of five. This change is not expected to affect manufacturers' costs.

Second, a tilt test is added before evaporative emissions testing. The tilt test consists of tipping a piece of equipment 90 degrees in three directions, without tilting toward the carburetor, and any fuel leaking from any part of the engine or evaporative control system would result in failure. This would reduce excess emissions from fuel leaks when equipment is turned on its side for cleaning, maintenance, or storage by ensuring that tilting in three directions does not result in fuel leaks. CARB staff does not expect the tilt test to have a significant effect on costs to manufacturers as it adds only a few minutes of staff time to a multi-month testing period. Furthermore, the current regulations include requirements that are intended to ensure emission control systems would not be negatively affected by this momentary tilting of the engine.

The Proposed Amendments include several other changes to the test procedures, which are not expected to affect costs to manufacturers. The exhaust test procedures have been updated to harmonize with updates to federal test procedures. Instructions for accelerated preconditioning for evaporative testing are detailed to ensure consistency. Further instructions are added for an existing requirement to determine fuel tank pressure limits.

f. Fuel Cap Tethers

The Proposed Amendments add a provision to the SORE regulations to require that fuel caps and their tethers must not cause fuel to spill when the fuel cap is removed from equipment. This would reduce potential excess emissions during refueling or when checking the amount of fuel in the fuel tank, which are currently not assessed in emissions testing or accounted for in the emissions inventory. This additional test is not expected to influence equipment costs. This may require some manufacturers to move the tether holding the fuel cap from inside the gas tank to the outside. For some, this may reduce the cost of the tether, as the material has less exposure to gasoline, while for others, it may increase the costs slightly, as they may have to weld a tab to attach the tether. Staff expects that any cost or cost-savings will be negligible.

3. Statement of the Need of the Proposed Regulation

CARB's SORE regulations have led to substantial emission reductions. SORE are up to 80 percent cleaner today than they were before the regulations began. Even so, total smog-forming emissions from SORE equipment exceed the smog-forming emissions from light-duty passenger cars in California in 2021. Without additional regulation, the summer average smog-forming emissions from SORE will be 1.8 times those from California's light-duty

passenger vehicle fleet in 2031.^{17,18} It is necessary to update the SORE regulations to meet the expected emission reductions put forth in the 2016 State SIP Strategy and achieve 100 percent zero-emission from off-road vehicles and equipment operations in the State by 2035 as directed by EO N-79-20. Further deployment of ZEE is not expected to occur without the Proposed Amendments. Without further regulation, the SORE equipment population is projected to be higher in 2043 than it is in 2021.¹⁹

Residential and commercial lawn and garden ZEE are already on the market. However, outreach and CSUF SORE survey data indicate some consumers are not readily opting for ZEE for several reasons. In order to determine the population that ZEE currently represents, the CSUF SORE survey included questions on ZEE. According to the CSUF survey, almost half of households own at least one piece of lawn and garden equipment. Nearly 40 percent of households own another piece of small off-road equipment such as an air compressor, generator, or pressure washer.²⁰ This led to an estimate of more than 26 million pieces of equipment owned by residential users statewide, 59 percent of which was ZEE. Residential users use their equipment less frequently than professional users, and thus replace equipment less frequently. The CSUF survey showed that the median age is six years for a residential lawn mower and five years for a trimmer/edger. Only 7 percent of households stated that they intended to buy any additional pieces of small off-road equipment or replacements for their current small off-road equipment in the next year.

Individual household respondents who noted that they had no plans to purchase new equipment in the next year were asked what factors would be important in a hypothetical purchase in deciding between gasoline-powered equipment and ZEE. Cost was the top response, followed closely by power and time to refuel/recharge. These results suggest that many individuals hold beliefs about ZEE that may be based on old information. Currently, residential ZEE have roughly the same price as their gasoline-powered counterparts. In many cases, ZEE cost less to purchase. Furthermore, current ZEE are available in a wide array of configurations and power. ZEE manufacturers market their equipment as having performance that is comparable to or better than SORE in many cases.

Businesses targeted by the CSUF survey were defined as those that do not conduct landscaping as their service, but may own small off-road equipment to maintain their own properties or conduct other outdoor work. The survey treated landscape vendors, both licensed and unlicensed, as a separate category. The survey indicated that, of the estimated two million pieces of small off-road equipment owned by businesses, 57 percent were electric. Among landscape vendors there were an estimated 803,000 pieces of lawn and garden equipment. Only 8 percent of this equipment was electric, although 60 percent of

¹⁷ CARB. 2020. 2020 Emissions Model for Small Off-Road Engines – SORE2020. Report prepared by staff of the CARB Air Quality Planning and Science Division. September 2020.

¹⁸ CARB. 2021. EMFAC2021 Volume III Technical Document. Version 1.0.1. Report prepared by staff of the CARB Air Quality Planning and Science Division. April 2021.

¹⁹ CARB. 2020. 2020 Emissions Model for Small Off-Road Engines – SORE2020. Report prepared by staff of the CARB Air Quality Planning and Science Division. September 2020.

²⁰ CSUF SSRC. 2019. Survey of Small Off-Road Engines (SORE) Operating within California: Results from Surveys with Four Statewide Populations. May 15, 2019. Prepared by the Social Science Research Center (SSRC) at California State University, Fullerton (CSUF), for CARB and the California Environmental Protection Agency, under CARB Agreement 16MLD011.

responding landscape vendors stated that they know of electric versions of the equipment types they own. Landscape vendors use their equipment more regularly than residential users, and turnover is faster in this market segment, so it is notable that only 8 percent of this extensively used equipment is ZEE. Per the survey, the age of lawn and garden equipment used by landscape vendors is about half that of residential equipment.

To better understand landscape vendors' rate of adoption of ZEE, the CSUF survey asked participating landscapers what qualities of the equipment were most important to them. Performance, run-time, and cost were the top three responses. With sufficient batteries to last an eight-hour workday, the average purchase price of professional ZEE is higher than for the SORE counterpart. As an example, the purchase price of a professional ZEE leaf blower with batteries is nearly twice as much as its gasoline counterpart. Upfront cost is a significant barrier to transforming the population of lawn and garden equipment in the professional market to ZEE, even though ZEE often have a lower total cost of ownership over the equipment lifetime. CARB staff does not expect at this time that the Proposed Amendments will bring down the cost of ZEE directly. Given the low ZEE adoption rate among professional users, the Proposed Amendments are needed to increase the deployment of ZEE so that the State can achieve the expected emission reductions in the 2016 State SIP Strategy and the goals of EO N-79-20. The Proposed Amendments to the SORE regulations would be one of a portfolio of strategies, in coordination with other State agencies, U.S. EPA and local air districts, to achieve 100 percent zero-emission from off-road vehicles and equipment operations in the State by 2035.

4. Major Regulation Determination

The Proposed Amendments have been determined to be a major regulation because the economic impact of the regulation on California is estimated to exceed \$50 million per year in one or more years of the regulatory horizon of 2023 through 2043. Cost increases are associated with purchasing ZEE and lower-emitting SORE generators, which are more expensive than SORE-powered equipment in the commercial lawn and garden sector of the market. The prices for residential ZEE are comparable, or in some cases lower. For both commercial and residential ZEE, users would save money on operational costs through lower gasoline costs and reduced maintenance and repair costs.

5. Baseline Information

For the SRIA, the economic and emissions impacts of the Proposed Amendments are evaluated against the business-as-usual (BAU) scenario each year for the regulatory horizon of 2023 through 2043. Staff selected this period due to the length of time it will take to transform over 99 percent of the SORE population to ZEE based on the modeling herein. The BAU case for the economic and emissions analyses is referred to as the "Baseline Scenario" in this document.

The economic analysis utilizes modeled population data based on CSUF survey data. CARB staff modeled population for the Baseline Scenario and all regulatory scenarios using 2018 as the base year (the year that most of the data collection was done in the CSUF survey). The population inventory used for the economic analysis separates the total amount of small off-road equipment in the state into several categories. First, the equipment are separated by

type of owner. There are three categories: residents, nonlandscaping businesses, and landscapers. Residents are individuals in the state that own residential-grade small off-road equipment for their private nonbusiness use. Businesses are defined as those that own small off-road equipment to maintain their own property or conduct work, excluding landscapers. Finally, landscapers include all businesses under North American Industry Classification System (NAICS) codes 541320 (Landscape and Architectural Services) and 561730 (Landscaping Services). The share of small off-road equipment belonging to residents, nonlandscaping businesses, and landscapers is based on the CSUF survey.

For economic analysis, staff used equipment population data for 2022 as the base year. Starting with this population data year, a fourth type of owner was derived: government. The government category is all government agencies (state and local) that own small off-road equipment. The fraction of small off-road equipment owned by government entities was estimated by assuming 0.24% of all nonlandscaping businesses in the state are government entities.²¹ The fraction of small off-road equipment owned by each group was assumed to not change over the regulatory horizon.

The population is then categorized by power type, whether SORE equipment or ZEE. ZEE are categorized as either cordless (battery-powered) or corded. Corded ZEE, while making up over half of the residential ZEE accounted for in the CSUF survey, do not appear to be gaining further market share.²² Corded equipment has been available for decades and may have reached full market penetration. Many retailers heavily advertise and sell cordless options to both residential and professional users. Therefore, the expected consumer behavior is the purchase of cordless ZEE. For the economic modeling, CARB staff assumed that any gains in the amount of ZEE in the market would be due to increased sales of cordless equipment, with the exception of pressure washers, as explained in C.1.c.v. Since cordless equipment generally has a higher purchase price than corded, this assumption is more conservative and avoids understating costs.

Finally, the population is categorized by equipment type. Staff included nine equipment types, which account for nearly all small off-road equipment regulated by CARB.²³ Tables A-5, A-6, A-7, and A-8 show the affected population of the nine equipment types. Residential users own more than 80 percent of the population of all small off-road equipment, where ZEE have a substantial market share. Figures A-1, A-2, A-3, and A-4 illustrate the amount of SORE equipment and ZEE owned by each of the four types of owner in 2022.

²¹ Regional Economic Models Inc. (REMI) Policy Insight+ v. 2.4 State and Local Government Employment in 2018

²² CSUF SSRC. 2019. Survey of Small Off-Road Engines (SORE) Operating within California: Results from Surveys with Four Statewide Populations. May 15, 2019. Prepared by the Social Science Research Center (SSRC) at California State University, Fullerton (CSUF), for CARB and the California Environmental Protection Agency, under CARB Agreement 16MLD011.

²³ Approximately 11 percent of SORE includes new engines which are used in construction equipment or vehicles or 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 new engines used in such equipment. These federally-regulated equipment types are preempted from California's SORE regulations and therefore not included in this analysis.

Table A-5. Inventory of small off-road equipment owned by businesses that are not landscapers for the economic base year of 2022.

Category	Population	Fraction of equipment that is ZEE (%)	Fraction of equipment owned by nonlandscaping businesses (%)
Chainsaws	126,693	5.9	4.9
Generator Sets	264,034	15.6	11.5
Lawn Mowers	135,402	4.6	2.5
Leaf Blowers/Vacuums	355,298	33.4	6.5
Pressure Washers	319,333	46.2	10.3
Pump < 2 hp	116,469	93.3	5.8
Riding Mowers	7,617	0.5	2.0
Snow Blowers	7,375	0.00	10.7
Trimmers/Edgers/Brush Cutters	307,577	22.8	4.2

Table A-6. Inventory of small off-road equipment owned by landscapers for the economic base year of 2022.

Category	Population	Fraction of equipment that is ZEE (%)	Fraction of equipment owned by landscaping businesses (%)
Chainsaws	156,092	3.0	6.0
Generator Sets	11,582	8.8	0.5
Lawn Mowers	136,242	3.5	2.5
Leaf Blowers/Vacuums	180,257	8.6	3.3
Pressure Washers	24,108	17.4	0.8
Pump < 2 hp	3,936	92.1	0.2
Riding Mowers	15,462	0.3	4.0
Snow Blowers	5,569	0.0	8.1
Trimmers/Edgers/Brush Cutters	258,581	5.9	3.6

Table A-7. Inventory of small off-road equipment owned by government entities for the economic base year of 2022.²⁴

Category	Population	Fraction of equipment that is ZEE (%)	Fraction of equipment owned by government entities (%)
Chainsaws	305	5.9	< 0.1
Generator Sets	635	15.6	< 0.1
Lawn Mowers	326	4.6	< 0.1
Leaf Blowers/Vacuums	855	33.4	< 0.1
Pressure Washers	768	46.2	< 0.1
Pump < 2 hp	280	93.3	< 0.1
Riding Mowers	18	0.5	< 0.1
Snow Blowers	18	0.00	< 0.1
Trimmers/Edgers/Brush Cutters	740	22.8	< 0.1

Table A-8. Inventory of small off-road equipment owned by residents for the economic base year of 2022.

Category	Population	Fraction of equipment that is ZEE (%)	Fraction of equipment owned by residents (%)
Chainsaws	2,315,631	41.7	89.1
Generator Sets	2,023,089	16.1	88.0
Lawn Mowers	5,163,631	29.1	95.0
Leaf Blowers/Vacuums	4,932,998	74.9	90.2
Pressure Washers	2,743,617	67.8	88.9
Pump < 2 hp	1,876,687	99.1	94.0
Riding Mowers	366,509	5.6	94.1
Snow Blowers	55,853	10.4	81.2
Trimmers/Edgers/Brush Cutters	6,688,114	62.8	92.2

²⁴ It was assumed that 0.24% of all businesses in the state are government entities for this analysis based on the Regional Economic Models Inc. (REMI) Policy Insight+ v. 2.4 State and Local Government Employment in 2018.

Figure A-1. Small off-road equipment population, by type, owned by residents in economic base year 2022.

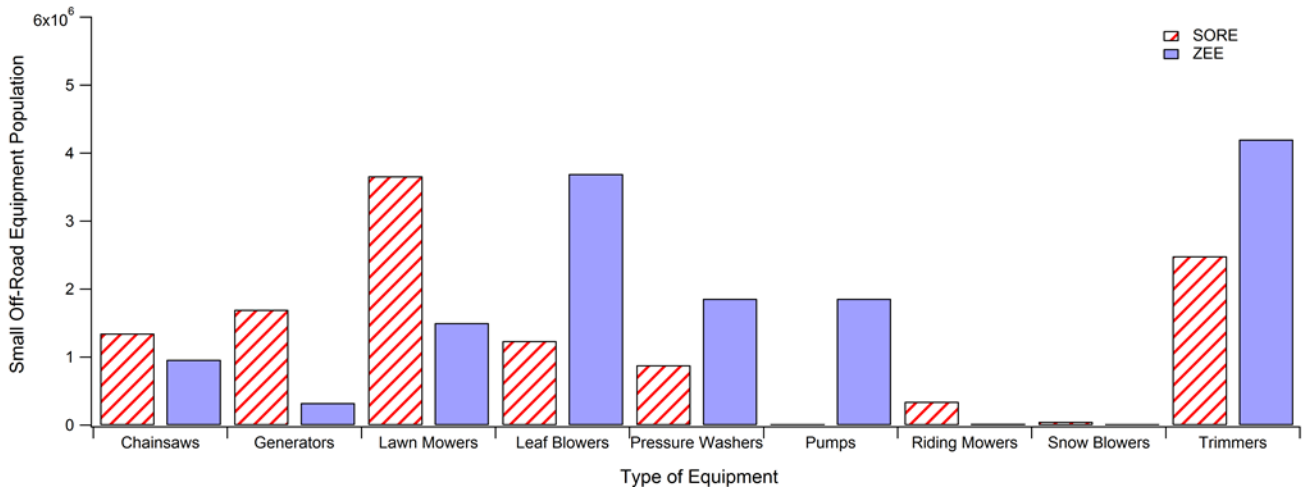


Figure A-2. Small off-road equipment population, by type, owned by nonlandscaping businesses in the economic base year of 2022.

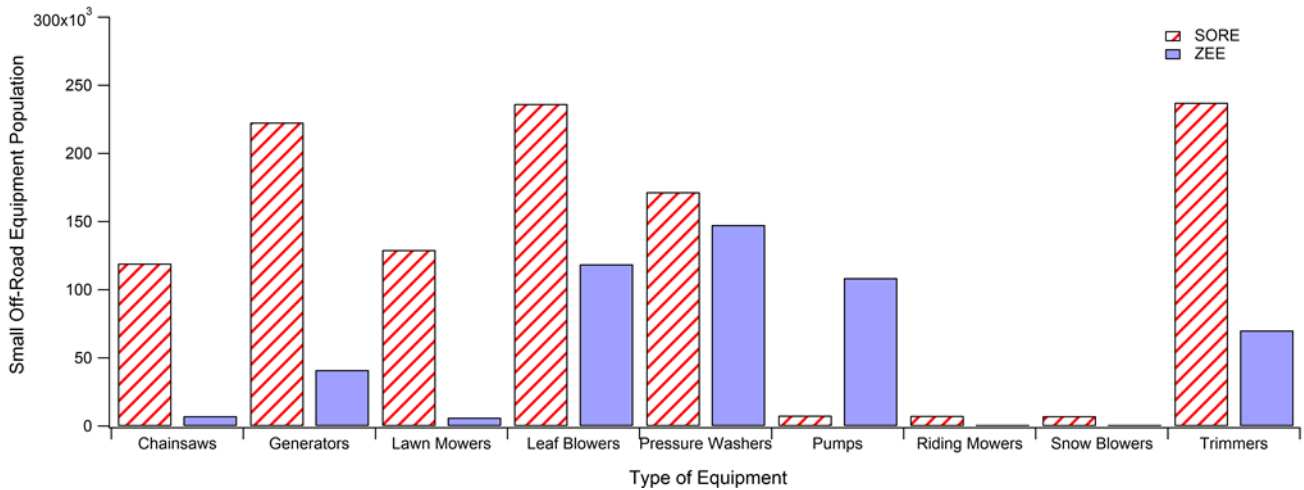


Figure A-3. Small off-road equipment population, by type, owned by landscaping businesses in economic base year 2022.

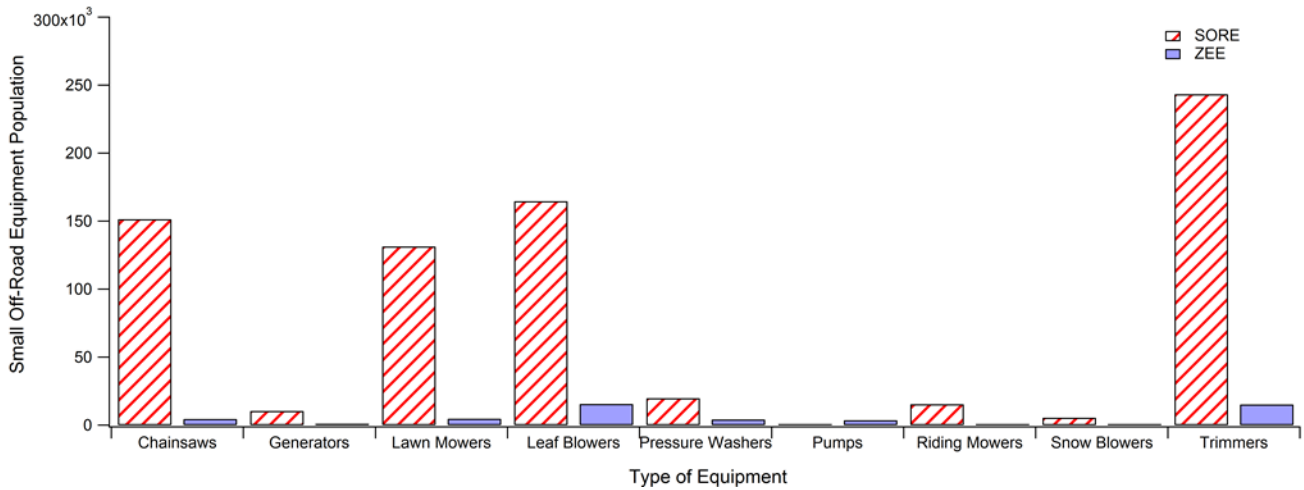
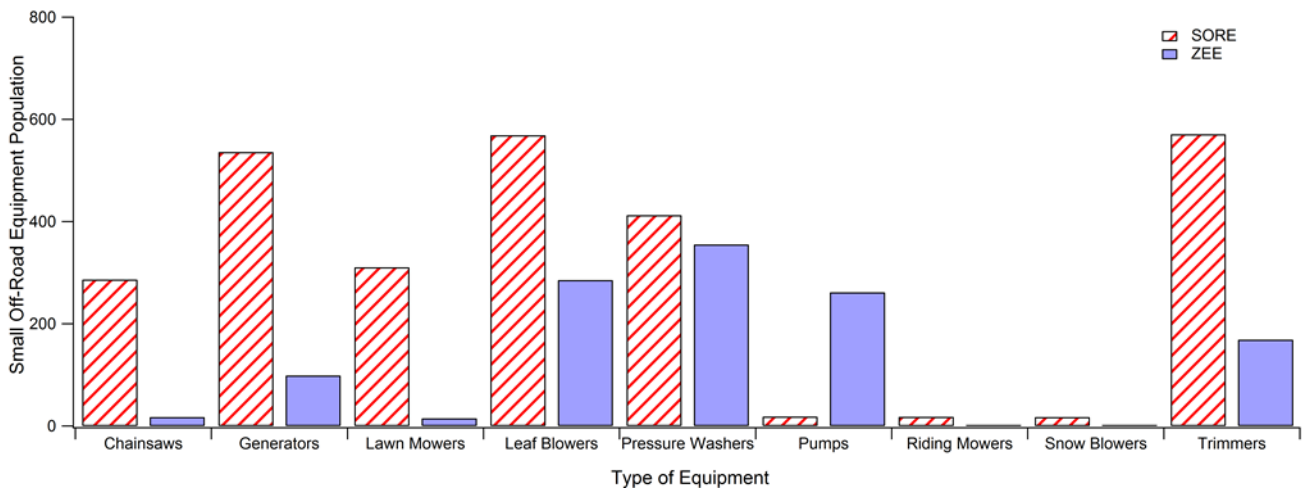


Figure A-4. Small off-road equipment population, by type, owned by government entities in economic base year 2022.



From the economic base year population, staff modeled the statewide small off-road equipment population into future years. Growth is expected in both ZEE and SORE equipment populations. The modeling utilized household growth projections in California along with historical shipment data for gasoline-powered equipment. The small off-road equipment population in the past has tracked well with household growth, so that was used as a proxy going forward.²⁵ Staff developed a survival curve for each category of equipment to calculate the population of a given MY over time. This curve is based on the age distribution of equipment from CSUF survey data. Median age for each equipment type was determined from the results of the CSUF survey. Table A-9 shows the median age of each equipment type by owner. Figure A-5 shows the modeled total population of small off-road

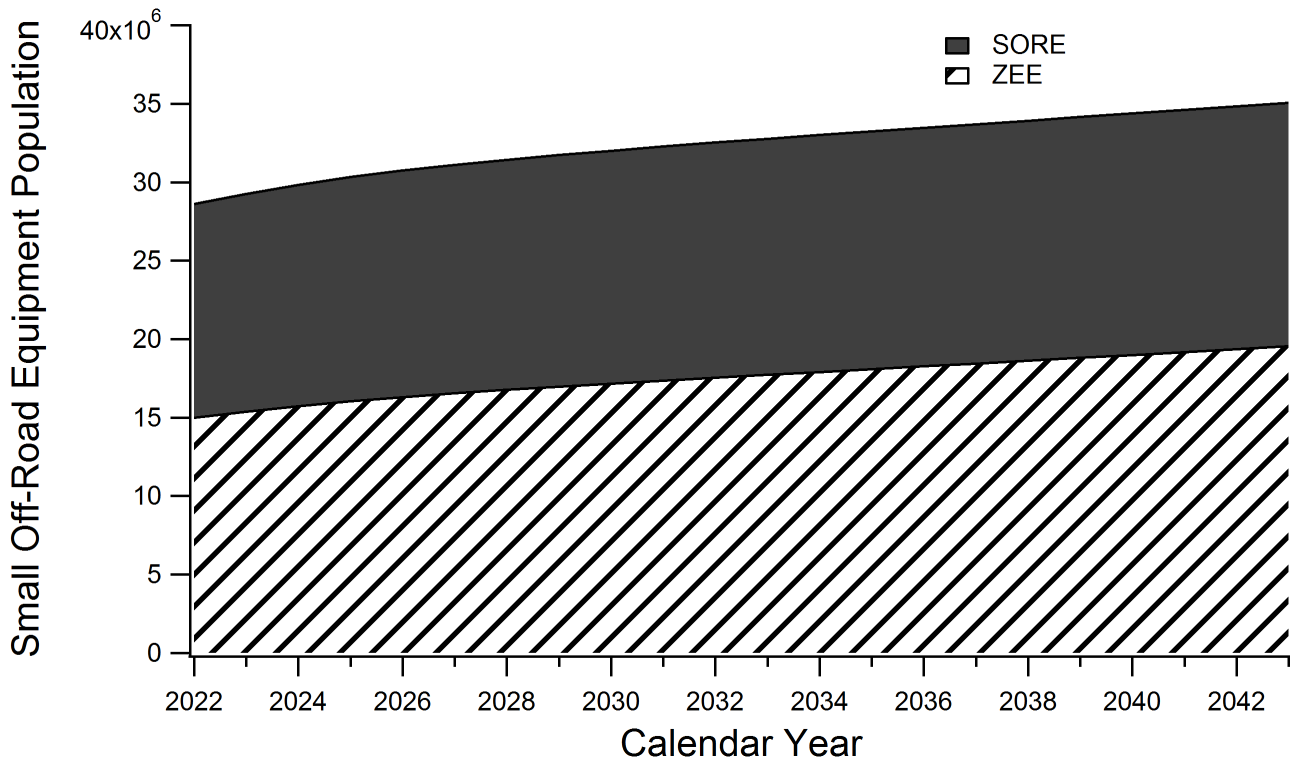
²⁵ CARB. 2020. 2020 Emissions Model for Small Off-Road Engines – SORE2020. Report prepared by staff of the CARB Air Quality Planning and Science Division. September 2020.

equipment for the economic base year of 2022 and during the regulatory horizon of 2023 through 2043 for the Baseline Scenario. In 2035, under the Baseline Scenario, only 54 percent of all small off-road equipment subject to the SORE regulations would be ZEE.

Table A-9. Median equipment age from the CSUF survey.

Type of Equipment	Resident-Owned Median Age (Years)	Business-Owned Median Age (Years)	Landscaper-Owned Median Age (Years)
Chainsaw	5	3	2
Lawn Mower	6	5	3
Leaf Blower	5	3	2
Riding Mower	8	-	5
Trimmer/Edger/Brush Cutter	5	3	2
Generator	7	5	4
Pressure Washer	5	3	3
Pump	6	8	3

Figure A-5. Modeled small off-road equipment population statewide under the Baseline Scenario.



The population inventory does not reflect recent economic changes associated with the COVID-19 pandemic.²⁶ Indeed, the Outdoor Power Equipment Institute reported record growth in sales across the industry in 2020 despite the economic conditions.²⁷ Additionally, generator sales in response to potential PSPS events in California have not yet been fully reflected in the SORE inventory, where we would expect an increase in generator emissions due to increased generator purchases and use during PSPS events. Because the prices of SORE equipment and ZEE are similar for residential users, CARB staff does not expect that any of the regulatory scenarios would induce a change in landscaping type such as removing lawns in favor of hardscaping. The cost of converting landscaping would be substantially higher than the increase in equipment costs.

6. Public Outreach and Input

CARB staff conducted extensive public outreach to solicit input for potential amendments to SORE regulations and received many comments from stakeholders. Stakeholder comments provided staff with useful information that they considered during development of the Proposed Amendments and alternative scenarios. Outreach activities included:

- Participation in conventions and community meetings attended by professional landscapers and local decision-makers;
- Informational briefing to the Board during a public meeting; and
- Three public workshops organized by CARB staff.

CARB staff attended four conventions held for landscapers in California. These conventions provided opportunities for staff to inform professional landscapers about upcoming regulation changes and about ZEE capabilities and availability. CARB staff attended the Green Schools Summit in Pasadena in November 2018, California Landscape Industry Show in Ontario in February 2019, Long Beach Landscape Expo in October 2019, and the NorCal Landscape Show in February 2020.

CARB staff presented information about zero-emission landscaping equipment and the potential for regulatory amendments aimed at transitioning from SORE equipment to ZEE at several community meetings attended by landscapers and local decision-makers in California. CARB staff gave presentations to the Pleasanton Committee on Energy and the Environment in January 2019, the San Francisco Integrated Pest Management Technical Advisory Committee in March 2019, the San Mateo Integrated Pest Management Workshop in April 2019, the San Francisco Commission on the Environment in November 2019, and the Tri Valley Air Quality Community Alliance in April 2021.

CARB staff also presented an informational update on ZEE to the Board in November 2018. Staff described demonstration projects that gave professional landscapers an opportunity to test professional-grade battery-operated landscaping equipment. Additionally, staff

²⁶ Bohn, S., Bonner, D., Lafortune, J., and Thorman, T. Income Inequality and Economic Opportunity in California. Public Policy Institute of California. December 2020.

²⁷ Outdoor Power Equipment Institute. Record Growth in U.S. Outdoor Power Equipment Shipments in 2020. December 16, 2020.

highlighted cities in California that had already replaced their SORE municipal landscaping equipment with ZEE and colleges and universities on the path to do the same.

CARB staff held the first public workshop on potential SORE regulation amendments on September 26, 2019, via webinar and in person. Staff presented regulatory concepts and a plan to require new small off-road equipment to be ZEE. The workshop was attended by industry, environmental groups, and interested citizens.

On November 19, 2019, CARB staff sent an email to stakeholders included on the subscriber lists maintained by CARB for the SORE Working Group (4,000 subscribers) and the Mobile Source Program (5,000 subscribers) to solicit input on potential alternatives to regulatory options presented in the September 2019 workshop.

CARB staff released draft amendment language on May 29, 2020, and held the second public workshop via webinar on June 9, 2020. At the workshop, CARB staff presented a brief history of the problems to be solved by each proposed amendment and a summary of the draft amendments. The staff presentation was followed by an 80-minute question and answer period. The webinar service logged 311 participants. Questions and comments were provided by environmental groups, industry, and interested citizens. CARB staff held the third public workshop on March 24, 2021. Updated draft regulatory text was posted online to facilitate an informed discussion. The staff presentation was followed by an 80-minute question and answer period. The webinar service logged 308 participants. Questions and comments were provided by environmental groups, industry, government agencies, and interested citizens. Several questions and comments were about the ability of zero-emission generators to meet emergency power needs. Staff requested feedback on several aspects of the Proposed Amendments, including the zero-emission generator credit program and updates to test procedures.

B. Benefits

The Revised Draft 2020 Mobile Source Strategy states that “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.”²⁸ An important strategy to reduce harmful effects from air pollution emissions is electrification, i.e., converting all fossil fuel-burning equipment to electric powered equipment. The SORE market is well prepared for electrification. The Proposed Amendments would support the goals of the 2016 State SIP Strategy and would reduce pollutants associated with existing California Ambient Air Quality Standards that have multiple known adverse health effects.²⁹ These pollutants include NO_x, which are key ingredients in the formation of tropospheric

²⁸ CARB. 2020. Revised Draft 2020 Mobile Source Strategy. Report prepared by staff of the Air Quality Planning and Science Division (AQPSD), California Air Resources Board (CARB). April 2021.

²⁹ CARB. 2016. California Ambient Air Quality Standards. List compiled by staff of the CARB Office of Communications on May 4, 2016.

ozone,³⁰ and particulate matter of diameter less than 2.5 microns (PM_{2.5}), which may deposit deep inside the lung. Long-term exposure to PM_{2.5} has been causally linked to premature death, particularly in people who have chronic heart or lung diseases, and reduced lung function in children.³¹ The Proposed Amendments would also reduce greenhouse gas (GHG) emissions and petroleum use.

1. Emission Benefits

a. Inventory Methodology

CARB staff quantified the emissions benefits anticipated to result from the Proposed Amendments using a model developed by CARB called SORE2020. This model is based on several data sources and projections. The SORE population and activity data inputs are based on the results of the CSUF survey.³² The population data encompass all SORE types, including a small amount of engines that are used in construction and farm equipment or vehicles under 175 horsepower that fall under section 209, subsection (e)(1)(A) of the Clean Air Act. The Clean Air Act, however, does not grant CARB the authority to regulate the emissions from this type of engine. Staff assumed that the population of these preempt engines would be unchanged from the Baseline Scenario under all regulatory scenarios. The Proposed Amendments and alternative scenarios assume no change in the total amount of equipment consumers will purchase relative to the Baseline Scenario and that the sum of SORE equipment and ZEE populations is the same as in the Baseline Scenario. Staff assumed that all equipment would be scrapped at the end of its life, and no used equipment sales were considered. In the Baseline Scenario, no further growth in the fraction of ZEE in the sector was modeled.

Staff used manufacturer certification test data and CARB's own test data to develop emission factors for each equipment type. The emission factors take into account deterioration factors (the rate at which emissions increase as equipment is used over its lifetime).

The SORE2020 model calculates emissions estimates for each type of SORE in tons per day through 2050 by multiplying the emission factor by activity data and total population of the equipment. SORE2020 outputs daily emissions estimates for total hydrocarbons (THC), total organic gases, ROG, carbon monoxide (CO), carbon dioxide (CO₂), NO_x, PM, particulate matter with diameter of 10 micrometers or less (PM₁₀), PM_{2.5}, and oxides of sulfur. Staff refined the model after outreach and workshops with the general public and industry

³⁰ The Royal Society. Ground-level ozone in the 21st century: future trends, impacts and policy implications. October 2008.

³¹ Xing, Y., Xu, Y., Shi, M., and Lian, Y. 2016. The impact of PM_{2.5} on the human respiratory system. *Journal of Thoracic Disease*. January 2016.

³² CSUF SSRC. 2019. Survey of Small Off-Road Engines (SORE) Operating within California: Results from Surveys with Four Statewide Populations. May 15, 2019. Prepared by the Social Science Research Center (SSRC) at California State University, Fullerton (CSUF), for CARB and the California Environmental Protection Agency, under CARB Agreement 16MLD011.

stakeholders. Further details on the model methodology can be found in the SORE2020 Technical Report.³³

The SORE2020 model run for the Proposed Amendments also included the expected effect of current emission reduction credit banks. The most recent complete credit bank data set available at the time of calculation was from the end of MY 2018. As of the end of MY 2018, manufacturers collectively held 2.0 billion grams worth of exhaust emission credits and 138 thousand grams of evaporative emission credits.³⁴ Based on CARB’s historical records of the emission reduction credit banks, the sum of banked credits has remained relatively constant over the last several years. Given this, staff assumed that the sum of banked credits would remain constant after MY 2018 due to the equal amounts of credits expiring (after five years) or being used and new credits being earned. For the Proposed Amendments, the SORE2020 model assumed that all available credits would be used by manufacturers for generators, and that the credits would be used equally across the four-year period when generators would be subject to more stringent emission standards (MYs 2024 through 2027). The exhaust and evaporative credit banks were treated separately and assumed to be completely exhausted by the end of MY 2027. Staff calculated that, using a sales-weighted average, manufacturers could use credits to certify MY 2024 through 2027 generators with emission rates higher than the newly-implemented emission standards, as shown in Tables B-1 and B-2. The SORE2020 model used these emission levels when calculating overall emission reductions.

Table B-1. Exhaust emission standards and modeled emission levels for MY 2024-2027 generators assuming complete use of banked credits under the Proposed Amendments.

Displacement category	HC + NO _x emission standard (g·kWh ⁻¹)	HC + NO _x emission level with credit use (g·kWh ⁻¹)
< 50 cc	6.0	10.4
50-80 cc, inclusive	6.0	8.5
> 80 cc - < 225 cc	6.0	6.7
225-825 cc, inclusive	3.0	3.8
> 825 cc	0.80	0.80 ³⁵

Table B-2. Evaporative emission standards and modeled emission levels for MY 2024-2027 generators assuming complete use of banked credits under the Proposed Amendments.

Displacement category	Hot soak plus diurnal emission standard (g·test ⁻¹)	Hot soak plus diurnal emission level with credit use (g·test ⁻¹)
≤ 80 cc	0.50	0.68
> 80 cc - < 225 cc	0.60	0.65
≥ 225 cc	0.70	0.85

³³ CARB. 2020. 2020 Emissions Model for Small Off-Road Engines – SORE2020. Report prepared by staff of the CARB Air Quality Planning and Science Division. September 2020.

³⁴ The credit banks are based on manufacturer reported sales data. They are subject to validation by CARB staff.

³⁵ No credit use was assumed as large spark-ignition engines in this displacement category have been subject to an equivalent emission standard since MY 2015.

b. Anticipated Emission Benefits

Table B-3 identifies the modeled annual average NO_x, ROG, and CO₂ emissions benefits of the Proposed Amendments. NO_x and ROG emission reductions are in tons per day (tpd). CO₂ emission reductions are in million metric tons per year (MMT/year). Staff calculated emission reduction benefits based on the difference in modeled emissions between the Baseline Scenario and Proposed Amendments scenario each year for the regulatory horizon of 2023 through 2043. Figures B-1 and B-2 graphically show the modeled emissions of NO_x and ROG, respectively, for the Baseline Scenario and Proposed Amendments. In the Baseline Scenario, NO_x and ROG emissions increase year over year due to an increase in population of SORE equipment.

Significant reductions in both NO_x and ROG emissions would begin in calendar year 2025 under the Proposed Amendments, years before emission standards for generators would be zero. Emission reduction benefits would continue to increase as more SORE equipment reach the end of their life and are replaced with ZEE. In 2031, the reductions are expected to be approximately 7.4 tpd of NO_x and 55 tpd of ROG. These are 43 percent and 51 percent reductions of NO_x and ROG, respectively, compared to Baseline Scenario emissions of 17.4 tpd of NO_x and 108 tpd of ROG. The cumulative total emission reductions from 2023 through 2043 as a result of the Proposed Amendments are approximately 59,307 tons of NO_x and 423,240 tons of ROG compared to the Baseline Scenario. By 2043, NO_x and ROG emissions would not reach zero but would be approximately 6.2 tpd and 27.4 tpd, respectively. The remaining emissions would be produced by engines that are used in federally-regulated construction and farm equipment or vehicles under 175 horsepower that are included in the SORE2020 model but are preempt and not subject to the SORE regulations.

Table B-3. Annual average emission reductions under the Proposed Amendments.

(Totals may not add up due to rounding.)

Year	ROG emission reductions (tpd)	NO_x emission reductions (tpd)	CO₂ emission reductions (MMT/year)
2023	0.00	0.00	0.00
2024	3.3	0.46	0.05
2025	10.9	1.4	0.13
2026	19.7	2.4	0.23
2027	28.4	3.4	0.31
2028	36.3	4.4	0.40
2029	43.4	5.5	0.48
2030	49.6	6.5	0.57
2031	55.0	7.4	0.64
2032	59.6	8.2	0.71
2033	63.7	8.9	0.77
2034	67.4	9.6	0.82
2035	70.8	10.1	0.87
2036	73.9	10.7	0.91
2037	76.7	11.1	0.94
2038	79.1	11.5	0.97
2039	81.2	11.8	1.0
2040	83.0	12.0	1.0
2041	84.6	12.3	1.0
2042	85.9	12.5	1.1
2043	87.1	12.6	1.1
Average	55.2	7.7	0.66
Total	423,240	59,307	13.9

Figure B-1. Annual average NO_x emissions under the Proposed Amendments and the Baseline Scenario.

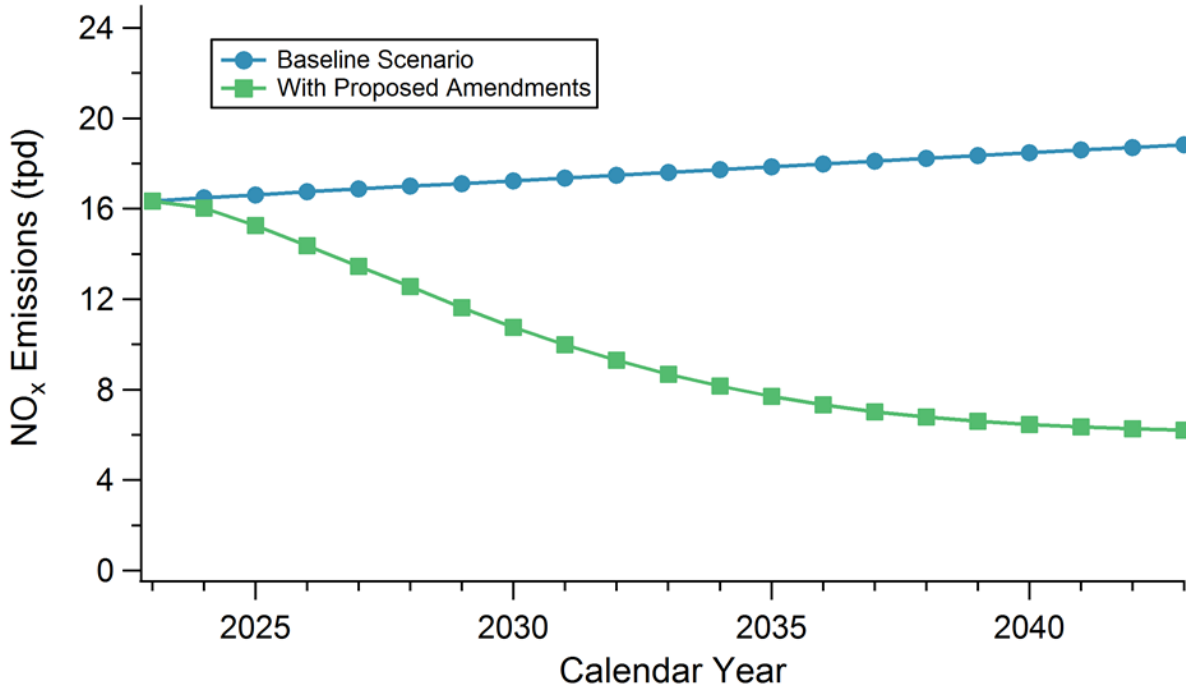
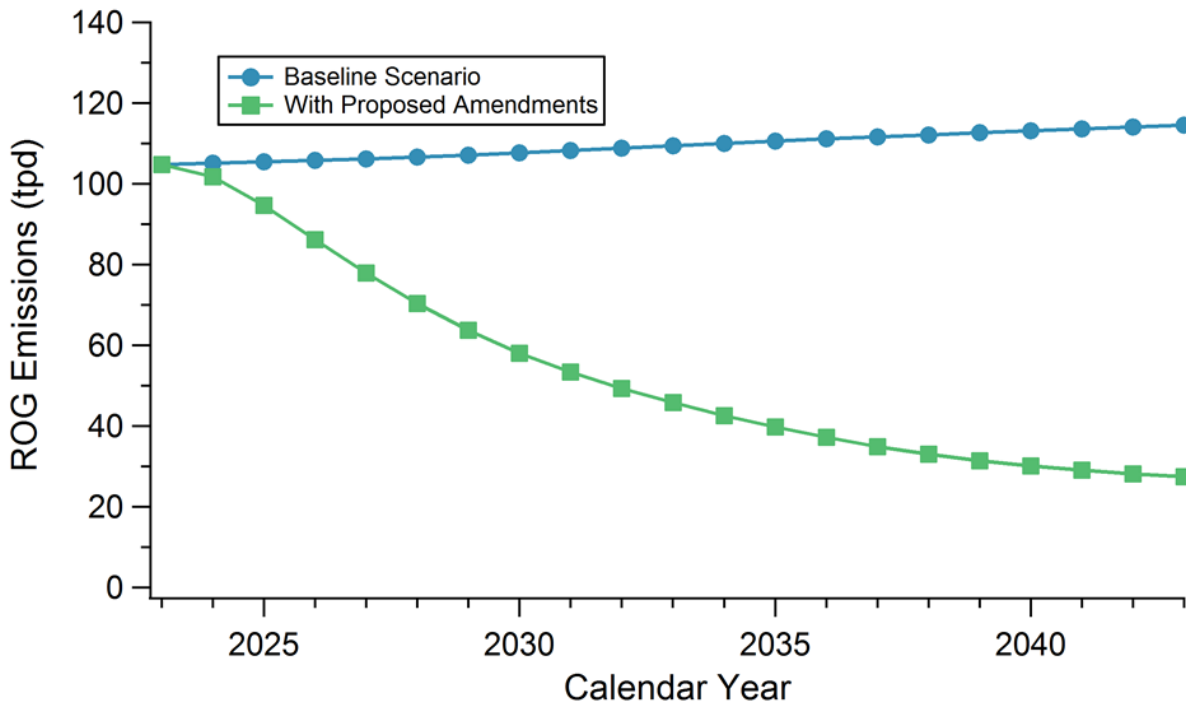


Figure B-2. Annual average ROG emissions under the Proposed Amendments and the Baseline Scenario.



A decrease in use of portable fuel containers (PFC) may result in greater ROG emission reductions than those calculated by the SORE2020 model. PFCs are used to transport gasoline from dispensing facilities (e.g., convenience stores and service stations) to SORE equipment. PFCs are a source of ROG emissions when they are being filled at the dispensing facilities, while they are being used to store fuel, and when they are used to fill SORE fuel tanks. Because of increased adoption of ZEE, staff expects a decreased need for PFC use, which would lead to further ROG emission reductions.

It is possible to estimate the ROG emission reductions from the decreased fueling of PFCs at gasoline dispensing facilities (GDFs) by combining several fueling emission factors with the reduction in gasoline use from the direct cost analysis. CARB has established emission factors for several aspects of fueling, including transfer of gasoline from a cargo tanker to the GDF storage tank (Phase I transfers) and from the storage tank to the vehicle (Phase II transfers) (CARB, 2013³⁶). The analysis assumed that all PFCs are fueled at GDFs that are equipped with underground storage tanks and Phase II enhanced vapor recovery controls.³⁷ The emission factors can be added to estimate potential emission reductions at GDFs as 8.82 pounds of ROG emitted per thousand gallons of gasoline dispensed. The reduction in gasoline dispensed as a result of the Proposed Amendments is based on total population of SORE equipment included in the economic analysis (i.e., preempt equipment is not included) in a given year and average usage rates and load factors for equipment per category, as described in Section C.1.d. Combining these values yields a ROG emission reduction beyond the reductions reported via SORE2020. The ROG emission reductions from reduced fuel dispensing are calculated as 1.3 tpd and 2.6 tpd for 2031 and 2043, respectively. In sum, 11,600 tons of ROG emissions from filling PFCs for fueling SORE equipment would be avoided over the regulatory horizon of 2023 through 2043. Further ROG emission reductions due to permeation from the PFCs, spillage, and fueling the SORE equipment are also likely but cannot be quantified at this time.

The Proposed Amendments will significantly reduce criteria air pollutants to achieve 2016 State SIP Strategy expected emission reductions and create associated health benefits. By setting more stringent criteria air pollutant standards, there will also be associated GHG reductions due to increased adoption of ZEE. Modeled results for 2023 through 2043 under

³⁶ CARB. 2013. Revised Emission Factors for Gasoline Marketing Operations at California Gasoline Dispensing Facilities. Report prepared by staff of the Monitoring and Laboratory Division, California Air Resources Board (CARB). December 23, 2013. The following emission factors in pounds of ROG emitted per thousand gallons gasoline dispensed (lbs/kgal) were added to estimate emission reductions that would occur at GDFs under the Proposed Amendments: (a) To estimate emissions while PFCs are open at GDFs: 8.4 lbs/kgal, the uncontrolled emission factor used to characterize Phase II fueling of vehicles that do not have onboard refueling vapor recovery systems; and (b) To estimate other GDF emissions that would be reduced if less gasoline were dispensed to PFCs: (i) 0.15 lbs/kgal for Phase I "revised EVR" bulk transfer losses, (ii) 0.24 lbs/kgal for Phase II "revised EVR" nozzle spillage, (iii) 0.009 lbs/kgal for Phase II "EVR Year 2017" hose permeation, and (iv) 0.024 lbs/kgal for "revised EVR" pressure driven losses.

³⁷ In 2000, CARB approved Enhanced Vapor Recovery (EVR) regulations for GDFs equipped with underground storage tanks. The EVR regulations were enacted to achieve additional emission reductions and to increase equipment reliability by adopting nearly 80 new performance standards or specifications and increasing testing requirements. Not all GDFs throughout California are required to install Phase II EVR controls. Using the emission factors for GDFs with underground storage tanks and Phase II EVR controls provides a conservative emission reduction estimate, i.e., one that may under-estimate the total emission reduction benefit of the Proposed Amendments from the filling of PFCs at GDF.

the Proposed Amendments totaled over 15 million tons of CO₂ emission reductions compared to the Baseline Scenario. As illustrated in Table B-3, CO₂ emissions reductions would begin in 2024 and increase in each subsequent year.

2. Benefits to Typical Businesses

To determine the Proposed Amendments' costs on typical businesses, the economic analysis for new small off-road equipment discusses all costs directly from a user perspective. Here, typical businesses are considered to be all affected businesses in California that are not small businesses (e.g., businesses that own and use small off-road equipment to maintain their property). A substantial benefit to typical businesses across the state from the Proposed Amendments would be the increased durability of the small off-road equipment they purchase. The Proposed Amendments would increase the durability requirements for SORE starting in MY 2024. While engine durability is not a feature that is necessarily advertised to consumers, increased durability would lead to a more reliable product, which staff assume would be appreciated by business users of generators faced with PSPS or other unexpected power outages. Under the Proposed Amendments, zero-emission generators certified with the zero-emission generator credit program must meet a 500-hour durability period. This will ensure that zero-emission generators will be able to run for the same time as SORE generators.

With regards to ZEE, ZEE batteries frequently outlive the lifetime of equipment. The first purchase of ZEE requires purchasing sufficient batteries for use time (e.g., an eight-hour workday), which is a significant contributor to the upfront cost for professional-grade equipment. ZEE batteries can often be used in several products within a manufacturer's family of ZEE. Subsequent purchases of equipment within a manufacturer's family of ZEE may require purchasing fewer batteries in addition to those that come with the equipment, therefore lowering the purchase price significantly, because the owner may use his or her existing batteries from previous purchases. In this analysis, upfront costs for ZEE purchases have been assumed to be constant and include battery costs, as staff has no means of tracing which equipment purchases are new versus subsequent. This creates the most conservative estimate. Maintenance is also much less intensive and required less frequently on ZEE. Having more durable equipment that is not taken out of service for maintenance reduces the need for backup equipment and spare parts. Furthermore, owners of ZEE will save travel time to a gasoline dispensing facility to fill PFCs with fuel for their SORE equipment. They will also not need to purchase replacement or extra PFCs.

3. Benefits to Small Businesses

To determine the Proposed Amendments' costs on small businesses, the economic analysis for new small off-road equipment discusses all costs directly from a user perspective. Examples of small businesses that would be affected by the Proposed Amendments are landscaping businesses, both licensed and unlicensed. The benefits to these businesses would be similar to those discussed in the typical business section, including more reliable ZEE, lower maintenance costs, and less frequent replacement of equipment.

4. Benefits to Individuals

a. Health Benefits

i Background on Health Benefits and Model

The Proposed Amendments would reduce NO_x, ROG, and PM_{2.5} emissions and reduce the formation of ozone, resulting in health benefits for individuals in California. These health benefits include fewer instances of premature mortality, fewer hospital and emergency room (ER) visits for asthma, and fewer lost days of work. As part of setting the National Ambient Air Quality Standards for PM, the U.S. EPA quantifies the health risk from exposure to PM, and CARB relies on the same health studies for this evaluation.³⁸ The evaluation method used in this analysis is the same as the one used for the Advanced Clean Truck Regulation and the 2018 amendments to the Low Carbon Fuel Standard.^{39,40}

Due to their small particle sizes, PM_{2.5} in air can reach the lower respiratory tract and potentially pass into the bloodstream to affect other organs.^{41,42} By this means, PM_{2.5} air pollution exposure leads not only to a potential increased cancer risk, but it also causes respiratory and cardiovascular diseases and even premature death; adverse health outcomes from PM_{2.5} include asthma, chronic heart disease, and heart attack.^{43,44,45,46} Moreover, PM_{2.5} air pollution can result in respiratory, cardiac, and mortality effects over short periods of exposure such as hours, days, or weeks.⁴⁷

As part of the health benefits analyses, CARB analyzed the value associated with four health outcomes: cardiopulmonary (related to the lungs or heart) mortality, hospitalizations for cardiovascular (related to the heart and blood vessels) illness, hospitalizations for respiratory illness, and ER visits for asthma. These health outcomes were selected because U.S. EPA identified these as having a causal or likely causal relationship with exposure to PM_{2.5}.⁴⁸ U.S. EPA examined other health endpoints such as cancer, reproductive and developmental effects, but determined there was only suggestive evidence for a relationship between these

³⁸ U.S. EPA. Quantitative Health Risk Assessment for Particulate Matter. June 2010.

³⁹ California Air Resources Board. Advanced Clean Trucks Regulation Standardized Regulatory Impact Assessment Report prepared by the staff of the Mobile Source Control Division. August 8, 2019.

⁴⁰ California Air Resources Board. 2018. Staff Report: Initial Statement of Reasons for the Proposed Amendments to the Low Carbon Fuel Standard Regulation. Report prepared by the staff of the Industrial Strategies Division. March 6, 2018.

⁴¹ CARB. Inhalable Particulate Matter and Health (PM_{2.5} and PM₁₀). (Web link: <https://ww2.arb.ca.gov/resources/inhalable-particulate-matter-and-health>. Last accessed July 16, 2021.)

⁴² U.S. EPA. Health and Environmental Effects of Particulate Matter (PM). (Web link: <https://www.epa.gov/pm-pollution/health-and-environmental-effects-particulate-matter-pm>. Last accessed July 16, 2021).

⁴³ CARB. Inhalable Particulate Matter and Health (PM_{2.5} and PM₁₀). (Web link: <https://ww2.arb.ca.gov/resources/inhalable-particulate-matter-and-health>. Last accessed July 16, 2021.)

⁴⁴ U.S. EPA. Integrated Science Assessment for Particulate Matter. December 2019.

⁴⁵ U.S. EPA. Health and Environmental Effects of Particulate Matter (PM). (Web link: <https://www.epa.gov/pm-pollution/health-and-environmental-effects-particulate-matter-pm>. Last accessed July 16, 2021).

⁴⁶ World Health Organization, Europe. 2013. Review of Evidence on Health Aspects of Air Pollution - REVIHAAP Project: Technical Report. 2013.

⁴⁷ U.S. EPA. Integrated Science Assessment for Particulate Matter. December 2019.

⁴⁸ U.S. EPA. Quantitative Health Risk Assessment for Particulate Matter. June 2010.

outcomes and PM exposure, and insufficient data to include these endpoints in the national health assessment analyses.⁴⁹

U.S. EPA has determined that both long-term and short-term exposure to PM_{2.5} play a causal role in premature mortality, meaning that a substantial body of scientific evidence shows a relationship between PM_{2.5} exposure and increased risk of death. This relationship persists when other risk factors such as smoking rates, poverty and other factors are taken into account.⁵⁰ While other mortality endpoints could be analyzed, the strongest evidence exists for cardiopulmonary mortality. The greater scientific certainty for this effect, along with the greater specificity of the endpoint, leads to an effect estimate for cardiopulmonary deaths that is both higher and more precise than that for all-cause mortality.⁵¹

Similarly, U.S. EPA has determined a causal relationship between nonmortality cardiovascular effects and short and long-term exposure to PM_{2.5} and a likely causal relationship between nonmortality respiratory effects and short and long-term PM_{2.5} exposure.⁵² These outcomes lead to hospitalizations and ER visits, and are included in this analysis.

A detailed summary of the health modeling methodology can be found in the health benefits technical report.⁵³

ii. Results

Table B-4 shows the estimated total avoided premature mortality, hospitalizations, and ER visits for asthma by California air basin that would result from implementation of the Proposed Amendments between 2023 and 2043, relative to the Baseline Scenario. Only the air basins with values of one or higher are shown. The biggest health benefits would occur in the South Coast and San Francisco Bay Area Air Basins. Table B-5 shows the estimated avoided health outcomes by year. As described in Section B.1.b, the Proposed Amendments are estimated to reduce overall emissions of NO_x and ROG in every year starting in 2024, and lead to net reduction in adverse health outcomes statewide, relative to the Baseline Scenario. Health benefits would begin in 2024, and the reduction in cases and deaths would continue to increase through the end of the regulatory horizon as more SORE equipment are replaced with ZEE and more units are purchased. Overall, the mortality rate due to cardiopulmonary causes will decrease by 892 over the regulatory horizon under the Proposed Amendments.

⁴⁹ Diesel particulate matter, a portion of PM 2.5, was deemed a TAC by CARB in 1998.

⁵⁰ Ibid.

⁵¹ Ostro, B. et al. Fine Particulate Air Pollution and Mortality in Nine California Counties: Results from CALFINE. Environmental Health Perspectives. January 2006.

⁵² U.S. EPA. Integrated Science Assessment (ISA) for Particulate Matter. December 2019.

⁵³ California Air Resources Board. Estimating Health Benefits Associated with Reductions in PM and NO_x Emissions: Detailed Description. Report prepared by staff of the Research Division. May 2019.

Table B-4. Modeled regional and statewide avoided mortality and morbidity incidents from 2023 through 2043 under the Proposed Amendments, central estimates and 95 percent confidence intervals.⁵⁴

(Totals may not add up due to rounding.)

Air Basin	Avoided premature cardiopulmonary mortality	Avoided cardiovascular hospitalizations	Avoided acute respiratory hospitalizations	Avoided ER visits for asthma
Lake County	1 (1 - 1)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)
Mojave Desert	3 (3 - 4)	0 (0 - 1)	1 (0 - 1)	1 (1 - 2)
Mountain Counties	5 (4 - 6)	0 (0 - 1)	1 (0 - 1)	2 (1 - 2)
North Central Coast	4 (3 - 5)	1 (0 - 1)	1 (0 - 1)	2 (1 - 3)
North Coast	1 (1 - 1)	0 (0 - 0)	0 (0 - 0)	0 (0 - 1)
Sacramento Valley	31 (24 - 38)	4 (0 - 7)	5 (1 - 8)	12 (7 - 16)
Salton Sea	3 (2 - 3)	0 (0 - 1)	0 (0 - 1)	1 (1 - 2)
San Diego County	51 (40 - 62)	7 (0 - 14)	9 (2 - 15)	20 (13 - 28)
San Francisco Bay Area	114 (89 - 140)	18 (0 - 35)	21 (5 - 38)	62 (39 - 85)
San Joaquin Valley	56 (44 - 68)	7 (0 - 13)	8 (2 - 14)	20 (13 - 28)
South Central Coast	18 (14 - 21)	3 (0 - 5)	3 (1 - 6)	8 (5 - 10)
South Coast	605 (473 - 739)	101 (0 - 199)	121 (28 - 213)	308 (195 - 421)
Statewide	892 (697 - 1090)	142 (0 - 278)	169 (40 - 298)	438 (277 - 599)

⁵⁴ The health benefits modeling is done using an incidence-per-ton methodology allowing for 95 percent confidence intervals and a central estimate to be calculated.

Table B-5. Annual statewide avoided mortality and morbidity incidents under the Proposed Amendments, central estimates and 95 percent confidence intervals.

(Totals may not add up due to rounding.)

Year	Avoided premature cardiopulmonary mortality	Avoided cardiovascular hospitalizations	Avoided acute respiratory hospitalizations	Avoided ER visits for asthma
2023	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)
2024	2 (2 - 3)	0 (0 - 1)	0 (0 - 1)	1 (1 - 2)
2025	8 (6 - 10)	1 (0 - 2)	1 (0 - 2)	4 (3 - 5)
2026	14 (11 - 17)	2 (0 - 4)	2 (1 - 4)	7 (4 - 10)
2027	20 (16 - 24)	3 (0 - 6)	3 (1 - 6)	10 (6 - 14)
2028	26 (20 - 32)	4 (0 - 7)	4 (1 - 8)	13 (8 - 18)
2029	31 (24 - 38)	5 (0 - 9)	6 (1 - 10)	16 (10 - 22)
2030	36 (28 - 44)	5 (0 - 11)	7 (2 - 12)	18 (12 - 25)
2031	41 (32 - 50)	6 (0 - 12)	7 (2 - 13)	20 (13 - 28)
2032	45 (35 - 55)	7 (0 - 14)	8 (2 - 15)	22 (14 - 31)
2033	49 (38 - 59)	8 (0 - 15)	9 (2 - 16)	24 (15 - 33)
2034	52 (41 - 63)	8 (0 - 16)	10 (2 - 17)	26 (16 - 35)
2035	55 (43 - 67)	9 (0 - 17)	10 (2 - 18)	27 (17 - 37)
2036	58 (45 - 70)	9 (0 - 18)	11 (3 - 20)	28 (18 - 39)
2037	60 (47 - 73)	10 (0 - 19)	12 (3 - 20)	29 (19 - 40)
2038	62 (48 - 76)	10 (0 - 20)	12 (3 - 21)	30 (19 - 41)
2039	64 (50 - 78)	10 (0 - 20)	12 (3 - 22)	31 (20 - 42)
2040	65 (51 - 80)	11 (0 - 21)	13 (3 - 23)	32 (20 - 43)
2041	67 (52 - 82)	11 (0 - 22)	13 (3 - 23)	32 (20 - 44)
2042	68 (53 - 83)	11 (0 - 22)	13 (3 - 24)	33 (21 - 45)
2043	69 (54 - 85)	11 (0 - 23)	14 (3 - 24)	33 (21 - 46)
Total	892 (697 - 1090)	142 (0 - 278)	169 (40 - 298)	438 (277 - 599)

iii. Economic Impact of Health Benefits

In accordance with U.S. EPA practice, health outcomes are monetized by multiplying each incident by a standard value derived from the economic studies.⁵⁵ Table B-6 provides the value per incident in 2019 dollars (2019\$). The value for avoided premature mortality is based on willingness to pay, which is a statistical construct based on the aggregated dollar amount that a large group of people would be willing to pay for a reduction in their individual risks of dying in a year.⁵⁶ The economic value associated with reduced premature mortality is a key benefit of the Proposed Amendments. This benefit, however, does not correspond to direct changes in expenditures for households and businesses and is not included in the macroeconomic modeling (Chapter E). Because avoided hospitalizations and ER visits

⁵⁵ U.S. EPA. 2010. Appendix B: Mortality Risk Valuation Estimates, Guidelines for Preparing Economic Analyses. December 2010.

⁵⁶ U.S. EPA. 2000. An SAB Report on EPA's White Paper Valuing the Benefits of Fatal Cancer Risk Reduction. July 27, 2000.

correspond to reductions in household expenditures on health care, these values are included in the macroeconomic modeling.

Unlike mortality valuation, the savings for avoided hospitalizations and ER visits for asthma are based on a combination of typical costs associated with hospitalization and the willingness of surveyed individuals to pay to avoid adverse outcomes that occur when hospitalized. These include hospital charges, post-hospitalization medical care, out-of-pocket expenses, and lost earnings of both individuals and family members, lost recreation value, and lost household production (e.g., valuation of time-losses from inability to maintain the household or provide childcare).⁵⁷ These monetized benefits from avoided hospitalizations and ER visits for asthma are included in the macroeconomic modeling (Chapter E).

Table B-6. Valuation per incident for avoided health outcomes (2019\$).

Outcome	Value per incident
Premature cardiopulmonary mortality	\$9,865,659
Cardiovascular hospitalization	\$58,275
Acute respiratory hospitalization	\$50,831
ER visit for asthma	\$834

Staff calculated the statewide valuation of health benefits by multiplying the value per incident in Table B-6 by the annual number and type of incidents. Table B-7 provides annual totals. Table B-8 provides a summarized total throughout the regulatory horizon. The estimated total valuation statewide of the health benefit derived from criteria emission reductions is approximately \$8.82 billion, with \$8.80 billion resulting from reduced premature mortality and \$17.2 million resulting from reduced hospitalizations and ER visits for asthma. The spatial distribution of these benefits across the state follows the distribution of the health impacts by air basin as described in Table B-4.

⁵⁷ Chestnut, L. G., Thayer, M. A., Lazo, J. K., and Van Den Eeden, S. K. 2008, The Economic Value Of Preventing Respiratory and Cardiovascular Hospitalizations. *Contemporary Economic Policy*, 24: 127–143. January 2006.

Table B-7. Annual valuation of avoided health outcomes under the Proposed Amendments (million 2019\$).

Year	Avoided premature cardiopulmonary mortality valuation	Avoided cardiovascular hospitalization valuation	Avoided acute respiratory hospitalization valuation	Avoided ER visit for asthma valuation	Annual total valuation
2023	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00
2024	\$19.73	\$0.00	\$0.00	\$0.00	\$19.73
2025	\$78.93	\$0.06	\$0.05	\$0.00	\$79.04
2026	\$138.12	\$0.12	\$0.10	\$0.01	\$138.34
2027	\$197.31	\$0.17	\$0.15	\$0.01	\$197.65
2028	\$256.51	\$0.23	\$0.20	\$0.01	\$256.95
2029	\$305.84	\$0.29	\$0.30	\$0.01	\$306.45
2030	\$355.16	\$0.29	\$0.36	\$0.02	\$355.83
2031	\$404.49	\$0.35	\$0.36	\$0.02	\$405.21
2032	\$443.95	\$0.41	\$0.41	\$0.02	\$444.79
2033	\$483.42	\$0.47	\$0.46	\$0.02	\$484.36
2034	\$513.01	\$0.47	\$0.51	\$0.02	\$514.01
2035	\$542.61	\$0.52	\$0.51	\$0.02	\$543.67
2036	\$572.21	\$0.52	\$0.56	\$0.02	\$573.32
2037	\$591.94	\$0.58	\$0.61	\$0.02	\$593.16
2038	\$611.67	\$0.58	\$0.61	\$0.03	\$612.89
2039	\$631.40	\$0.58	\$0.61	\$0.03	\$632.62
2040	\$641.27	\$0.64	\$0.66	\$0.03	\$642.60
2041	\$661.00	\$0.64	\$0.66	\$0.03	\$662.33
2042	\$670.86	\$0.64	\$0.66	\$0.03	\$672.19
2043	\$680.73	\$0.64	\$0.71	\$0.03	\$682.11
Total	\$8,800.17	\$8.28	\$8.59	\$0.37	\$8,817.40

Table B-8. Statewide valuation from avoided health outcomes under the Proposed Amendments.

Outcome	Avoided incidents	Valuation (million 2019\$)
Premature cardiopulmonary mortality	892	\$8,800.17
Cardiovascular Hospitalization	142	\$8.28
Acute Respiratory Hospitalization	169	\$8.59
ER Visit for asthma	438	\$0.37
Total	1,642	\$8,817.40

b. Social Cost of Carbon

The Proposed Amendments will significantly reduce criteria air pollutants to achieve 2016 State SIP Strategy expected emission reductions and associated health benefits. By setting more stringent criteria air pollutant emission standards, there will be associated GHG reductions due to increased adoption of ZEE. The benefit of these GHG reductions can be

estimated using the Social Cost of Carbon (SC-CO₂), which provides a dollar valuation of the damages caused by one ton of carbon pollution and represents the monetary benefit today of reducing carbon emissions in the future.

In this analysis, CARB utilizes the current federal Interagency Working Group (IWG) supported SC-CO₂ values to consider the social costs of actions taken to reduce GHG emissions. This is consistent with the approach presented in California’s 2017 Climate Change Scoping Plan,⁵⁸ with U.S. Presidential Executive Order 12866 and the Office of Management and Budget (OMB) Circular A-4 of September 17, 2003, and reflects the best available science in the estimation of the socio-economic impacts of carbon.⁵⁹

IWG describes SC-CO₂ as follows:

The social cost of carbon (SC-CO₂) for a given year is an estimate, in dollars, of the present discounted value of the future damage caused by a 1-metric ton increase in carbon dioxide (CO₂) emissions into the atmosphere in that year, or equivalently, the benefits of reducing CO₂ emissions by the same amount in that year. The SC-CO₂ is intended to provide a comprehensive measure of the net damages – that is, the monetized value of the net impacts – from global climate change that result from an additional ton of CO₂.

These damages include, but are not limited to, changes in net agricultural productivity, energy use, human health, property damage from increased flood risk, as well as nonmarket damages, such as the services that natural ecosystems provide to society. Many of these damages from CO₂ emissions today will affect economic outcomes throughout the next several centuries.⁶⁰

Table B-9 presents the range of IWG SC-CO₂ values used in regulatory assessments, including California’s 2017 Climate Change Scoping Plan.

Table B-9. Social cost of carbon 2020-2040 (2007\$ per metric ton).

Year	5 Percent Discount Rate	3 Percent Discount Rate	2.5 Percent Discount Rate
2020	\$12	\$42	\$62
2025	\$14	\$46	\$68
2030	\$16	\$50	\$73
2035	\$18	\$55	\$78
2040	\$21	\$60	\$84

The SC-CO₂ is year specific; that is, environmental damages are estimated for a given year in the future and the value of the damages is discounted back to the present. The SC-CO₂ increases over time as systems become stressed from the aggregate impacts of climate change and future emissions cause incrementally larger damages. The SC-CO₂ is highly

⁵⁸ California Air Resources Board. California’s 2017 Climate Change Scoping Plan. Report prepared by the Industrial Strategies Division. November 2017.

⁵⁹ Office of Management and Budget. Circular A-4. September 17, 2003.

⁶⁰ National Academies of Sciences, Engineering, and Medicine. Valuing Climate Damages: Updating Estimation of the Social Cost of Carbon Dioxide. 2017.

sensitive to the discount rate. The discount rate is the rate at which future benefits (or costs) are reduced such that they can be compared to a benefit received in the present. In the context of the SC-CO₂, it is intended to represent the tradeoff for society between present and future welfare. Higher discount rates decrease the present value of future environmental benefits (avoided damages). IWG estimates the SC-CO₂ across a range of discount rates that encompass a variety of assumptions regarding the correlation between climate damages and consumption of goods and is consistent with OMB's Circular A-4 guidance including the range of discounts. CARB utilizes the IWG standardized range of discount rates, from 2.5 to 5 percent to represent varying valuation of future damages.⁶¹ Because the IWG SC-CO₂ prices are in 2007 dollars, staff applied an inflation adjustment, using the California Consumer Product Index (CPI), to convert them into 2019 dollars, consistent with the rest of this analysis.⁶²

If all of the expected emissions reduction projected under the Proposed Amendment are achieved and assumed to be equivalent to CO₂ emission reductions, the avoided SC-CO₂ in a given year is the total emission reductions in metric tons of carbon dioxide equivalents (MTCO₂e) multiplied by the SC-CO₂ (in \$/MTCO₂e) for that year. The annual emission reductions from the Proposed Amendments and the estimated benefits are shown in Table B-10 below. The total benefits range from \$339 million to \$1.43 billion through 2043, depending on the discount rate.

⁶¹ National Academies of Sciences, Engineering, and Medicine. Valuing Climate Damages: Updating Estimation of the Social Cost of Carbon Dioxide. 2017.

⁶² California Department of Finance. Consumer Price Index for U.S. and California. All Urban Consumers. December 2020.

Table B-10. Avoided social cost of carbon under the Proposed Amendments (million 2019\$).

Year	GHG Emissions Reductions (MMT CO ₂ e)	5% Discount Rate	3% Discount Rate	2.5% Discount Rate
2023	0.0	\$0.0	\$0.0	\$0.0
2024	0.0	\$0.8	\$2.7	\$4.0
2025	0.1	\$2.4	\$7.9	\$11.7
2026	0.2	\$4.1	\$13.7	\$20.1
2027	0.3	\$6.0	\$19.3	\$28.2
2028	0.4	\$7.6	\$25.0	\$36.2
2029	0.5	\$9.4	\$30.7	\$45.0
2030	0.6	\$11.8	\$36.7	\$53.6
2031	0.6	\$13.3	\$42.3	\$61.4
2032	0.7	\$15.6	\$47.6	\$68.6
2033	0.8	\$16.8	\$52.5	\$75.3
2034	0.8	\$19.0	\$57.1	\$81.4
2035	0.9	\$20.1	\$61.4	\$87.1
2036	0.9	\$22.2	\$65.4	\$92.3
2037	0.9	\$23.1	\$69.2	\$98.3
2038	1.0	\$25.0	\$72.6	\$102.7
2039	1.0	\$25.7	\$75.8	\$106.7
2040	1.0	\$27.6	\$78.8	\$110.3
2041	1.0	\$28.1	\$81.5	\$113.6
2042	1.1	\$29.9	\$82.8	\$116.7
2043	1.1	\$30.2	\$85.2	\$119.6
Total	13.9	\$338.6	\$1,008.3	\$1,432.8

There is an active discussion within government and academia about the role of SC-CO₂ in assessing regulations, quantifying avoided climate damages, and the values themselves. In January 2017, the National Academies of Sciences, Engineering, and Medicine (NASEM) released a report examining potential approaches for a comprehensive update to the SC-CO₂ methodology to ensure resulting cost estimates reflect the best-available science. The NASEM review did not modify the estimated values of the SC-CO₂, but evaluated the models, assumptions, handling of uncertainty, and discounting used in the estimation of the SC-CO₂. The report titled, "Valuing Climate Damages: Updating Estimation of the Social Cost of Carbon Dioxide," recommends near-term improvements to the existing IWG SC-CO₂ as well as long-term comprehensive updates. CARB will continue to follow updates to the IWG SC-CO₂, outlined in the NASEM report, and incorporate appropriate peer-reviewed modifications to estimates based on the latest available data and science.⁶³

It is important to note that the SC-CO₂, while intended to be a comprehensive estimate of the damages caused by carbon globally, does not represent the cumulative cost of climate

⁶³ National Academies of Sciences, Engineering, and Medicine. Valuing Climate Damages: Updating Estimation of the Social Cost of Carbon Dioxide. 2017.

change and air pollution to society. There are additional costs to society outside of the SC-CO₂, including costs associated with changes in co-pollutants, the social cost of other GHGs including methane and nitrous oxide, and costs that cannot be included due to modeling and data limitations. The Intergovernmental Panel on Climate Change (IPCC) has stated that the IWG SC-CO₂ estimates are likely underestimated due to the omission of significant impacts that cannot be accurately monetized, including important physical, ecological, and economic impacts.⁶⁴ CARB will continue engaging with experts to evaluate the comprehensive California-specific impacts of climate change and air pollution.

c. Other Benefits

In addition to emission reductions, the Proposed Amendments offer other benefits to equipment users. Users of SORE equipment are exposed to CO, PM_{2.5}, and toxic air contaminants when operating the equipment.⁶⁵ By opting for ZEE, users would be exposed to these air contaminants less frequently.

Small off-road equipment creates noise while in operation. The University of Florida reports that leaf blowers, edgers, hedge trimmers, pressure washers, and riding mowers create sound above the Occupational Health and Safety Administration's 85 decibel (dB) threshold above which a hearing conservation program is necessary.⁶⁶ According to the Occupational Safety and Health Administration (OSHA), electric lawn mowers expose users to noise from 63 to 85 dB, depending on the mower. SORE lawn mowers expose users to 82 to 91 dB, depending on the lawn mower, with the vast majority over 85 dB.⁶⁷ Electric chainsaws expose users to 61 to 84 dB, while SORE chainsaws expose users to 86 to 91 dB.⁶⁸ Chronic occupational exposure to sounds over 80 dB has been shown to be correlated with an increased risk for hypertension.⁶⁹

Specifically related to gasoline-powered lawn and garden equipment, it has been shown that the noise exposure and associated health effects from these will be more pronounced in workers because they will be operating in close proximity to this equipment for a significant amount of time, such as 8 hours for their work day.⁷⁰ These workers often lack resources to

⁶⁴ Intergovernmental Panel on Climate Change, Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Climate Change 2007: Mitigation of Climate Change. 2007.

⁶⁵ Baldauf, R., Fortune, C., Weinstein, J., Wheeler, M., Blanchard, F. 2006. Air contaminant exposures during the operation of lawn and garden equipment. *Journal of Exposure Science and Environmental Epidemiology*. January 25, 2006

⁶⁶ University of Florida. Noise Levels for Common Equipment. 2021.

⁶⁷ OSHA. How Do We Protect Our Ears? December 2018.

⁶⁸ Ibid.

⁶⁹ Bolm-Audroff, U., Hegewald, J., Pretzsch, A., Freiberg, A., Neinhaus, A., and Seidler, A. Occupational Noise and Hypertension Risk: A Systematic Review and Meta Analysis. *International Journal of Environmental Research and Public Health*. August 28, 2020.

⁷⁰ Tint, P., Tarmas, G., Koppel, T., Reinhold, K., and Kalle, S. 2012. Vibration and Noise Caused by Lawn Maintenance Machines in Association with Risk to Health. *Agronomy Research*. 2012.

protect themselves from high noise levels such as using hearing protection devices.^{71,72} While the people in the community will also be exposed to the noise from lawn equipment, they will be farther away from the source and their exposure will be intermittent.⁷³ ZEE, when compared to SORE equipment, are quieter, which reduces noise at the worksite as well as in the community where the equipment is operating. Some local jurisdictions, such as the cities of Dana Point and Los Angeles, have noise ordinances that limit when SORE equipment can be used.^{74,75} Using ZEE may allow for longer working hours with this equipment.

Furthermore, residential users of ZEE would not have to store PFCs at their residence, nor take the time to go refill them at a GDF.

C. Direct Costs

1. Direct Cost Inputs and Analysis

To estimate the direct cost to all affected entities (residents, nonlandscaping businesses, landscapers, and government), this analysis combined the previously described equipment population data from the CSUF survey with activity data to model the population of both ZEE and SORE equipment each year starting in 2023 and continuing through 2043. This was done using the SORE2020 model described in Chapter B. Then the analysis combined the modeled population with the prices and factors described in the following sections to estimate direct costs to various segments of the economy. These costs were split into upfront and ongoing costs. All inputs and resultant monetary values are in 2019 dollars.

a. New Equipment Manufacturing

There may be a cost to SORE and small off-road equipment manufacturers to comply with the Proposed Amendments. Manufacturers would have to produce engines for generators that are compliant with the MY 2024 emissions limits or use or buy emission credits to satisfy the regulatory requirements. This may require more research and development and changes to their manufacturing processes, which could result in costs. Once the emission standards become zero, some manufacturers may choose not to have a ZEE product line and may experience reduced sales in the California market. Because all the major manufacturers of both SORE equipment and ZEE are based outside of California, these direct costs are assumed to be passed on to equipment users and are estimated based on the difference in market prices users would pay for compliant equipment compared to the price of equipment that would have been purchased in the Baseline Scenario.

⁷¹ Tint, P., Tarmas, G., Koppel, T., Reinhold, K., and Kalle, S. 2012. Vibration and Noise Caused by Lawn Maintenance Machines in Association with Risk to Health. *Agronomy Research*. 2012.

⁷² Kearney, G.D., Balanay, J.G., and Mannarino, A.J. 2017. Effectiveness of a Multifaceted Occupational Noise and Hearing Loss Intervention Among Landscaping and Groundskeeping Workers. *Journal of Environmental Health*. October 2017.

⁷³ Tint, P., Tarmas, G., Koppel, T., Reinhold, K., and Kalle, S. 2012. Vibration and Noise Caused by Lawn Maintenance Machines in Association with Risk to Health. *Agronomy Research*. 2012.

⁷⁴ City of Dana Point, CA municipal code 6.20.012

⁷⁵ City of Los Angeles, CA municipal code Chapter XI - Noise Regulation, Article 2 - Special Noise Sources, Section 112.04 (c)

b. Scaling of Professional Sector Costs

Based on the results of the CSUF Survey, not all professional users use their equipment in a similar manner. A typical landscaper has a higher average annual use time for lawn and garden equipment than a typical nonlandscaping business users. Similarly, a typical nonlandscaping business user operates pressure washers, pumps, and generators more than a typical landscaper does. To account for this, professionally owned equipment is treated as a combination of residential-grade and professional-grade for relevant users. The relative amounts of business-owned lawn and garden equipment that were calculated to be residential-grade and professional-grade were based on activity data from the SORE2020 model, which is based on the results of the CSUF survey. Fuel and electricity consumption and maintenance costs for business-owned equipment were calculated based on the equipment grade. Residential fuel, electricity and maintenance costs were used for business-owned residential-grade equipment, and professional fuel, electricity and maintenance costs were used for business-owned professional-grade equipment. Because government here is considered as a subset of nonlandscaping businesses, the same scaling was used for government-owned SORE equipment that was used for nonlandscaping businesses. For pressure washers and generators owned by landscaping businesses, staff assumed, based on activity in the SORE2020 model, that they used this equipment the same amount as typical residential users. Pumps owned by landscaping businesses were assumed to be professional-grade based on activity. Table C-1 shows the fraction of business-owned lawn and garden equipment that is treated as residential-grade and the fraction that is treated as professional-grade by equipment type. Table C-2 shows the fractions of landscaper-owned SORE equipment that is treated as residential-grade and professional-grade equipment.

Table C-1. Percentage of business-owned equipment that are treated as professional-grade and residential-grade equipment.

Type of Equipment	Fraction that is treated as professional-grade	Fraction that is treated as residential-grade
Chainsaw	29%	71%
Lawn Mower	29%	71%
Leaf Blower	70%	30%
Riding Mower	100%	0%
Snow Blower	100%	0%
Trimmer/Edger/Brush Cutter	33%	67%

Table C-2. Fractions of landscaper-owned equipment that are treated as professional-grade and residential-grade equipment.

Type of Equipment	Fraction that is treated as professional-grade	Fraction that is treated as residential-grade
Generator	0%	100%
Pressure Washer	0%	100%
Pump	100%	0%

c. Upfront Costs

i. Equipment Price Inputs

The upfront costs to residents, nonlandscaping businesses, landscapers, and government entities are the purchase of new SORE equipment or ZEE. The analysis estimated these costs using current retail equipment prices.

ZEE are categorized as either cordless (battery-powered) or corded. Corded ZEE, while making up over half of the residential ZEE accounted for in the CSUF survey, do not appear to be gaining further market share.⁷⁶ Corded equipment has been available for decades and may have reached full market penetration. Many retailers heavily advertise and sell cordless options to both residential and professional users. Therefore, the expected consumer behavior is the purchase of cordless ZEE. For the economic modeling, CARB staff assumed that any gains in the amount of ZEE in the market would be due to increased sales of cordless equipment, with the exception of pressure washers.

For residential-grade equipment, the median price of the top ten most popular models of a given type of equipment was used as an estimate of the cost. For residential ZEE, the analysis assumed that all new ZEE purchased would be cordless for reasons stated in the preceding paragraph. Residents who already own corded equipment were assumed to continue to use corded equipment. Residential-grade ZEE frequently come packaged with enough batteries for average use. The analysis assumes equipment prices (in 2019\$) will remain constant over the regulatory horizon, except as described for ZEE battery prices in Section C.1.c.ii. Between 2017 and today, prices for SORE equipment have both increased and decreased, depending on equipment type, but on average, there is no trend in prices. ZEE prices have decreased from 2017 to today, in line with what is expected from battery price decreases.⁷⁷ It is possible that, as ZEE grows in market share, economies of scale will be created and equipment prices for consumers will decrease as production becomes more efficient. The assumption that prices would not change is most conservative, as any further price reductions in ZEE would lower the overall cost of the Proposed Amendments.

The analysis also uses the median price of popular models as an estimate of the cost of professional-grade equipment. This equipment is owned by landscapers, nonlandscaping businesses, and government entities, collectively referred to as professional users. Professional-grade equipment costs include enough batteries for ZEE to operate for the relevant portion of a full eight-hour workday (as calculated from the CSUF survey). Based on the same analysis, noted at the beginning of this Section C.1.c.i., all professional-grade ZEE were assumed to be cordless except as noted in Section C.1.c.v for pressure washers. As noted in Section C.1.b, some professional users were assumed to purchase residential-grade equipment based on the typical amount of annual use. Generators that are currently available

⁷⁶ CSUF SSRC. 2019. Survey of Small Off-Road Engines (SORE) Operating within California: Results from Surveys with Four Statewide Populations. May 15, 2019. Prepared by the Social Science Research Center (SSRC) at California State University, Fullerton (CSUF), for CARB and the California Environmental Protection Agency, under CARB Agreement 16MLD011.

⁷⁷ CARB. 2021. Technical Support Document: Analysis of Historical Trends in SORE Equipment and ZEE Pricing. Microsoft Excel workbook prepared by staff of the Monitoring and Laboratory Division. October 2021.

and that meet the MY 2024 emission standards in the Proposed Amendments were used to estimate the price of generators for MYs 2024 through 2027.

The example equipment and battery needs can be found in Tables G-1 through G-4 in the Appendix. An 8.5 percent sales tax was added to the equipment prices.⁷⁸ Tables C-3 and C-4 show the upfront cost of purchasing SORE equipment and ZEE for residential and professional-grade equipment along with the incremental cost of opting for ZEE over SORE.

Table C-3. Current upfront price of residential-grade SORE⁷⁹ equipment and ZEE and the incremental cost to opt for ZEE over SORE.

Type of Equipment	SORE equipment price	ZEE price	Incremental cost over Baseline Scenario
Chainsaw	\$156.24	\$594.58	\$438.34
Generator Set	\$861.49	\$2,169.95	\$1,308.46
Lawn Mower	\$303.79	\$432.92	\$129.13
Leaf Blower/Vacuum	\$161.67	\$324.42	\$162.75
Pressure Washer	\$400.37	\$356.97	-\$43.40
Pump < 2 hp	\$243.15	\$268.00	\$24.85
Riding Mower	\$2,633.60	\$3,253.92	\$620.32
Snow Blower	\$432.72	\$433.99	\$1.27
Trimmer/Edger/Brush Cutter	\$165.03	\$215.92	\$50.89

⁷⁸ The sales tax varies across the state from a minimum of 7.25% up to 10.25% in some municipalities; a value of 8.5% was used for staff’s analysis based on a statewide population weighted average.

⁷⁹ Current SORE price for equipment that is close to the median price of the most popular models.

Table C-4. Current upfront price of professional-grade SORE⁸⁰ equipment and ZEE and the incremental cost to opt for ZEE over SORE.⁸¹

Type of Equipment	SORE equipment price	ZEE price	Incremental cost over Baseline Scenario
Chainsaw	\$390.55	\$694.37	\$303.82
Generator Set	\$5,304.57	\$6,943.89	\$1,639.32
Lawn Mower	\$1,409.42	\$1,030.71	-\$378.71
Leaf Blower/Vacuum	\$477.39	\$1,746.77	\$1,269.38
Pressure Washer	\$1,170.82	\$3,036.92/\$9,980.81 ⁸²	\$1,866.10/\$8,809.99
Pump < 2 hp	\$454.62	\$594.58	\$139.96
Riding Mower	\$11,337.17	\$21,156.42	\$9,819.25
Snow Blower	\$1,626.42	\$1,461.50	-\$164.92
Trimmer/Edger/Brush Cutter	\$368.85	\$867.83	\$498.98

Some categories of residential-grade equipment, such as trimmers and edgers, have a minimal incremental cost for ZEE options. Also, for both professional lawn mowers and snow blowers, ZEE have a lower price than their SORE equivalents. ZEE pumps are already a large portion of the market, and they are currently competitively priced. The CSUF survey found that 94 percent of pumps owned by residents and 65 percent of pumps owned by nonlandscaping businesses were electric.⁸³ For other types of equipment, especially in the professional market, there is a substantial increase in the purchase price associated with switching to ZEE.

ii. Decreasing Battery Costs

Historically, lithium-ion battery prices have decreased over time, and this trend is expected to continue into the future. Bloomberg New Energy Finance projects that lithium-ion battery prices will decrease from \$131 per kWh in 2021 to \$70 per kWh in 2030.⁸⁴ The battery price decreases were applied only to the actual battery energy storage (i.e., the cells in the battery) for each equipment type.

The professional leaf blower package (leaf blower, backpack battery, and battery charger) used in the economic analysis costs \$1,609.93 (not including sales tax) in 2021 and comes with 1.15 kWh of energy storage. At \$131 per kWh, the cell cost is \$150.39, and the remaining equipment cost is \$1,459.54. In 2030, the battery cost is projected to be \$80.36

⁸⁰ Current SORE price for equipment that is close to the median price of popular models.

⁸¹ Landscapers are assumed to purchase professional-grade lawn and garden equipment. Nonlandscaping business purchase prices of lawn and garden equipment are scaled by the factors in Table C-1. Nonlandscaping businesses are assumed to purchase professional-grade generators, pressure washers, and pumps. Landscaper purchase prices of these equipment types are scaled by the factors in Table C-2.

⁷⁷ Price for corded and cordless versions of the equipment, respectively. See Section C.1.c.v for a full discussion of pressure washers.

⁸³ CSUF SSRC. 2019. Survey of Small Off-Road Engines (SORE) Operating within California: Results from Surveys with Four Statewide Populations. May 15, 2019. Prepared by the Social Science Research Center (SSRC) at California State University, Fullerton (CSUF), for CARB and the California Environmental Protection Agency, under CARB Agreement 16MLD011.

⁸⁴ Martin, Chris. 2019. Better Batteries. October 11, 2019. Bloomberg.

per kWh, while the remaining equipment cost would be the same. Therefore, in 2030, the total cost (not including sales tax) is estimated to be \$1,539.90. The same estimation methodology was applied to all equipment types for the relevant amount of energy storage included. After 2030, the prices were assumed to remain constant given the lack of projected battery prices beyond 2030 in the Bloomberg New Energy Finance report.

Tables C-5 and C-6 show the 2021 and projected 2030 prices for residential- and professional-grade ZEE. The estimated ZEE price decreases between 2021 and 2030 range from 2.2 percent for the professional-grade chainsaw, to 7.1 percent for the residential-grade pressure washer. The residential riding mower uses a lead-acid battery, so no price reduction was applied. Similarly, no price reduction was applied to the professional corded pressure washer, which has no battery.

Table C-5. Current and projected prices of residential-grade ZEE based on decreasing battery cost calculations (including sales tax).

Type of Equipment	2021 ZEE price	2030 ZEE price
Chainsaw	\$594.58	\$567.64
Generator Set	\$2,169.95	\$2,069.61
Lawn Mower	\$432.92	\$405.12
Leaf Blower/Vacuum	\$324.42	\$305.88
Pressure Washer	\$356.97	\$331.55
Pump < 2 hp	\$268.00	\$256.08
Riding Mower	\$3,253.92	\$3,253.92
Snow Blower	\$433.99	\$418.10
Trimmer/Edger/Brush Cutter	\$215.92	\$209.30

Table C-6. Current and projected prices of professional-grade ZEE based on decreasing battery cost calculations (including sales tax).

Type of Equipment	2021 ZEE price	2030 ZEE price
Chainsaw	\$694.37	\$679.34
Generator Set	\$6,943.89	\$6,542.55
Lawn Mower	\$1,030.71	\$984.96
Leaf Blower/Vacuum	\$1,746.77	\$1,670.79
Pressure Washer	\$3,036.92/\$9,980.81 ⁸⁵	\$3,036.92/\$9,579.46
Pump < 2 hp	\$594.58	\$579.09
Riding Mower	\$21,156.42	\$20,266.89
Snow Blower	\$1,461.50	\$1,366.19
Trimmer/Edger/Brush Cutter	\$867.83	\$843.05

⁸¹ Price for corded and cordless versions of the equipment respectively. See Section C.1.b.v for a full discussion of pressure washers.

iii. Snow Blowers

The Proposed Amendments would not change the CO emission standard for SORE with displacement less than or equal to 825 cc. Engines used exclusively to power products which are used exclusively in wintertime, such as snow blowers, are not required to certify to or comply with the HC + NO_x emission standards, but are required to meet the CO emission standards. Although the manufacturer of one engine family certified for sale in California that includes engines with displacement greater than 825 cc lists snow blowers as an equipment type in which the engines may be used, staff are not aware of any snow blowers available in California that use SORE with displacement greater than 825 cc. Therefore, this analysis assumes snow blowers in California would not be required to certify to or comply with more stringent emission standards under the Proposed Amendments. Staff assumed that despite there being no regulatory push to ZEE, snow blowers would transition to ZEE along with other categories for economic reasons. This is due to the median price of snow blowers used in the analysis. For residential users, the median ZEE snow blower price is nearly equal to the SORE equipment snow blower price. For professional users, the median ZEE snow blower has a lower purchase price than its SORE equipment counterpart. Owners of snow blowers may purchase other types of ZEE and see that they can perform equally to SORE. Further, upon their next snow blower purchase, they may note that they have batteries that will work in a ZEE snow blower from another equipment type within a ZEE brand's product line. By not having to purchase a battery with their ZEE snow blower they may experience additional savings. Therefore, given all other equipment subject to the SORE regulations would be ZEE, staff assumed that snow blowers would follow the same trajectory as other equipment types subject to the Proposed Amendments.

iv. Generators

One of the reasons that the Proposed Amendments would allow more time for generators to meet emission standards of zero is to provide time for market development. Per the CSUF survey, only 14 percent of residential generators and 11 percent of nonlandscaping business-owned generators are currently zero-emission generators, much lower than most other equipment types. Zero-emission generators are relatively newer to the market and will need more time to gain market share. Many professional-grade generators use engines other than SORE. Generators that are powered by compression-ignition engines, such as those that use diesel fuel, and stationary generators are not subject to the SORE regulations or the Proposed Amendments. Stationary generators remain in a single location because they are not designed to be moved for storage or use. They are frequently installed on a concrete pad near a home or business to provide emergency back-up power during outages to the home or business. These generators are frequently powered by natural gas or propane and usually are found in nonurban areas where homes are more spread out in order to meet safety requirements.⁸⁶ Most zero-emission generators are essentially battery banks with a built-in power inverter. Some models have the ability to accept solar panels for charging. Hydrogen fuel cell powered generators are also currently available in the market and could become more prevalent. For purposes of this report, we refer to all of these SORE alternatives as zero-emission generators.

⁸⁶ Agrell, D. and Truini, J. 2019. Should you buy a standby generator? Popular Mechanics. August 25, 2019.

To estimate the costs for analysis, staff assumed that the price of a professional-grade zero-emission generator would be \$6,944 in 2021. This is the price of two Goal Zero Yeti 3000X portable power stations (\$3,200 plus tax each). The manufacturer reports that each unit can power a 55 watt hour (Wh) refrigerator for 55 hours or a 1,500 Wh circular saw for two hours of continuous use.⁸⁷ One 3000x unit takes 9 hours to charge.⁸⁸ The analysis, therefore, assumed that with two of these units fully charged, the average business user could power the equipment they need in a way that is equivalent to gasoline-powered generator use. A user who was powering a refrigerator could charge one unit while the other is in use and have ample time to swap the units. In the event of a power outage, the two units could power a refrigerator for 110 hours.

Market research revealed that both residential and professional-grade SORE generators that would meet the proposed MYs 2024 through 2027 emission standards are currently available in the market. The price inputs used for residential and professional-grade generators for this period are \$1,891.45 and \$12,152.00, respectively. The professional-grade generator is a generator used on ships and in the maritime industry and costs nearly twice as much as the price of an equivalent professional-grade zero-emission generator estimated for this analysis. No other professional-grade generator currently in the market would meet the MY 2024 emission standards. Once the Proposed Amendments were adopted, manufacturers would likely make professional-grade generators that complied with the proposed emission standards and were priced lower than the marine generator. This is likely because there are many other SORE that would meet the proposed emission standards and could be used in a generator. Another possibility is that manufacturers may transition directly to producing zero-emission generators. However, this analysis used the most conservative estimate – the price of the currently available marine generator. It is likely the upfront costs for users of professional-grade generators would be lower.

As discussed in Section B.1.a, this analysis incorporates credit use. Based on the credit banks as of the end of MY 2018, the analysis assumed that manufacturers would use the entire banks for offsetting excess emissions from generators for MYs 2024 through 2027. Split evenly over the four-year period, manufacturers would be able to produce 6.3 percent of all generators at the current emission levels, using credits from the credit bank to make up the difference between current and future emission standards.⁸⁹ The current emission levels are calculated from a sales-weighted average of current certification levels and CARB test data. The microeconomic analysis assumed that 6.3 percent of the new generator production for MYs 2024 through 2027 would be at the current Baseline Scenario prices of \$861.49 and \$5,304.57 for residential and professional-grade SORE generators, respectively.

v. Pressure Washers

Pressure washers, unlike many types of small off-road equipment included in the SORE regulations, are not typically moved over a large distance while in use. Furthermore, pressure

⁸⁷ Goal Zero. Goal Zero Yeti 3000x Portable Power Station.

⁸⁸ Ibid.

⁸⁹ CARB. 2021. Technical Support Document: Compilation and Evaluation of Small Off-Road Engine Certification Data. Microsoft Excel workbook prepared by staff of the Monitoring and Laboratory Division. October 2021.

washers require a source of water for use, and while this could be a portable tank, they are typically attached to continuous water supplies. Per the CSUF survey, 67 percent of resident owned pressure washers were ZEE; 96 percent of the ZEE-electric pressure washers were corded electric. For nonlandscaping businesses, 45 percent of pressure washers were ZEE; 93 percent of those were corded electric.

However, many brands now sell residential-grade cordless pressure washers with batteries that can be used in other equipment within the brand. Therefore, to make the most conservative estimate, the analysis assumed that a cordless pressure washer would be used as the residential ZEE example unit, as the market is headed towards more cordless equipment.

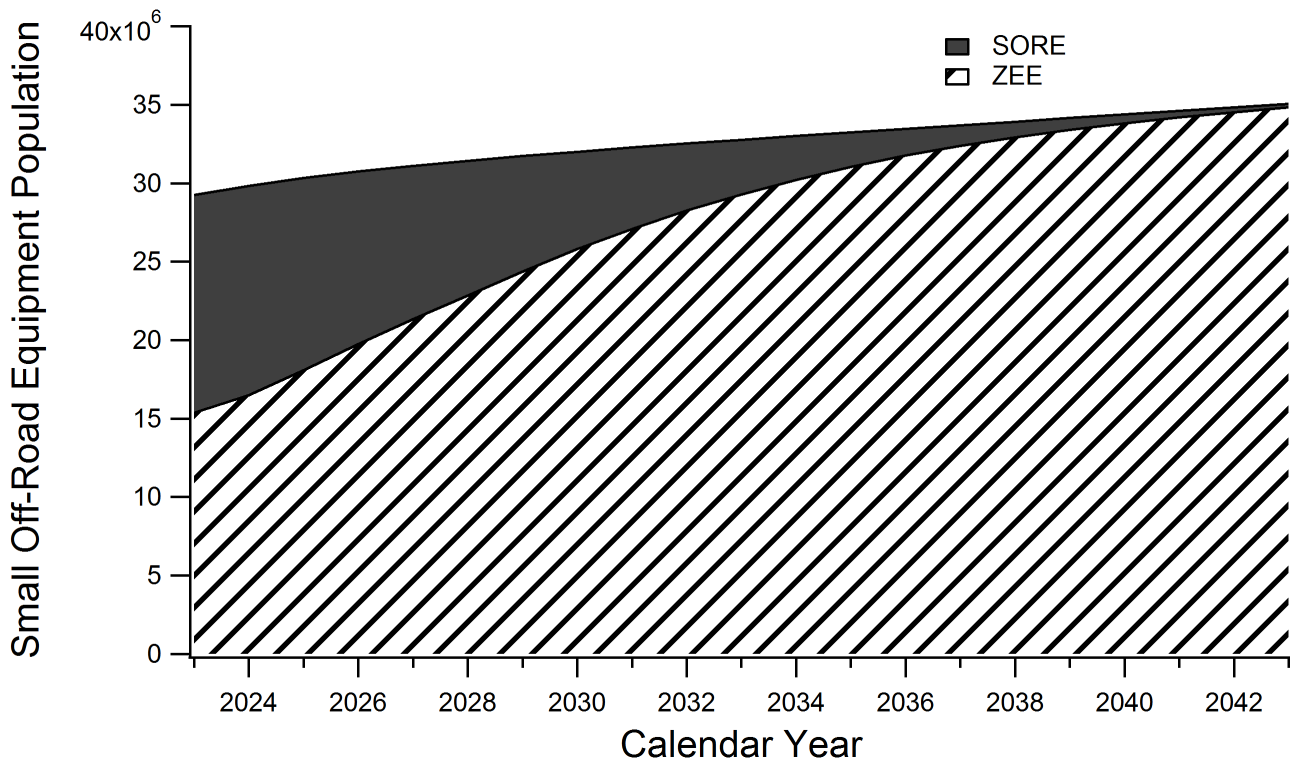
While cordless electric pressure washers are readily available on the residential market, the professional-grade ZEE pressure washer market currently is almost exclusively corded. CARB staff is not aware of any cordless professional-grade pressure washers available for sale at the time of this writing. Staff expects that some professional users may need cordless units. Under the Proposed Amendments, manufacturers may produce cordless versions of their equipment to meet the new demand. This analysis assumes some users of professional-grade power washers would use zero-emission generators to provide power for professional-grade corded pressure washers. That would allow a pressure washer to be "cordless" in the sense that it would not need to be plugged into a fixed electrical receptacle. The analysis assumed that, throughout the regulatory horizon, 75 percent of professional grade pressure washers purchased would be corded while 25 percent would be cordless. With these assumptions, the purchase price of a cordless professional-grade ZEE pressure washer would be equivalent to the sum of the purchase price of the representative corded professional-grade ZEE pressure washer (\$3,036.92, including tax) and the zero-emission professional-grade generator (\$6,943.89, including tax) mentioned in Section C.1.c.i. This yielded an estimated price of \$9,980.81 for a cordless professional-grade ZEE pressure washer. Per the CSUF survey, 65 percent of nonlandscaping business respondents noted that their pressure washers were one to five years old; 22 percent responded that their pressure washers were older than five years. Assuming the lifetime of a professional-grade pressure washer is five years, and a SORE pressure washer costs \$1,170.82 (from Table C-4), the upfront increase in cost of ownership of ZEE versus SORE would be \$373 and \$1,762 per year for corded and cordless pressure washers, respectively. It is likely that a manufactured cordless professional-grade pressure washer would have a lower purchase price than the assumed cost, here, therefore making this a conservative estimate.

Due to the assumed high cost of cordless professional-grade pressure washers and their relatively low use times, the analysis is sensitive to the price and fraction of cordless professional-grade ZEE pressure washers. The CSUF survey showed that 72 percent of nonlandscaping business respondents that owned pressure washers used them less frequently than once a week. With such infrequent use, a typical professional user would not break even within the lifetime of the equipment. To illustrate the sensitivity, if all professional-grade pressure washers were corded, the cost-savings of the Proposed Amendments would increase by \$1.5 billion accrued over the regulatory horizon. The increased costs for owners of professional-grade pressure washers could be reduced by renting a pressure washer as needed for a day as opposed to ownership given their infrequent use.

vi. Summary of Upfront Costs

The analysis assumed professional and residential-grade equipment population growth would be proportional to market share and scaled by overall human population growth in California. New annual sales were determined from the SORE2020 model using data from the CSUF survey and certification and sales data reported to CARB. Figure C-1 shows the modeled increase in the fraction of ZEE in the total statewide population between 2023 and 2043 as a result of the Proposed Amendments. Under the Proposed Amendments scenario, it is projected that 93.4 percent of equipment subject to the SORE regulations would be ZEE in 2035. EO N-79-20 sets a goal to transition to 100 percent zero-emission off-road vehicles and equipment by 2035 where feasible. The remaining 6.6 percent would continue to transition over the following years, reaching 99.4 percent ZEE in 2043.

Figure C-1. Modeled small off-road equipment population statewide under the Proposed Amendments.



Given the sales estimates and the price inputs, the net upfront cost of the Proposed Amendments relative to the Baseline Scenario is calculated by adding together the cost-savings of not purchasing SORE equipment with the cost of purchasing ZEE. Table C-7 shows the modeled annual incremental upfront cost to residential and professional users statewide.

Table C-7. Modeled SORE equipment and ZEE upfront costs to residential and professional users per year under the Proposed Amendments relative to the Baseline Scenario (million 2019\$).

(Negative values indicate cost-savings. Totals may differ slightly due to rounding.)

Year	Gasoline equipment costs-Professional	Gasoline equipment costs-Residential	Electric equipment costs-Professional	Electric equipment costs-Residential	Total equipment costs-Professional	Total equipment costs-Residential	Total equipment costs
2023	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00
2024	\$46.63	-\$138.38	\$356.17	\$500.04	\$402.80	\$361.66	\$764.46
2025	\$48.39	-\$137.01	\$355.70	\$498.34	\$404.09	\$361.33	\$765.41
2026	\$50.16	-\$135.61	\$355.66	\$497.37	\$405.82	\$361.76	\$767.58
2027	\$51.97	-\$134.19	\$355.61	\$496.41	\$407.58	\$362.22	\$769.80
2028	-\$288.10	-\$534.49	\$549.81	\$954.26	\$261.71	\$419.77	\$681.48
2029	-\$290.35	-\$537.85	\$551.34	\$957.35	\$260.99	\$419.50	\$680.49
2030	-\$292.64	-\$541.25	\$553.30	\$961.20	\$260.66	\$419.95	\$680.61
2031	-\$294.94	-\$544.69	\$556.94	\$968.05	\$262.00	\$423.36	\$685.36
2032	-\$297.27	-\$548.16	\$560.63	\$974.98	\$263.36	\$426.82	\$690.17
2033	-\$299.63	-\$551.68	\$564.35	\$981.99	\$264.72	\$430.31	\$695.03
2034	-\$302.02	-\$555.23	\$568.11	\$989.08	\$266.09	\$433.85	\$699.94
2035	-\$304.43	-\$558.82	\$571.92	\$996.25	\$267.49	\$437.43	\$704.91
2036	-\$306.87	-\$562.45	\$575.76	\$1,003.50	\$268.89	\$441.05	\$709.94
2037	-\$309.34	-\$566.12	\$579.64	\$1,010.84	\$270.30	\$444.72	\$715.01
2038	-\$311.84	-\$569.83	\$583.56	\$1,018.26	\$271.72	\$448.43	\$720.14
2039	-\$314.36	-\$573.59	\$587.52	\$1,025.76	\$273.16	\$452.17	\$725.33
2040	-\$316.92	-\$577.38	\$591.52	\$1,033.36	\$274.60	\$455.98	\$730.58
2041	-\$319.50	-\$581.22	\$595.56	\$1,041.04	\$276.06	\$459.82	\$735.88
2042	-\$322.11	-\$585.09	\$599.65	\$1,048.81	\$277.54	\$463.72	\$741.25
2043	-\$324.75	-\$589.02	\$603.78	\$1,056.66	\$279.03	\$467.64	\$746.67
Average	-\$223.71	-\$453.43	\$505.55	\$857.79	\$281.84	\$404.36	\$686.19
Total	-\$4,697.92	-\$9,522.06	\$10,616.53	\$18,013.55	\$5,918.61	\$8,491.49	\$14,410.04

Overall, there would be substantial upfront costs to all current users of SORE equipment who would switch to using ZEE under the Proposed Amendments. This increased cost is due to the estimated higher prices of ZEE and generators that meet the more stringent, generator-specific MY 2024 emission standards, as compared to SORE equipment currently on the market. As illustrated in Table C-7, there would be an increased cost over the Baseline Scenario each year modeled starting in MY 2024 when the more stringent emission standards would go into effect. For MYs 2024 through 2027, professional-grade equipment users would not experience a statewide cost-savings as a result of not purchasing SORE equipment due to the increased price of the MY 2024 compliant generator. The increased cost over the Baseline Scenario for the lower-emitting generator would offset the cost-savings from the other equipment categories switching to ZEE. During the first four years of implementing the Proposed Amendments, professional-grade equipment users would bear higher upfront costs despite owning less than 10 percent of the total population of equipment. Starting in MY 2028, residential-grade equipment users would bear higher upfront costs when professional-grade equipment users began to experience the cost savings from the switch to zero-emission generators. The increased upfront cost associated with purchasing new compliant small off-road equipment statewide would average \$686.19 million per year throughout the regulatory horizon. The total increase in upfront costs would be \$14.41 billion accrued through 2043.

d. Ongoing Costs

i. Fuel and Electricity

Fuel for SORE equipment and electricity to charge batteries on cordless ZEE were considered as ongoing costs. Power for the equipment included in this analysis is based on representative model data from manufacturers reported on sales websites and through direct contact with manufacturers. The average load factor for each equipment type from SORE2020 was multiplied by the power, if the reported power did not already have a load factor applied. The analysis combined these data with an estimated mean use rate based on CSUF survey data to estimate annual energy consumption. SORE and ZEE were assumed to have the same load factor and usage rate. Tables C-8 and C-9 provide the resulting annual energy consumption for current SORE and ZEE for residential and professional equipment. Fuel prices and electricity rates are based on the forecast from the California Energy Commission assuming a moderate level of demand going forward.⁹⁰ Table C-10 provides these costs and rates. The analysis assumed all fuel is California reformulated gasoline. The analysis used forecasted fuel and electricity rates for 2030 to model costs for 2030 through 2043. Electricity rates were differentiated for professional and residential users. Table C-11 shows the estimated ongoing fuel and electricity costs as compared to the Baseline Scenario.

⁹⁰ California Energy Commission staff. Final 2019 Integrated Energy Policy Report. Provided to CARB in October 2020. IEPR forecasts have been updated since this analysis was first conducted. However, to make the updated analysis consistent with the originally-submitted SRIA, staff used the older IEPR forecasts.

Table C-8. Estimated annual energy consumption for residential-grade SORE and ZEE.

Equipment Type	Estimated annual gasoline consumption for SORE (gal/year)	Estimated annual electricity consumption for ZEE (kWh/year)
Chainsaw	3.9	7.29
Generator Set	33.23	68.00
Lawn Mower	2.6	7.14
Leaf Blower/Vacuum	2.49	5.87
Pressure Washer	9.86	14.81
Pump < 2 hp	0.7	1.71
Riding Mower	37.35	39.84
Snow Blower	0.24	0.66
Trimmer/Edger/Brush Cutter	1.79	6.30

Table C-9. Estimated annual energy consumption for professional-grade SORE and ZEE.⁹¹

Equipment Type	Estimated annual gasoline consumption for SORE (gal/year)	Estimated annual electricity consumption for ZEE (kWh/year)
Chainsaw	27.26	77.42
Generator Set	97.03	198.56
Lawn Mower	35.33	259.20
Leaf Blower/Vacuum	75.57	130.13
Pressure Washer	29.07	520.53
Pump < 2 hp	22.2	30.24
Riding Mower	270.60	773.14
Snow Blower	10.73	45.05
Trimmer/Edger/Brush Cutter	26.73	81.08

Table C-10. Gasoline and electric rates used for cost modeling calculated by the California Energy Commission⁹² (2019\$).

Year	Price of gallon of gasoline (\$/Gal)	Price for kWh of electricity for businesses (\$/kWh)	Price for kWh of electricity for residents (\$/kWh)
2023	3.2016	0.1752	0.2052
2024	3.2212	0.17724	0.2069
2025	3.2313	0.1797	0.2086
2026	3.2304	0.1830	0.2094
2027	3.2644	0.1859	0.2116
2028	3.2550	0.1891	0.2140
2029	3.2960	0.1916	0.2185
2030 ⁹³	3.2706	0.1944	0.2232

⁹¹ Landscapers are assumed to use their lawn and garden equipment at the professional rate. Nonlandscaping business use of lawn and garden equipment is scaled by the factors in Table C-1. Nonlandscaping businesses are assumed to use their generators, pressure washers, and pumps at the professional rate. Landscaper use of these equipment types is scaled by the factors in Table C-2.

⁹² California Energy Commission staff. Final 2019 Integrated Energy Policy Report. February 2020.

⁹³ 2030 rates were used for all subsequent years modeled.

Table C-11. Modeled SORE and ZEE energy costs for residential and professional users per year under the Proposed Amendments relative to the Baseline Scenario (million 2019\$).

(Negative values indicate cost-savings.)

Year	Gasoline costs-Professional	Gasoline costs-Residential	Electricity costs-Professional	Electricity costs-Residential	Total energy costs-Professional	Total energy costs-Residential	Total energy costs
2023	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00
2024	-\$11.14	-\$8.49	\$2.80	\$1.11	-\$8.34	-\$7.38	-\$15.72
2025	-\$34.00	-\$22.56	\$7.70	\$2.97	-\$26.30	-\$19.59	-\$45.89
2026	-\$58.15	-\$37.92	\$13.20	\$5.01	-\$44.95	-\$32.91	-\$77.86
2027	-\$82.24	-\$53.76	\$18.73	\$7.08	-\$63.51	-\$46.68	-\$110.19
2028	-\$105.21	-\$73.23	\$24.34	\$9.74	-\$80.87	-\$63.49	-\$144.36
2029	-\$133.13	-\$107.63	\$30.22	\$14.40	-\$102.91	-\$93.23	-\$196.14
2030	-\$157.63	-\$143.65	\$36.02	\$19.76	-\$121.61	-\$123.89	-\$245.50
2031	-\$180.21	-\$178.87	\$40.77	\$24.57	-\$139.44	-\$154.30	-\$293.74
2032	-\$200.31	-\$212.43	\$44.99	\$29.15	-\$155.32	-\$183.28	-\$338.60
2033	-\$218.08	-\$243.74	\$48.61	\$33.43	-\$169.47	-\$210.31	-\$379.78
2034	-\$233.83	-\$272.68	\$51.72	\$37.38	-\$182.11	-\$235.30	-\$417.41
2035	-\$247.46	-\$298.75	\$54.35	\$40.94	-\$193.11	-\$257.81	-\$450.92
2036	-\$258.97	-\$321.40	\$56.50	\$44.02	-\$202.47	-\$277.38	-\$479.85
2037	-\$268.74	-\$341.20	\$58.27	\$46.70	-\$210.47	-\$294.50	-\$504.97
2038	-\$276.85	-\$358.45	\$59.72	\$49.03	-\$217.13	-\$309.42	-\$526.55
2039	-\$283.62	-\$373.13	\$60.91	\$51.01	-\$222.71	-\$322.12	-\$544.83
2040	-\$289.07	-\$385.28	\$61.87	\$52.63	-\$227.20	-\$332.65	-\$559.85
2041	-\$293.64	-\$395.59	\$62.68	\$53.99	-\$230.96	-\$341.60	-\$572.56
2042	-\$297.58	-\$404.51	\$63.38	\$55.16	-\$234.20	-\$349.35	-\$583.55
2043	-\$300.96	-\$412.12	\$63.98	\$56.16	-\$236.98	-\$355.96	-\$592.94
Average	-\$187.18	-\$221.21	\$40.99	\$30.20	-\$146.19	-\$191.01	-\$337.20
Total	-\$3,930.82	-\$4,645.39	\$860.76	\$634.24	-\$3,070.06	-\$4,011.15	-\$7,081.21

Overall, there would be substantial statewide energy cost-savings to residential and professional users as a result of opting for ZEE under the Proposed Amendments. These cost-savings are due to the gasoline cost savings exceeding the electricity costs at the same level of equipment utilization. ZEE are on average much more efficient than SORE equipment. SORE are generally thermodynamically very inefficient, shown by high levels of unburned and partially burned fuel emitted while equipment is in use. As an example, take a popular residential-grade SORE generator that costs \$549.⁹⁴ At 50 percent load, the generator can run for 12 hours on its fuel tank capacity of 3.2 gallons and produce 20,400 Wh of energy. The energy contained in 3.2 gallons of gasoline is 113,600 Wh.⁹⁵ This represents a thermal efficiency of 18 percent, meaning 82 percent of the energy in the gasoline is wasted. The only loss in efficiency from a zero-emission generator would come from the power inverter. At 50 percent load, a typical inverter is 90-95 percent efficient.⁹⁶ Professional users would experience much greater cost-savings over time due to the greater amount of time they use their equipment as compared to residents. The average annual cost-savings throughout the regulatory horizon for energy for small off-road equipment is \$337.20 million, peaking at \$592.94 million in 2043. At that time, more than 99 percent of SORE regulated by CARB would be ZEE, and cost-savings would increase at a lower rate. The total energy cost-savings is estimated to be \$7.08 billion accrued over the regulatory horizon.

ii. Preventative Maintenance

Preventative maintenance helps to ensure that engines work properly throughout their lifetime. CARB staff estimated maintenance costs for each type of SORE equipment based on statewide average equipment use times from the SORE2020 emission inventory model, typical engine parts costs for equipment for residential and professional uses, manufacturer-recommended maintenance frequencies for each engine part per equipment user manuals, and maintenance frequencies estimated from CSUF survey responses.⁹⁷ CARB staff used maintenance frequencies estimated from the CSUF survey responses to develop weighted average maintenance costs by sector because the survey results indicate not all SORE owners conduct regular maintenance. In addition, SORE equipment maintenance costs are higher for professional landscapers than for other professional owners and residential owners because they use and maintain their equipment more often and they are more likely to pay a dealer or small engine shop to perform at least some of the maintenance. The CSUF survey found that 82 percent of landscapers who own SORE perform maintenance. In contrast, the CSUF survey results indicate that most residential owners do not perform any manufacturer-recommended maintenance. The survey found that nonlandscaping business and government users typically perform maintenance less frequently than landscapers but more frequently than residential users. The percent of users performing maintenance is detailed in Table C-12. Some users perform maintenance on their own, or with help from a friend or neighbor. Those are

⁹⁴ Home Depot. Ryobi i4022X. Retrieved from: <https://www.homedepot.com/p/RYOBI-4000-Watt-Gasoline-Powered-Digital-Inverter-Generator-RYi4022X/308737029#product-overview>. Last accessed April 15, 2021.

⁹⁵ B2BEV. 2019. Innolith Claims To 1,000 Wh/kg Battery Energy Density. April 9, 2019. (Web link: <https://www.b2bev.com/innolith-claims-to-1000-wh-kg-battery-energy-density/>. Last accessed July 8, 2021)

⁹⁶ Pennsylvania State University. Efficiency of Inverters. EME 812: Utility Solar Power and Concentration. 2021. (Web link: <https://www.e-education.psu.edu/eme812/node/738>. Last accessed August 3, 2021)

⁹⁷ CARB. 2021. Technical Support Document: Evaluation of Maintenance Frequencies and Costs for Small Off-Road Engines in California. Microsoft Excel workbook compiled by staff of the Monitoring and Laboratory Division. October 2021.

assumed to have no labor costs. Others take their equipment to the dealer for maintenance and would incur labor costs.

Table C-12. Percentage of users who perform equipment maintenance on specified schedule.⁹⁸

Maintenance Schedule	Resident	Business and Government	Landscaper
No maintenance	62.4%	53.6%	17.8%
Occasional maintenance ⁹⁹ ; do not pay for labor	22.7%	19.4%	26.5%
Occasional maintenance ¹⁰⁰ ; do pay for labor	8.9%	13.5%	33.1%
Maintenance per recommended schedule; do not pay for labor	4.3%	8.0%	10.1%
Maintenance per recommended schedule; do pay for labor	1.7%	5.5%	12.5%

Maintenance is much less intensive and required less frequently on ZEE. Maintenance tasks required for ZEE would also be required for SORE equipment (e.g., blade sharpening). This analysis does not account for maintenance costs that are required for both SORE equipment and ZEE as no change from the Baseline Scenario would occur.

This analysis also does not include estimates of costs for major repairs or fixing engines when they break and therefore may underestimate total costs to keep engines working properly. This results in conservative cost-savings estimates for using ZEE instead of SORE equipment, as it results in lower estimates of maintenance costs for gasoline-powered equipment, and therefore less cost savings under the Proposed Amendments relative to the Baseline Scenario.

The weighted average costs to maintain residential and professional SORE per piece of equipment are shown in Table C-13, and incremental costs for SORE equipment maintenance compared to ZEE are shown in Table C-14. The statewide costs associated with maintenance for each modeled year under the Proposed Amendments relative to the Baseline Scenario are shown in Table C-15.

⁹⁸ All data from: CSUF SSRC. 2019. Survey of Small Off-Road Engines (SORE) Operating within California: Results from Surveys with Four Statewide Populations. May 15, 2019. Prepared by the Social Science Research Center (SSRC) at California State University, Fullerton (CSUF), for CARB and the California Environmental Protection Agency, under CARB Agreement 16MLD011.

⁹⁹ For residents, maintenance is assumed to be every three years. For business and government owners, maintenance is assumed to be every two years. For landscapers, maintenance is assumed to be every year. These timetables are based on weighted averages of aggregated data from the CSUF, survey.

¹⁰⁰ For residents, maintenance is assumed to be every three years. For business and government owners, maintenance is assumed to be every two years. For landscapers, maintenance is assumed to be every year. These timetables are based on weighted averages of aggregated data from the CSUF, survey.

Overall, staff expect cost-savings under the Proposed Amendments for both residential and professional users from reduced maintenance costs. By using ZEE instead of SORE equipment, maintenance needs and costs would be greatly reduced for owners. The average annual maintenance cost-savings would be \$108.46 million, and the total would be \$2.28 billion accrued over the regulatory horizon. Professional users experience 52 percent of these cost-savings.

Table C-13. Weighted annual average maintenance cost per piece of SORE equipment and ZEE (2019\$).

Equipment Type	Professional SORE: Landscapers	Professional SORE: Businesses & Government	Residential SORE	Professional ZEE: Landscapers	Professional ZEE: Businesses & Government	Residential ZEE
Chainsaw	\$33.87	\$9.16	\$5.85	\$0	\$0	\$0
Generator Set	\$36.96	\$29.60	\$9.02	\$0	\$0	\$0
Lawn Mower	\$107.01	\$15.43	\$5.07	\$0	\$0	\$0
Leaf Blower /Vacuum	\$70.80	\$30.67	\$8.55	\$0	\$0	\$0
Pressure Washer	\$13.24	\$13.24	\$1.21	\$0	\$0	\$0
Pump < 2 hp	\$27.62	\$11.96	\$3.86	\$0	\$0	\$0
Riding Mower	\$85.82	\$48.67	\$16.94	\$0	\$0	\$0
Snow Blower	\$5.94	\$3.35	\$0.00	\$0	\$0	\$0
Trimmer/Edger/Brush Cutter	\$77.67	\$19.43	\$5.83	\$0	\$0	\$0

Table C-14. Weighted annual average incremental maintenance cost difference per piece of SORE equipment compared to ZEE (2019\$).

Equipment Type	Professional incremental cost: Landscapers	Professional incremental cost: Businesses & Government	Residential incremental cost
Chainsaw	-\$33.87	-\$9.16	-\$5.85
Generator Set	-\$36.96	-\$29.60	-\$9.02
Lawn Mower	-\$107.01	-\$15.43	-\$5.07
Leaf Blower/Vacuum	-\$70.80	-\$30.67	-\$8.55
Pressure Washer	-\$13.24	-\$13.24	-\$1.21
Pump < 2 hp	-\$27.62	-\$11.96	-\$3.86
Riding Mower	-\$85.82	-\$48.67	-\$16.94
Snow Blower	-\$5.94	-\$3.35	-\$0.00
Trimmer/Edger/Brush Cutter	-\$77.67	-\$19.43	-\$5.83

Table C-15. Modeled statewide SORE maintenance costs for professional and residential users per year due to the Proposed Amendments relative to the Baseline Scenario (million 2019\$).

(Negative values indicate cost-savings.)

Year	Professional users-maintenance cost	Residential users-maintenance cost	Total engines-maintenance cost
2023	\$0.00	\$0.00	\$0.00
2024	-\$4.41	-\$3.59	-\$8.00
2025	-\$12.73	-\$10.03	-\$22.76
2026	-\$21.64	-\$16.94	-\$38.58
2027	-\$30.20	-\$23.66	-\$53.86
2028	-\$38.08	-\$30.25	-\$68.33
2029	-\$45.47	-\$37.35	-\$82.82
2030	-\$52.03	-\$44.17	-\$96.20
2031	-\$57.61	-\$50.31	-\$107.92
2032	-\$62.46	-\$55.89	-\$118.35
2033	-\$66.60	-\$60.85	-\$127.45
2034	-\$70.15	-\$65.24	-\$135.39
2035	-\$73.13	-\$69.06	-\$142.19
2036	-\$75.60	-\$72.32	-\$147.92
2037	-\$77.60	-\$75.08	-\$152.68
2038	-\$79.14	-\$77.36	-\$156.50
2039	-\$80.39	-\$79.26	-\$159.65
2040	-\$81.31	-\$80.77	-\$162.08
2041	-\$82.04	-\$82.03	-\$164.07
2042	-\$82.64	-\$83.09	-\$165.73
2043	-\$83.15	-\$84.00	-\$167.15
Average	-\$56.02	-\$52.44	-\$108.46
Total	-\$1,176.38	-\$1,101.25	-\$2,277.63

iii. Two-stroke Oil Costs

The cost of oil for two-stroke engines was considered separately from other maintenance costs. Two-stroke engines do not have a separate oil reservoir, and instead lubricate the engine with oil mixed in with the gasoline. This oil is burned or exhausted when running the engine and is consumed. Therefore, oil must be added each time gasoline is added to the fuel tank. Two-stroke oil is generally added in a 1:50 ratio with the gasoline. This means that for every one gallon of gasoline added, 2.6 ounces (oz) of two-stroke oil should be mixed in to the fuel.

The three SORE equipment categories included in this analysis for which two-stroke oil costs were calculated are chainsaws, leaf blowers/vacuums, and trimmers/edgers/brush cutters. The fraction of the population of each of these equipment types that uses two-stroke engines was obtained from the SORE2020 model. One hundred percent of chainsaws, 90 percent of leaf blowers, and 80 percent of trimmers/edgers/brush cutters were assumed to use two-stroke engines in this analysis.

The cost of two-stroke oil was calculated with total volume of gasoline used in a given year, scaling by the ratio of fuel to oil, and then multiplying by the price of the oil. Professional users were assumed to purchase a gallon of oil at a time to use for all of their equipment. Residential users were assumed to purchase 2.6 oz bottles of oil each time they need to add a gallon of fuel to a piece of SORE equipment due to their much lower use time. The statewide costs associated with the purchase of two-stroke oil for each modeled year under the Proposed Amendments relative to the Baseline Scenario are shown in Table C-16.

Overall, cost-savings would occur under the Proposed Amendments for both residential and professional users from reduced purchase of two-stroke oil. Two-stroke oil is not needed for ZEE. The average annual cost-savings would be \$46.40 million, and the total would be \$974.34 million accrued over the regulatory horizon. Even though they use less oil than professional users, residential users would experience 61 percent of the cost-savings under the Proposed Amendments due to the higher cost associated with 2.6 oz bottles of oil as compared to gallon jugs.

Table C-16. Annual costs associated with the purchase of two-stroke oil for residential and professional users due to the Proposed Amendments relative to the Baseline Scenario (million 2019\$).

(Negative values indicate cost-savings.)

Year	Professional two-stroke oil cost	Residential two-stroke oil cost	Total two-stroke oil cost
2023	\$0.00	\$0.00	\$0.00
2024	-\$1.43	-\$2.38	-\$3.81
2025	-\$4.69	-\$6.86	-\$11.55
2026	-\$8.10	-\$11.72	-\$19.82
2027	-\$11.33	-\$16.42	-\$27.75
2028	-\$14.19	-\$20.64	-\$34.83
2029	-\$16.62	-\$24.27	-\$40.89
2030	-\$18.61	-\$27.33	-\$45.94
2031	-\$20.15	-\$29.86	-\$50.01
2032	-\$21.35	-\$31.97	-\$53.32
2033	-\$22.30	-\$33.75	-\$56.05
2034	-\$23.06	-\$35.27	-\$58.33
2035	-\$23.63	-\$36.48	-\$60.11
2036	-\$24.07	-\$37.47	-\$61.54
2037	-\$24.39	-\$38.25	-\$62.64
2038	-\$24.60	-\$38.83	-\$63.43
2039	-\$24.76	-\$39.31	-\$64.07
2040	-\$24.85	-\$39.66	-\$64.51
2041	-\$24.93	-\$39.96	-\$64.89
2042	-\$25.00	-\$40.25	-\$65.25
2043	-\$25.06	-\$40.54	-\$65.60
Average	-\$18.24	-\$28.15	-\$46.40
Total	-\$383.12	-\$591.22	-\$974.34

iv. Summary of Ongoing Costs

The net ongoing cost of the Proposed Amendments relative to the Baseline Scenario is calculated by adding the cost of electricity and the cost-savings associated with gasoline purchases, maintenance, and two-stroke oil together. Table C-17 shows the annual incremental ongoing cost to residential and professional users statewide.

Table C-17. Modeled ongoing costs to residential and professional users per year due to the Proposed Amendments relative to the Baseline Scenario (million 2019\$).

(Negative values indicate cost-savings. Totals may differ slightly due to rounding.)

Year	Energy Costs - Professional	Energy Costs- Residential	Maintenance and Oil Costs - Professional	Maintenance and Oil Costs - Residential	Total ongoing costs- Professional	Total ongoing costs- Residential	Total ongoing costs
2023	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00
2024	-\$8.34	-\$7.38	-\$5.84	-\$5.97	-\$14.18	-\$13.35	-\$27.53
2025	-\$26.30	-\$19.59	-\$17.42	-\$16.89	-\$43.72	-\$36.48	-\$80.20
2026	-\$44.95	-\$32.91	-\$29.74	-\$28.66	-\$74.69	-\$61.57	-\$136.26
2027	-\$63.51	-\$46.68	-\$41.53	-\$40.08	-\$105.04	-\$86.76	-\$191.80
2028	-\$80.87	-\$63.49	-\$52.27	-\$50.89	-\$133.14	-\$114.38	-\$247.52
2029	-\$102.91	-\$93.23	-\$62.09	-\$61.62	-\$165.00	-\$154.85	-\$319.85
2030	-\$121.61	-\$123.89	-\$70.64	-\$71.50	-\$192.25	-\$195.39	-\$387.64
2031	-\$139.44	-\$154.30	-\$77.76	-\$80.17	-\$217.20	-\$234.47	-\$451.67
2032	-\$155.32	-\$183.28	-\$83.81	-\$87.86	-\$239.13	-\$271.14	-\$510.27
2033	-\$169.47	-\$210.31	-\$88.90	-\$94.60	-\$258.37	-\$304.91	-\$563.28
2034	-\$182.11	-\$235.30	-\$93.21	-\$100.51	-\$275.32	-\$335.81	-\$611.13
2035	-\$193.11	-\$257.81	-\$96.76	-\$105.54	-\$289.87	-\$363.35	-\$653.22
2036	-\$202.47	-\$277.38	-\$99.67	-\$109.79	-\$302.14	-\$387.17	-\$689.31
2037	-\$210.47	-\$294.50	-\$101.99	-\$113.33	-\$312.46	-\$407.83	-\$720.29
2038	-\$217.13	-\$309.42	-\$103.74	-\$116.19	-\$320.87	-\$425.61	-\$746.48
2039	-\$222.71	-\$322.12	-\$105.15	-\$118.57	-\$327.86	-\$440.69	-\$768.55
2040	-\$227.20	-\$332.65	-\$106.16	-\$120.43	-\$333.36	-\$453.08	-\$786.44
2041	-\$230.96	-\$341.60	-\$106.97	-\$121.99	-\$337.93	-\$463.59	-\$801.52
2042	-\$234.20	-\$349.35	-\$107.64	-\$123.34	-\$341.84	-\$472.69	-\$814.53
2043	-\$236.98	-\$355.96	-\$108.21	-\$124.54	-\$345.19	-\$480.50	-\$825.69
Average	-\$146.19	-\$191.01	-\$74.26	-\$80.59	-\$220.46	-\$271.60	-\$492.06
Total	-\$3,070.06	-\$4,011.15	-\$1,559.50	-\$1,692.47	-\$4,629.56	-\$5,703.62	-\$10,333.18

Overall, substantial cost-savings would be realized in ongoing costs to all current users of SORE equipment who would switch to using ZEE under the Proposed Amendments. This cost-savings is due to the lower energy costs associated with ZEE as compared to SORE and a reduction in maintenance and two-stroke oil costs from not using SORE. As illustrated in Table C-17, cost-savings would increase each year starting in MY 2024 when the more stringent emission standards would go into effect. During the first six years of implementing the Proposed Amendments, professional-grade equipment users would see greater ongoing cost-savings than residential users despite owning less than 10 percent of the total population of equipment due to their higher use time and frequency of equipment turnover. As more residential users purchased ZEE, residential annual cost-savings would surpass professional annual cost-savings in 2030. The total ongoing cost associated with the Proposed Amendments statewide would average -\$492.06 million per year over the regulatory horizon, totaling -\$10.33 billion accrued through 2043.

e. Total Costs

Table C-18 shows the annual costs associated with the Proposed Amendments. In all the tables in this section, two-stroke oil costs are added to maintenance costs to obtain the total gasoline equipment maintenance cost. The Proposed Amendments are estimated to lead to an average annual net direct cost of \$194.14 million dollars and a total net direct cost of \$4.08 billion accrued over the regulatory horizon. The Proposed Amendments would yield statewide cost-savings starting in 2037 when the savings from avoided gasoline purchases and maintenance costs become greater than the increased upfront cost of ZEE. As discussed in Sections C.2 through C.5 owners of certain types of equipment may see cost-savings much sooner. Figure C-2 plots the costs, cost-savings, and overall net costs. Table C-21 shows the net cost of the Proposed Amendments for professional and residential users.

Table C-19 shows the annual costs for professional users (nonlandscaping businesses, landscapers, and government entities). Table C-20 shows the costs for residential users. Over the regulatory horizon, professional users would have an accrued net cost of \$1.29 billion versus an accrued net cost of \$2.79 billion for residents. This difference is due to the use time of the equipment by professional users compared to residential users. Professionals use their equipment more often and therefore would experience more cost-savings from avoided gasoline purchases and maintenance costs than residential users. Residential users would experience an annual net cost-savings later in the regulatory horizon. While, overall, the Proposed Amendments would result in net annual cost-savings starting in 2037 on a statewide basis, professional users are expected to experience net cost-savings starting in 2034 and residential users are expected to experience net cost-savings starting in 2041. The following sections include additional discussion of these costs for professional and residential users on an individual basis.

Table C-18. Modeled costs to professional and residential users per year under the Proposed Amendments relative to the Baseline Scenario (million 2019\$).

(Negative values indicate cost-savings. Totals may differ slightly due to rounding.)

Year	Gasoline equipment cost	Electric equipment cost	Gasoline equipment maintenance cost	Gasoline cost	Electricity cost	Total cost	Total cost-savings	Net cost
2023	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00
2024	-\$91.75	\$856.21	-\$11.81	-\$19.63	\$3.91	\$860.12	-\$123.19	\$736.93
2025	-\$88.62	\$854.03	-\$34.31	-\$56.55	\$10.67	\$864.70	-\$179.48	\$685.22
2026	-\$85.44	\$853.02	-\$58.40	-\$96.07	\$18.21	\$871.23	-\$239.91	\$631.32
2027	-\$82.22	\$852.02	-\$81.61	-\$136.00	\$25.81	\$877.83	-\$299.83	\$578.00
2028	-\$822.59	\$1,504.07	-\$103.16	-\$178.44	\$34.08	\$1,538.15	-\$1,104.19	\$433.96
2029	-\$828.20	\$1,508.69	-\$123.71	-\$240.75	\$44.62	\$1,553.31	-\$1,192.66	\$360.65
2030	-\$833.89	\$1,514.50	-\$142.14	-\$301.28	\$55.77	\$1,570.27	-\$1,277.31	\$292.96
2031	-\$839.63	\$1,524.99	-\$157.93	-\$359.08	\$65.33	\$1,590.32	-\$1,356.64	\$233.68
2032	-\$845.44	\$1,535.61	-\$171.68	-\$412.74	\$74.14	\$1,609.75	-\$1,429.86	\$179.89
2033	-\$851.31	\$1,546.34	-\$183.50	-\$461.82	\$82.04	\$1,628.38	-\$1,496.63	\$131.75
2034	-\$857.25	\$1,557.19	-\$193.72	-\$506.52	\$89.10	\$1,646.29	-\$1,557.49	\$88.80
2035	-\$863.25	\$1,568.16	-\$202.30	-\$546.21	\$95.29	\$1,663.45	-\$1,611.76	\$51.69
2036	-\$869.32	\$1,579.26	-\$209.44	-\$580.37	\$100.52	\$1,679.78	-\$1,659.13	\$20.65
2037	-\$875.46	\$1,590.47	-\$215.32	-\$609.94	\$104.98	\$1,695.45	-\$1,700.72	-\$5.27
2038	-\$881.67	\$1,601.81	-\$219.92	-\$635.31	\$108.76	\$1,710.57	-\$1,736.90	-\$26.33
2039	-\$887.95	\$1,613.28	-\$223.73	-\$656.75	\$111.92	\$1,725.20	-\$1,768.43	-\$43.23
2040	-\$894.30	\$1,624.88	-\$226.59	-\$674.35	\$114.50	\$1,739.38	-\$1,795.24	-\$55.86
2041	-\$900.72	\$1,636.60	-\$228.95	-\$689.23	\$116.67	\$1,753.27	-\$1,818.90	-\$65.63
2042	-\$907.21	\$1,648.46	-\$230.99	-\$702.09	\$118.54	\$1,767.00	-\$1,840.29	-\$73.29
2043	-\$913.77	\$1,660.44	-\$232.76	-\$713.09	\$120.14	\$1,780.58	-\$1,859.62	-\$79.04
Average	-\$677.14	\$1,363.33	-\$154.86	-\$408.39	\$71.19	\$1,434.53	-\$1,240.39	\$194.14
Total	-\$14,219.99	\$28,630.03	-\$3,251.97	-\$8,576.22	\$1,495.00	\$30,125.03	-\$26,048.18	\$4,076.85

Table C-19. Modeled costs to professional users (nonlandscaping businesses, landscapers, and government entities) per year under the Proposed Amendments relative to the Baseline Scenario (million 2019\$).

(Negative values indicate cost-savings. Total may differ slightly due to rounding.)

Year	Gasoline equipment cost	Electric equipment cost	Gasoline equipment maintenance cost	Gasoline costs	Electricity costs	Total costs	Total cost-savings	Net costs
2023	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00
2024	\$46.63	\$356.17	-\$5.84	-\$11.14	\$2.80	\$405.60	-\$16.98	\$388.62
2025	\$48.39	\$355.70	-\$17.42	-\$34.00	\$7.70	\$411.79	-\$51.42	\$360.37
2026	\$50.16	\$355.66	-\$29.74	-\$58.15	\$13.20	\$419.02	-\$87.89	\$331.13
2027	\$51.97	\$355.61	-\$41.53	-\$82.24	\$18.73	\$426.31	-\$123.77	\$302.54
2028	-\$288.10	\$549.81	-\$52.27	-\$105.21	\$24.34	\$574.15	-\$445.58	\$128.57
2029	-\$290.35	\$551.34	-\$62.09	-\$133.13	\$30.22	\$581.56	-\$485.57	\$95.99
2030	-\$292.64	\$553.30	-\$70.64	-\$157.63	\$36.02	\$589.32	-\$520.91	\$68.41
2031	-\$294.94	\$556.94	-\$77.76	-\$180.21	\$40.77	\$597.71	-\$552.91	\$44.80
2032	-\$297.27	\$560.63	-\$83.81	-\$200.31	\$44.99	\$605.62	-\$581.39	\$24.23
2033	-\$299.63	\$564.35	-\$88.90	-\$218.08	\$48.61	\$612.96	-\$606.61	\$6.35
2034	-\$302.02	\$568.11	-\$93.21	-\$233.83	\$51.72	\$619.83	-\$629.06	-\$9.23
2035	-\$304.43	\$571.92	-\$96.76	-\$247.46	\$54.35	\$626.27	-\$648.65	-\$22.38
2036	-\$306.87	\$575.76	-\$99.67	-\$258.97	\$56.50	\$632.26	-\$665.51	-\$33.25
2037	-\$309.34	\$579.64	-\$101.99	-\$268.74	\$58.27	\$637.91	-\$680.07	-\$42.16
2038	-\$311.84	\$583.56	-\$103.74	-\$276.85	\$59.72	\$643.28	-\$692.43	-\$49.15
2039	-\$314.36	\$587.52	-\$105.15	-\$283.62	\$60.91	\$648.43	-\$703.13	-\$54.70
2040	-\$316.92	\$591.52	-\$106.16	-\$289.07	\$61.87	\$653.39	-\$712.15	-\$58.76
2041	-\$319.50	\$595.56	-\$106.97	-\$293.64	\$62.68	\$658.24	-\$720.11	-\$61.87
2042	-\$322.11	\$599.65	-\$107.64	-\$297.58	\$63.38	\$663.03	-\$727.33	-\$64.30
2043	-\$324.75	\$603.78	-\$108.21	-\$300.96	\$63.98	\$667.76	-\$733.92	-\$66.16
Average	-\$223.71	\$505.55	-\$74.26	-\$187.18	\$40.99	\$555.93	-\$494.54	\$61.38
Total	-\$4,697.92	\$10,616.53	-\$1,559.50	-\$3,930.82	\$860.76	\$11,674.44	-\$10,385.39	\$1,289.05

Table C-20. Modeled costs to residential users per year under the Proposed Amendments relative to the Baseline Scenario (million 2019\$).

(Negative values indicate cost-savings. Total may differ slightly due to rounding.)

Year	Gasoline equipment cost	Electric equipment cost	Gasoline equipment maintenance cost	Gasoline costs	Electricity costs	Total costs	Total cost-savings	Net costs
2023	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00
2024	-\$138.38	\$500.04	-\$5.97	-\$8.49	\$1.11	\$501.15	-\$152.84	\$348.31
2025	-\$137.01	\$498.34	-\$16.89	-\$22.56	\$2.97	\$501.31	-\$176.46	\$324.85
2026	-\$135.61	\$497.37	-\$28.66	-\$37.92	\$5.01	\$502.38	-\$202.19	\$300.19
2027	-\$134.19	\$496.41	-\$40.08	-\$53.76	\$7.08	\$503.49	-\$228.03	\$275.46
2028	-\$534.49	\$954.26	-\$50.89	-\$73.23	\$9.74	\$964.00	-\$658.61	\$305.39
2029	-\$537.85	\$957.35	-\$61.62	-\$107.63	\$14.40	\$971.75	-\$707.10	\$264.65
2030	-\$541.25	\$961.20	-\$71.50	-\$143.65	\$19.76	\$980.96	-\$756.40	\$224.56
2031	-\$544.69	\$968.05	-\$80.17	-\$178.87	\$24.57	\$992.62	-\$803.73	\$188.89
2032	-\$548.16	\$974.98	-\$87.86	-\$212.43	\$29.15	\$1,004.13	-\$848.45	\$155.68
2033	-\$551.68	\$981.99	-\$94.60	-\$243.74	\$33.43	\$1,015.42	-\$890.02	\$125.40
2034	-\$555.23	\$989.08	-\$100.51	-\$272.68	\$37.38	\$1,026.46	-\$928.42	\$98.04
2035	-\$558.82	\$996.25	-\$105.54	-\$298.75	\$40.94	\$1,037.19	-\$963.11	\$74.08
2036	-\$562.45	\$1,003.50	-\$109.79	-\$321.40	\$44.02	\$1,047.52	-\$993.64	\$53.88
2037	-\$566.12	\$1,010.84	-\$113.33	-\$341.20	\$46.70	\$1,057.54	-\$1,020.65	\$36.89
2038	-\$569.83	\$1,018.26	-\$116.19	-\$358.45	\$49.03	\$1,067.29	-\$1,044.47	\$22.82
2039	-\$573.59	\$1,025.76	-\$118.57	-\$373.13	\$51.01	\$1,076.77	-\$1,065.29	\$11.48
2040	-\$577.38	\$1,033.36	-\$120.43	-\$385.28	\$52.63	\$1,085.99	-\$1,083.09	\$2.90
2041	-\$581.22	\$1,041.04	-\$121.99	-\$395.59	\$53.99	\$1,095.03	-\$1,098.80	-\$3.77
2042	-\$585.09	\$1,048.81	-\$123.34	-\$404.51	\$55.16	\$1,103.97	-\$1,112.94	-\$8.97
2043	-\$589.02	\$1,056.66	-\$124.54	-\$412.12	\$56.16	\$1,112.82	-\$1,125.68	-\$12.86
Average	-\$453.43	\$857.79	-\$80.59	-\$221.21	\$30.20	\$887.99	-\$755.23	\$132.76
Total	-\$9,522.06	\$18,013.55	-\$1,692.47	-\$4,645.39	\$634.24	\$18,647.79	-\$15,859.92	\$2,787.87

Figure C-2. Statewide costs, cost-savings, and overall net costs under the Proposed Amendments.

(Negative values indicate cost-savings.)

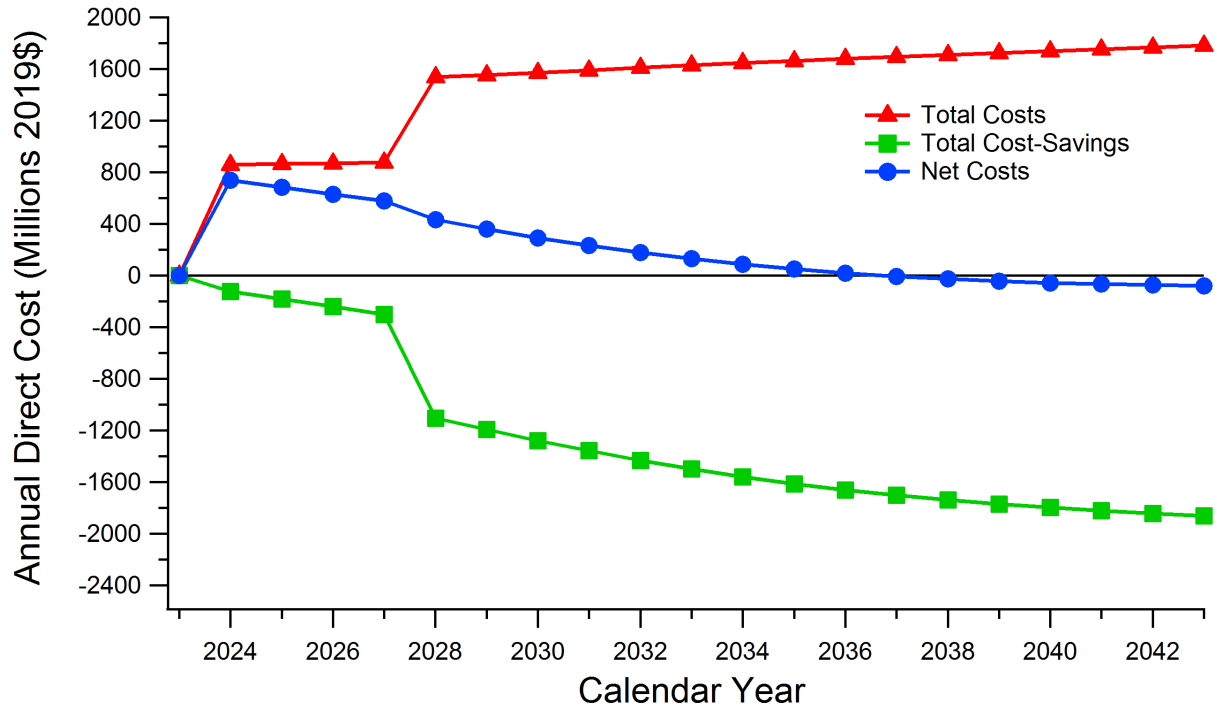


Table C-21. Modeled net costs as a result of the Proposed Amendments for residential and professional users during the regulatory horizon (million 2019\$).

(Negative values indicate net cost-savings.)

Year	Net cost professional users	Net cost residential users	Total net cost
2023	\$0.00	\$0.00	\$0.00
2024	\$388.62	\$348.31	\$736.93
2025	\$360.37	\$324.85	\$685.22
2026	\$331.13	\$300.19	\$631.32
2027	\$302.54	\$275.46	\$578.00
2028	\$128.57	\$305.39	\$433.96
2029	\$95.99	\$264.65	\$360.65
2030	\$68.41	\$224.56	\$292.96
2031	\$44.80	\$188.89	\$233.68
2032	\$24.23	\$155.68	\$179.89
2033	\$6.35	\$125.40	\$131.75
2034	-\$9.23	\$98.04	\$88.80
2035	-\$22.38	\$74.08	\$51.69
2036	-\$33.25	\$53.88	\$20.65
2037	-\$42.16	\$36.89	-\$5.27
2038	-\$49.15	\$22.82	-\$26.33
2039	-\$54.70	\$11.48	-\$43.23
2040	-\$58.76	\$2.90	-\$55.86
2041	-\$61.87	-\$3.77	-\$65.63
2042	-\$64.30	-\$8.97	-\$73.29
2043	-\$66.16	-\$12.86	-\$79.04
Average	\$61.38	\$132.76	\$194.14
Total	\$1,289.05	\$2,787.87	\$4,076.85

2. Direct Costs on Typical Businesses

The analysis defined typical businesses as all affected businesses in California that are not small businesses. Costs under the Proposed Amendments will be most heavily felt by landscapers who use SORE daily. Per the U.S. Census Bureau, 99 percent of all California landscaping businesses are small businesses. Therefore, landscapers are included in Section C.3, which discusses direct costs on small businesses.¹⁰¹

A typical business consequently is one that does not do landscaping work but may own small off-road equipment such as pumps and generators to maintain its own property or conduct work outdoors. Based on CSUF survey data, 32 percent of all businesses in the state that are

¹⁰¹ U.S. Census Bureau. 2021. Census Business Builder: Small Business Edition for Landscapers in California. 2021. (Database can be accessed at: <https://cbb.census.gov/sbe/#>. Last accessed March 28, 2021)

not landscaping businesses own at least one piece of small off-road equipment.¹⁰² Therefore, most typical businesses would have no costs associated with the Proposed Amendments, as most do not own any small off-road equipment.

For typical businesses that own lawn and garden equipment, their costs would be between those of residents and landscapers. Based on their use time and equipment needs, they may purchase residential- or professional-grade equipment. By purchasing residential-grade equipment, they may experience cost-savings sooner if they use the equipment more frequently than residential users. However, if they choose to purchase professional-grade equipment, they would likely not experience cost-savings, as they use the equipment less frequently than landscapers.

For equipment subject to the SORE regulations that is not lawn and garden equipment, typical business users represent professional users in the economic analysis. Business users have higher average use times than landscapers for pumps, pressure washers, and generators.

As an example, a business may use a contractor for landscape maintenance or have no lawn or garden to maintain, but may have other SORE. A car dealership may own a pressure washer to wash the vehicles on the lot. For this example, staff assumed that the car washing station has a water source, but not power, and therefore would require a cordless pressure washer when purchasing a ZEE pressure washer. For this example, staff also assumed that the business has a generator for maintaining critical services during a power outage. Table C-22 shows the upfront and ongoing costs for such a car dealership, at 2023 prices and average use times.

Table C-22. Cost breakdown for a typical nonlandscaping business that has purchased a cordless pressure washer and generator at 2023 prices.

(Negative values indicate cost-savings.)

Cost line item	SORE costs	ZEE costs	Cost difference
Equipment price	\$6,475.39	\$16,674.68	\$10,199.29
Maintenance	\$42.84	\$0.00	-\$42.84
Gasoline cost	\$403.72	\$0.00	-\$403.72
Electricity cost	\$0.00	\$125.90	\$125.90
Upfront costs	\$6,475.39	\$16,674.68	\$10,199.29
Annual operational costs	\$446.56	\$125.90	-\$320.66
Total cost after one year	\$6,921.95	\$16,800.58	\$9,878.63
Total cost after five years	\$8,708.20	\$17,304.18	\$8,595.98
Total cost after ten years	\$10,941.02	\$17,933.69	\$6,992.67

This hypothetical typical business would incur increased costs due to the Proposed Amendments. Professional-grade zero-emission generators and cordless pressure washers

¹⁰² CSUF SSRC. 2019. Survey of Small Off-Road Engines (SORE) Operating within California: Results from Surveys with Four Statewide Populations. May 15, 2019. Prepared by the Social Science Research Center (SSRC) at California State University, Fullerton (CSUF), for CARB and the California Environmental Protection Agency, under CARB Agreement 16MLD011.

have some of the largest differences in purchase price compared to their SORE counterparts. Even with the assumption that the business would keep and use each piece of equipment for ten years, the business would incur a \$6,993 incremental cost. As discussed in Sections C.1.c.iv and C.1.c.v, it is likely that the cost of these ZEE would decrease over the next several years due to continued innovation and a shift in the market towards ZEE, which would create economies of scale for the sector. Furthermore, if this business could use a corded pressure washer, upfront costs could be reduced by more than \$6,000. Notably, given the lower upfront cost of a corded ZEE pressure washer, it is possible that a car dealership or other stationary user of a professional-grade pressure washer may alter their site logistics to allow for corded ZEE use. This change may come at a significantly lower upfront cost. A car dealership likely uses their pressure washer much more frequently than the average use of less than once per week. With more frequent use, the dealership would see a lower cost and may even see cost-savings within the pressure washer's lifetime. With average use of a cordless ZEE pressure washer, the \$6,993 net cost after ten years would be less than two hundredths of a percent of the annual revenue of an average new car dealership (\$46,030,751), and two tenths of a percent of the annual revenue of an average used car dealership (\$4,945,696) in California.¹⁰³

Finally, as an example of the wide range of prices and usage times within the SORE category, staff calculated the number of years that it would take a professional user using professional-grade equipment at the longer use time (whether nonlandscaping business user or landscaper) to break even with ZEE versus SORE for each equipment category at 2023 prices. Table C-23 shows the results along with the upfront and annual ongoing costs. The same usage assumptions as in the above examples were used. Median lifetime cost was estimated based on the assumption that equipment is kept the same number of years as the median age of equipment from the CSUF survey and shown in Table A-9.

¹⁰³ U.S. Census Bureau. 2012 Economic Census. 2012. Adjusted for inflation using California CPI, as described in Chapter B.4.

Table C-23. Upfront and annual ongoing costs for professional-grade SORE and ZEE, at 2023 prices.

(Negative values indicate cost-savings.)

Type of equipment	SORE upfront cost	ZEE upfront cost	SORE annual ongoing cost	ZEE annual ongoing cost	Number of years of ownership before cost-savings with ZEE	Median lifetime cost
Chainsaw	\$390.55	\$689.69	\$139.47	\$13.56	2	\$47.32
Generator Set	\$5,304.57	\$6,818.88	\$347.61	\$34.79	5	\$263.03
Lawn Mower	\$1,409.42	\$1,016.46	\$220.13	\$45.41	1	-\$917.10
Leaf Blower/ Vacuum	\$477.39	\$1,723.11	\$358.81	\$22.80	4	\$573.70
Corded Pressure Washer	\$1,170.82	\$3,036.92	\$95.81	\$91.11	N/A ¹⁰⁴	\$1,852.01
Pump < 2 hp	\$454.62	\$589.76	\$98.69	\$5.30	1	-\$145.04
Riding Mower	\$11,337.17	\$20,879.35	\$952.17	\$135.46	12	\$7,092.05
Snow Blower	\$1,626.42	\$1,431.81	\$40.30	\$7.89	1	-\$291.82
Trimmer/Edger/ Brush Cutter	\$368.85	\$860.11	\$177.68	\$14.21	3	\$164.32

For some SORE equipment types, professional users who purchase ZEE instead of SORE equipment would experience cost-savings within a lifetime equivalent to the median equipment age in the CSUF survey at 2023 prices. This is a conservative assumption as prices of batteries are expected to continue to decrease. For some other equipment types, cost-savings could occur for equipment that are kept longer than the median age from the CSUF survey. There are two notable exceptions. First, a typical professional corded ZEE pressure washer owner would not break even within the unit's lifetime solely as a result of ongoing cost-savings. The same is true of a cordless unit which has an even higher upfront cost. As described in Section C.1.c.v the average frequency of use of a professional-grade pressure washer is less than once per week, which would lead to minimal opportunities for savings through operational cost-savings. As discussed in Section C.1.c.v, it is likely that the price of professional-grade ZEE pressure washers would decrease as a result of the Proposed Amendments, due to more manufacturers entering the ZEE pressure washer market. It is likely that a typical professional user of a pressure washer would have a more economically favorable outcome if they were to rent a pressure washer when needed as opposed to purchasing one. Furthermore, staff assume that owners of professional-grade cordless pressure washers use their equipment at the average professional rate. It is likely that a professional user that requires a cordless professional-grade pressure washer uses it more frequently than once a week, and will likely see savings much sooner than a typical user.

Second, the break-even point for professional ZEE riding mowers would be 12 years, which is longer than the five year median age of professional riding mowers in the CSUF survey. It is likely that more manufacturers may enter the market due to the Proposed Amendments, thereby driving down the upfront cost.

¹⁰⁴ A typical professional user may not see cost-savings within the lifetime of a professional-grade corded or cordless pressure washer.

3. Direct Costs on Small Businesses

a. Small Landscapers

Landscaping businesses (NAICS 561730) employ more than 88,000 workers in approximately 8,600 businesses in California.¹⁰⁵ Further, there are approximately 51,000 sole-proprietorship landscaping businesses in California.¹⁰⁶ Ninety-nine percent of landscaping businesses in the state are considered small businesses.¹⁰⁷ The five most common lawn and garden tools that landscapers reported owning and using in the CSUF survey are chainsaws, lawn mowers, leaf blowers, string trimmers, and hedge trimmers. With these pieces of equipment, a one-person landscaping company would be able to conduct the majority of jobs. For this example, staff assumed that the landscaper would purchase all of these pieces of equipment at once. This is a very conservative estimate, as it is highly unlikely that an existing landscaping business would need all new equipment at once. Pieces are typically replaced as they reach the end of their life. Table C-24 shows the cost breakdown for this example landscaper at 2023 prices.

Table C-24. Cost breakdown for a one-person landscaping business that has purchased a lawn mower, leaf blower, hedge trimmer, chainsaw, and string trimmer at 2023 prices. (Negative values indicate cost-savings.)

Cost line item	SORE costs	ZEE costs	Cost difference
Equipment price	\$3,015.06	\$5,149.48	\$2,134.42
Maintenance	\$367.03	\$0.00	-\$367.03
Two-Stroke Oil Cost	\$79.88	\$0.00	-\$79.88
Gasoline cost	\$613.49	\$0.00	-\$613.49
Electricity cost	\$0.00	\$109.28	\$109.28
Upfront costs	\$3,015.06	\$5,149.48	\$2,134.42
Annual operational costs	\$1,060.40	\$109.28	-\$951.11
Total cost after one year	\$4,075.46	\$5,258.76	\$1,183.31
Total cost after two years	\$5,135.85	\$5,368.05	\$232.19
Total cost after three years	\$6,196.25	\$5,477.33	-\$718.92
Total cost after four years	\$7,256.65	\$5,586.62	-\$1,670.03
Total cost after five years	\$8,317.04	\$5,695.90	-\$2,621.14

Despite an increased upfront cost of \$2,134 for a complete suite of ZEE, the landscaping business in this example would start saving money between two and three years after purchasing ZEE due to decreased fuel and maintenance costs. Most professional-grade lawn and garden equipment used by landscapers is less than five years old.¹⁰⁸ Over five years, the

¹⁰⁵ U.S. Census Bureau. 2021. Census Business Builder: Small Business Edition for Landscapers in California. 2021. (Database can be accessed at: <https://cbb.census.gov/sbe/#>. Last accessed March 28, 2021)

¹⁰⁶ Ibid.

¹⁰⁷ Based on a small business definition of fewer than 100 employees, per Gov. Code § 14837(d)(1)(A).

¹⁰⁸ CSUF SSRC. 2019. Survey of Small Off-Road Engines (SORE) Operating within California: Results from Surveys with Four Statewide Populations. May 15, 2019. Prepared by the Social Science Research Center (SSRC)

landscaping business in this example would experience a cost-savings of \$2,621. Businesses in this industry with one to four employees are the most numerous (5,457) among businesses with employees and have revenues of \$199,866 on average.¹⁰⁹ It is likely that one-person landscaping businesses have a lower annual revenue. The increased upfront cost difference of \$2,134 is roughly 1 percent of the average revenue of a landscaping business with fewer than 5 employees. This hypothetical example assumes that a landscaping business would purchase its ZEE all at once. In reality, ZEE purchase costs would likely be spread out over several years as landscapers purchase new ZEE when SORE equipment breaks.

Landscaping businesses surveyed in the CSUF survey had a mean of ten employees. Based on median populations from the CSUF survey data, a small landscaping business with ten employees likely has three chainsaws, two lawn mowers, one riding mower, two leaf blowers, two string trimmers and two hedge trimmers. Table C-25 provides the cost breakdown including annual ongoing costs for SORE equipment and ZEE. The same assumption as with the one-person landscaping business is made about purchasing all of this equipment at once in 2023.

Table C-25. Cost breakdown for a ten-person landscaping business that has purchased three chainsaws, two lawn mowers, two leaf blowers, two hedge trimmers, two string trimmers and one riding mower at 2023 prices.

(Negative values indicate cost-savings.)

Cost line item	SORE costs	ZEE costs	Cost difference
Equipment price	\$17,757.84	\$31,868.00	\$14,110.16
Maintenance	\$853.74	\$0.00	-\$853.74
Two-stroke oil cost	\$204.80	\$0.00	-\$204.80
Gasoline cost	\$2,180.61	\$0.00	-\$2,180.61
Electricity cost	\$0.00	\$369.40	\$369.40
Upfront costs	\$17,757.84	\$31,868.00	\$14,110.16
Annual operational costs	\$3,239.15	\$369.40	-\$2,869.76
Total cost after one year	\$20,996.99	\$32,237.40	\$11,240.40
Total cost after two years	\$24,236.15	\$32,606.80	\$8,370.65
Total cost after three years	\$27,475.30	\$32,976.20	\$5,500.89
Total cost after four years	\$30,714.46	\$33,345.60	\$2,631.14
Total cost after five years	\$33,953.61	\$33,715.00	-\$238.62

The ten-employee landscaping business in this example would reach a break-even point before five years of ZEE ownership. The cost-savings after five years of ownership, which corresponds to the median age of professional lawn and garden equipment, would be \$238.62. The average ten-employee small landscaping business has an annual revenue of

at California State University, Fullerton (CSUF), for CARB and the California Environmental Protection Agency, under CARB Agreement 16MLD011.

¹⁰⁹ Estimated based on revenues per employee by establishment size (U.S. Census Bureau. Economic Census: 2012 Statistics of U.S. Businesses (SUSB). 2015.) and employees per establishment size (U.S. Census Bureau. Annual Economic Surveys. 2018.).

\$901,691.¹¹⁰ The added upfront cost of buying this suite of equipment for a ten-employee business represents less than 2 percent of its annual revenue and provides a small net savings when considering the lifetime costs.

b. Dealers and Small-Engine Repair Shops

Dealers of SORE and small-engine repair shops would not experience direct costs as a result of the Proposed Amendments but are expected to be indirectly impacted due to lost revenue from the reduced maintenance requirements for ZEE. These indirect impacts are analyzed in the context of the California economy in Chapter E, but are also described here to provide additional information. As discussed previously, ZEE do not have the same maintenance requirements that SORE equipment do, so statewide reductions in engine repair costs are expected. As an increasing number of professional and residential users experience cost-savings from avoided SORE maintenance, dealers and small-engine repair shops could experience a decrease in revenue. In California, there are 78 businesses that are classified as “home and garden equipment repair” (NAICS 811411). These 78 businesses average \$1.7 million per year in revenue, for a total of \$132.6 million per year as of 2018.¹¹¹ There are 334 businesses in California that are classified as outdoor power equipment stores (NAICS 444210).¹¹² These businesses are also all small businesses and have \$449.1 million per year in combined revenue as of 2018.¹¹³ Based on the estimated overall maintenance cost-savings to small off-road equipment purchasers under the Proposed Amendments, CARB staff estimated there would be an average annual lost revenue of \$24.96 million per year expected for home and garden equipment repair and outdoor power equipment stores during the regulatory horizon.¹¹⁴

Staff does not expect a substantial impact on revenue from equipment sales, as the total number of equipment pieces sold is assumed to remain the same under the Proposed Amendments. Dealers and small-engine repair shops have many overlapping lines of business, with many dealers also performing repairs and repair shops also selling equipment. Determination of whether a business is considered a dealer or repair shop is based on where the majority of its business falls. The analysis assumes that home and garden equipment repair and outdoor power equipment stores would be impacted in proportion to their

¹¹⁰ Estimated based on revenues per employee by establishment size (U.S. Census Bureau. Economic Census: 2012 Statistics of U.S. Businesses (SUSB). 2015.) and employees per establishment size (U.S. Census Bureau. Annual Economic Surveys. 2018.).

¹¹¹ Estimated based on revenues per employee by establishment size (U.S. Census Bureau. Economic Census: 2012 Statistics of U.S. Businesses (SUSB). 2015.) and employees per establishment size (U.S. Census Bureau. Annual Economic Surveys. 2018.).

¹¹² The NAICS definition of Outdoor Power Equipment Stores describes the industry as, “establishments primarily engaged in retailing new outdoor power equipment or retailing new outdoor power equipment in combination with activities, such as repair services and selling replacement parts.”

¹¹³ Estimated based on revenues per employee by establishment size (U.S. Census Bureau. Economic Census: 2012 Statistics of U.S. Businesses (SUSB). 2015.) and employees per establishment size (U.S. Census Bureau. Annual Economic Surveys. 2018.).

¹¹⁴ CARB. 2021. Technical Support Document: Evaluation of Maintenance Frequencies and Costs for Small Off-Road Engines in California. Microsoft Excel workbook compiled by staff of the Monitoring and Laboratory Division. October 2021.

revenue. The Proposed Amendments would therefore represent a 4.3 percent annual loss of revenue for home and garden equipment repair and outdoor power equipment stores.

There is expected to be some additional loss of revenue from repair of SORE that was not accounted for in this analysis, including major repairs when engines break, but this cannot be quantified. The remaining revenue for these businesses likely comes from sales of new equipment (including preempt equipment), repair of equipment other than SORE, such as saws and hand tools, from repair that would be conducted on both ZEE and SORE, including blade sharpening, as well as from sales of new equipment.

4. Summary of Economic Impact on Professional Users

In 2024, all professional users of small off-road equipment on a statewide level are expected to incur a \$403 million increase in upfront costs under the Proposed Amendments (Table C-7). This would account for 53 percent of the total statewide upfront costs in 2024 associated with buying new ZEE despite professional-grade equipment accounting for less than 10 percent of the total equipment population. This cost is due to the fact that the incremental cost for opting for professional-grade ZEE is higher than the incremental cost for residential-grade ZEE. This upfront cost would increase each year until 2028, when it would decrease to \$262 million (Table C-7). This decrease in cost is a result of the emission standards for generator engines being zero for MY 2028. As described in Section C.1.c.iv, the price of a MY 2024 compliant generator is nearly twice as much as the price for an equivalent professional-grade zero-emission generator estimated for this analysis. The upfront costs in 2028 are lower than those in 2024 through 2027 because of the lower price of professional-grade zero-emission generators. The net upfront cost would increase with each following year through 2043 when it would be \$279 million.

In 2024, professional users are predicted to have statewide savings of \$14.18 million in ongoing operational costs for small off-road equipment as a result of avoided SORE maintenance and gasoline costs under the Proposed Amendments (Table C-17). Professional users would realize 45 percent of the total statewide ongoing operational cost-savings despite accounting for less than 10 percent of the total equipment population due to their higher usage of equipment. The savings in ongoing operational costs would increase each year through 2043 and reach a maximum of \$345 million.

Professional users would realize an overall statewide net cost-savings under the Proposed Amendments starting in 2034 due to savings in ongoing operational costs (Table C-19). The ten-year lag in savings for the professional category as a whole, as compared to the three-to-five-year lag with the typical landscaper examples described in Section C.3.a, is due to the high prices of ZEE pressure washers and generators relative to SORE equipment, as described in the typical business example in Section C.2. It is unlikely that the typical small landscaping business has one of these items. It is possible that a small business landscaper could purchase a small residential-grade zero-emission generator to help charge spare batteries during the workday. Such a generator would cost significantly less than the professional-grade zero-emission generator included in this analysis.

5. Direct Costs on Individuals

Individuals most likely to be affected by the Proposed Amendments are homeowners who do their own landscaping. More than half (56 percent) of California households do not own any lawn and garden equipment, and they will not be directly impacted by the Proposed Amendments, per the CSUF survey. The remaining 44 percent of households owning equipment could be impacted. From CSUF survey data, the three most frequently owned types of residential lawn and garden equipment are lawn mowers, leaf blowers, and string trimmers/edgers/brush cutters. As an example, consider a new homeowner who needs these three pieces of equipment to maintain their yard. Table C-26 shows the cost breakdown of purchasing ZEE instead of SORE equipment at 2023 prices.

Table C-26. Cost breakdown for a homeowner that has purchased a lawn mower, leaf blower, and a string trimmer at 2023 prices.

Cost line item	SORE costs	ZEE costs	Cost difference
Equipment price	\$630.49	\$956.75	\$326.26
Maintenance	\$19.45	\$0.00	-\$19.45
Two-stroke oil cost	\$11.97	\$0.00	-\$11.97
Gasoline cost	\$22.03	\$0.00	-\$22.03
Electricity cost	\$0.00	\$3.95	\$3.95
Upfront costs	\$630.49	\$956.75	\$326.26
Annual operational costs	\$53.45	\$3.95	-\$49.50
Total cost after one year	\$683.94	\$960.70	\$276.76
Total cost after five years	\$897.72	\$976.48	\$78.76
Total cost after seven years	\$1,004.61	\$984.38	-\$20.24
Total cost after ten years	\$1,164.95	\$996.22	-\$168.74

If all three pieces of equipment were purchased at once, it would take seven years after purchase for the homeowner to break even. This is a much longer timeframe than for professional users who would experience cost-savings more quickly due to more frequent use. Seven years is longer than the CSUF survey median ages for these three equipment types. However, a seven year life is common for residential ZEE, and cost-savings are possible.

From CSUF survey data, 79 percent of residents who own string trimmers reported their trimmers were more than three years old, and 25 percent reported they were more than ten years old. For lawn mowers, 75 percent of households responded as having one that was between 3 and 20 years old. A majority of residential lawn and garden equipment owners responded that they plan to keep their equipment until it breaks or fails. At the rate they use these pieces of equipment, the equipment can easily last more than ten years. Residential lawn and garden equipment owners who purchased ZEE instead of SORE equipment would eventually experience cost-savings if they kept it for its full life.

As a second example, staff assumed that an individual in a rural area may own a generator to run some electric equipment during a PSPS or other unplanned outage, and a riding mower

to maintain a large area of grass. Table C-27 shows the cost breakdown of purchasing ZEE instead of SORE equipment at 2023 prices.

Table C-27. Cost breakdown for a homeowner that has purchased a generator and riding mower at 2023 prices.

Cost line item	SORE costs	ZEE costs	Cost difference
Equipment price	\$3,495.09	\$5,392.61	\$1,897.52
Maintenance	\$25.97	\$0.00	-\$25.97
Fuel cost	\$225.97	\$0.00	-\$225.97
Electricity cost	\$0.00	\$22.13	\$22.13
Upfront costs	\$3,495.09	\$5,392.61	\$1,897.52
Annual operational costs	\$251.94	\$22.13	-\$229.81
Total cost after one year	\$3,747.03	\$5,414.74	\$1,667.71
Total cost after five years	\$4,754.78	\$5,503.24	\$748.46
Total cost after nine years	\$5,762.53	\$5,591.74	-\$170.78
Total cost after ten years	\$6,014.46	\$5,613.87	-\$400.59

The example homeowner of these two pieces of equipment would reach the break-even point before nine years of ownership. After ten years of ownership¹¹⁵, the homeowner would have saved \$400 by purchasing ZEE instead of SORE. This example demonstrates that individuals would break even within the equipment’s expected lifetime under the Proposed Amendments even when purchasing the equipment with the most substantial upfront cost increases. Usage and equipment ages used in this example are common, so an individual who uses their equipment significantly less than average or replaces or upgrades their equipment before the end of its life may not break even.

Finally, as an illustration of the wide range of prices and usage times within the SORE category, staff calculated the number of years that it would take a residential user to break even with ZEE versus SORE for each equipment category. Table C-28 shows the results along with the upfront and annual ongoing costs. The same usage assumptions as in the above examples were used. Median lifetime cost was estimated based on the assumption that equipment is kept the same number of years as the median age of equipment from the CSUF survey and shown in Table A-9.

¹¹⁵ Per the CSUF survey, 39 percent of resident owned generators and 48 percent of “other lawn and garden equipment” (which included riding mowers) were at least ten years old.

Table C-28. Upfront and annual ongoing costs for residential users of small off-road equipment.

(Negative values indicate cost-savings.)

Type of equipment	SORE upfront cost	ZEE upfront cost	SORE annual ongoing cost	ZEE annual ongoing cost	Number of years of ownership before cost-savings with ZEE	Median lifetime cost
Chainsaw	\$156.24	\$586.19	\$30.97	\$1.50	15	\$282.57
Generator Set	\$861.49	\$2,138.69	\$115.41	\$13.95	13	\$566.96
Lawn Mower	\$303.79	\$424.26	\$13.39	\$1.47	10	\$48.90
Leaf Blower/ Vacuum	\$161.67	\$318.64	\$23.83	\$1.20	7	\$43.82
Pressure Washer	\$400.37	\$349.05	\$32.78	\$3.04	1	-\$200.03
Pump < 2 hp	\$243.15	\$264.28	\$6.10	\$0.35	4	-\$13.37
Riding Mower	\$2,633.60	\$3,253.92	\$136.52	\$8.17	5	-\$406.47
Snow Blower	\$432.72	\$429.04	\$0.77	\$0.14	1	-\$7.48
Trimmer/Edger/ Brush Cutter	\$165.03	\$213.85	\$16.22	\$1.29	3	-\$25.81

For most equipment types, residential users could experience cost-savings from purchasing ZEE instead of SORE within a lifetime equivalent to the median age in the CSUF survey at 2023 prices. For some other equipment types, cost-savings could occur for equipment that are kept longer than the median age from the CSUF survey. Using 2023 prices is a conservative assumption, as battery prices are expected to continue to decrease. Repair of SORE equipment is not considered in the analysis. Staff expects that including repairs would lead to a shorter break-even time. Because residents do not typically perform regular maintenance on their SORE equipment (see Section C.1.d.ii), it likely requires more frequent repairs or replacement than ZEE.

Two equipment types for which residential users may not realize cost-savings are chainsaws and generators. SORE chainsaws are small, currently inexpensive, and typically used infrequently by residents, making it unlikely that cost-savings would be realized by residential users purchasing zero-emission chainsaws. For the reasons discussed in C.1.c.iv, zero-emission generators currently often have a higher purchase price than SORE generators. While the cost to purchase a zero-emission generator may decrease in the coming years, it will likely still be significantly higher than an equivalent SORE generator. While a 13-year period to break even is beyond the median age for residential generators, many users keep their generators for at least 13 years. Of residential generator owners in the CSUF survey, 39 percent said their generator was at least 10 years old.

In 2024, residential users of small off-road equipment on a statewide level would be expected to incur a \$362 million increase in upfront cost under the Proposed Amendments (Table C-7). This would account for 47 percent of the total statewide costs in 2024 associated with buying new equipment despite residential equipment accounting for over 90 percent of the total population of equipment. This cost is due to the higher purchase price of residential-grade ZEE relative to SORE equipment, as described in Table C-3. This upfront cost would increase slightly until 2028, when it would increase significantly to \$420 million

(Table C-7). This increase in cost is due to the generator emission standards being zero starting in MY 2028. The price of a MY 2024 residential-grade emission-compliant generator is lower than that of a zero-emission generator. The net upfront cost would increase slightly with each following year through 2043, when it would be \$468 million.

In 2024, residential users are expected to have statewide savings of \$13.35 million in ongoing operational costs for small off-road equipment as a result of avoided SORE maintenance and gasoline costs under the Proposed Amendments (Table C-17). The savings in ongoing operational costs would increase each year through 2043 and reach a maximum of \$481 million.

Residential users would realize a statewide net cost-savings under the Proposed Amendments starting in 2041 due to savings in ongoing operational costs (Table C-20). This is seven years after professional users are expected to experience a statewide net cost-savings. This delay is due to the longer period residential users keep their equipment and the lower rate at which they use it. Residential users often keep their small off-road equipment for more than 10 years. CSUF survey data show that they typically choose not to replace it until it breaks. Therefore, even though ZEE is more prevalent in residential use today than in professional use, it will take much longer for many residential users to adopt ZEE.

Statewide, over the regulatory horizon of 2023 through 2043, residential users would experience an accrued net cost of \$2.79 billion due to the Proposed Amendments (Table C-20). Per U.S. Census data, there are 13,072,122 occupied housing units in California.¹¹⁶ From CSUF survey data, only 44 percent of California households own powered lawn and garden equipment, and 40 percent own some other type of small off-road equipment. Assuming that 50 percent of the households in California own at least one piece of small off-road equipment, the net cost of the Proposed Amendments would amount to \$21.34 per household per year over 20 years. Per U.S. Census data, the median income of California households before taxes is \$75,277.¹¹⁷ The incremental cost would therefore be less than 1/10th of one percent of their pre-tax income. This indicates that a demand response to the slightly increased prices under the Proposed Amendments would be minimal and is not expected to have a significant effect on the results presented in this section.

D. Fiscal Impacts

1. Local government

a. Incremental Cost

Under the Proposed Amendments, as local governments upgrade their small off-road equipment to ZEE over time, they would bear higher upfront incremental costs to purchase the new equipment that met the emission standards under the Proposed Amendments, but also would realize fuel and maintenance savings. The net of these incremental costs and cost-savings represents a fiscal impact to local governments. Staff estimated the fiscal impact on local governments based on the government entities' portion of the small off-road

¹¹⁶ U.S. Census Bureau. Financial Characteristics. 2018.

¹¹⁷ Ibid.

equipment population, as shown in Table A-6. Staff then apportioned the population owned by local government, based on its 77 percent share of total government employment in California.¹¹⁸ Over the regulatory horizon, local government entities would incur a \$4.54 million incremental cost to purchase new small off-road equipment that met the emission standards under the Proposed Amendments (Table D-1).

b. Utility User Taxes

Many cities and counties in California levy a Utility User Tax on electricity usage. This tax varies from city to city and ranges from no tax to 11 percent. Staff used a value of 3.53 percent in this analysis, representing a population-weighted average.¹¹⁹ By increasing the amount of electricity used, there would be an increase in the amount of the Utility User Tax revenue collected by cities and counties starting in 2024, totaling \$52.77 million over the regulatory horizon (Table D-1).

c. Gasoline Taxes

Fuel taxes on gasoline fund transportation improvements at the state, county, and local levels. The local sales tax rate on gasoline is 2.25 percent per gallon in California.¹²⁰ Replacing gasoline-powered SORE with ZEE would decrease the total amount of gasoline dispensed in the state, resulting in a reduction in annual fuel tax revenue collected by local governments starting in 2024. The expected decrease in annual revenue ranges from \$0.44 million in 2024 to \$16.04 million in 2043, totaling \$192.97 million over the regulatory horizon (Table D-1).

d. Local Sales Taxes

Sales taxes are levied in California to fund a variety of programs at the state and local level. As discussed in Section A.5, the bulk of the small off-road equipment market is residential equipment, and ZEE have higher purchase prices on average than their SORE counterparts. In the professional market, ZEE have significantly higher purchase prices. For this analysis, staff calculated the average local sales tax to be 4.56 percent. This is based on the portion of the state sales tax that is apportioned back to local programs and an average of local (i.e., county and city), levied sales taxes.¹²¹ The Proposed Amendments would lead to net increases in local government revenue, with a statewide peak annual gain of \$31.85 in 2024 and a total gain of \$530.88 million over the regulatory horizon (Table D-1).

e. Total Fiscal Impacts on Local Government

Table D-1 shows the estimated annual and total fiscal impacts to local governments due to the Proposed Amendments relative to the Baseline Scenario. Staff estimates that the fiscal impact to local governments would be a net gain in revenue of \$89.56 million over the years

¹¹⁸ Regional Economic Models Inc. (REMI) Policy Insight+ v. 2.4. State and Local Government employment in 2018. 2018.

¹¹⁹ California State Controller's Office. User Utility Tax Revenue and Rates. December 10, 2018.

¹²⁰ California Department of Tax and Fee Administration. Sales Tax Rates for Fuels. 2020.

¹²¹ California Department of Tax and Fee Administration. Tax Rates by County and City. October 2020.

2024 through 2026 and a net gain in revenue of \$386.14 million over the regulatory horizon. The initial annual gains due to increased sales tax revenue would be increasingly offset by reductions in gasoline tax revenue as more of the equipment population became ZEE. This analysis estimates a net annual gain of \$30.92 million for local governments in 2024, compared to a net annual gain of \$14.21 million in 2043.

Table D-1. Estimated fiscal impacts on local governments under the Proposed Amendments (million 2019\$).

(Negative values indicate revenue losses. Totals may differ slightly due to rounding.)

Calendar year	Incremental cost	Utility user tax revenue	Gas tax revenue	Local sales tax revenue	Total fiscal impact ¹²²
2023	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00
2024	\$0.62	\$0.14	-\$0.44	\$31.85	\$30.92
2025	\$0.60	\$0.38	-\$1.27	\$31.36	\$29.86
2026	\$0.59	\$0.64	-\$2.16	\$30.89	\$28.78
2027	\$0.57	\$0.91	-\$3.06	\$30.43	\$27.72
2028	\$0.28	\$1.20	-\$4.01	\$26.22	\$23.13
2029	\$0.25	\$1.58	-\$5.42	\$25.71	\$21.62
2030	\$0.22	\$1.97	-\$6.78	\$25.31	\$20.28
2031	\$0.19	\$2.31	-\$8.08	\$25.15	\$19.19
2032	\$0.17	\$2.62	-\$9.29	\$25.05	\$18.21
2033	\$0.15	\$2.90	-\$10.39	\$24.99	\$17.34
2034	\$0.13	\$3.15	-\$11.40	\$24.97	\$16.58
2035	\$0.12	\$3.36	-\$12.29	\$24.99	\$15.94
2036	\$0.11	\$3.55	-\$13.06	\$25.04	\$15.42
2037	\$0.09	\$3.71	-\$13.72	\$25.12	\$15.01
2038	\$0.09	\$3.84	-\$14.29	\$25.24	\$14.70
2039	\$0.08	\$3.95	-\$14.78	\$25.37	\$14.47
2040	\$0.07	\$4.04	-\$15.17	\$25.53	\$14.32
2041	\$0.07	\$4.12	-\$15.51	\$25.70	\$14.24
2042	\$0.07	\$4.18	-\$15.80	\$25.89	\$14.21
2043	\$0.06	\$4.24	-\$16.04	\$26.08	\$14.21
Average	\$0.22	\$2.51	-\$9.19	\$25.28	\$18.39
Total	\$4.54	\$52.77	-\$192.97	\$530.88	\$386.14

2. State Government

a. Incremental Cost

Under the Proposed Amendments, as the State government upgrades its small off-road equipment to ZEE over time, it would bear higher upfront incremental costs to purchase the new equipment that met the emission standards under the Proposed Amendments, but also would realize fuel and maintenance savings. The net of these incremental costs and cost-savings represents a fiscal impact to the State government. Staff estimated the fiscal impact

¹²² The total fiscal impact is calculated as the sum of the revenue columns minus incremental costs.

on the State government based on the government entities' portion of the small off-road equipment population, as shown in Table A-6. Staff then apportioned the population of small off-road equipment owned by the State based on its 23 percent share of total government employment in California.¹²³ Over the regulatory horizon, state government would incur \$1.36 million incremental cost to purchase new small off-road equipment that meets the emission standards under the Proposed Amendments (Table D-2).

b. CARB Staff Certification Costs

ZEE do not require CARB certification, and staff expects manufacturers would certify fewer SORE families starting in MY 2024. As a result, fewer CARB staff would be required for certification of SORE. These staff would be redirected to other CARB programs, so no cost-savings would be realized.

c. Energy Resources Fee

The Energy Resource Fee is a \$0.0003/kWh surcharge levied on consumers of electricity purchased from electrical utilities. The revenue collected is deposited into the Energy Resources Programs Account of the General Fund, which is used for ongoing energy programs and projects deemed appropriate by the Legislature, including but not limited to, activities of the California Energy Commission. The increase in ZEE post-2024 would create a small net gain in funds for the State government through this fee (Table D-2). The total increase in Energy Resource Fee revenue over the regulatory horizon would be \$2.19 million.

d. Gasoline Excise Tax

Fuel taxes on gasoline fund transportation improvements at the state, county, and local levels. The gasoline excise tax levied by the state was assumed to remain at its current rate of \$0.505/gal. Replacing gasoline-powered SORE with ZEE would decrease the total amount of gasoline dispensed in the state, resulting in a reduction in annual revenue for the state from the gas excise tax starting in 2024. The expected decrease in annual revenue ranges from \$3.08 million in 2024 to \$110.11 million in 2043, totaling \$1.32 billion over the regulatory horizon (Table D-2).

e. State Sales Tax

Sales taxes are levied in California to fund a variety of programs at the state and local level. For this analysis, staff assumed state sales tax would remain constant through 2043, with 3.53 percent going to State programs and the General Fund. As discussed in Section A.5, the bulk of the small off-road equipment market is residential equipment, and ZEE have higher purchase prices on average than their SORE counterparts. In the professional market, ZEE have higher purchase prices. The Proposed Amendments would lead to net increases in state sales tax revenue, with a peak annual gain of \$27.52 million in 2024 and a total gain of \$458.70 million over the regulatory horizon (Table D-2).

¹²³ Regional Economic Models Inc. (REMI) Policy Insight+ v. 2.4. State and Local Government Employment in 2018. 2018.

f. Fiscal Impacts on State Government

Table D-2 shows the estimated annual and total fiscal impacts to the State government due to the Proposed Amendments relative to the Baseline Scenario. Staff estimate that the fiscal impact to State government would be a net gain in revenue of \$53.87 million over the years 2024 through 2026 and a net reduction in revenue of \$864.92 million over the regulatory horizon, as reductions in gasoline excise tax revenue would occur as more of the equipment population became ZEE.

Table D-2. Estimated fiscal impacts on State government under the Proposed Amendments (million 2019\$).

(Negative values indicate revenue losses. Totals may differ slightly due to rounding.)

Calendar year	Incremental costs	Energy resource fee revenue	Gasoline excise tax revenue	State sales tax revenue	Fiscal impact ¹²⁴
2023	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00
2024	\$0.19	\$0.01	-\$3.08	\$27.52	\$24.26
2025	\$0.18	\$0.02	-\$8.84	\$27.10	\$18.09
2026	\$0.18	\$0.03	-\$15.02	\$26.69	\$11.52
2027	\$0.17	\$0.04	-\$21.04	\$26.30	\$5.13
2028	\$0.08	\$0.05	-\$27.68	\$22.66	-\$5.06
2029	\$0.07	\$0.07	-\$36.89	\$22.22	-\$14.68
2030	\$0.07	\$0.08	-\$46.52	\$21.87	-\$24.64
2031	\$0.06	\$0.10	-\$55.44	\$21.73	-\$33.67
2032	\$0.05	\$0.11	-\$63.73	\$21.64	-\$42.03
2033	\$0.05	\$0.12	-\$71.31	\$21.59	-\$49.64
2034	\$0.04	\$0.13	-\$78.21	\$21.57	-\$56.55
2035	\$0.04	\$0.14	-\$84.34	\$21.59	-\$62.65
2036	\$0.03	\$0.15	-\$89.61	\$21.63	-\$67.86
2037	\$0.03	\$0.15	-\$94.18	\$21.71	-\$72.35
2038	\$0.03	\$0.16	-\$98.10	\$21.81	-\$76.16
2039	\$0.02	\$0.16	-\$101.41	\$21.92	-\$79.35
2040	\$0.02	\$0.17	-\$104.12	\$22.06	-\$81.92
2041	\$0.02	\$0.17	-\$106.42	\$22.21	-\$84.06
2042	\$0.02	\$0.17	-\$108.41	\$22.37	-\$85.89
2043	\$0.02	\$0.17	-\$110.11	\$22.53	-\$87.42
Average	\$0.06	\$0.10	-\$63.07	\$21.84	-\$41.19
Total	\$1.36	\$2.19	-\$1,324.45	\$458.70	-\$864.92

¹²⁴ The total fiscal impact is calculated as the change in revenue minus incremental costs.

E. Macroeconomic Impacts

1. Methods for Determining Economic Impacts

This section describes the estimated total impact of the Proposed Amendments on the California economy. The Proposed Amendments will result in incremental cost and cost-savings for businesses to comply with the regulation. These costs result in direct changes in expenditures in the economy as these costs are passed on to professional and residential users of SORE. These changes in expenditures by users will indirectly affect employment, output, and investment in sectors that supply goods and provide services to affected businesses.

These direct and indirect effects lead to induced effects, such as changes in personal income that affect consumer expenditures across other spending categories. The total economic impact is the sum of these effects and is presented in this chapter. The total economic impact of the Proposed Amendments is simulated relative to the Baseline Scenario using the cost estimates described in Chapter C. The analysis focuses on the changes in major macroeconomic indicators from 2023 through 2043, including employment, output, personal income, and gross state product (GSP). The years of the analysis are used to simulate the Proposed Amendments through more than 12 months post full implementation.

Regional Economic Models, Inc. (REMI) Policy Insight Plus Version 2.4 is used to estimate the macroeconomic impacts of the Proposed Amendments on the California economy. REMI is a structural economic forecasting and policy analysis model that integrates input-output, computable general equilibrium, econometric and economic geography methodologies.¹²⁵ REMI Policy Insight Plus provides year-by-year estimates of the total economic impacts of the Proposed Amendments, pursuant to the requirements of SB 617 and the California Department of Finance.¹²⁶ CARB uses the REMI single-region, 160-sector model. Several adjustments were made to the model reference case to reflect the impacts of COVID-19 and to reflect the Department of Finance conforming forecasts. First, the REMI model's National Control was updated with a short-term national forecast based on the U.S. Economic Outlook for 2020-2022 from the University of Michigan's Research Seminar in Quantitative Economics (RSQE)¹²⁷ release on April 9, 2020, which was made available in the latest REMI model. Second, the National and Regional Controls in REMI were updated to reflect the most recent Department of Finance conforming forecasts which include population projections dated January 2020 and U.S. real GDP forecasts, and California civilian employment growth numbers Dated May 2020. Because the Department of Finance forecasts only extended to 2023, CARB staff assumed that post-2023, U.S. income and employment would continue to grow at the same rate as projected in the RSQE forecast, while California civilian employment would continue to recover at the rate forecasted by the Department of Finance, until it returned to baseline levels.

¹²⁵ For further information and model documentation see: <https://www.remi.com/model/pi/>.

¹²⁶ Senate Bill 617 (Calderon, Stats. of 2011, Ch. 496; amending Gov. Code §§ 11346.2, 11346.3, 11346.5, 11346.9, 11347.3, 1139.1, 13401, 13402, 13403, 13404, 13405, 13406, 13407 and adding Gov. Code §§ 11342.548, 11346.36, 11349.1.5); Department of Finance Standardized Regulatory Impact Assessment for Major Regulations, Cal. Code Regs., tit. 1, §§ 2000 et seq.

¹²⁷ This update assumes that the economic contraction is severe but that aggressive federal response to the pandemic maintains the possibility of a vigorous recovery: <https://lsa.umich.edu/econ/rsqe.html>.

2. Inputs of the Assessment

The estimated economic impact of the Proposed Amendments is sensitive to modeling assumptions. This section provides a summary of the assumptions and inputs used to determine the suite of policy variables that best reflect the macroeconomic impacts of the Proposed Amendments. The direct costs and savings estimated in Chapter C and the nonmortality related health benefits estimated in Chapter B are translated into REMI policy variables and used as inputs for the macroeconomic analysis.¹²⁸

The emission standards of zero for MY 2024 would result in an increase in new purchases of ZEE, as described in Chapter C. Switching to ZEE will also result in ongoing incremental cost and cost-savings: professional and residential users will realize fuel savings from reduced gasoline use, increased electricity costs from ZEE, and reduced equipment maintenance and repair costs. The upfront incremental costs of the lower emission and zero-emission equipment is expected to be passed through to users (i.e., professional and residential users), while also realizing net ongoing cost-savings.

The costs and cost-savings realized by businesses that use the affected equipment are input into the model as a change in production costs for the affected industry. The share of costs and cost-savings realized across different industries are estimated based on the baseline populations as described in Chapter A, where the primarily affected industry is landscapers (NAICS 5617).¹²⁹ Also affected are all other businesses that use the equipment; the cost is assumed to be distributed across these industries according to their share of state employment.¹³⁰

These costs and cost-savings realized by professional users correspond with changes in final demand for industries supplying those particular goods or services, as shown in Table E-1. As the direct costs on SORE equipment manufacturers are incurred out of state, it is assumed here that the changes in demand for the SORE supply chain also occur out of state. This change in demand is therefore omitted from evaluation in the economic model. All other changes in demand related to SORE equipment are included in this analysis. The reduced gasoline costs for professional and residential users correspond to a decrease in demand for petroleum products manufacturing (NAICS 324). The increased electricity use corresponds to an increase in demand for the electric power generation, transmission, and distribution industry (NAICS 2211). The decrease in expenditures on repair and maintenance corresponds to a decrease in demand for the personal and household goods repair and maintenance industry (NAICS 8114).

¹²⁸ Refer to G. Appendix for a full list of REMI inputs for this analysis.

¹²⁹ The landscape architectural services (NAICS 541320) industry is not modeled as having direct impacts, as it represents professional and technical services focused on design and planning work.

¹³⁰ Based on employment shares estimated for 159 industries from 2018 employment data from the REMI PI+ (v2.4) model.

Table E-1. Sources of changes in production costs or prices and final demand by industry.

Source of Cost or Savings	Industries or Individuals with Change in Production Cost or Prices (NAICS)	Industries with Changes in Final Demand (NAICS)
Small Off-Road Equipment	Landscapers (5617), other businesses & individuals	Upfront cost: SORE mfg. (3331, out of state)
Gasoline and two-stroke oil	Landscapers (5617), other businesses & individuals	Recurring cost: Petroleum Products mfg. (324)
Electricity	Landscapers (5617), other businesses & individuals	Recurring cost: Electric power generation, transmission, and distribution (2211)
Repair & Maintenance (savings)	Landscapers (5617), other businesses & individuals	Recurring Savings: Personal and Household Goods Repair and Maintenance (8114)

The incremental equipment cost incurred by residential users is input into the model as an increase in the consumer spending for Tools and Equipment for Home and Garden.¹³¹ The incremental changes in expenditures on fuel, electricity, and maintenance and repair are input into the model as a change in consumer spending for the relevant consumer categories: motor vehicles fuels and lubricants, electricity, and household maintenance, respectively. The consumer spending policy variable affects the economy through changes in expenditures on goods and services based on the relative increase or decrease of expenditures in the specified category, corresponding with an equivalent reallocation of the spending on all other consumption categories and savings.

In addition to these changes in production costs or prices and final demand, there will also be economic impacts as a result of the fiscal effects, primarily from reductions in tax and fee revenue, equipment costs, and passed-through compliance costs. These changes in government revenue and changes in costs are modeled as changes in state and local government spending, assuming these revenue decreases are not offset elsewhere.

3. Results of the Assessment

The results from the REMI model provide estimates of the impact of the Proposed Amendments on the California economy. These results represent the annual incremental change from the implementation of the Proposed Amendments relative to the Baseline Scenario. The California economy is forecasted to grow post-2020. Therefore, negative impacts reported here should be interpreted as a slowing of growth and positive impacts as an acceleration of growth resulting from the Proposed Amendments. The results are reported here in four-year intervals from 2023 through 2043.

a. California Employment Impacts

Table E-2 presents the impact of the Proposed Amendments on total employment in California across all private industries and the public sector. Employment comprises estimates of the number of jobs, full-time plus part-time, by place of work for all industries. Full-time

¹³¹ Tools and Equipment for Home and Garden is a component of Personal Consumption Expenditures as described by BEA <https://www.bea.gov/media/5711>. This PCE category within REMI best represents the types of equipment affected under this proposed regulation.

and part-time jobs are counted at equal weight. Employees, sole proprietors, and active partners are included, but unpaid family workers and volunteers are not included. The employment impacts represent the net change in employment across the economy, which is composed of positive impacts for some industries and negative impacts for others. The Proposed Amendments are estimated to result in an initial decrease in employment growth that is less than 0.03 percent of baseline employment that diminishes towards the end of the regulatory horizon.

Table E-2. California employment impacts under the Proposed Amendments.

Metric	2023	2027	2031	2035	2039	2043
California Employment	22,603,913	24,725,694	24,765,385	25,011,315	25,539,578	26,209,650
% Change	0.00%	-0.02%	-0.01%	0.00%	0.00%	0.00%
Change in Total Jobs	0	-4,908	-1,465	-836	-614	-453

The total employment impacts presented above are net of changes at the industry level. The overall trend in employment changes by major sector are illustrated in Figure E-1. Table E-3 shows the changes in employment by industries that are directly impacted by the Proposed Amendments. As the requirements of the Proposed Amendments go into effect, the industries generally realizing reductions in production cost or increases in final demand see an increase in employment growth. There is initially a decrease in job growth that corresponds with the higher SORE cost from the emission standards of zero that is not immediately offset by fuel savings. Over time, as the operational savings from zero-emission equipment accrue, landscaping businesses begin to realize gasoline fuel cost-savings and other operational savings that more than offset the incremental equipment cost. These gasoline fuel savings result in lower production costs, diminishing the negative initial impact on job growth over the regulatory period. The oil and gas extraction industry and personal and household goods repair and maintenance industry see a decreased employment growth rate due to a reduction in final demand for their goods and services. The reduced fuel consumption also reduces tax revenues, resulting in lower state and local government spending and employment as seen in Table E-3.

Figure E-1. Job impacts under the Proposed Amendments by major sector.

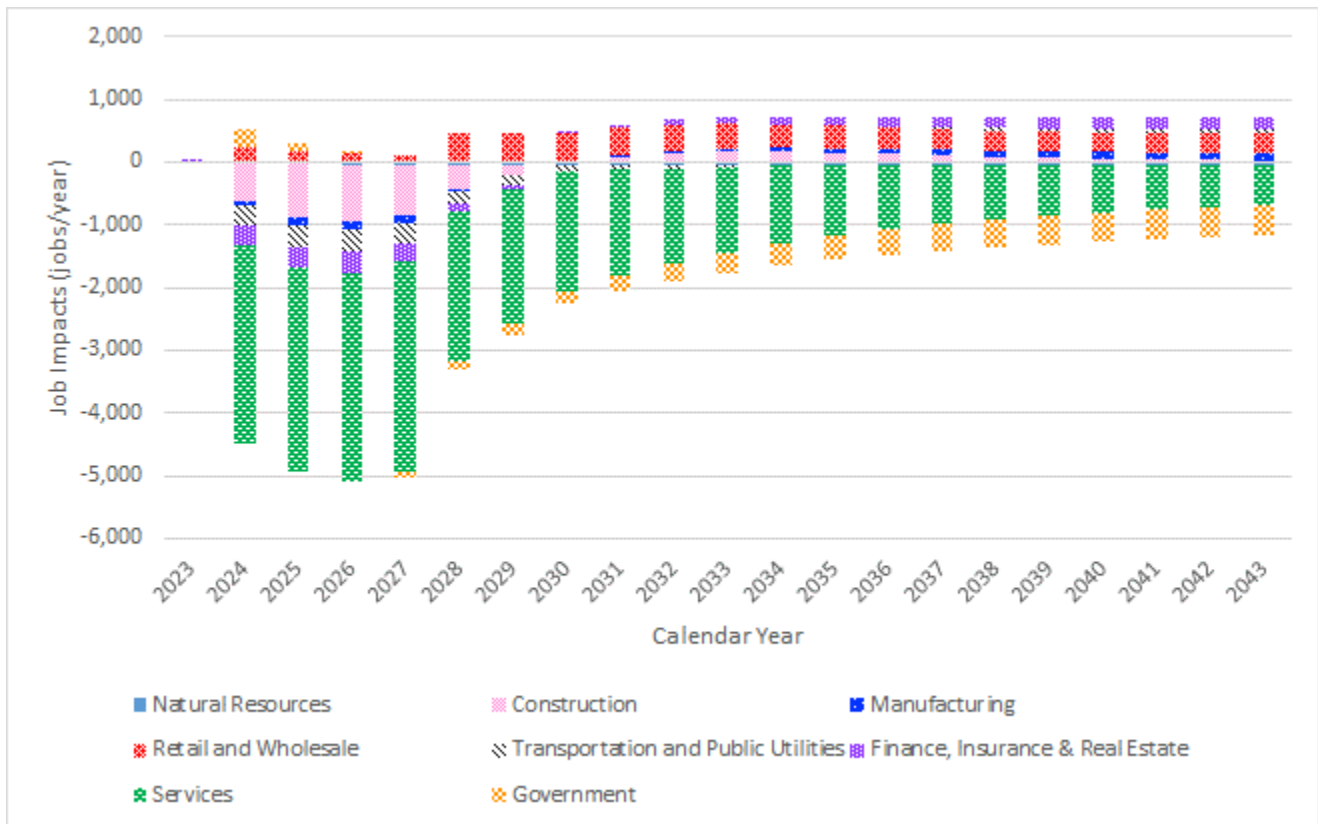


Table E-3. Job impacts by primary and secondary industries under the Proposed Amendments.

Industry	Unit	2023	2027	2031	2035	2039	2043
Electric power generation, distribution (2211)	% Change	0.00%	0.03%	0.11%	0.15%	0.17%	0.17%
Electric power generation, distribution (2211)	Change in Jobs	0	12	41	58	64	65
Petroleum and coal products manufacturing (324)	% Change	0.00%	-0.11%	-0.24%	-0.33%	-0.36%	-0.35%
Petroleum and coal products manufacturing (324)	Change in Jobs	0	-15	-31	-40	-42	-40
Agriculture, construction, and mining machinery manufacturing (3331)	% Change	0.00%	0.06%	0.08%	0.08%	0.08%	0.08%
Agriculture, construction, and mining machinery manufacturing (3331)	Change in Jobs	0	2	3	3	3	3
Retail trade (44-45)	% Change	0.00%	0.01%	0.02%	0.01%	0.01%	0.01%
Retail trade (44-45)	Change in Jobs	0	134	372	302	262	248
Services to buildings and dwellings (5617)	% Change	0.00%	-0.03%	0.00%	0.02%	0.02%	0.02%
Services to buildings and dwellings (5617)	Change in Jobs	0	-92	12	64	90	100
Personal and household goods repair and maintenance (8114)	% Change	0.00%	-1.65%	-3.13%	-3.97%	-4.31%	-4.40%
Personal and household goods repair and maintenance (8114)	Change in Jobs	0	-325	-593	-723	-762	-757
State & Local Government	% Change	0.00%	0.00%	-0.01%	-0.02%	-0.02%	-0.02%
State & Local Government	Change in Jobs	0	-81	-246	-387	-462	-479

b. California Business Impacts

Gross output is used as a measure for business impacts because it represents an industry's sales or receipts and tracks the quantity of goods or services produced in a given time period. Output is the sum of the amount of production, including all intermediate goods purchased as well as value added (compensation and profit), across all private industries and the public sector. Output is affected by production cost and demand changes. As production cost increases or demand decreases, output is expected to contract. As production costs decline or demand increases, industry will likely experience output growth.

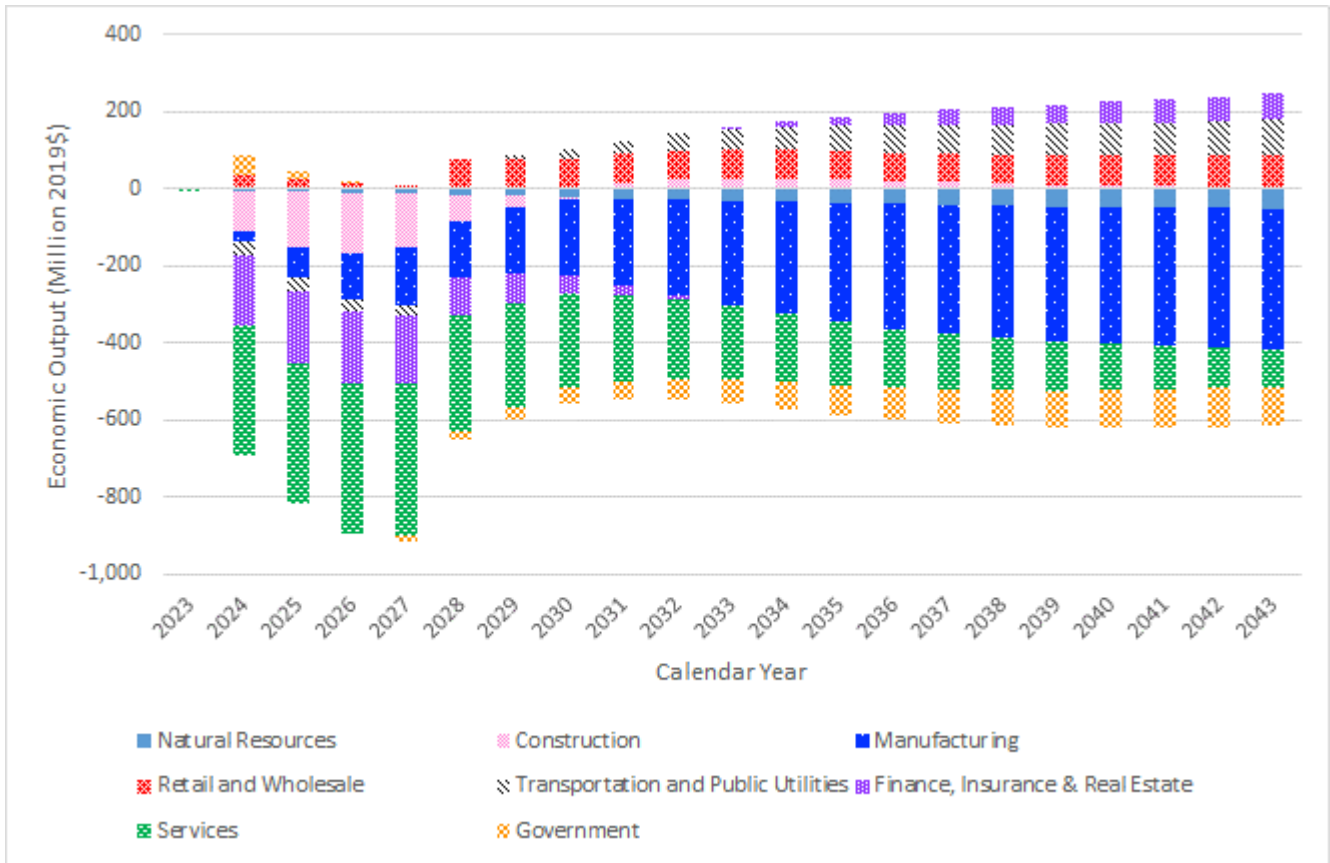
The results of the assessment of impacts due to the Proposed Amendments show a decrease in output of \$772 million in 2027 and a decrease of \$369 million in 2043 as shown in Table E-4, representing a change that does not exceed 0.01 percent of baseline output. The results for each impacted industry are also shown in Table E-4. The trend in output changes is illustrated by major sector in Figure E-2. Similar to the employment impacts, there is an initial negative impact on the services sector that diminishes over time and negative impacts on petroleum and coal products manufacturing and on personal and household goods repair and maintenance. The public sector also experiences negative impacts as seen in Table E-4. The negative output impact on manufacturing is primarily driven by the petroleum and coal products manufacturing industry, which is estimated to see a sizeable decrease in final demand for gasoline.

Table E-4. Change in output growth by industry under the Proposed Amendments.

Industry	Metric	2023	2027	2031	2035	2039	2043
California Economy	Output (2019M\$)*	4,848,370	5,519,530	5,804,974	6,209,827	6,785,735	7,466,638
California Economy	% Change	0.00%	-0.01%	-0.01%	-0.01%	-0.01%	0.00%
California Economy	Change (2019M\$)	0	-772	-454	-398	-393	-369
Electric power generation, transmission, and distribution (2211)	% Change	0.00%	0.03%	0.11%	0.15%	0.17%	0.17%
Electric power generation, transmission, and distribution (2211)	Change (2019M\$)	0	13	47	71	84	90
Petroleum and coal products manufacturing (324)	% Change	0.00%	-0.11%	-0.24%	-0.33%	-0.36%	-0.36%
Petroleum and coal products manufacturing (324)	Change (2019M\$)	0	-116	-258	-369	-432	-460
Agriculture, construction, and mining machinery manufacturing (3331)	% Change	0.00%	0.06%	0.08%	0.08%	0.08%	0.08%
Agriculture, construction, and mining machinery manufacturing (3331)	Change (2019M\$)	0	2	2	2	2	3
Retail trade (44-45)	% Change	0.00%	0.01%	0.02%	0.02%	0.01%	0.01%
Retail trade (44-45)	Change (2019M\$)	0	17	53	48	46	48
Services to buildings and dwellings (5617)	% Change	0.00%	-0.03%	0.00%	0.02%	0.02%	0.03%
Services to buildings and dwellings (5617)	Change (2019M\$)	0	-7	1	5	8	10
Personal and household goods repair and maintenance (8114)	% Change	0.00%	-1.65%	-3.15%	-4.01%	-4.36%	-4.45%
Personal and household goods repair and maintenance (8114)	Change (2019M\$)	0	-44	-81	-101	-110	-112
State & Local Government	% Change	0.00%	0.00%	-0.01%	-0.02%	-0.02%	-0.02%
State & Local Government	Change (2019M\$)	0	-15	-47	-76	-94	-100

*Millions of fixed 2019 dollars (2019M\$)

Figure E-2. Change in output under the Proposed Amendments by major sector.



c. Impacts on Investments in California

Private domestic investment consists of purchases of residential and nonresidential structures and of equipment and software by private businesses and nonprofit institutions. It is used as a proxy for impacts on investments in California because it provides an indicator of the future productive capacity of the economy.

The relative changes to growth in private investment for the Proposed Amendments are shown in Table E-5 and show a decrease of private investment by about \$231 million in 2027 and an increase of \$41 million in 2043, not exceeding 0.05 percent of baseline investment.

Table E-5. Change in gross domestic private investment growth under the Proposed Amendments.

Metric	2023	2027	2031	2035	2039	2043
Private Investment (2019M\$)	360,677	465,577	489,344	525,926	578,181	636,163
% Change	0.00%	-0.05%	0.00%	0.01%	0.01%	0.01%
Change (2019M\$)	0	-231	13	48	43	41

d. Impacts on Individuals in California

The Proposed Amendments result in impacts to individuals as the incremental costs of affected equipment are passed on to residential users, who also realize fuel cost-savings. Additionally, the costs incurred by affected businesses and the public sector will cascade through the economy and impact individuals. One measure of this impact is the change in real personal income, which includes worker compensation and government and business transfer payments, adjusted for inflation.

Table E-6 shows the annual change in real personal income across all individuals in California. Total personal income growth initially decreases by about \$634 million in 2027, then subsequently begins an upward trend, with a decrease of \$24 million in 2043. The change in personal income estimated here can also be divided by the California population to show the average or per capita impact on personal income. Personal income initially decreases by about \$7 per person in 2027 and increases by about \$2 per person in 2043.

Table E-6. Change in personal income growth under the Proposed Amendments.

Metric	2023	2027	2031	2035	2039	2043
Personal Income (2019M\$)	2,676,344	2,960,342	3,174,945	3,428,717	3,733,237	4,064,924
% Change in Personal Income	0.00%	-0.02%	-0.01%	0.00%	0.00%	0.00%
Change in Personal Income (2019M\$)	0	-634	-205	-104	-54	-24
Personal Income per capita (2019\$)	63,970	69,706	73,469	77,803	83,400	89,829
% Change in Personal Income per capita	0.00%	-0.01%	0.00%	0.00%	0.00%	0.00%
Change in Personal Income per capita (2019\$)*	0	-7	2	3	3	2

*The difference in sign between change in personal income and personal income per capita is due to a small change in population estimated by the REMI model as a result of the Proposed Amendments.

e. Impacts on Gross State Product (GSP)

Gross State Product (GSP) is the market value of all goods and services produced in California and is one of the primary indicators used to gauge the health of an economy. Under the Proposed Amendments, GSP growth is anticipated to decrease by about \$521 million in 2027 and decrease by \$117 million in 2043 as shown in Table E-7. These changes do not exceed 0.02 percent of baseline GSP.

Table E-7. Changes in gross state product (GSP) growth under the Proposed Amendments.

Metric	2023	2027	2031	2035	2039	2043
GSP (2019M\$)	2,872,990	3,291,459	3,492,618	3,739,328	4,044,768	4,392,774
% Change	0.00%	-0.02%	-0.01%	0.00%	0.00%	0.00%
Change (2019M\$)	0	-521	-204	-161	-143	-117

f. Creation or Elimination of Businesses

The REMI model cannot directly estimate the creation or elimination of businesses. Changes in jobs and output for the California economy described above can be used to understand some potential impacts. The overall jobs and output impacts of the Proposed Amendments are very small relative to the total California economy, representing changes less than 0.03 percent. However, impacts in some specific sectors are larger, as described in previous sections. The trend of decreasing production costs for the services to buildings and dwellings industry has the potential to result in an expansion or increase in the number of businesses in this industry if sustained over time. The decreasing trend in demand for gasoline following from the Proposed Amendments has the potential to result in a decrease in the number of businesses in this industry if sustained over time. The personal and household maintenance and repair industry sees the largest relative decrease in industry employment and output from the Proposed Amendments and may be indicative of potential business contraction or eliminations. In particular, we expect small-engine repair shops to see significant impacts to their business. Zero-emission equipment do not contain an engine and are expected to need significantly less repair than SORE equipment. Some standard maintenance, such as sharpening lawn mower blades or replacing trimmer heads, will still be required on SORE, but this type of maintenance is more likely to be performed by the owner or the dealer selling the equipment.

g. Incentives for Innovation

The Proposed Amendments to the SORE regulations are written to provide maximum flexibility to manufacturers, while still meeting California's air quality goals. A new zero-emission generator credit program is being added to incentivize an early switch to zero-emission generators by allowing credit generation to offset emissions from SORE.

h. Competitive Advantage or Disadvantage

The small off-road equipment manufacturers that must comply with requirements of the Proposed Amendments are mostly based outside of California and therefore do not present any competitiveness impacts for this industry inside California. Small off-road equipment dealers may potentially find themselves at a competitive disadvantage as a result of the Proposed Amendments. Businesses, or individuals could purchase small off-road equipment out of state and bring it into California for use. Due to the small price differences on the household side of the market between SORE equipment and ZEE, this is unlikely to happen at the individual level. However, the higher upfront costs associated with professional ZEE may make this enticing for large businesses. The additional costs of transportation for purchasing and repair may prevent some of this. In contrast, online sales of noncompliant equipment are expected to be low, as CARB staff search for such equipment and have initiated enforcement mechanisms against online retailers selling noncompliant SORE. The requirements result in an incremental net savings to professional users of the equipment. These net savings are anticipated to be realized generally across professional users and are not anticipated to result in any competitive advantages or disadvantages within industries.

4. Summary and Agency Interpretation of the Assessment Results

As analyzed here, CARB estimates the Proposed Amendments are unlikely to have a significant impact on the California economy, as summarized in Table E-8. Overall, the changes in the growth of jobs, GSP, and output are projected to be less than 0.03 percent of the baseline values. The Proposed Amendments result in fuel savings that grow over time, leading to eventual growth in the services sector, including landscaping. The fuel savings for professional and residential users represents decreased demand for gasoline, portending a decrease in growth for the oil and gas industry. The repair and maintenance cost-savings to users of electric powered equipment results in decreased sales to the household goods repair and maintenance industry, leading to relatively large declines in employment in the industry. This analysis also shows the negative impact estimated for state and local government output and employment due to fuel tax revenue decreases, without any offsetting revenues.

Table E-8. Summary of macroeconomic impacts of the Proposed Amendments.

Indicator	Metric	2023	2027	2031	2035	2039	2043
GSP	% Change	0.00%	-0.02%	-0.01%	0.00%	0.00%	0.00%
GSP	Change (2019M\$)	0	-521	-204	-161	-143	-117
Personal Income	% Change	0.00%	-0.02%	-0.01%	0.00%	0.00%	0.00%
Personal Income	Change (2019M\$)	0	-634	-205	-104	-54	-24
Employment	% Change	0.00%	-0.02%	-0.01%	0.00%	0.00%	0.00%
Employment	Change in Jobs	0	-4,908	-1,465	-836	-614	-453
Output	% Change	0.00%	-0.01%	-0.01%	-0.01%	-0.01%	0.00%
Output	Change (2019M\$)	0	-772	-454	-398	-393	-369
Private Investment	% Change	0.00%	-0.05%	0.00%	0.01%	0.01%	0.01%
Private Investment	Change (2019M\$)	0	-231	13	48	43	41

F. Regulatory Alternatives Considered

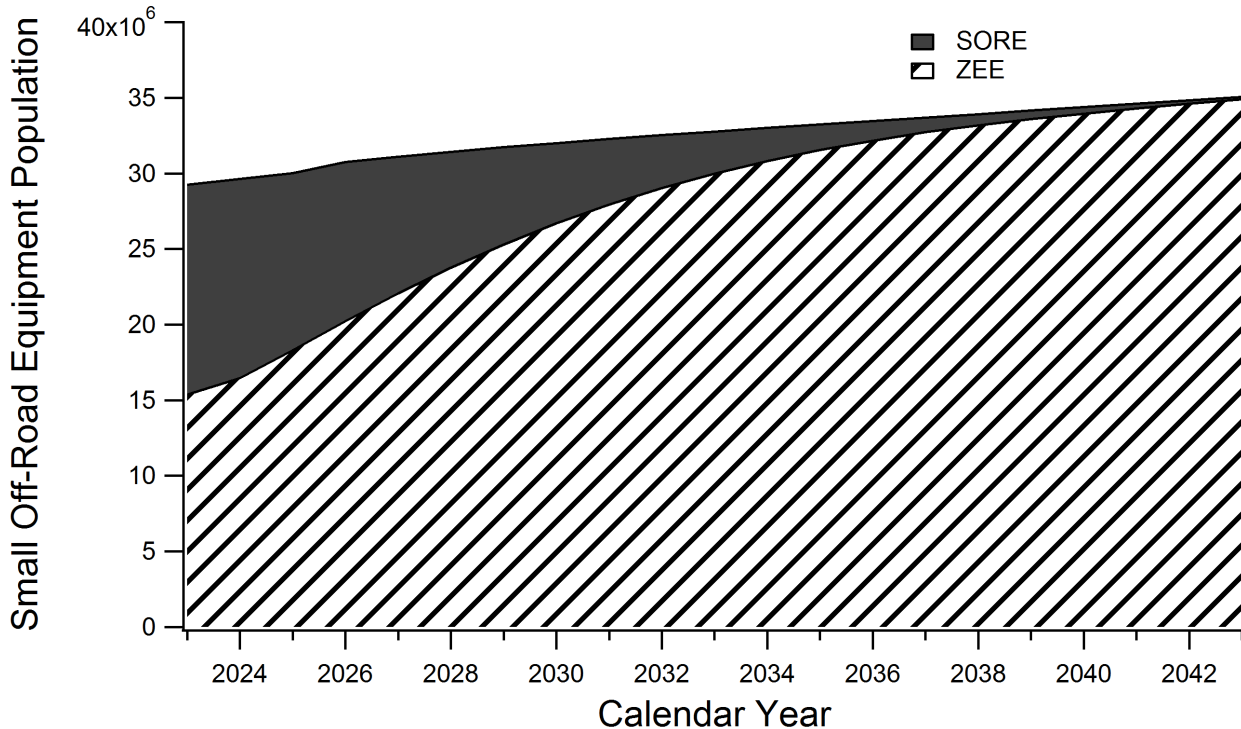
1. Alternative 1

Alternative 1 would increase the adoption of ZEE faster than the Proposed Amendments and has been suggested by many environmental organizations and members of the public. This alternative would set the emission standards to zero for all SORE, including generators, for MY 2024 and subsequent model years.

No further emission reduction credit generation would be possible after MY 2023. For economic modeling in Alternative 1, staff considered the current emission credit banks. Manufacturers could use their remaining credit banks and would likely do so sooner as opposed to holding on to them for several years. The analysis assumed that manufacturers would use all of their remaining credits to produce 4.9 percent of the number of engines that would have been produced in the Baseline Scenario in MY 2024 and still meet the proposed emission standards of zero. This percentage is limited by the current evaporative emission credit bank, which would allow for the manufacture of fewer SORE than the exhaust emission credit bank.

The fraction of ZEE in the overall population would increase sooner in Alternative 1, as shown in Figure F-1, than with the Proposed Amendments (Figure C-1). Under Alternative 1, 94.9 percent of the small off-road equipment population subject to the SORE regulations would be ZEE in 2035, compared to 93.4 percent under the Proposed Amendments. EO N-79-20 sets a goal to transition to 100 percent zero-emission off-road vehicles and equipment by 2035 where feasible. The remaining 5.1 percent would continue to transition over the following years, reaching 99.5 percent ZEE in 2043, as compared to 99.4 percent under the Proposed Amendments.

Figure F-1. Modeled small off-road equipment population statewide under Alternative 1.



a. Costs

Staff assumed that cost inputs would be the same as in the Proposed Amendments, as the only change is the removal of the delay for generator standards being set to zero. Table F-1 shows annual costs for Alternative 1. There is no expected increase in upfront costs in 2028 in Alternative 1 because emission standards for generators would be zero for MY 2024 and subsequent model years. Instead, costs would gradually increase as population increases. Cost-savings in Alternative 1 would increase as more ZEE were adopted. The rate of change in annual cost-savings would decrease through 2043. In 2043, annual cost-savings would be approximately \$1.87 billion. Net savings would occur statewide starting in the year 2035, two years earlier than with the Proposed Amendments. Alternative 1 would have a net cost of \$2.49 billion accrued through 2043, which is a smaller cost than with the Proposed Amendments. Figure F-2 illustrates the total costs and cost-savings of Alternative 1. For reference, the same graphical representation of direct costs for the Proposed Amendments is Figure C-2.

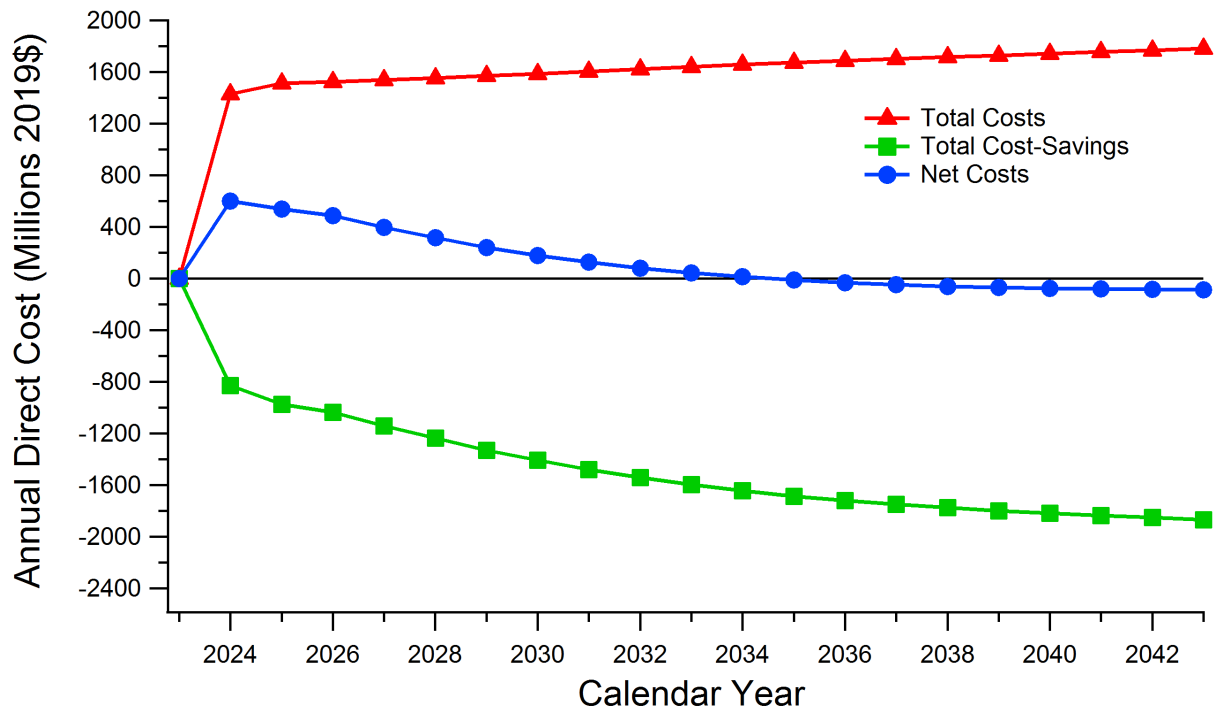
Table F-1. Modeled costs to professional and residential users per year under Alternative 1 relative to the Baseline Scenario (million 2019\$).

(Negative values indicate cost-savings. Totals may differ slightly due to rounding.)

Year	Gasoline equipment costs	Electric equipment costs	Gasoline equipment maintenance costs	Gasoline costs	Electricity costs	Total costs	Total cost-savings	Net costs
2023	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00
2024	-\$761.49	\$1,420.20	-\$13.69	-\$52.21	\$7.91	\$1,428.11	-\$827.39	\$600.72
2025	-\$806.10	\$1,492.66	-\$40.63	-\$128.30	\$19.78	\$1,512.44	-\$975.03	\$537.41
2026	-\$811.54	\$1,496.06	-\$64.07	-\$160.40	\$26.44	\$1,522.50	-\$1,036.01	\$486.49
2027	-\$817.03	\$1,499.49	-\$90.07	-\$233.04	\$38.24	\$1,537.73	-\$1,140.14	\$397.59
2028	-\$822.59	\$1,504.07	-\$113.75	-\$299.59	\$49.85	\$1,553.92	-\$1,235.93	\$317.99
2029	-\$828.20	\$1,508.69	-\$134.57	-\$366.56	\$61.10	\$1,569.79	-\$1,329.33	\$240.46
2030	-\$833.89	\$1,514.50	-\$152.55	-\$420.91	\$71.88	\$1,586.38	-\$1,407.35	\$179.03
2031	-\$839.63	\$1,524.99	-\$167.72	-\$471.49	\$80.47	\$1,605.46	-\$1,478.84	\$126.62
2032	-\$845.44	\$1,535.61	-\$180.60	-\$515.31	\$87.95	\$1,623.56	-\$1,541.35	\$82.21
2033	-\$851.31	\$1,546.34	-\$191.43	-\$552.93	\$94.30	\$1,640.64	-\$1,595.67	\$44.97
2034	-\$857.25	\$1,557.19	-\$200.59	-\$585.46	\$99.72	\$1,656.91	-\$1,643.30	\$13.61
2035	-\$863.25	\$1,568.16	-\$208.10	-\$612.83	\$104.26	\$1,672.42	-\$1,684.18	-\$11.76
2036	-\$869.32	\$1,579.26	-\$214.23	-\$635.41	\$107.93	\$1,687.19	-\$1,718.96	-\$31.77
2037	-\$875.46	\$1,590.47	-\$219.18	-\$654.27	\$110.95	\$1,701.42	-\$1,748.91	-\$47.49
2038	-\$881.67	\$1,601.81	-\$222.93	-\$669.89	\$113.41	\$1,715.22	-\$1,774.49	-\$59.27
2039	-\$887.95	\$1,613.28	-\$226.00	-\$682.93	\$115.44	\$1,728.72	-\$1,796.88	-\$68.16
2040	-\$894.30	\$1,624.88	-\$228.28	-\$693.85	\$117.12	\$1,742.00	-\$1,816.43	-\$74.43
2041	-\$900.72	\$1,636.60	-\$230.18	-\$703.33	\$118.57	\$1,755.17	-\$1,834.23	-\$79.06
2042	-\$907.21	\$1,648.46	-\$231.84	-\$711.92	\$119.86	\$1,768.32	-\$1,850.97	-\$82.65
2043	-\$913.77	\$1,660.44	-\$233.35	-\$719.84	\$121.05	\$1,781.49	-\$1,866.96	-\$85.47
Average	-\$812.77	\$1,482.06	-\$160.18	-\$470.02	\$79.34	\$1,561.40	-\$1,442.97	\$118.43
Total	-\$17,068.12	\$31,123.16	-\$3,363.76	-\$9,870.47	\$1,666.23	\$32,789.39	-\$30,302.35	\$2,487.04

Figure F-2. Statewide costs, cost-savings, and overall net costs under Alternative 1.

(Negative values indicate cost-savings.)



b. Benefits

i. Emissions Benefits

For emissions modeling in Alternative 1, staff considered the emissions credit banks as discussed in Section F.1. For MY 2024, staff assumed manufacturers would produce 4.9 percent of engines produced in the Baseline Scenario with both exhaust and evaporative emissions equal to the emissions of the current average engine. This percentage is limited by the current evaporative emission credit bank, which would allow for the manufacture of fewer average engines than the exhaust emission credit bank. The engines produced in MY 2024 would use the remaining evaporative emission credit bank, leaving some exhaust credits unused. To account for this, staff assumed that all MY 2023 engines would emit 0.74 g·kWh⁻¹ excess exhaust emissions above the current emission standards, because manufacturers would be unable to use the remaining exhaust emission credits for MY 2024. Table F-2 shows annual emission reductions for NO_x, ROG, and CO₂. Figures F-3 and F-4 show the reductions in NO_x and ROG emissions for each modeled year.

Emission reductions would begin in 2024, which is the same as in the Proposed Amendments. Emissions in 2043 under Alternative 1 would be similar to those with the Proposed Amendments, approximately 6.2 tpd and 27.2 tpd, for NO_x and ROG, respectively. Over the regulatory horizon, this would lead to a total of 61,299 tons of NO_x emission reductions and 432,979 tons of ROG emission reductions compared to the Baseline Scenario. These reductions are only marginally higher than the emission reductions under the Proposed Amendments.

Table F-2. Annual average emission reductions under Alternative 1.

(Totals may not add up due to rounding.)

Year	ROG emission reductions (tpd)	NO _x emission reductions (tpd)	CO ₂ emission reductions (MMT/year)
2023	-0.13	-0.02	0.00
2024	3.2	0.45	0.05
2025	11.1	1.5	0.17
2026	20.5	2.6	0.29
2027	29.9	3.8	0.40
2028	38.4	5.0	0.51
2029	45.8	6.0	0.60
2030	52.1	7.0	0.68
2031	57.4	7.9	0.74
2032	61.9	8.7	0.80
2033	65.9	9.3	0.85
2034	69.4	9.9	0.89
2035	72.6	10.5	0.92
2036	75.5	10.9	0.95
2037	78.1	11.3	0.98
2038	80.2	11.6	1.0
2039	82.1	11.9	1.0
2040	83.7	12.1	1.0
2041	85.1	12.3	1.0
2042	86.3	12.5	1.1
2043	87.3	12.7	1.1
Average	56.5	8.0	0.72
Total	432,979	61,299	15.1

Figure F-3. Annual average NO_x emissions under Alternative 1 and the Baseline Scenario.

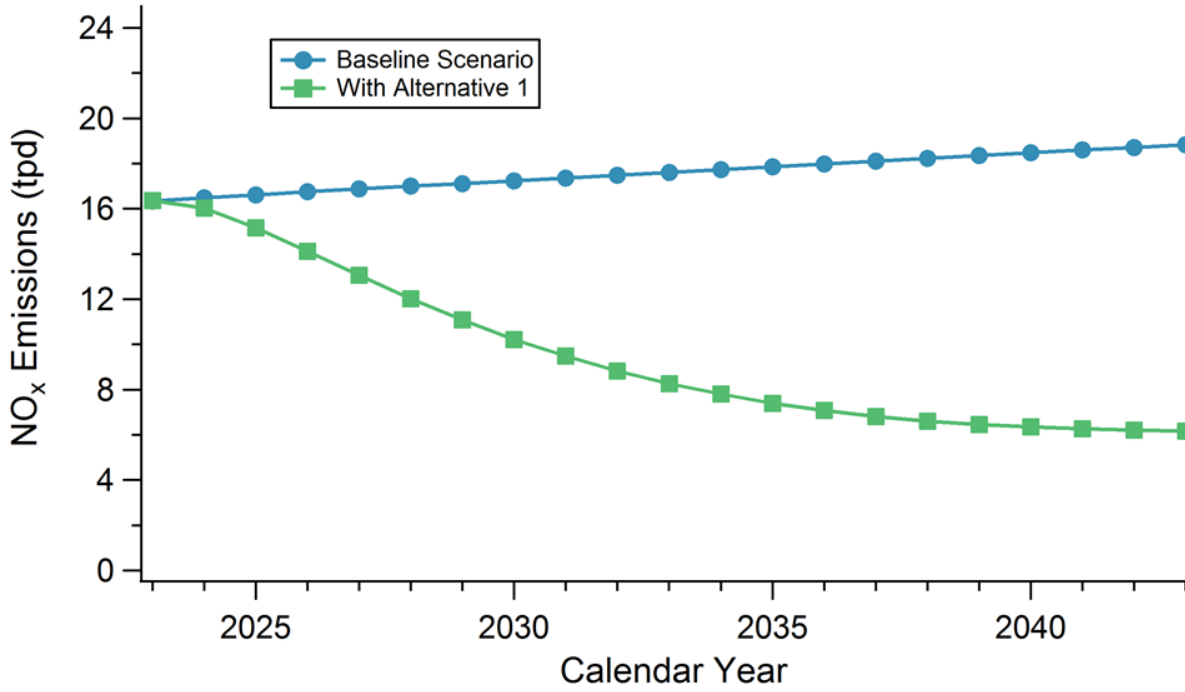
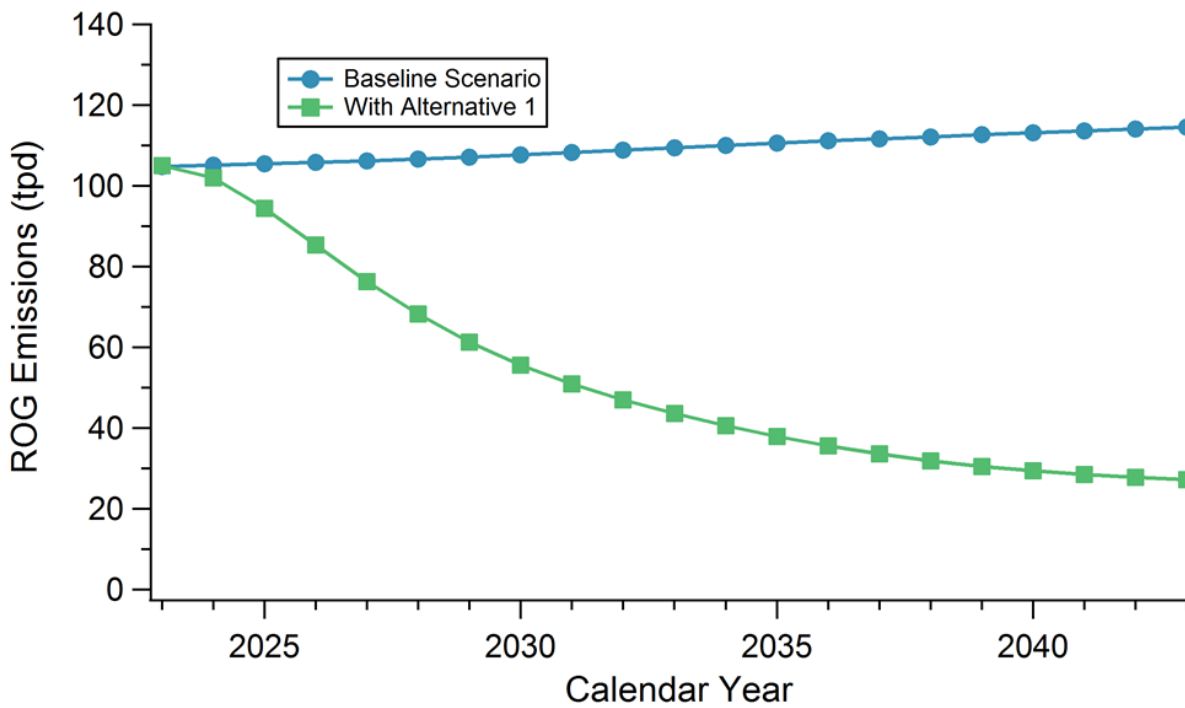


Figure F-4. Annual average ROG emissions under Alternative 1 and the Baseline Scenario.



ii. Health Benefits

Table F-3 shows the avoided health outcomes as a result of Alternative 1 by air basin, and Table F-4 shows the same outcomes annually. Tables F-5 and F-6 show the valuation of these avoided health outcomes annually and summed across all years. The total incidence of avoided health outcomes and their valuation are both slightly higher in Alternative 1 as compared to the Proposed Amendments.

Table F-3. Modeled regional and statewide avoided mortality and morbidity incidents from 2023 through 2043 under Alternative 1, central estimates and 95 percent confidence intervals.

(Totals may not add up due to rounding.)

Air Basin	Avoided premature cardiopulmonary mortality	Avoided cardiovascular hospitalizations	Avoided acute respiratory hospitalizations	Avoided ER visits for asthma
Lake County	1 (1 - 1)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)
Mojave Desert	3 (3 - 4)	0 (0 - 1)	1 (0 - 1)	1 (1 - 2)
Mountain Counties	5 (4 - 6)	0 (0 - 1)	1 (0 - 1)	2 (1 - 2)
North Central Coast	4 (3 - 5)	1 (0 - 1)	1 (0 - 1)	2 (1 - 3)
North Coast	1 (1 - 1)	0 (0 - 0)	0 (0 - 0)	0 (0 - 1)
Sacramento Valley	32 (25 - 39)	4 (0 - 8)	5 (1 - 8)	12 (8 - 17)
Salton Sea	3 (2 - 4)	0 (0 - 1)	0 (0 - 1)	1 (1 - 2)
San Diego County	52 (41 - 64)	7 (0 - 14)	9 (2 - 15)	21 (13 - 29)
San Francisco Bay Area	117 (91 - 143)	18 (0 - 36)	22 (5 - 38)	64 (40 - 88)
San Joaquin Valley	57 (45 - 70)	7 (0 - 13)	8 (2 - 14)	21 (13 - 28)
South Central Coast	18 (14 - 22)	3 (0 - 5)	3 (1 - 6)	8 (5 - 11)
South Coast	621 (485 - 759)	104 (0 - 204)	124 (29 - 219)	316 (200 - 433)
Statewide	915 (715 - 1119)	145 (0 - 285)	173 (41 - 306)	450 (284 - 615)

Table F-4. Annual statewide avoided mortality and morbidity incidents under Alternative 1, central estimates and 95 percent confidence intervals.

(Totals may not add up due to rounding.)

Year	Avoided premature cardiopulmonary mortality	Avoided cardiovascular hospitalizations	Avoided acute respiratory hospitalizations	Avoided ER visits for asthma
2023	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)
2024	2 (2 - 3)	0 (0 - 1)	0 (0 - 1)	1 (1 - 2)
2025	8 (6 - 10)	1 (0 - 2)	1 (0 - 2)	4 (3 - 6)
2026	15 (12 - 18)	2 (0 - 4)	2 (1 - 4)	8 (5 - 10)
2027	22 (17 - 27)	3 (0 - 6)	4 (1 - 6)	11 (7 - 15)
2028	28 (22 - 34)	4 (0 - 8)	5 (1 - 9)	14 (9 - 19)
2029	34 (26 - 41)	5 (0 - 10)	6 (1 - 10)	17 (11 - 23)
2030	39 (30 - 47)	6 (0 - 11)	7 (2 - 12)	19 (12 - 26)
2031	43 (34 - 53)	7 (0 - 13)	8 (2 - 14)	21 (14 - 29)
2032	47 (37 - 57)	7 (0 - 14)	9 (2 - 15)	23 (15 - 32)
2033	50 (39 - 62)	8 (0 - 15)	9 (2 - 17)	25 (16 - 34)
2034	53 (42 - 65)	8 (0 - 17)	10 (2 - 18)	26 (17 - 36)
2035	56 (44 - 69)	9 (0 - 18)	11 (3 - 19)	28 (18 - 38)
2036	59 (46 - 72)	9 (0 - 19)	11 (3 - 20)	29 (18 - 39)
2037	61 (48 - 74)	10 (0 - 19)	12 (3 - 21)	30 (19 - 41)
2038	63 (49 - 77)	10 (0 - 20)	12 (3 - 21)	31 (19 - 42)
2039	64 (50 - 79)	11 (0 - 21)	13 (3 - 22)	31 (20 - 43)
2040	66 (51 - 81)	11 (0 - 21)	13 (3 - 23)	32 (20 - 44)
2041	67 (53 - 82)	11 (0 - 22)	13 (3 - 23)	33 (21 - 44)
2042	68 (54 - 84)	11 (0 - 22)	13 (3 - 24)	33 (21 - 45)
2043	70 (54 - 85)	12 (0 - 23)	14 (3 - 24)	34 (21 - 46)
Total	915 (715 - 1119)	145 (0 - 285)	173 (41 - 306)	450 (284 - 615)

Table F-5. Annual valuation of avoided health outcomes under Alternative 1 (millions 2019\$).

(Totals may not add up due to rounding.)

Year	Avoided premature cardiopulmonary mortality valuation	Avoided cardiovascular hospitalization valuation	Avoided acute respiratory hospitalization valuation	Avoided ER visit for asthma valuation	Annual total valuation
2023	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00
2024	\$19.73	\$0.00	\$0.00	\$0.00	\$19.73
2025	\$78.93	\$0.06	\$0.05	\$0.00	\$79.04
2026	\$147.98	\$0.12	\$0.10	\$0.01	\$148.21
2027	\$217.04	\$0.17	\$0.20	\$0.01	\$217.43
2028	\$276.24	\$0.23	\$0.25	\$0.01	\$276.74
2029	\$335.43	\$0.29	\$0.30	\$0.01	\$336.04
2030	\$384.76	\$0.35	\$0.36	\$0.02	\$385.48
2031	\$424.22	\$0.41	\$0.41	\$0.02	\$425.06
2032	\$463.69	\$0.41	\$0.46	\$0.02	\$464.57
2033	\$493.28	\$0.47	\$0.46	\$0.02	\$494.23
2034	\$522.88	\$0.47	\$0.51	\$0.02	\$523.88
2035	\$552.48	\$0.52	\$0.56	\$0.02	\$553.58
2036	\$582.07	\$0.52	\$0.56	\$0.02	\$583.18
2037	\$601.81	\$0.58	\$0.61	\$0.03	\$603.02
2038	\$621.54	\$0.58	\$0.61	\$0.03	\$622.76
2039	\$631.40	\$0.64	\$0.66	\$0.03	\$632.73
2040	\$651.13	\$0.64	\$0.66	\$0.03	\$652.46
2041	\$661.00	\$0.64	\$0.66	\$0.03	\$662.33
2042	\$670.86	\$0.64	\$0.66	\$0.03	\$672.19
2043	\$690.60	\$0.70	\$0.71	\$0.03	\$692.04
Total	\$9,027.08	\$8.45	\$8.79	\$0.38	\$9,044.70

Table F-6. Statewide valuation from avoided health outcomes under Alternative 1.

Outcome	Avoided incidents	Valuation (million 2019\$)
Premature cardiopulmonary mortality	915	\$9,027.08
Cardiopulmonary hospitalization	145	\$8.45
Acute respiratory hospitalization	173	\$8.79
ER visit for asthma	450	\$0.38
Total	1,683	\$9,044.70

Alternative 1 would result in an estimated 15.1 MMT of CO₂ emissions avoided. These emission reductions represent a benefit of the avoided social cost of carbon valued between \$363 million and \$1.54 billion, depending on the discount rate. For comparison, the Proposed Amendments would result in an estimated 13.9 MMT of CO₂ emissions avoided, representing a benefit of the avoided social cost of carbon valued between \$339 million and \$1.43 billion, depending on the discount rate.

c. Economic Impacts

Alternative 1 is a more stringent regulation with the emission standards of zero for all small off-road equipment going into effect starting in MY 2024. This results in greater incremental fuel cost-savings but equipment costs similar to those incurred under the Proposed Amendments. The macroeconomic impacts analysis results are qualitatively similar to the results of the Proposed Amendments, but of a smaller magnitude as shown in Table F-7. Figures F-5 and F-6 show the job impacts and output changes of Alternative 1, respectively.

Table F-7. Change in growth of economic indicators under Alternative 1.

Indicator	Metric	2023	2027	2031	2035	2039	2043
GSP	% Change	0.00%	-0.01%	-0.01%	0.00%	0.00%	0.00%
GSP	Change (2019M\$)	0	-250	-184	-139	-116	-95
Personal Income	% Change	0.00%	-0.01%	0.00%	0.00%	0.00%	0.00%
Personal Income	Change (2019M\$)	0	-281	-132	-50	-13	6
Employment	% Change	0.00%	-0.01%	0.00%	0.00%	0.00%	0.00%
Employment	Change in Jobs	0	-2,198	-1,134	-594	-407	-315
Output	% Change	0.00%	-0.01%	-0.01%	-0.01%	-0.01%	0.00%
Output	Change (2019M\$)	0	-403	-436	-381	-354	-333
Private Investment	% Change	0.00%	-0.02%	0.00%	0.01%	0.01%	0.01%
Private Investment	Change (2019M\$)	0	-106	1	39	41	41

Figure F-5. Job impacts under Alternative 1 by major sector.

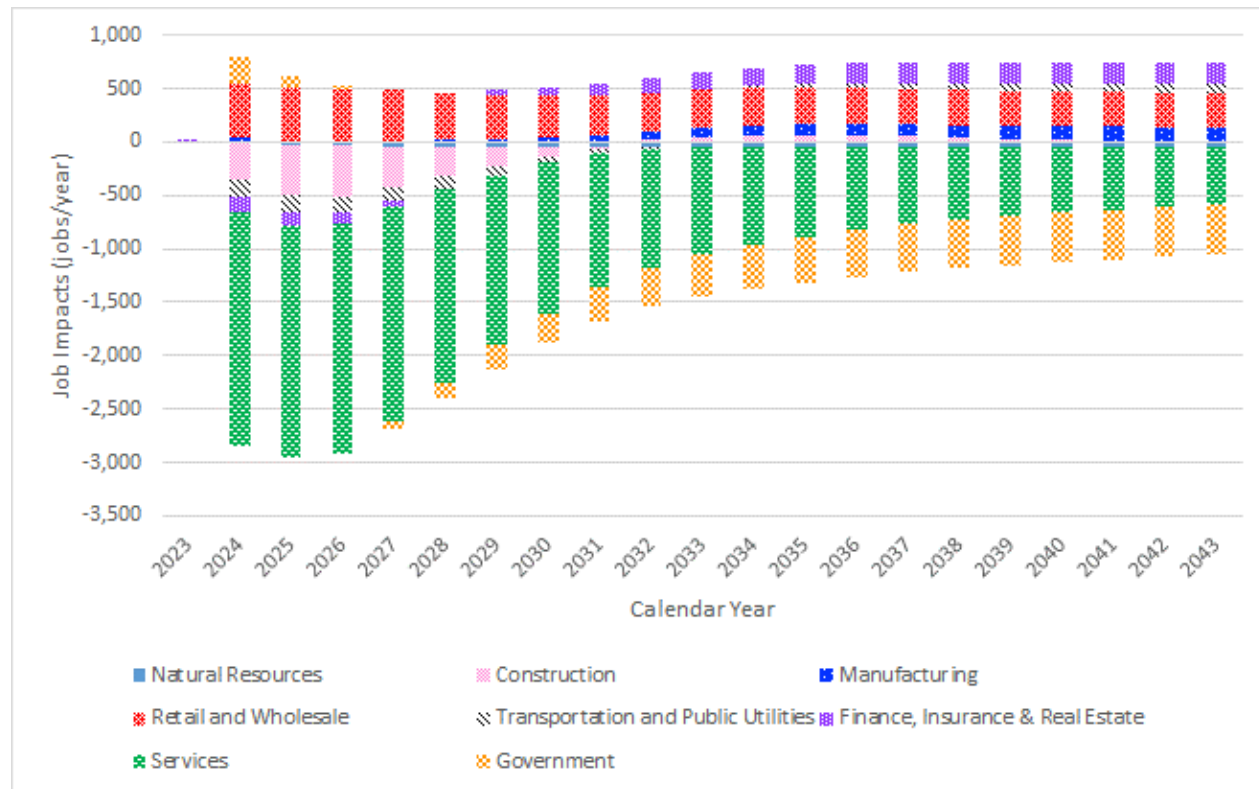
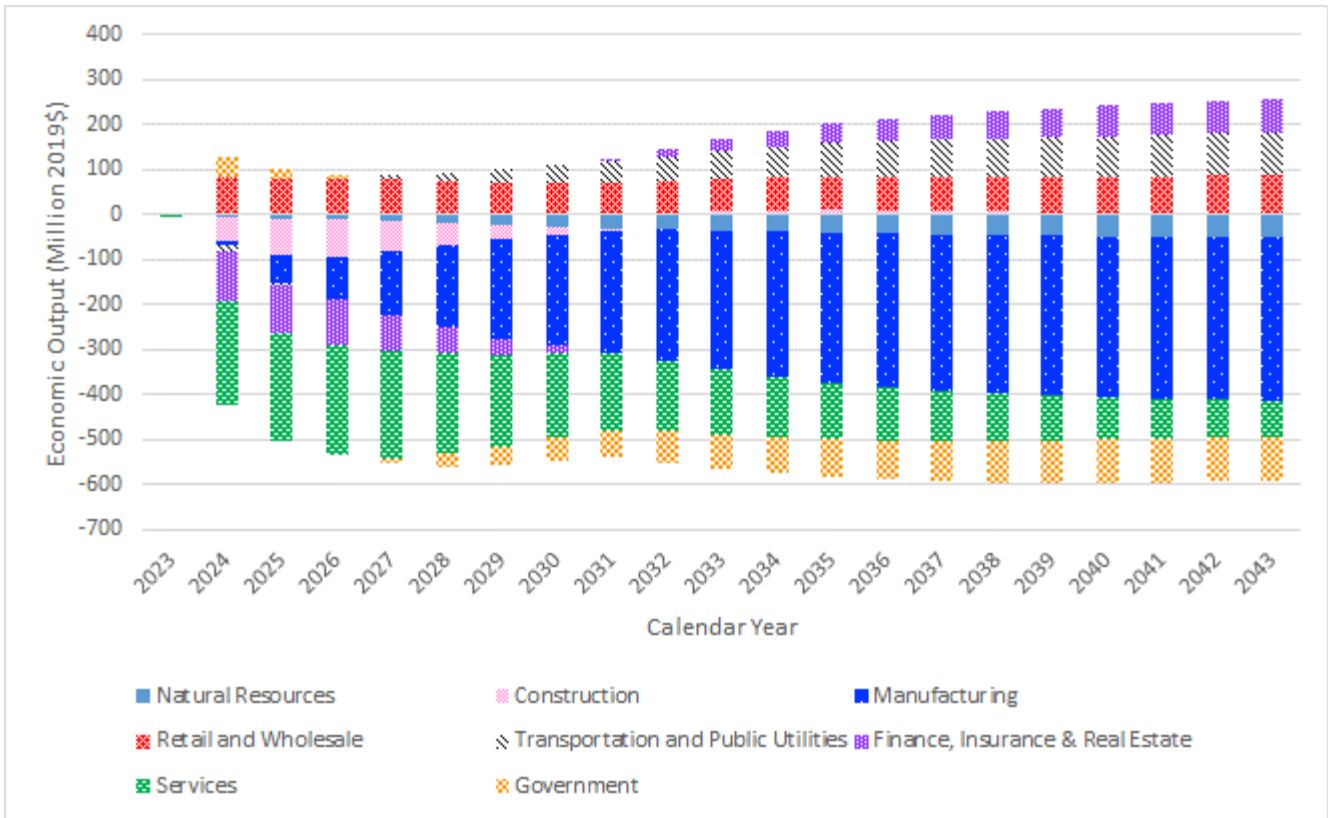


Figure F-6. Changes in output under Alternative 1 by major sector.



d. Cost-Effectiveness

The metric to quantify cost-effectiveness of the Proposed Amendments and Alternative 1 is the ratio of total monetized benefits divided by total monetized costs. A comparison of this type is an appropriate cost-effectiveness measure because the harm associated with increased emissions is captured in the estimates of monetized health impacts. A benefit-cost ratio greater than one implies that the benefits of the scenario are greater than its costs. Benefits include both the estimated valuation of health benefits and cost-savings after subtracting tax and fee revenue impacts to state and local governments. Table F-8 indicates that the Proposed Amendments would have a cumulative net benefit of \$4.27 billion and a benefit-cost ratio of 1.30, meaning benefits would be greater than costs during the regulatory horizon of 2023 through 2043. Alternative 1 would have a net benefit of \$5.83 billion, and a benefit-cost ratio of 1.41, meaning Alternative 1 would be more cost-effective than the Proposed Amendments.

Table F-8. Cost-benefit comparison of the Proposed Amendments and Alternative 1 (billion 2019\$).

Scenario	Total direct costs	Health benefits	Direct cost-savings (benefit)	Tax & fee revenue	Total benefit	Net benefit	Benefit-cost ratio
Proposed Amendments	\$14.41	\$8.82	\$10.33	-\$0.47	\$18.68	\$4.27	1.30
Alternative 1	\$14.06	\$9.04	\$11.57	-\$0.73	\$19.89	\$5.83	1.41

e. Reason for Rejecting

Staff rejected Alternative 1 on technological feasibility grounds. The primary reason for not pursuing this alternative is to provide more time for the zero-emission generator market to mature. Currently, as noted in Section C.1.c.iv, the availability and variety of zero-emission generators is limited. Manufacturers of zero-emission generators may not be poised to meet the entire market demand that could occur if fewer SORE generators were produced starting in MY 2024. Currently, based on population modelling done using the SORE2020 model, demand for generators is relatively constant, year over year. Requiring zero-emission generators in MY 2024 could increase the price of available zero-emission generators due to demand. This price increase would create added costs for residential users and professional users in the state.

One of the leading companies making zero-emission generators that could be considered a replacement for a SORE generator describes on its website the time involved in developing a zero-emission generator. It took over three years from the founding of the business to create its first zero-emission generator with performance equivalent to SORE generators.¹³² Giving manufacturers an additional four MYs before emission standards of zero are implemented for generators would ensure adequate time for product development, manufacturing, and marketing of a new product.

The additional four year period (MYs 2024 through 2027) allowing sale of SORE generators that meet more stringent emission standards in the Proposed Amendments would ease concerns about the need for generators for power backup. Some small portable generators are purchased for home backup power, and zero-emission generators that can cover a multi-day power outage have a higher purchase price than SORE generators.

2. Alternative 2

Alternative 2 would allow for a more gradual adoption of ZEE than the Proposed Amendments. Starting in MY 2024, more stringent exhaust and evaporative emission standards would be implemented for all SORE. Then, in MY 2026, the emission standards would be zero for SORE used in all equipment except generators. The emission standards for generator engines would be zero for MY 2030 and subsequent model years. This alternative would allow for a longer transition period to ZEE, and allow manufacturers who have invested in and are producing lower-emitting SORE to continue to do so for a few more model years. Tables F-9 through F-12 show the emission standards for this alternative.

¹³² Goal Zero. Goal Zero – Our Story.

Emission reduction credit generation would be allowed for all SORE through MY 2025 and exclusively for generators through MY 2029. Based on CARB’s historical records of the emission reduction credit banks, the sum of banked credits has remained relatively constant over the last several years. Therefore, to evaluate this alternative staff assumed that the amount of banked credits at the end of MY 2023 would be equal to the amount at the end of MY 2018 and that the banked credits would all be used in MYs 2024 and 2025 for all equipment types. Staff did not assume any manufacturer preference for one equipment type over another. In terms of emissions modeling, this means that all SORE produced in MYs 2024 and 2025 could emit slightly above the emission standards, as shown in Tables F-9 and F-11. The cost would be slightly lower than in a scenario in which only equipment that met the emission standards were produced. The population of ZEE would grow more gradually than in the Proposed Amendments, as shown in Figure F-7, given that emission standards for SORE generators would not be zero until MY 2030. Under Alternative 2, 89.3 percent of the small off-road equipment population subject to the SORE regulations would be ZEE in 2035, as compared to 93.4 percent under the Proposed Amendments. EO N-79-20 sets a goal to transition to 100 percent zero-emission off-road vehicles and equipment by 2035 where feasible. The remaining 10.7 percent would continue to transition over the following years, reaching 98.8 percent ZEE in 2043, as compared to 99.4 percent under the Proposed Amendments.

Table F-9. MYs 2024-2025 SORE exhaust emission standards and emission levels assuming complete use of banked credits under Alternative 2.

Displacement category	Emissions durability period (hours)	HC + NO _x emission standard (g·kWh ⁻¹)	HC + NO _x emission level with credit use (g·kWh ⁻¹)
< 50 cc, handheld	300	20.0	22.5
50-80 cc, inclusive, handheld	300	13.0	15.2
> 80 cc - < 225 cc, handheld	500	6.0	6.4
< 225 cc, nonhandheld	500	6.0	6.4
225-825 cc, inclusive	1,000	3.0	3.3
> 825 cc	1,000	0.80	1.3

Table F-10. MYs 2026-2029 exhaust emission standards under Alternative 2.

Displacement category	Emissions durability period (hours)	HC + NO _x emission standard for generators (g·kWh ⁻¹)	HC + NO _x emission standard for all other SORE (g·kWh ⁻¹)
< 225 cc	500	6.0	0.00
225-825 cc, inclusive	1,000	3.0	0.00
> 825 cc	1,000	0.80	0.00

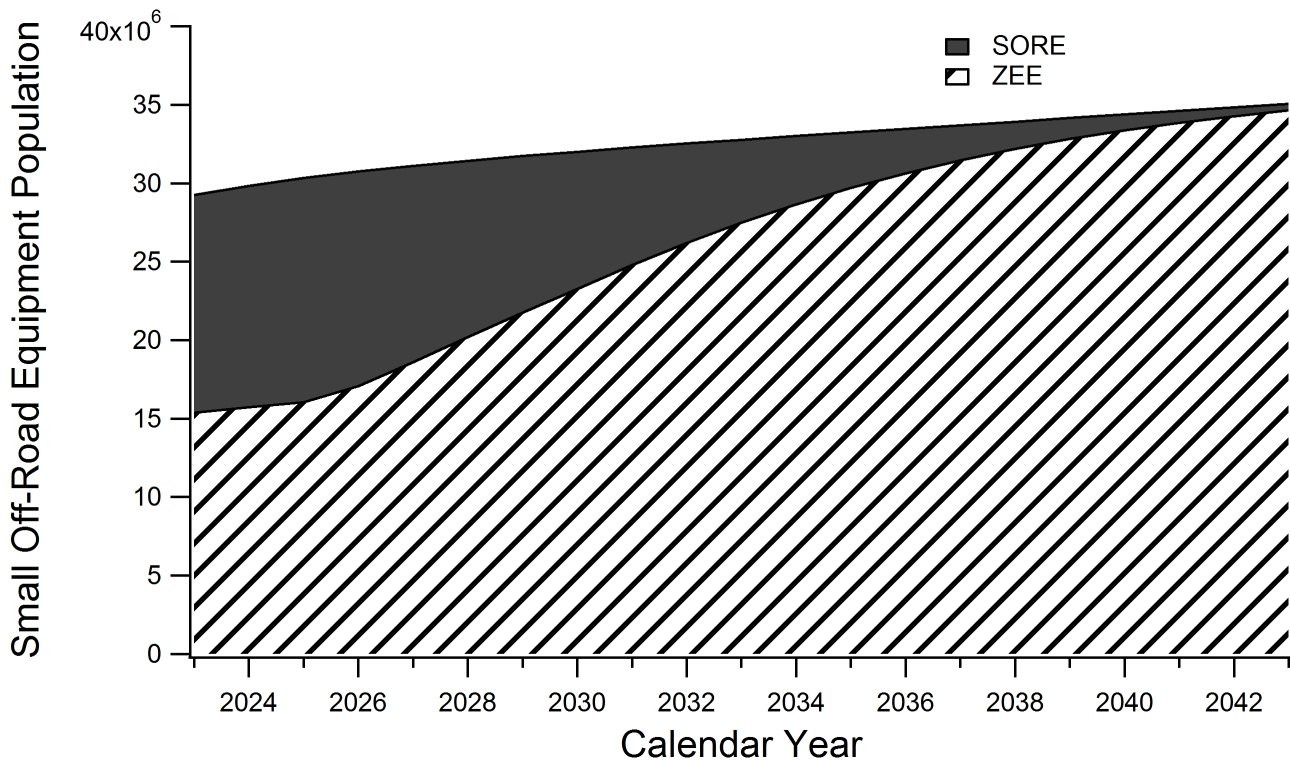
Table F-11. MYs 2024-2025 SORE evaporative emission standards and emission levels assuming complete use of banked credits under Alternative 2.

Displacement category	Hot soak plus diurnal emission standard (g·test ⁻¹)	Hot soak plus diurnal emission level with credit use (g·test ⁻¹)	Hot soak emission level with credit use (g·test ⁻¹)	Diurnal emission level with credit use (g·test ⁻¹)
≤ 80 cc	0.50	0.55	0.13	0.42
> 80 cc - < 225 cc, except walk-behind mowers	0.60	0.61	0.06	0.56
> 80 cc - < 225 cc walk-behind mowers	0.60	0.61	0.06	0.56
≥ 225 cc	0.70	0.75	0.11	0.64

Table F-12. MYs 2026-2029 evaporative emission standards and emission levels under Alternative 2.

Displacement category	Hot soak plus diurnal emission standard for generators (g·test ⁻¹)	Hot soak emission level for generators (g·test ⁻¹)	Diurnal emission level for generators (g·test ⁻¹)	Hot soak plus diurnal emission standard for all other SORE (g·test ⁻¹)
≤ 80 cc	0.50	0.12	0.38	0.00
> 80 cc - < 225 cc, except walk-behind mowers	0.60	0.06	0.54	0.00
> 80 cc - < 225 cc walk-behind mowers	0.60	0.06	0.54	0.00
≥ 225 cc	0.70	0.10	0.60	0.00

Figure F-7. Modeled small off-road equipment population statewide under Alternative 2.



a. Costs

For MYs 2024 and 2025, SORE produced for sale or lease for use or operation in California would be required to meet the more stringent emission standards in Tables F-10 and F-12 in Alternative 2. Staff used manufacturers’ certification data to identify existing equipment that meet these emission standards. An example unit for each SORE equipment category was used to estimate the price of SORE equipment in 2024 and 2025. Tables F-13 and F-14 show the prices with sales tax included. The residential lawnmower chosen for this alternative exceeds the MY 2024 emissions standards, but could be produced with emissions credit usage. Should manufacturers choose not to spend credits on this lawnmower, it is expected that the upfront cost of a compliant residential-grade lawnmower would be higher. Therefore, this analysis would be underestimating the net direct costs of this alternative.

Tables G-5 and G-6 identify the specific equipment used as the representative example in each category. Snow blowers are not required to certify to or comply with the HC + NO_x emission standards as set out in the regulations, but are required to meet the CO emission standards. The CO emission standards in this alternative would not change from the existing emission standards; therefore, it is assumed that currently compliant snow blowers would not be affected.

Table F-13. Upfront cost to purchase residential-grade SORE equipment that would comply with the MY 2024 emission standards in Alternative 2.

Type of equipment	Current SORE cost	MY 2024 compliant SORE cost	Incremental cost over Baseline Scenario
Chainsaw	\$156.24	\$204.41	\$48.17
Generator Set	\$861.49	\$1,891.45	\$1029.96
Lawn Mower	\$303.79	\$423.14	\$119.35
Leaf Blower/Vacuum	\$161.67	\$650.95	\$489.28
Pressure Washer	\$400.37	\$354.14	-\$46.23
Pump < 2 hp	\$243.15	\$325.49	\$82.34
Riding Mower	\$2,633.60	\$5,782.22	\$3,148.62
Snow Blower	\$432.72	\$432.72	\$0
Trimmer/Edger/Brush Cutter	\$165.03	\$215.92	\$50.89

Table F-14. Upfront cost to purchase professional-grade SORE equipment that would comply with the MY 2024 emission standards in Alternative 2.

Type of equipment	Current SORE cost	MY 2024 compliant SORE cost	Incremental cost over Baseline Scenario
Chainsaw	\$390.55	\$492.85	\$102.30
Generator Set	\$5,304.57	\$12,152.00	\$6,847.43
Lawn Mower	\$1,409.42	\$3,228.78	\$1819.36
Leaf Blower/Vacuum	\$477.39	\$650.95	\$173.56
Pressure Washer	\$1,170.82	\$2,682.18	\$1,511.36
Pump < 2 hp	\$454.62	\$325.49	-\$129.13
Riding Mower	\$11,377.17	\$25,971.81	\$14,634.64
Snow Blower	\$1,626.42	\$1,626.42	\$0
Trimmer/Edger/Brush Cutter	\$368.85	\$465.47	\$96.62

As described in Section F.2, staff assumed current credit banks would be completely used for engines in MYs 2024 through 2025. Staff calculated that manufacturers would be able to use credits to produce 3.5 percent of the number of engines that would have been produced in the Baseline Scenario for MYs 2024 through 2025 and still meet the emission standards in Alternative 2. This would fully use the credits banked as of the end of MY 2023 if the amount of banked credits were the same as the amount at the end of MY 2018. Therefore, in the cost analysis for this alternative, staff assumed that the purchase price of 3.5 percent of new engine production in MYs 2024 through 2025 would be equal to that of currently compliant equipment across all categories. From MY 2026 through 2029, staff assumed all generators were compliant with the more stringent emission standards.

Table F-15 shows the upfront and ongoing costs in Alternative 2 each year. Figure F-8 graphically shows the annual costs and cost-savings. For reference, the same graphical representation of direct costs for the Proposed Amendments is Figure C-2. Assuming that price and continued availability of SORE equipment would influence consumers' purchases,

less ZEE would be purchased over the regulatory horizon under Alternative 2 than under the Proposed Amendments. Cost-savings from purchasing and using ZEE would not be seen until 2026, because ZEE would not make any gains in market share relative to the Baseline Scenario if SORE equipment were still readily available. Cost-savings would be seen statewide starting in the year 2039. The net cost of this alternative accrued through 2043 would be \$5.88 billion. This is \$1.81 billion dollars more than the Proposed Amendments would cost over the same regulatory horizon.

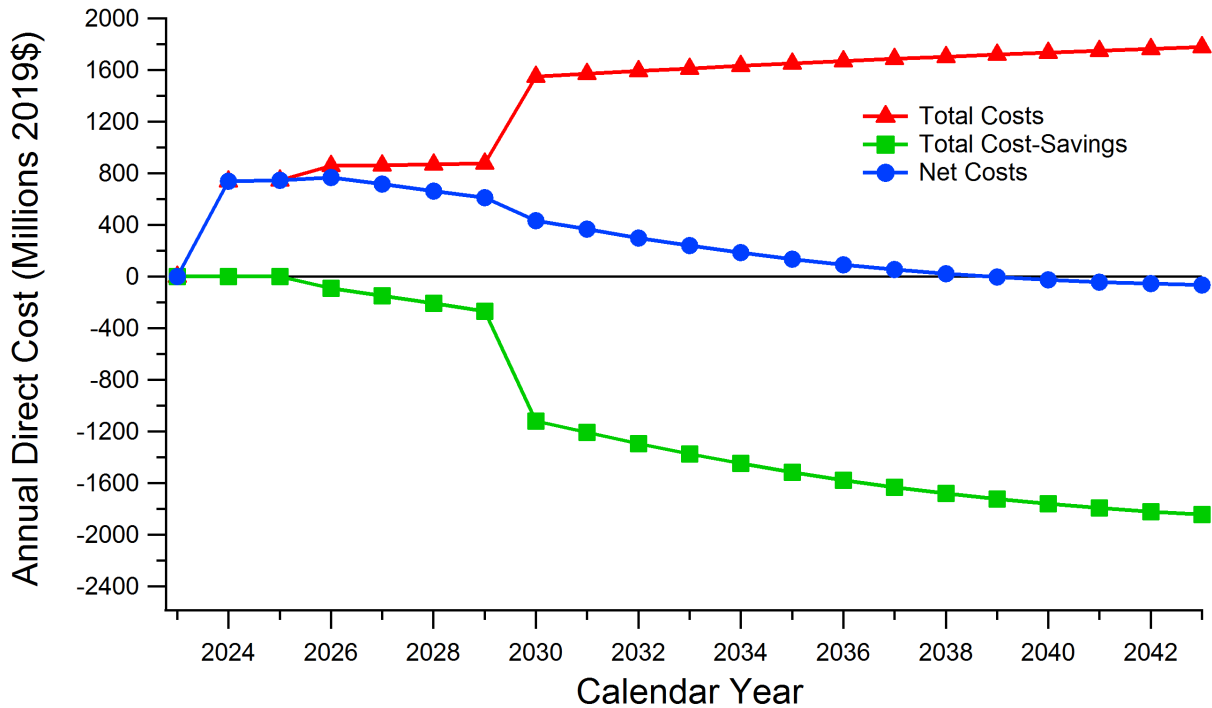
Table F-15. Modeled costs to professional and residential users per year under Alternative 2 relative to the Baseline Scenario (million 2019\$).

(Negative values indicate cost-savings. Totals may differ slightly due to rounding.)

Year	Gasoline equipment costs	Electric equipment costs	Gasoline equipment maintenance costs	Gasoline costs	Electricity costs	Total costs	Total cost-savings	Net costs
2023	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00
2024	\$738.73	\$0.00	\$0.00	\$0.00	\$0.00	\$738.73	\$0.00	\$738.73
2025	\$744.77	\$0.00	\$0.00	\$0.00	\$0.00	\$744.77	\$0.00	\$744.77
2026	-\$59.22	\$853.02	-\$11.82	-\$19.79	\$4.03	\$857.05	-\$90.83	\$766.22
2027	-\$55.69	\$852.02	-\$34.34	-\$57.39	\$11.04	\$863.06	-\$147.42	\$715.64
2028	-\$52.11	\$851.60	-\$58.44	-\$97.23	\$18.87	\$870.47	-\$207.78	\$662.69
2029	-\$48.48	\$851.20	-\$81.68	-\$137.94	\$26.76	\$877.96	-\$268.10	\$609.86
2030	-\$833.89	\$1,514.50	-\$103.25	-\$180.26	\$35.40	\$1,549.90	-\$1,117.40	\$432.50
2031	-\$839.63	\$1,524.99	-\$123.88	-\$240.69	\$45.72	\$1,570.71	-\$1,204.20	\$366.51
2032	-\$845.44	\$1,535.61	-\$142.40	-\$304.05	\$56.26	\$1,591.87	-\$1,291.89	\$299.98
2033	-\$851.31	\$1,546.34	-\$158.28	-\$362.81	\$65.96	\$1,612.30	-\$1,372.40	\$239.90
2034	-\$857.25	\$1,557.19	-\$172.10	-\$417.40	\$74.91	\$1,632.10	-\$1,446.75	\$185.35
2035	-\$863.25	\$1,568.16	-\$184.01	-\$467.36	\$82.93	\$1,651.09	-\$1,514.62	\$136.47
2036	-\$869.32	\$1,579.26	-\$194.31	-\$512.89	\$90.11	\$1,669.37	-\$1,576.52	\$92.85
2037	-\$875.46	\$1,590.47	-\$202.95	-\$553.34	\$96.40	\$1,686.87	-\$1,631.75	\$55.12
2038	-\$881.67	\$1,601.81	-\$210.16	-\$588.17	\$101.72	\$1,703.53	-\$1,680.00	\$23.53
2039	-\$887.95	\$1,613.28	-\$216.09	-\$618.32	\$106.26	\$1,719.54	-\$1,722.36	-\$2.82
2040	-\$894.30	\$1,624.88	-\$220.73	-\$644.21	\$110.11	\$1,734.99	-\$1,759.24	-\$24.25
2041	-\$900.72	\$1,636.60	-\$224.58	-\$666.10	\$113.34	\$1,749.94	-\$1,791.40	-\$41.46
2042	-\$907.21	\$1,648.46	-\$227.47	-\$684.07	\$115.96	\$1,764.42	-\$1,818.75	-\$54.33
2043	-\$913.77	\$1,660.44	-\$229.86	-\$699.25	\$118.18	\$1,778.62	-\$1,842.88	-\$64.26
Average	-\$521.58	\$1,219.52	-\$133.16	-\$345.30	\$60.66	\$1,350.82	-\$1,070.68	\$280.14
Total	-\$10,953.17	\$25,609.83	-\$2,796.35	-\$7,251.27	\$1,273.96	\$28,367.29	-\$22,484.29	\$5,883.00

Figure F-8. Statewide costs, cost-savings, and overall net costs under Alternative 2.

(Negative values indicate cost-savings.)



b. Benefits

i. Emissions Benefits

Table F-16 shows the annual emission reductions for NO_x, ROG, and CO₂ for Alternative 2. Figures F-9 and F-10 show the emission reductions for NO_x and ROG for each year from 2023 through 2043. Emission reductions would occur later in Alternative 2 compared to the Proposed Amendments. Over the regulatory horizon this would lead to a total of 56,495 tons of NO_x emissions reductions and 395,438 tons of ROG emissions reductions compared to the Baseline Scenario. These emission reductions are 5 percent and 7 percent lower than the emission reductions due to the Proposed Amendments for NO_x and ROG, respectively.

Table F-16. Annual average emission reductions under Alternative 2.

(Totals may not add up due to rounding.)

Year	ROG emission reductions (tpd)	NO_x emission reductions (tpd)	CO₂ emission reductions (MMT/year)
2023	0.00	0.00	0.00
2024	1.8	0.26	0.00
2025	6.1	0.82	0.00
2026	12.8	1.7	0.05
2027	21.2	2.8	0.14
2028	29.7	3.8	0.23
2029	37.4	4.9	0.32
2030	44.2	5.8	0.40
2031	50.2	6.8	0.49
2032	55.5	7.7	0.58
2033	60.0	8.5	0.65
2034	64.0	9.2	0.72
2035	67.5	9.8	0.78
2036	70.7	10.3	0.83
2037	73.6	10.8	0.88
2038	76.3	11.2	0.92
2039	78.7	11.6	0.95
2040	80.9	11.9	0.98
2041	82.7	12.1	1.0
2042	84.3	12.4	1.0
2043	85.8	12.6	1.1
Average	51.6	7.4	0.57
Total	395,438	56,495	12.0

Figure F-9. Annual average NO_x emissions under Alternative 2 and the Baseline Scenario.

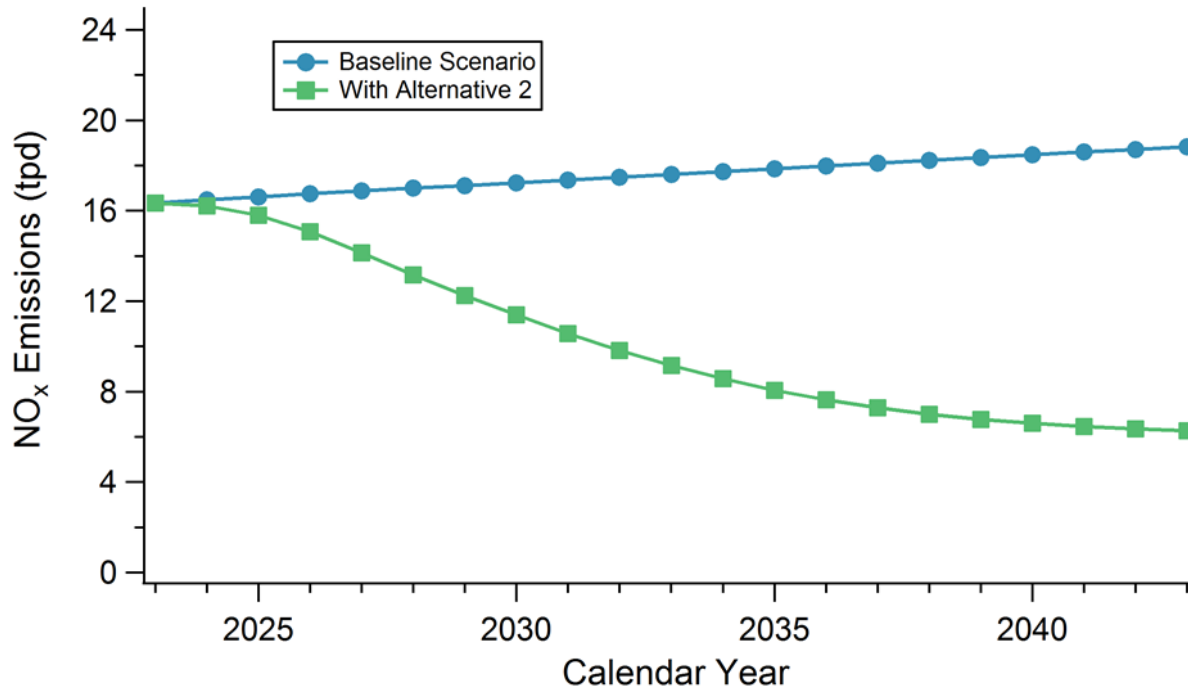
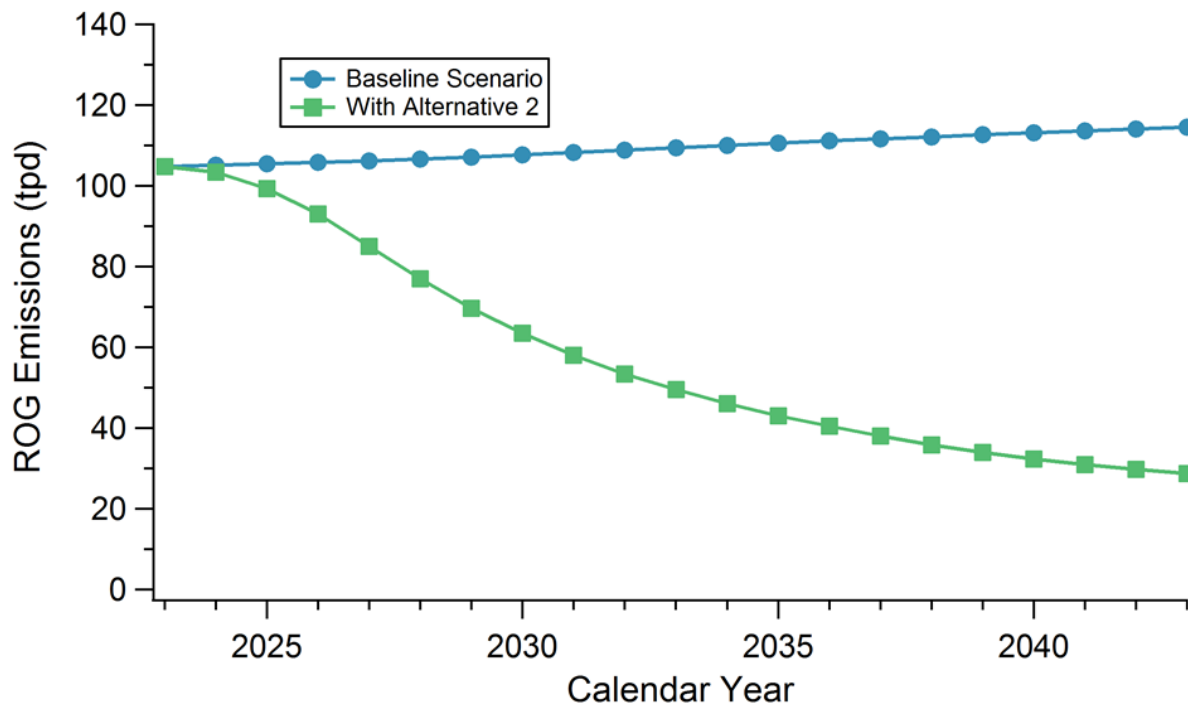


Figure F-10. Annual average ROG emissions under Alternative 2 and the Baseline Scenario.



ii. Health Benefits

Table F-17 shows the avoided health outcomes under Alternative 2 by air basin, and Table F-18 shows those same outcomes annually. Tables F-19 and F-20 show the valuation of these avoided health outcomes annually and as summed over all years. The total incidence of avoided health outcomes and their valuation are both slightly smaller than in the Proposed Amendments.

Table F-17. Modeled regional and statewide avoided mortality and morbidity incidents from 2023 through 2043 under Alternative 2, central estimates and 95 percent confidence intervals.

(Totals may differ slightly due to rounding.)

Air Basin	Avoided premature cardiopulmonary mortality	Avoided cardiovascular hospitalizations	Avoided acute respiratory hospitalizations	Avoided ER visits for asthma
Lake County	1 (1 - 1)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)
Mojave Desert	3 (2 - 4)	0 (0 - 1)	1 (0 - 1)	1 (1 - 2)
Mountain Counties	5 (4 - 6)	0 (0 - 1)	1 (0 - 1)	2 (1 - 2)
North Central Coast	4 (3 - 5)	1 (0 - 1)	1 (0 - 1)	2 (1 - 3)
North Coast	1 (1 - 1)	0 (0 - 0)	0 (0 - 0)	0 (0 - 1)
Sacramento Valley	29 (23 - 36)	4 (0 - 7)	4 (1 - 7)	11 (7 - 15)
Salton Sea	3 (2 - 3)	0 (0 - 1)	0 (0 - 1)	1 (1 - 2)
San Diego County	47 (37 - 58)	7 (0 - 13)	8 (2 - 14)	19 (12 - 26)
San Francisco Bay Area	106 (82 - 129)	17 (0 - 33)	20 (5 - 35)	58 (36 - 79)
San Joaquin Valley	53 (41 - 64)	6 (0 - 12)	8 (2 - 13)	19 (12 - 26)
South Central Coast	16 (13 - 20)	3 (0 - 5)	3 (1 - 5)	7 (5 - 10)
South Coast	563 (440 - 688)	95 (0 - 186)	113 (26 - 199)	286 (181 - 391)
Statewide	830 (649 - 1014)	132 (0 - 260)	158 (37 - 279)	407 (257 - 557)

Table F-18. Annual statewide avoided mortality and morbidity incidents under Alternative 2, central estimates and 95 percent confidence intervals.

(Totals may differ slightly due to rounding.)

Year	Avoided premature cardiopulmonary mortality	Avoided cardiovascular hospitalizations	Avoided acute respiratory hospitalizations	Avoided ER visits for asthma
2023	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)
2024	1 (1 - 1)	0 (0 - 0)	0 (0 - 0)	0 (0 - 1)
2025	3 (2 - 3)	0 (0 - 1)	0 (0 - 1)	1 (1 - 2)
2026	7 (5 - 8)	1 (0 - 2)	1 (0 - 2)	3 (2 - 5)
2027	13 (10 - 15)	2 (0 - 4)	2 (1 - 4)	6 (4 - 9)
2028	19 (15 - 23)	3 (0 - 5)	3 (1 - 6)	10 (6 - 13)
2029	25 (20 - 31)	4 (0 - 7)	4 (1 - 8)	13 (8 - 18)
2030	31 (24 - 38)	5 (0 - 9)	6 (1 - 10)	16 (10 - 21)
2031	37 (29 - 45)	6 (0 - 11)	7 (2 - 12)	18 (12 - 25)
2032	41 (32 - 51)	6 (0 - 13)	8 (2 - 13)	21 (13 - 28)
2033	46 (36 - 56)	7 (0 - 14)	9 (2 - 15)	23 (14 - 31)
2034	49 (39 - 60)	8 (0 - 15)	9 (2 - 16)	24 (15 - 33)
2035	53 (41 - 64)	8 (0 - 17)	10 (2 - 18)	26 (16 - 36)
2036	56 (44 - 68)	9 (0 - 18)	11 (3 - 19)	27 (17 - 37)
2037	58 (46 - 71)	9 (0 - 19)	11 (3 - 20)	29 (18 - 39)
2038	61 (47 - 74)	10 (0 - 19)	12 (3 - 21)	30 (19 - 40)
2039	63 (49 - 77)	10 (0 - 20)	12 (3 - 22)	31 (19 - 42)
2040	65 (50 - 79)	11 (0 - 21)	13 (3 - 22)	31 (20 - 43)
2041	66 (52 - 81)	11 (0 - 21)	13 (3 - 23)	32 (20 - 44)
2042	68 (53 - 83)	11 (0 - 22)	13 (3 - 24)	33 (21 - 45)
2043	69 (54 - 84)	11 (0 - 22)	14 (3 - 24)	33 (21 - 45)
Total	830 (649 - 1014)	132 (0 - 260)	158 (37 - 279)	407 (257 - 557)

Table F-19. Annual valuation of avoided health outcomes under Alternative 2 (million 2019\$).

Year	Avoided premature cardiopulmonary mortality valuation	Avoided cardiovascular hospitalization valuation	Avoided acute respiratory hospitalization valuation	Avoided ER visit for asthma valuation	Annual total valuation
2023	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00
2024	\$9.87	\$0.00	\$0.00	\$0.00	\$9.87
2025	\$29.60	\$0.00	\$0.00	\$0.00	\$29.60
2026	\$69.06	\$0.06	\$0.05	\$0.00	\$69.17
2027	\$128.25	\$0.12	\$0.10	\$0.01	\$128.48
2028	\$187.45	\$0.17	\$0.15	\$0.01	\$187.78
2029	\$246.64	\$0.23	\$0.20	\$0.01	\$247.09
2030	\$305.84	\$0.29	\$0.30	\$0.01	\$306.45
2031	\$365.03	\$0.35	\$0.36	\$0.02	\$365.75
2032	\$404.49	\$0.35	\$0.41	\$0.02	\$405.27
2033	\$453.82	\$0.41	\$0.46	\$0.02	\$454.70
2034	\$483.42	\$0.47	\$0.46	\$0.02	\$484.36
2035	\$522.88	\$0.47	\$0.51	\$0.02	\$523.88
2036	\$552.48	\$0.52	\$0.56	\$0.02	\$553.58
2037	\$572.21	\$0.52	\$0.56	\$0.02	\$573.32
2038	\$601.81	\$0.58	\$0.61	\$0.03	\$603.02
2039	\$621.54	\$0.58	\$0.61	\$0.03	\$622.76
2040	\$641.27	\$0.64	\$0.66	\$0.03	\$642.60
2041	\$651.13	\$0.64	\$0.66	\$0.03	\$652.46
2042	\$670.86	\$0.64	\$0.66	\$0.03	\$672.19
2043	\$680.73	\$0.64	\$0.71	\$0.03	\$682.11
Total	\$8,188.50	\$7.69	\$8.03	\$0.34	\$8,204.56

Table F-20. Statewide valuation from avoided health outcomes under Alternative 2.

Outcome	Avoided incidents	Valuation (million 2019\$)
Premature cardiopulmonary mortality	830	\$8,188.50
Cardiovascular hospitalization	132	\$7.69
Acute Respiratory hospitalization	158	\$8.03
ER visit for asthma	407	\$0.34
Total	1,528	\$8,204.56

Alternative 2 would result in an estimated 12.0 MMT of CO₂ emissions avoided. These emissions reductions represent a benefit of the avoided social cost of carbon valued between \$298 million and \$1.25 billion, depending on the discount rate. For comparison, the Proposed Amendments would result in an estimated 13.9 MMT of CO₂ emissions avoided, representing a benefit of the avoided social cost of carbon valued between \$339 million and \$1.43 billion, depending on the discount rate.

c. Economic Impacts

Alternative 2 is a less stringent alternative with the emission standards of zero for equipment not going into effect until 2026. This results in lower incremental fuel cost-savings, but also

higher incremental equipment cost due to the more stringent emission standards for SORE equipment. The macroeconomic impacts analysis results are qualitatively similar to the results of the Proposed Amendments, but of a larger magnitude as shown in Table F-21. Figures F-11 and F-12 show the job impacts and output changes of Alternative 2, respectively.

Table F-21. Change in growth of economic indicators under Alternative 2.

Indicator	Metric	2023	2027	2031	2035	2039	2043
GSP	% Change	0.00%	-0.02%	-0.01%	-0.01%	0.00%	0.00%
GSP	Change (2019M\$)	0	-504	-271	-189	-176	-153
Personal Income	% Change	0.00%	-0.02%	-0.01%	-0.01%	0.00%	0.00%
Personal Income	Change (2019M\$)	0	-684	-322	-190	-129	-93
Employment	% Change	0.00%	-0.02%	-0.01%	0.00%	0.00%	0.00%
Employment	Change in Jobs	0	-4,975	-2,233	-1,186	-910	-719
Output	% Change	0.00%	-0.01%	-0.01%	-0.01%	-0.01%	-0.01%
Output	Change (2019M\$)	0	-450	-566	-422	-441	-425
Private Investment	% Change	0.00%	-0.05%	-0.01%	0.01%	0.01%	0.01%
Private Investment	Change (2019M\$)	0	-247	-40	42	38	34

Figure F-11. Job impacts under Alternative 2 by major sector.

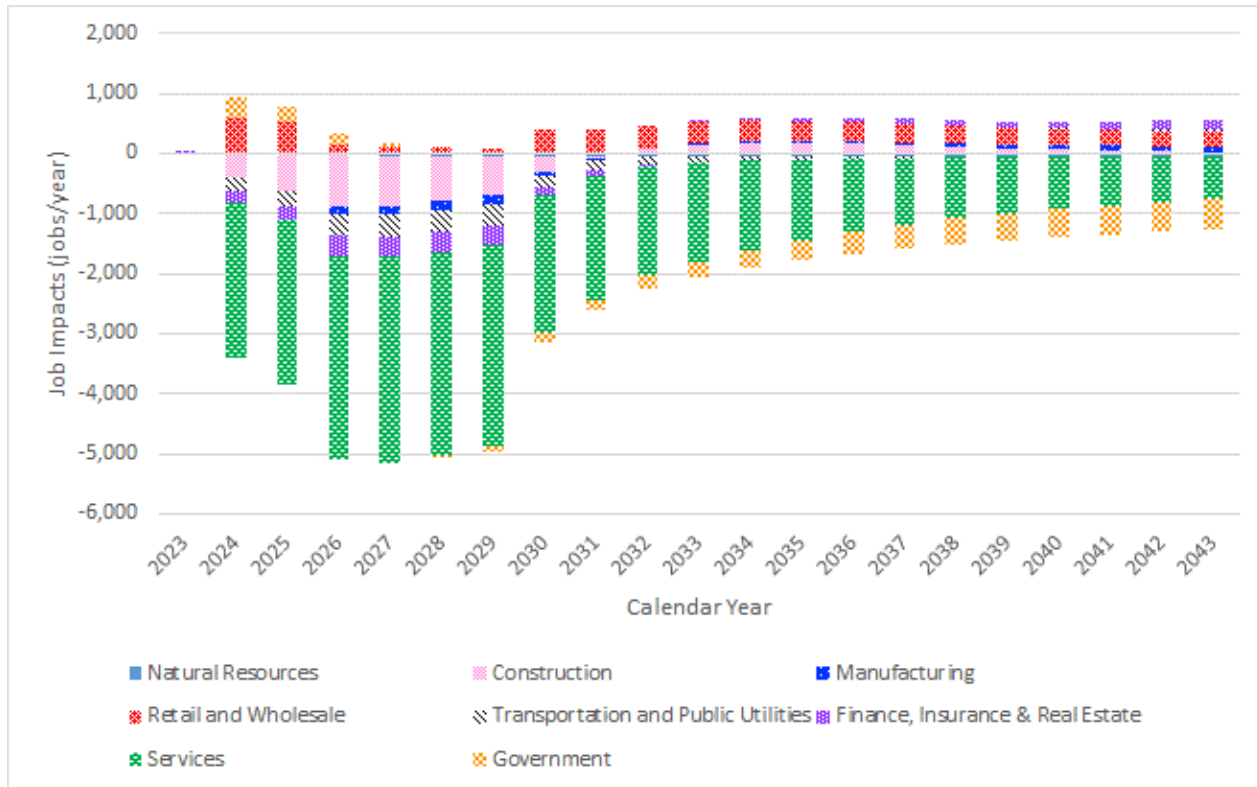
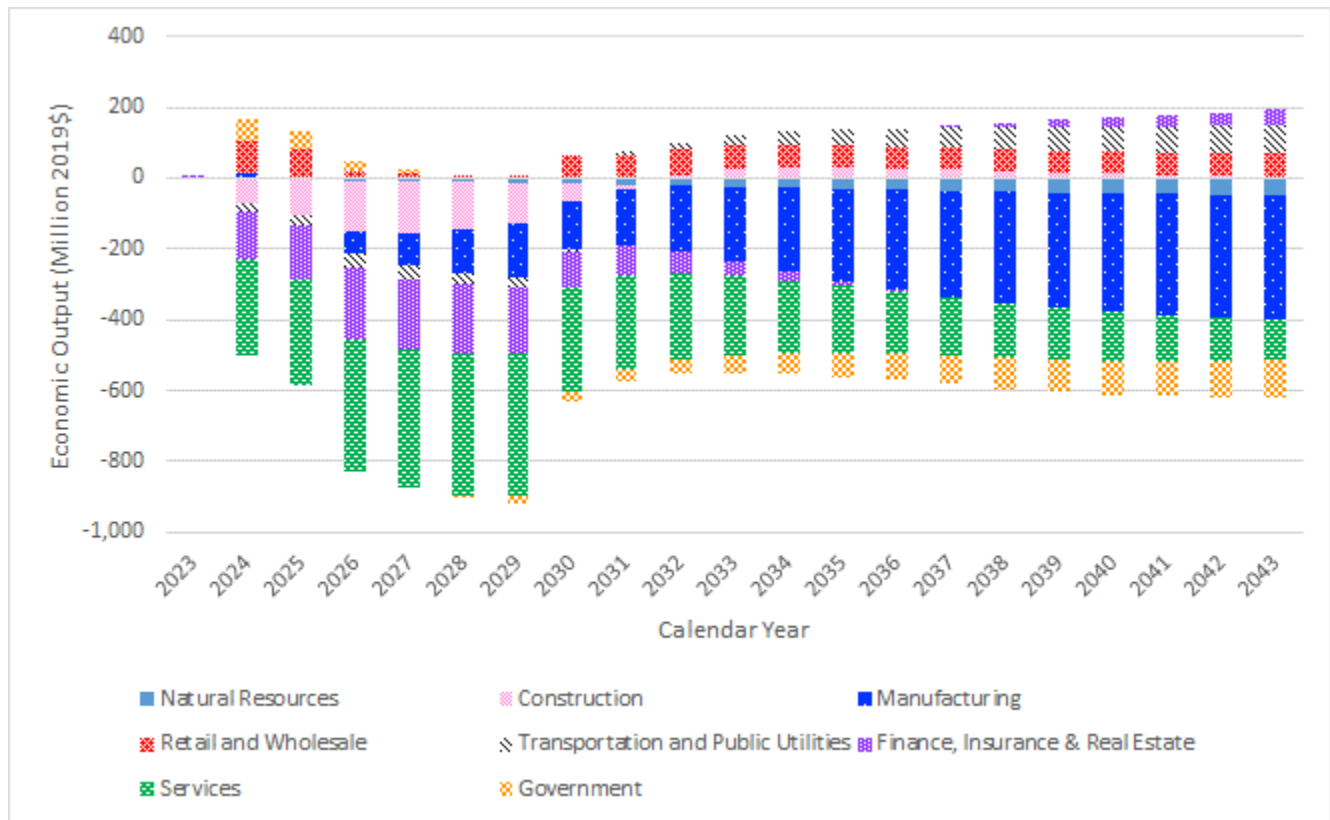


Figure F-12. Changes in output under Alternative 2 by major sector.



d. Cost-Effectiveness

Table F-22 indicates that the Proposed Amendments have a cumulative net benefit of \$4.27 billion and a benefit-cost ratio of 1.30, meaning benefits are more than costs during the regulatory horizon. Alternative 2 has a net benefit of \$2.43 billion and a benefit-cost ratio of 1.17, meaning that Alternative 2 is less cost-effective than the Proposed Amendments.

Table F-22. Cost-benefit comparison of Proposed Amendments and Alternative 2 (billion 2019\$).

Scenario	Total direct costs	Health benefits	Direct cost-savings (benefit)	Tax & fee revenue	Total benefit	Net benefit	Benefit-cost ratio
Proposed Amendments	\$14.41	\$8.82	\$10.33	-\$0.47	\$18.68	\$4.27	1.30
Alternative 2	\$14.66	\$8.20	\$8.77	\$0.11	\$17.09	\$2.43	1.17

e. Reason for Rejecting

Staff rejected Alternative 2 for two reasons. First, Alternative 2 would not be as cost effective as the Proposed Amendments or Alternative 1. Alternative 2 would have a \$1.81 billion higher direct cost and a lower benefit-cost ratio than the Proposed Amendments. Second, Alternative 2 would make it more difficult for California to achieve its air quality goals both

under EO N-79-20 and the 2016 State SIP Strategy. Under Alternative 2, only 89.3 percent of the small off-road equipment population subject to the SORE regulations would be ZEE in 2035, as compared to 93.4 percent under the Proposed Amendments. EO N-79-20 sets a goal to transition to 100 percent zero-emission off-road vehicles and equipment by 2035 where feasible. The remaining 10.7 percent would continue to transition in the following years, reaching 98.8 percent ZEE in 2043. This transition would be much slower than under the Proposed Amendments. Emission reductions in 2031 under Alternative 2 would be 6.8 tpd and 50.2 tpd of NO_x and ROG, respectively. These reductions are fewer than those expected under the Proposed Amendments. While these reductions would meet the expected emissions reductions for SORE in the 2016 State SIP Strategy, they would fail to maximize health benefits that could be achieved and would make less progress toward the “further deployment of cleaner technologies” reductions called for in the 2016 State SIP Strategy. As provided in CARB’s enabling statutory authority, “[t]he control and elimination of ... air pollutants is of prime importance for the protection and preservation of the public health and well-being, and for the prevention of irritation to the senses, interference with visibility, and damage to vegetation and property.” (HSC section 43000, subd. (b)). Therefore, since public health benefits are one of the primary purposes of CARB’s statutory mandate for adopting and implementing regulations, like the Proposed Amendments, Alternative 2’s failure to maximize health benefits to the same extent as the Proposed Amendments would not be consistent with HSC section 43000, subsection (b), and it must be rejected for this reason and on cost-effectiveness grounds.

G. Appendix

1. Equipment Used in Economic Analysis

Tables G-1 through G-6 show the makes and models of the median-priced equipment used in the economic analysis along with links to websites where the equipment can be purchased and the list price. This pricing research was conducted in late 2020, so prices on the linked websites may not exactly match the prices listed in the table. The prices listed in the tables do not include the 8.5 percent average sales tax included in the economic analysis.

For professional-grade ZEE, the cost of additional batteries and battery chargers not included in the purchase prices of the equipment were included such that the user would be expected to have a sufficient number of batteries to use the equipment throughout an eight-hour workday without having to recharge batteries. Table G-4 notes the number of additional batteries and chargers for each equipment type. For analysis of Alternative 2, some equipment prices were scaled or estimated from other types of equipment that used similar engines, as noted. This was done because few examples of equipment of those types that meet the proposed MY 2024 emission standards were found.

Table G-1. Currently-compliant residential SORE used in the economic analysis (sales tax not included).

Type of equipment	Price used in analysis	Make and model of equipment	Citation (Web links were last accessed in November 2020)
Chainsaw	\$144	Ryobi RY 3716	https://www.homedepot.com/p/RYOBI-16-in-37cc-2-Cycle-Gas-Chainsaw-with-Heavy-Duty-Case-RY3716/206465479
Generator Set	\$794	Briggs and Stratton #030744	https://www.homedepot.com/p/Briggs-Stratton-5500-Watt-Recoil-Start-Gasoline-Powered-Portable-Generator-with-OHV-Engine-030744/307723298
Lawn Mower	\$280	Troy-Bilt TB170 XP Space Saver	https://www.homedepot.com/p/Troy-Bilt-XP-21-in-149-cc-Gas-Vertical-Storage-Walk-Behind-Push-Mower-with-3-in-1-TriAction-Cutting-System-TB170-XP-Space-Saver/311512185
Leaf Blower/ Vacuum	\$149	Echo PB-2520	https://www.homedepot.com/p/ECHO-170-MPH-453-CFM-25-4-cc-Gas-2-Stroke-Cycle-Handheld-Leaf-Blower-PB-2520/303393700
Pressure Washer	\$369	Ryobi RY803001	https://www.homedepot.com/p/RYOBI-3000-PSI-2-3-GPM-Honda-Gas-Pressure-Washer-RY803001/303316335
Pump < 2 hp	\$224	GPT Co. XG10	https://www.lowes.com/pd/1-07-HP-Cast-Iron-Gas-powered-Utility-Pump/1001056450
Riding Mower	\$2,427	John Deere BG21077	https://www.homedepot.com/p/John-Deere-E140-48-in-22-HP-V-Twin-Gas-Hydrostatic-Lawn-Tractor-California-Compliant-BG21077/303161820
Snow Blower	\$399	Briggs & Stratton #1697099	https://www.homedepot.com/p/Briggs-Stratton-18-in-127-cc-Single-Stage-Gas-Snow-Blower-1697099/311214764
Trimmer/Edger/ Brush Cutter	\$152	Toro 51978	https://www.homedepot.com/p/Toro-2-Cycle-25-4cc-Attachment-Capable-Straight-Shaft-Gas-String-Trimmer-51978/202071363

Table G-2. Residential ZEE used in the economic analysis (sales tax not included).

Type of equipment	Price used in analysis	Make and model of equipment	Citation (Web links last accessed in November 2020, unless otherwise noted)
Chainsaw	\$548	DEWALT DCCS670T1 + 1 extra battery	https://www.homedepot.com/p/DEWALT-16-in-60-Volt-MAX-Lithium-Ion-Cordless-FLEXVOLT-Brushless-Chainsaw-with-One-2-0-Ah-Battery-and-Charger-DCCS670T1/307606876 https://www.homedepot.com/p/DEWALT-FLEXVOLT-20-Volt-60-Volt-MAX-Lithium-Ion-12-0Ah-Battery-DCB612/305345662 (accessed June 2021)
Generator Set	\$2,000	Goal Zero Yeti 1500	https://www.goalzero.com/shop/portable-power/goal-zero-yeti-1500x-portable-power-station/
Lawn Mower	\$399	Ego LM2102SP	https://www.homedepot.com/p/EGO-21-in-56V-Lithium-Ion-Cordless-Electric-Walk-Behind-Self-Propelled-Mower-7-5-Ah-Battery-and-Charger-Included-LM2102SP/206515944
Leaf Blower/ Vacuum	\$299	Ego LB6500	https://www.lowes.com/pd/EGO-Power-56-Volt-Lithium-Ion-Brushless-Cordless-Electric-Leaf-Blower-Battery-Included/1003130708 .
Pressure Washer	\$329	Sun Joe 24V-X2- PW1200	https://www.homedepot.com/p/Sun-Joe-48V-1196-PSI-Maximum-1-GPM-Cold-Water-Cordless-Portable-Electric-Pressure-Washer-Kit-w-2-x-4-0-Ah-Batteries-Plus-Charger-24V-X2-PW1200/315418077
Pump < 2 hp	\$247	RYOBI P750-P163 + 2 extra batteries	https://www.homedepot.com/p/RYOBI-18-Volt-ONE-1-10-HP-Lithium-Ion-Hybrid-Transfer-Pump-with-ONE-2-0-Ah-Battery-and-18-Volt-Charger-P750-P163/309952774 https://www.homedepot.com/p/RYOBI-ONE-18V-Lithium-Ion-4-0-Ah-Battery-2-Pack-and-Charger-Kit-PSK006/315424283 (accessed June 2021)
Riding Mower	\$2,999	RYOBI- 48111	https://www.homedepot.com/p/RYOBI-38-in-100-Ah-Battery-Electric-Rear-Engine-Riding-Lawn-Mower-RY48111/300422546
Snow Blower	\$399	Greenworks SN200	https://www.homedepot.com/p/Greenworks-20-in-40-Volt-Battery-Brushless-Single-Stage-Cordless-Snow-Thrower-with-6-0-Ah-Battery-and-Charger-SN-200/314749823 .
Trimmer/Edger/ Brush Cutter	\$199	DEWALT - DCST922P1	https://www.homedepot.com/p/DEWALT-20-Volt-MAX-Lithium-Ion-Brushless-Cordless-String-Trimmer-with-One-5-Ah-Battery-and-Charger-DCST922P1/311222449

Table G-3. Currently compliant professional SORE used in the economic analysis (sales tax not included).

Type of equipment	Price used in analysis	Make and model of equipment	Citation (Web links last accessed in November 2020)
Chainsaw	\$360	Stihl MS-211	https://www.stihlusa.com/products/chain-saws/homeowner-saws/ms211cbe/
Generator Set	\$4,889	Honda EU7000iS	https://powerequipment.honda.com/generators/models/eu7000is
Lawn Mower	\$1,299	Honda HRC216HXA	https://powerequipment.honda.com/lawn-mowers/models/hrc216hxa
Leaf Blower/Vacuum	\$440	Husqvarna 967 14 43-01	https://www.leafblowersdirect.com/Husqvarna-967-14-43-01-Leaf-Blower/p96132.html
Pressure Washer	\$1,079	Simpson SW4035HADM	https://www.pressurewashersdirect.com/Simpson-65203-Pressure-Washer/p94378.html
Pump < 2 hp	\$419	Honda GX-25	https://www.northerntool.com/shop/tools/product_200585735_200585735
Riding Mower	\$10,486	John Deere Z920M	https://www.deere.com/en/mowers/commercial-mowers/commercial-zero-turn-ztrak-mowers/z920m-mower/
Snow Blower	\$1,499	Toro Power Max HD 928	https://www.toro.com/en/homeowner/snow-blowers/power-max-hd-928-oae-38840?bvstate=pg:3/ct:r
Trimmer/Edger/Brush Cutter	\$340	Husqvarna 525LST	https://www.husqvarna.com/us/products/trimmers/525lst/967175501/

Table G-4. Professional ZEE used in the economic analysis (sales tax not included).

Type of equipment	Price used in analysis	Make and model of equipment	Citation (Web links last accessed in November 2020, unless otherwise noted)
Chainsaw	\$640	Stihl MSA 200	https://www.hutsoninc.com/stihl/chain-saws/battery-saws/msa200cbq/
Generator Set	\$6,400	Goal Zero 3000X (x 2)	https://www.goalzero.com/shop/portable-power/goal-zero-yeti-3000x-portable-power-station/
Lawn Mower	\$979	Greenworks 48SPM21 + 3 extra batteries	https://greenworkscommercial.com/48spm21-48v-24v-21-dual-volt-self-propelled-lawn-mower-with-battery-and-charger https://www.sohars.com/greenworks-bam704-24-48v-4ah-dual-voltage-battery/
Leaf Blower/ Vacuum	\$1,609	Stihl BGA 100 + AR 3000 + battery charger	https://www.stihlusa.com/products/batteries-and-accessories/batteries/ar3000/ https://www.stihlusa.com/products/blowers-and-shredder-vacs/battery-blowers/bga100/ https://www.stihlusa.com/products/accessories/batteries-and-accessories/al500/
Pressure Washer (corded)	\$2,799	Pressure Pro EE3035A	https://www.pressurewashersdirect.com/Pressure-Pro-EE3035A-AS-Pressure-Washer/p10070.html
Pressure Washer (cordless)	\$9,199	Pressure Pro EE3035A + Goal Zero 3000X (x 2)	Assumed to be the corded ZEE professional-grade unit + 2 zero-emission generator sets to supply enough power for a day's work
Pump < 2 hp	\$548	Milwaukee 2771-21 + 2 extra batteries	https://www.homedepot.com/p/Milwaukee-M18-18-Volt-1-4-HP-Lithium-Ion-Cordless-Transfer-Pump-Kit-with-1-3-0Ah-Battery-and-Charger-2771-21/300510182 https://www.homedepot.com/p/Milwaukee-M18-18-Volt-Lithium-Ion-XC-Extended-Capacity-5-0-Ah-Battery-Pack-2-Pack-48-11-1852/205783065 (accessed June 2021)
Riding Mower	\$19,500	Mean Green CXR-60	https://www.ecoequipmentsupply.com/products-high-performance-electric-lawnmowers/cxr-52/
Snow Blower	\$1,349	Toro 39902 + 2 extra batteries	https://www.snowblowersdirect.com/Toro-39902-Snow-Thrower/p99220.html https://www.snowblowersdirect.com/Toro-88660/p99227.html
Trimmer/Edger/ Brush Cutter	\$798	Husqvarna 536 LiLx, + 2 extra batteries + battery charger	https://www.husqvarna.com/us/products/trimmers/536lilx/967326812/ https://www.husqvarna.com/us/accessories/battery/battery-bli200/967091901/?q=967326812 https://www.husqvarna.com/us/accessories/battery/qc330-battery-charger/967091403/?q=967326812

Table G-5. MY 2024 compliant residential sore equipment used in the economic analysis for Alternative 2 (sales tax not included).

Type of equipment	Price used in analysis	Make and model of equipment	Citation (Web links last accessed in November 2020)
Chainsaw	\$257	N/A	Scaled from price of MY 2024 compliant residential trimmer assuming that the price increase for a residential chainsaw is proportional to that for a residential trimmer
Generator Set	\$1,743	Kohler PA-PRO90-3001-PC	https://www.homedepot.com/p/KOHLER-9-000-Watt-Gasoline-Powered-Recoil-Start-Portable-Generator-with-Command-PRO-Commercial-Engine-PA-PRO90-3001-PC/3038398836
Lawn Mower	\$390	Mowox MNA152613	https://www.homedepot.com/p/MOWOX-21-in-3-n-1-Zero-Turn-Self-Propelled-Gas-High-Wheel-Walk-Behind-Mower-with-B-S-725is-163-cc-Engine-with-InStart-MNA152613/311148953
Leaf Blower/ Vacuum	\$600	Stihl BR 800 X MAGNUM®	https://www.sohars.com/stihl-br-800-x-magnum-79-9cc-912-cfm-commercial-backpack-blower/
Pressure Washer	\$326	Champion 100382 (2600-PSI Pressure Washer)	https://www.amazon.com/Champion-2600-PSI-2-2-GPM-Dolly-Style-Pressure/dp/B06XPCGSKT
Pump < 2 hp	\$300	Red Lion Semi- Trash Water Pump 6RLAG-2LST 208cc	https://www.tractorsupply.com/tsc/product/red-lion-2-in-aluminum-semi-trash-pump-6rlag-2lst
Riding Mower	\$5,327	N/A	Scaled from price of MY 2024 compliant residential generator assuming that the price increase for a residential riding mower is proportional to that for a residential generator
Snow Blower	\$399	Briggs & Stratton #1697099	https://www.homedepot.com/p/Briggs-Stratton-18-in-127-cc-Single-Stage-Gas-Snow-Blower-1697099/311214764
Trimmer/Edger/ Brush Cutter	\$199	Craftsman WS4200	https://www.lowes.com/pd/CRAFTSMAN-Craftsman-30cc-SS-Trimmed/5000859435

Table G-6. MY 2024 compliant professional sore equipment used in the economic analysis for Alternative 2 (sales tax not included).

Type of equipment	Price used in analysis	Make and model of equipment	Citation (Web links last accessed in November 2020)
Chainsaw	\$452	N/A	Scaled from price of MY 2024 compliant professional trimmer assuming that the price increase for a professional chainsaw is proportional to that for a professional trimmer
Generator Set	\$11,200	Westerbeke 5.0 MCG	https://citimarinestore.com/en/westerbeke-marine-generators/7537-westerbeke-mcga-5kw-marine-generator.html
Lawn Mower	\$3,023	N/A	Scaled from price of MY 2024 compliant professional generator assuming that the price increase for a professional lawn mower is proportional to that for a professional generator
Leaf Blower/ Vacuum	\$600	Stihl BR 800 X MAGNUM®	https://www.sohars.com/stihl-br-800-x-magnum-79-9cc-912-cfm-commercial-backpack-blower/
Pressure Washer	\$2,741	N/A	Scaled from price of MY 2024 compliant professional generator assuming that the price increase for a professional pressure washer is proportional to that for a professional generator
Pump < 2 hp	\$300	Red Lion Semi- Trash Water Pump 6RLAG-2LST 208cc	https://www.tractorsupply.com/tsc/product/red-lion-2-in-aluminum-semi-trash-pump-6rlag-2lst
Riding Mower	\$23,941	N/A	Scaled from price of MY 2024 compliant professional generator assuming that the price increase for a professional riding mower is proportional to that for a professional generator
Snow Blower	\$1,499	Toro Power Max HD 928	https://www.toro.com/en/homeowner/snow-blowers/power-max-hd-928-oae-38840?bvstate=pg:3/ct:r
Trimmer/Edger/Brush Cutter	\$429	Honda HHT35SUKAT	https://www.powerequipmentdirect.com/Honda-HHT35SUKAT/p6419.html

2. Macroeconomic Appendix

Table G-7. REMI inputs for the Proposed Amendments (million 2019\$).

REMI Policy Variable	REMI Industry /Spending Category	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043
Production Cost	Services to buildings and dwellings	55.9	37.5	18.3	(0.7)	(16.8)	(32.1)	(43.8)	(53.7)	(62.0)	(68.8)	(74.5)	(79.1)	(82.8)	(85.8)	(87.9)	(89.6)	(90.8)	(91.8)	(92.5)	(93.2)
Production Cost	All industries (excluding 5617)	353.8	344.9	336.0	327.3	162.8	146.5	131.4	118.5	107.0	96.6	87.2	79.2	72.5	67.0	62.5	58.9	56.3	54.3	52.9	51.8
Consumer Spending (w/ reallocation)	Tools and equipment for house and garden	381.0	380.7	381.1	381.6	442.3	442.0	442.4	446.0	449.7	453.4	457.1	460.9	464.7	468.5	472.4	476.4	480.4	484.5	488.6	492.7
Exogenous Final Demand	Electric power generation, transmission, and distribution	2.7	7.5	12.8	18.2	23.6	29.3	35.0	39.6	43.7	47.2	50.2	52.8	54.9	56.6	58.0	59.1	60.1	60.9	61.5	62.1
Exogenous Final Demand	Petroleum and coal products mfg.	(12.2)	(37.6)	(64.3)	(90.9)	(115.9)	(145.4)	(171.1)	(194.6)	(215.2)	(233.4)	(249.4)	(263.2)	(274.8)	(284.6)	(292.7)	(299.4)	(304.8)	(309.3)	(313.2)	(316.6)
Exogenous Final Demand	Personal and household goods repair	(4.3)	(12.4)	(21.0)	(29.3)	(37.0)	(44.2)	(50.5)	(55.9)	(60.7)	(64.7)	(68.1)	(71.0)	(73.4)	(75.4)	(76.8)	(78.1)	(79.0)	(79.7)	(80.2)	(80.7)
Consumer Spending (w/ reallocation)	motor vehicles fuels and lubricants	(8.2)	(21.9)	(36.8)	(52.2)	(71.1)	(104.5)	(139.5)	(173.7)	(206.3)	(236.7)	(264.8)	(290.1)	(312.1)	(331.3)	(348.1)	(362.3)	(374.1)	(384.1)	(392.8)	(400.2)
Consumer Spending (w/ reallocation)	electric power generation, transmission, and distribution	1.1	2.9	4.9	6.9	9.5	14.0	19.2	23.9	28.3	32.5	36.3	39.8	42.7	45.4	47.6	49.5	51.1	52.4	53.6	54.5
Consumer Spending (w/ reallocation)	Household maintenance and repair	(3.5)	(9.7)	(16.4)	(23.0)	(29.4)	(36.3)	(42.9)	(48.9)	(54.3)	(59.1)	(63.4)	(67.1)	(70.2)	(72.9)	(75.1)	(77.0)	(78.4)	(79.6)	(80.7)	(81.6)
Government Spending	State Government	23.8	18.2	12.3	6.6	(2.9)	(11.8)	(21.2)	(29.7)	(37.5)	(44.7)	(51.2)	(57.0)	(61.9)	(66.1)	(69.7)	(72.8)	(75.2)	(77.3)	(79.0)	(80.4)
Government Spending	Local Government	30.3	29.7	29.2	28.7	24.8	23.8	22.9	22.2	21.5	20.9	20.4	20.0	19.6	19.3	19.1	19.0	18.9	18.9	18.9	18.9