State of California
Air Resources Board

Low Carbon Fuel Standard 2023 Amendments

Standardized Regulatory Impact Assessment (SRIA)

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California Air Resources Board
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Contents

List of Tables

List of Figures

I. Introduction

This Standardized Regulatory Impact Assessment (SRIA) assesses the economic impacts of California Air Resources Board (CARB or Board) staff's developing proposal to update the Low Carbon Fuel Standard (LCFS or regulation). The LCFS is one of the key policies implemented by CARB to reduce greenhouse gas (GHG) emissions from the transportation sector, which accounts for approximately 50% of the statewide GHG emissions when accounting for transportation fuel production and use.

California has been on the road to reducing transportation emissions through fuels since California's Global Warming Solutions Act of 2006, also known as AB 32 (Núñez and Pavley, Chapter 488, Statutes of 2006), was signed into law. Most recently, the 2022 Scoping Plan Update[1] laid out a cost-effective and technologically feasible path to achieve the mandates in AB 1279 (Muratsuchi, Chapter 337, Statutes of 2022) which calls for both reducing anthropogenic emissions by 85% below 1990 levels and achieving carbon neutrality by 2045. Successful implementation of the outcomes recommended by the 2022 Scoping Plan Update would substantially reduce emissions through fuels and support implementation of Governor Newsom's Zero Emission Vehicle Executive order (N-79-20).

To achieve transportation sector emissions reductions, the State has taken leadership action to adopt regulations for light-, medium-, and heavy-duty on-road vehicles and off-road mobile sources.[2] These regulations call for the increasing deployment of zero-emission vehicles and off-road mobile sources over the coming decades. More recently, the Clean Truck Partnership further bolstered the deployment of clean trucks in the state.[3] These policies drastically reduce transportation emissions. The LCFS is a companion policy that supports transportation emissions reductions by providing an incentive for cleaner transportation fuels such as electricity and hydrogen to be produced and deployed. The transition away from petroleum and to zero-emission vehicles will deliver both air quality and climate benefits to California. Importantly, the transportation sector is in a period of transition and low carbon fuels are still needed for the legacy combustion fleets that will persist through 2045.

CARB initially approved the LCFS regulation in 2009 as an early action measure under AB 32. The LCFS requires reductions in the carbon intensity (CI) of California's transportation fuels over time. The regulation sets annual benchmarks for the average carbon intensity of fuels,

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[1] CARB (2022), The 2022 Scoping Plan Update for Achieving Carbon Neutrality explains the overarching framework of California's GHG policies. *2022 Scoping Plan Update (ca.gov)*

[2] Zero Emission Vehicle, Advanced Clean Cars II (ACC II), Advanced Clean Fleets (ACF), Advanced Clean Trucks (ACT), Commercial Harbor Craft, the Short-Lived Climate Pollutant Reduction Strategy, 2020 Mobile Source Strategy, Sustainable Freight Action Plan, In-Use Locomotive Regulation, and Innovative Clean Transit (ICT).

[3] CARB (2023), CARB and truck and engine manufacturers announce unprecedented partnership to meet clean air goals. *CARB and truck and engine manufacturers announce unprecedented partnership to meet clean air goals | California Air Resources Board*

which gradually become more stringent over time. The carbon intensity of a fuel is the amount of carbon emitted through its life cycle.[4]

Over the past 13 years, the basic framework of the LCFS has worked well and continues to support growth in an increasingly diverse and low-carbon transportation fuel pool. Since implementation, the LCFS has helped displace over 25 billion gallons of petroleum fuel. The volume of low-carbon fuels supplied for use in California has nearly tripled, and as of 2023, the State's current diesel fuel is over 50% biomass-based (i.e., not fossil-based).

The LCFS is contributing to the rapidly increasing use of low-carbon fuels in California. Before the LCFS, the only low-CI fuels with significant market share were fossil natural gas and ethanol. Figure 1[5] shows the increasing growth in cleaner fuels from 2011 through 2022. The value of credits generated in the LCFS is approximately $4 billion per year, which incentivizes the development of innovative low-carbon fuel. Since the LCFS went into effect, California has achieved a reduction of more than 12.5% in the average CI of the transportation fuel pool from a 2010 baseline, exceeding the 2022 benchmark of 10% CI reduction.[6] Other states have also adopted similar programs, including Oregon and Washington, broadening the impact of this successful mitigation policy beyond California.

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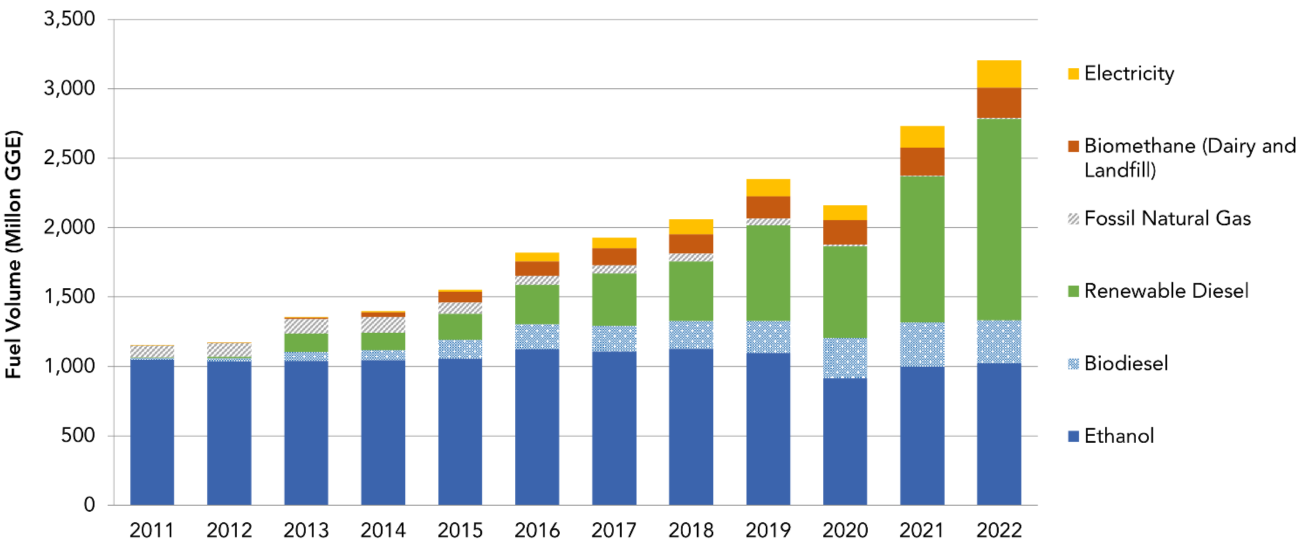
[4] The carbon intensity (CI) of a fuel refers to the amount of life cycle greenhouse gas emissions, per unit of fuel energy, expressed in grams of carbon dioxide equivalent per megajoule (gCO_2e/MJ). Lowering the average CI of fuels in California means that for the same amount of vehicle miles travelled in California, the transportation sector will emit less GHG overall.

[5] *Figure 2*, Alternative Fuel Volumes and Credit Generation (updated April 28, 2023). LCFS Data Dashboard: *https://www.arb.ca.gov/fuels/lcfs/dashboard/dashboard.htm.* Accessed August 7, 2023.

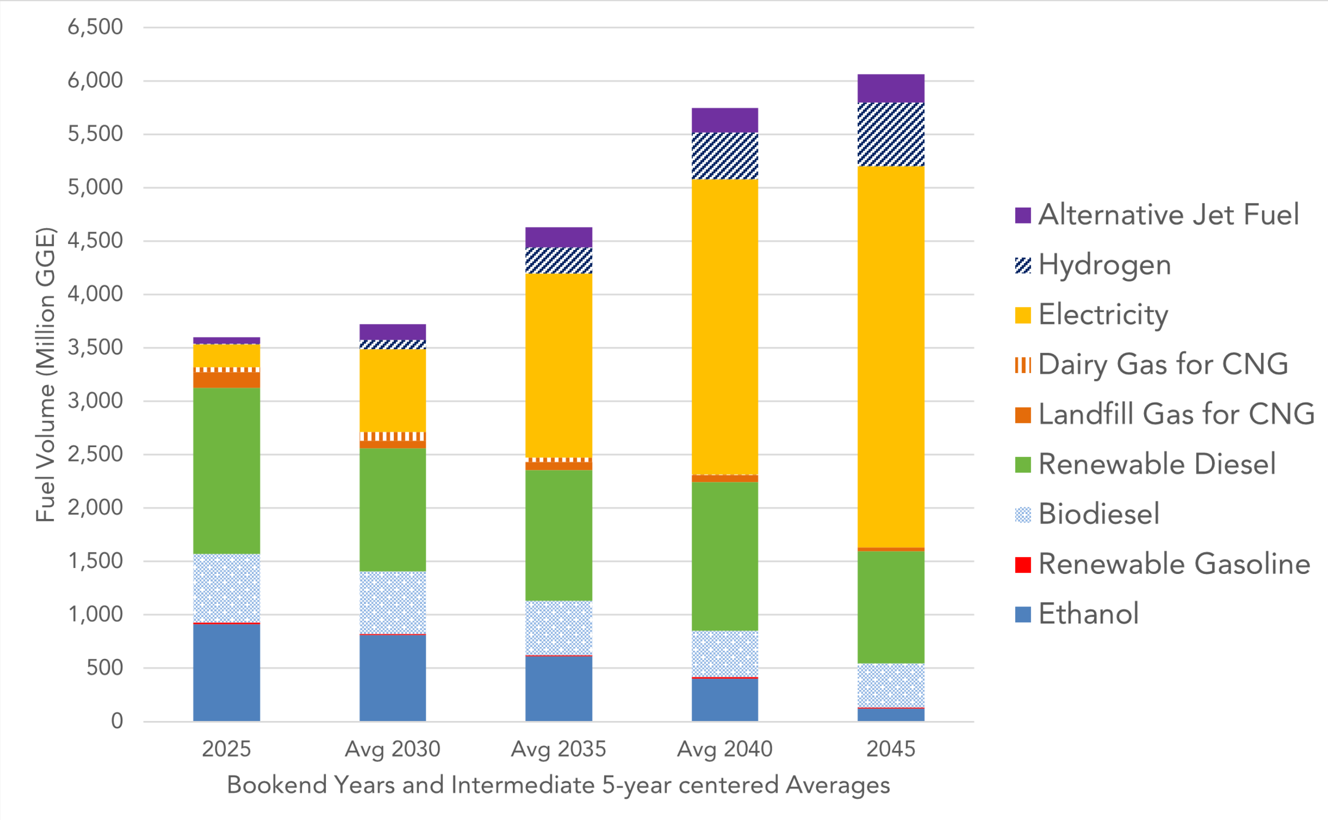
[6] *Figure 1*, 2011-2021 Performance of the Low Carbon Fuel Standard (updated April 28, 2023). LCFS Data Dashboard: *https://www.arb.ca.gov/fuels/lcfs/dashboard/dashboard.htm.* Accessed August 7, 2023.

Figure 1: Alternative Fuel Volumes



The regulation has been updated multiple times since its inception to reflect the increasing need for a diversity of fuels and more ambitious climate goals. For example, in 2018, the LCFS amendments included a signaling of the needed support for ZEVs through the LCFS and other policies. Beginning in 2019, the LCFS began crediting ZEV refueling infrastructure capacity for light-duty vehicles, acknowledging the need for widespread ZEV fueling deployment, and other electricity-based credit generation opportunities to support early ZEV adoption. Since then, the LCFS has seen nearly a four-fold increase in electricity credits and provided support for 3,800 fast chargers and 67 hydrogen stations. With this current rulemaking update, staff are proposing several changes to the regulation to reflect the effectiveness of the program in recent years, the need to accelerate the CI reduction goals and policy objectives in line with the 2022 Scoping Plan Update and AB 1279, and to maintain program integrity and increase program efficacy. The most significant proposed change is increasing the stringency of CI reduction targets through 2030 and extension of declining CI targets through 2045. Other major proposed changes include establishing intrastate fossil jet fuel as a required fuel, creating a provision to support medium and heavy-duty zero-emission vehicle (ZEV) refueling infrastructure, establishing a phase-out date for the crediting of petroleum projects, and revising indirect accounting eligibility to focus on direct delivery of biomethane. Staff began conceptually discussing many of these items during an informal public process initiated in October 2020, hosting nine public workshops and two community meetings. The outcome of these proposed changes would be to accelerate the drastic reduction in the carbon intensity of the fuels California uses and increase the deployment of zero-emission fuels and infrastructure, as shown in Figure 2.

Figure 2: Low-CI Fuel Mix - Proposed Amendments



The analysis in this SRIA provides an economic assessment of the proposed amendments to the LCFS regulation. The formal rulemaking package will include an Initial Statement of Reasons that goes into the rationale for each proposed amendment and may reflect any changes proposed after the completion of this SRIA.

Table 1 provides an overview of the costs, benefits, and cost effectiveness of the proposed amendments, with links provided to each metric's associated part of the report.

Table 1. Summary of Statewide Impacts of the Proposed Amendments

Category of Cost or Benefit	Value	Section in SRIA
Cumulative Direct Costs (million 2021$)	162,462	0
Cumulative Direct Cost Savings (million 2021$)	128,416	II.B
NOx Reduction (cumulative tons/average tpd)	17,397/2.07	II.A.3
PM2.5 Reduction (cumulative tons/average tpd)	4,108/0.49	II.A.3
GHG Reduction (cumulative MMT CO2e)	558	II.A.2

Category of Cost or Benefit	Value	Section in SRIA
Avoided Cardiopulmonary Mortalities	364	II.D.2
Monetized Health Benefits (million 2021$)	4,978	II.D.2.e)
Social Cost of Carbon Benefit (million 2021$)	14,500 to 61,100	II.D.1
Employment Impact	-0.01% change	V.C.1
Cost-Effectiveness	$61/MT CO_2e	III.A.5

The preliminary proposal for target setting and revisions to the LCFS was discussed publicly at a workshop on November 9, 2022, allowing stakeholders to submit feedback and propose alternatives for consideration. Staff will present a formal package of proposed amendments for Board consideration in 2024. Continued interactions with stakeholders, external researchers, and other regulatory agencies will inform the proposal.

A. Regulatory History of the LCFS

In 2022, Californians used approximately 12.3 billion gallons of gasoline and 2 billion gallons of diesel fuel. The production, transport, and use of these fuels are responsible for nearly half of the California's GHG emissions.[7] The proposed amendments are necessary for the LCFS to continue to contribute to California's near- and long-term climate goals.

Executive Order S-01-07 ordered the establishment of the LCFS as a discrete early action item under the California Global Warming Solutions Act of 2006 (Assembly Bill (AB) 32, codified at Health and Safety Code section 38500 *et seq.*). In 2009, the Board approved the LCFS to achieve a 10% reduction in the carbon intensity of California transportation fuel by 2020 relative to a 2010 baseline, and in 2011 approved amendments to the regulation to clarify, streamline, and enhance certain provisions. In 2015, the Board re-adopted the LCFS in compliance with a court order arising from a challenge to the original regulation. In 2016, the Legislature passed SB 32 (Pavley, Chapter 249, Statutes of 2016), which requires California to reduce its overall greenhouse gas emission levels 40% below 1990 levels by 2030. In 2017, the Board approved the 2017 Scoping Plan Update calling for more aggressive targets in the LCFS. In 2018, the Board adopted LCFS amendments strengthening CI benchmarks to achieve a 20% CI reduction by 2030 and adding new crediting opportunities. In 2019, the Board adopted amendments that strengthened the cost containment mechanisms in the program and added equity spending requirements.

B. Proposed Amendments and Statement of Need

CARB staff is proposing to amend the LCFS regulation to build on the current LCFS regulation. The proposed changes continue progress already made in the transportation fuel sector by

[7] CARB. (2022). California Greenhouse Gas Emissions for 2000 to 2020 Trends of Emissions and Other Indicators. California Greenhouse Gas Emissions for 2000 to 2020 Trends of Emissions and Other Indicators

increasing the stringency and certainty of the program to align with more recent long-term State climate goals identified in the 2022 Scoping Plan Update and AB 1279 (Muratsuchi, Chapter 337, Statutes of 2022), which call for both reducing anthropogenic emissions by 85% below 1990 levels and achieving carbon neutrality by 2045. In addition to supporting the long-term climate goals of California, updating the LCFS will also support the strategies identified in the 2022 Scoping Plan Update to reduce transportation emissions through fuels, and support the deployment of ZEVs called for in Governor Newsom's Zero Emission Vehicle Executive order (N-79-20) and the Clean Truck Partnership[8] established between CARB and the nation's truck manufacturers. And finally, the proposed amendments also support complementary regulations such as Advanced Clean Cars II (ACC II), Advanced Clean Trucks (ACT), and Advanced Clean Fleets (ACF) by incentivizing the ZEV fueling infrastructure needed as ZEV deployment grows. The following is a summary of the proposed LCFS amendments:

- Increase the stringency of CI reduction targets through 2030 and extend targets through 2045;
- Eliminate the exemption for intrastate fossil jet fuel;
- Incentivize fuel production and refueling infrastructure buildout needed to meet California's long-term climate goals, including opportunities to leverage federal funding for low-carbon hydrogen production and ZEV fueling;
- Update standard values in the regulation and LCA modeling tools;
- Increase the flexibility of the program to adjust for potential future market overperformance by including a mechanism that would automatically accelerate the compliance targets under certain conditions; and
- Streamline implementation of the program.

The following sections provide a brief overview of the changes to the LCFS included in the SRIA evaluation. The Initial Statement of Reasons published with the 45-day package will contain additional details and rationale for each change.

1. Annual Carbon Intensity Benchmarks Pre- and Post-2030

The LCFS regulation defines a carbon intensity benchmark for each year. As CARB identified in the 2022 Scoping Plan Update, achieving the State's climate goals will require the use of a portfolio of low-carbon transportation fuels beyond the amount expected to result from the current compliance schedule. CARB staff used the 2022 Scoping Plan Update, public feedback, market data, and modeling tools to evaluate a variety of transportation fuel pathways and conduct scenario analysis to inform the proposed pre- and post-2030 targets and annual benchmarks for carbon intensity reduction through 2045. This approach helped staff explore the possible future transport fuel mixes that could result from updating the LCFS regulation, as

[8] CARB (2023), CARB and truck and engine manufacturers announce unprecedented partnership to meet clean air goals. *CARB and truck and engine manufacturers announce unprecedented partnership to meet clean air goals | California Air Resources Board*

well as the relative overall costs, feasibility, and impact on the LCFS credit market that could result from the different scenarios.

Based on feedback received from stakeholders, staff evaluated[9] a range of CI benchmark trajectories. Table 2 shows the proposed benchmarks as compared to the benchmarks in the current regulation for years 2024 through 2045, which then remains static at the 2045 value in the following years. The proposed amendments include a near-term step-down in CI benchmark stringency in 2025. A step-down in stringency was strongly supported by feedback provided by stakeholders, particularly in response to the February and May 2023 technical workshops. The step-down reflects the current effectiveness of the program, which suggests that the pace of CI reductions can be increased through the benchmarks.

Table 2: CI Benchmarks from 2024-2046

Year	Current Target	Proposed CI Reduction Target
2024	12.5%	12.5%
2025	13.75%	18.75%
2026	15.0%	21.0%
2027	16.25%	23.25%
2028	17.5%	25.5%
2029	18.75%	27.75%
2030	20.0%	30.0%
2031	20.0%	34.5%
2032	20.0%	39.0%
2033	20.0%	43.5%
2034	20.0%	48.0%
2035	20.0%	52.5%
2036	20.0%	57.0%
2037	20.0%	61.5%
2038	20.0%	66.0%
2039	20.0%	70.5%
2040	20.0%	75.0%
2041	20.0%	78.0%
2042	20.0%	81.0%
2043	20.0%	84.0%
2044	20.0%	87.0%

[9] Staff developed the California Transportation Supply (CATS) model to support scenario analyses for the LCFS program. The CATS model is an optimization model that identifies the lowest cost options for providing fuel in California to meet transportation fuel demand. The CATS model is primarily being used to compare results of different policy changes across the different scenarios.

Year	Current Target	Proposed CI Reduction Target
2045	20.0%	90.0%
2046	20.0%	90.0%

2. Acceleration Mechanism

Staff is proposing to include an Automatic Acceleration Mechanism (AAM) to increase the stringency of the CI benchmarks of the program when specific regulatory conditions are satisfied. Under the current staff proposal, the AAM would advance the upcoming year's CI benchmark after being activated. For example, if the AAM is activated in 2029 based on 2028 LCFS reporting, the 2030 CI reduction target would be increased to 34.5%. An AAM can support the deeper transportation sector decarbonization needed through mid-century by increasing regulatory clarity for the market, acting alongside existing provisions that also help to provide program certainty, such as the maximum credit price[10] and the Credit Clearance Market (CCM).[11]

An AAM would operate to potentially increase program stringency, using regulatory criteria, to accommodate documented rapid advances in transportation fuel decarbonization. An AAM would operate in a way that is predictable and easy to understand, based on publicly available data, and would bolster market stability during periods where credit generation rapidly and consistently outpaces deficit generation. Similar to maximum price and CCM provisions, an AAM would play an important role in supporting LCFS implementation, deterring market manipulation, maintaining support for the program, and providing the certainty necessary for the long-term investments required to meet the State's decarbonization goals.

Staff engaged extensively with stakeholders to develop an AAM, including holding a dedicated workshop on this topic in May 2023. An AAM would only be activated by specific market conditions defined in the LCFS regulations that result in a specified imbalance in the number of credits versus deficits over a certain time period.

3. Eliminate Exemption for Intrastate Fossil Jet Fuel

Staff is proposing to eliminate the exemption for intrastate fossil jet fuel from the LCFS regulation. The aviation sector has historically relied on jet fuel produced from fossil fuels, and fossil jet fuel is currently exempted from generating deficits in the LCFS program. Lower carbon alternative jet fuels exist today and are further bolstered through federal incentives, and in order to achieve the deep emissions reductions called for in AB 1279 and the 2022 Scoping Plan Update, California must accelerate GHG emissions reductions from all sectors, including the aviation sector.

[10] Cal. Code Regs., tit. 17, § 95487(a)(2)(D).

[11] Cal. Code Regs., tit. 17, § 95485(c).

4. Changes to Avoided Methane Crediting

Staff is proposing to phase out avoided methane crediting for dairy and swine manure pathways, and for landfill-diversion pathways by 2040 by identifying the latest date for certification or recertification of a fuel pathway with avoided methane crediting. Pathways certified to reflect avoided methane emissions generally have very low CIs due to the baseline assumption that captured methane used as a transportation fuel would otherwise be emitted into the atmosphere. The proposed amendments would allow at least one 10-year crediting period inclusive of avoided methane for applications certified through December 31, 2029, and allow a 5-year crediting period for recertified pathways between January 1, 2030, and December 31, 2034.

5. Changes to Biomethane Deliverability Requirements

Staff is proposing to align the deliverability requirements for biomethane with the requirements applicable to other fuels, which must be physically consumed in California or, in the case of low-CI electricity, meet specific deliverability requirements. Currently, the LCFS regulation allows for indirect accounting of biomethane when injected into the North American natural gas pipeline without requirements that this fuel be demonstrated to have been physically delivered to California. Indirect accounting, also known as book-and-claim accounting, allows dispensers of CNG, LNG, or L-CNG to vehicles in California or producers of hydrogen to contractually match biomethane that is injected into the North American gas pipeline to fossil gas used in transportation in California.

6. Expand Zero Emission Vehicle Infrastructure Crediting to Medium- and Heavy-Duty Sector

To support the increased market penetration of ZEVs, staff is proposing an amendment to expand the current ZEV infrastructure crediting provision for the light-duty sector to the medium- and heavy-duty (MHD) sector.

The proposal would allow ZEV infrastructure crediting for hydrogen refueling infrastructure and fast charging infrastructure for the MHD sector, with a regulatory limit on total credits set to 2.5% each of prior quarter deficits.

7. Allow Indirect Accounting for Low Carbon Intensity Hydrogen Injected into Hydrogen Pipelines

Staff proposes to expand the existing book-and-claim provisions to include low-CI hydrogen injected into the pipeline network.

To leverage available federal incentives and ensure the program is supporting low-carbon hydrogen, staff is proposing to align book-and-claim eligibility with the hydrogen production incentive eligibility under the Inflation Reduction Act (Pub.L. No. 117-169 (August 16, 2022)). Specifically, staff is proposing well-to-wheel CI thresholds of less than or equal to 55 g/MJ for gaseous hydrogen and less than or equal to 90 g/MJ for liquid hydrogen. Staff is proposing to exclude hydrogen derived from fossil gas from book-and-claim eligibility unless low-CI hydrogen is produced using book-and-claim of biomethane.

8. Changes to Project-Based Crediting

Staff is proposing changes to the project-based crediting provisions to align with the direction provided in the 2022 Scoping Plan Update to reduce GHG emissions across the economy while recognizing the broader trend away from fossil fuel production in tandem with demand. Specifically, staff is proposing to phase out crediting of petroleum projects by 2040.

In addition, staff is proposing to limit direct air capture project eligibility to projects located in the United States. Focusing on projects located in the United States would align the LCFS with federal incentives for direct air capture projects, which also requires projects be within the United States and would support achieving national climate goals.

9. Modifying Crediting Potential for Electric Forklifts

Staff is proposing to modify the crediting for electric forklifts to account for the significant advancement in forklift electrification. Many smaller classes of forklifts have successfully transitioned to zero-emission technology and the technologies are widely available. The proposed amendments decrease the number of credits generated by forklifts less than <12,000 pound lift capacities, to reflect that not all zero-emission forklifts replace a fossil forklift. Since forklifts with larger lift capacities (i.e., greater than 12,000 pounds) largely still use fossil fuels, the proposed crediting change is limited to smaller forklifts.

10. Other Proposed Amendments

Additional amendments are proposed to simplify and streamline application and reporting requirements to encourage greater participation and improve administrative efficiency. These amendments do not affect the economic or air quality benefits or impacts and will be described in detail in the Initial Statement of Reasons published as part of the 45-day rulemaking package.

C. Major Regulation Determination

Any agency that anticipates promulgating a regulation that will have an economic impact on California business enterprises and individuals in an amount exceeding $50 million in any 12-month period between the date it is filed with the Secretary of State through 12 months after it is fully implemented (defined as major regulation) is required to prepare a SRIA.[12] The proposed amendments to the LCFS regulation would be fully implemented in 2045 and are estimated to result in an annual economic impact exceeding $50 million starting in 2024. CARB staff has estimated that the proposed amendments could result in direct annual costs to regulated entities of up to $10.4 billion between 2024 and 2046.

D. Baseline Information

The economic and emissions impacts of the proposed amendments are estimated against a baseline scenario. This section describes the general process, including the data and model

[12] See Cal. Code Regs., tit. 13, § 2001, et seq.

used to develop the baseline and proposed amendments scenario.[13] The proposed amendments represent one potential path to achieve the CI reductions shown in Table 2. As the proposed amendments retain the market flexibility of the current LCFS, it is not possible to predict the exact path or fuels used for future compliance.

The LCFS is a flexible policy tool to reduce emissions by encouraging the development and use of low-carbon transportation fuels to meet increasingly stringent annual carbon intensity benchmarks, similar to the Renewable Portfolio Standard for the electricity sector. The LCFS interacts with many different State and federal regulations. Estimating the baseline fuel demand requires accounting for compliance with existing regulations and standards, changes in fuel consumption as the fleet turns over to vehicles that meet more stringent emission standards, and the expected price of fuels in the future.

The baseline reflects the changing transportation fuel mix from implementation of State and federal laws and regulations that impact future on-road transportation fuel demand that existed or had been adopted as of Summer 2023, which include the ACF regulation, and both the existing ACC II and ACT regulations. The baseline also includes the newly signed Clean Truck Partnership. The baseline does not include any light-duty vehicle transportation fuel demand reductions that would result from successful implementation of vehicle-miles traveled (VMT) reductions. The baseline energy demand for medium- and heavy-duty sectors includes the same vehicle sales and population growth, VMT, and zero-emission technology assumptions currently reflected in CARB's latest version of its emission inventory tool, EMission FACtor 2021 (EMFAC2021). The light-duty vehicle energy demand is calculated using a combination of vehicle populations and growth modeled for the 2022 Scoping Plan Update, VMT from the Department of Motor Vehicles, and fuel efficiencies from EMFAC2021.

The most important policies that drive change in fuel demand and/or carbon intensity that are represented in the baseline are the following:

- Low Carbon Fuel Standard: Under the current LCFS, a 20% reduction in average fuel CI will be achieved by 2030. This target then remains constant for years 2030 and beyond.
- Advanced Clean Cars II: ACC II requires 100% of new vehicle sales to be zero-emission or plug-in hybrid electric by 2035 for manufacturers producing passenger cars, trucks, and SUVs.
- Advanced Clean Trucks: ACT requires truck manufacturers to sell ZEVs as an increasing percentage of their annual California sales from 2024 to 2035. By 2035, zero-emission truck/chassis sales must be 55% of Class 2b – 3 truck sales, 75% of Class 4 – 8 straight truck sales, and 40% of truck tractor sales.
- Advanced Clean Fleets: ACF requires trucking fleets to turn over their fleets to ZEV technology starting in 2024, with specific transition timelines based on fleet types. The ACF rule includes an end to combustion truck sales in 2036.

[13] The projected volumes of low-CI fuel and credits from eligible activities presented at the end of this section should be considered illustrative and only represent possible paths to achieve compliance under the given scenario conditions.

- U.S. Environmental Protection Agency's (U.S. EPA) Renewable Fuel Standard: The U.S. EPA's RFS mandates minimum volumes of renewable fuels, which are required to be blended into transportation fuels. Staff assumes that the RFS will continue to operate, providing monetary incentive for biofuels such as ethanol, biodiesel, renewable diesel, renewable natural gas, and electric vehicle deployment. While the U.S. EPA recently proposed mandated volumes for the RFS program through 2025, the program does not expire or sunset in 2025. In addition, the costs and supply variability provided across scenarios yield estimates and ranges that can account for the uncertainty in the post-2025 RFS.
- U.S. EPA Revised 2023 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emission Standards and National Highway Traffic Safety Administration (NHTSA) Corporate Average Fuel Economy (CAFE) standards for Model Years 2024-2026 Passenger Cars and Light Trucks: These regulations require vehicle manufacturers to comply with new GHG vehicle emission standards and fuel economy standards through 2026. U.S. EPA and NHTSA have also separately proposed more stringent GHG vehicle emission and fuel economy standards, respectively, for later model years.
- Inflation Reduction Act of 2022: This bill revised Section 45 of the Internal Revenue Code to establish and/or increase the tax credits available for production of low-carbon fuels and CO_2 capture and storage/sequestration.
- California Phase 2 GHG Standards for On-Road Medium- and Heavy-Duty Vehicles: This regulatory program primarily establishes greenhouse gas (GHG) emissions standards for new medium- and heavy-duty vehicles and engines.
- The requirements of Clean Energy, Jobs, and Affordability Act of 2022[14] that dictates retail electricity be supplied by zero-carbon sources equal to 90% of supply in 2035, 95% in 2040, and 100% by 2045, with State agencies required to procure 100% zero-carbon electricity in 2035.
- The longer-term requirements of the 100 Percent Clean Energy Act of 2018[15] that requires electricity be supplied by zero-carbon sources by 2045. This requirement will affect the CI of electricity.

1. California Transportation Supply Model

To compare the economic impacts of the proposed amendments and alternatives to baseline conditions, staff created an optimization model called the California Transportation Supply (CATS) model. Since CATS, and really no modeling tool, can fully capture all real-world conditions, the tool is primarily being used to compare results of different policy changes across the different scenarios. This model estimates an optimal fuel supply that may be

[14] Senate Bill 1020 (Laird, Chapter 361, Statutes of 2022). California Legislature. Clean Energy, Jobs, and Affordability Act of 2022. Signed Sept. 16, 2022. *Bill Text - SB-1020 Clean Energy, Jobs, and Affordability Act of 2022. (ca.gov)*

[15] Senate Bill 100 (De León, Chapter 312, Statutes of 2018). California Legislature. California Renewables Portfolio Standard Program: emissions of greenhouse gases. Signed Sept. 10, 2018. *Bill Text - SB-100 California Renewables Portfolio Standard Program: emissions of greenhouse gases*

delivered to California to meet a specified mobility demand in California in a given year. All policy related inputs are determined by CARB staff. The optimization model is constrained by a set of policies, technologies, and cost considerations that are intended to approximate current and future market conditions under different scenarios. Anticipated mobility demand each year is used to estimate energy demand by vehicle technology type (e.g., light-duty electric vehicle, gasoline vehicle, etc.), and the model then identifies a variety of fuel production pathways that could be optimally used to meet that demand given costs and policy considerations. Staff developed feedstock supply curves and feedstock-to-fuel conversion pathways that are detailed below.

2. Fuel Pathways and Supply

The LCFS does not specify which fuels must be used to comply with annual benchmarks. Rather, the LCFS was designed to allow flexibility on the production and use of low-carbon fuels to achieve the carbon-intensity reductions required by the regulation. To determine fuel mixes likely available for California, CATS seeks to minimize the cost of supplying all defined fuel pools such that fuel demand constraints are met. Many fuels can be produced with various feedstocks and feedstock-to-fuel conversion technologies, which have different costs and carbon intensities. Therefore, CATS includes cost assumptions for feedstock-technology-fuel combinations. See the CATS Technical Document v0.2 for a comprehensive overview of the model design and citations.[16] The model outputs include the estimated credit price per year, which staff used to project the cost of the proposed amendments.

Rather than attempting to develop an exhaustive list of all future fuel pathways and combinations, CARB focused on established, near-term fuel production pathways for which technology and cost data are available. In this way, CATS does not reflect future innovation that may occur to produce new/different low-CI fuels nor innovation that may occur to further reduce the CI or costs of the existing low-carbon fuels available. Table 3 presents each alternative fuel considered in this analysis including the feedstock from which the fuel is made, and the conversion process used to produce fuel from the feedstock (there may be multiple conversion technologies for an alternative fuel).

Table 3: Alternative Fuel Technology Pathways Included in the Baseline and the Scenario of Proposed Amendments

Alternative Fuel	Conversion Technology	Feedstock
Ethanol	Fermentation	Grains and sugar
Biodiesel	Fatty acid methyl ester conversion (FAME)	Fats, oils, and greases
Renewable diesel, jet, and gasoline	Hydrotreating	Fats, oils, and greases

[16] CARB. (2023). California Transportation Supply (CATS) model – Technical Documentation v0.2. *CATS Technical v0.2.pdf*

Alternative Fuel	Conversion Technology	Feedstock
Renewable natural gas (CNG and LNG)	Anaerobic digestion; upgrading of biogas	Landfills, dairy manure
Hydrogen	Steam methane reforming	Natural gas, renewable natural gas
Hydrogen	Electrolysis	Water
Electricity	Grid-Average	California Grid Electricity Mix
Electricity	Zero Carbon Intensity	Solar, Wind, Hydro
Electricity	Fuel Cell or combustion	Biogas

3. Fuel Pool Demand

For the CATS model to produce estimates of fuel mixes and credit prices, it optimizes fuel supply based on the energy demands within the transportation sector. Staff projected the energy demands of each fuel pool, and used the CATS model to identify the quantity of fuel that is produced through specific feedstock-technology pathways to satisfy the demand of specified fuel pools at the lowest possible cost. For the baseline scenario, seven different fuel pools were defined:

1. Gasoline fuel demand
2. Diesel fuel demand
3. Compressed natural gas (CNG) fuel demand
4. Light-duty vehicle (LDV) electricity demand
5. Heavy-Duty Vehicle (HDV) electricity demand
6. LDV hydrogen demand
7. HDV hydrogen demand
8. Jet fuel demand

For a given scenario, the model will solve for the lowest cost mixture of fuel for each of the seven fuel pools such that the overall model constraints are met. This section documents the assumptions and methods used to define fuel pool demand through 2046.

a) Gasoline Fuel Pool

Demand for California's gasoline fuel pool was estimated using the gasoline vehicle stock for light-duty ($S_{LDV,G}$) and medium-duty ($S_{MDV,G}$) vehicles and the off-road gasoline fuel demand ($D_{PW,G}$) outputs from the Scoping Plan Scenario developed for the 2022 Scoping Plan Update.[17]

The total gasoline fuel pool demand (D_G) was determined using Equation 1, where VMT_{LDV} is the average annual vehicle miles traveled (VMT) per vehicle in California's fleet as estimated using an October 2018 snapshot of California Department of Motor Vehicles (DMV) data.

[17] CARB 2022, The 2022 Scoping Plan Update for Achieving Carbon Neutrality explains the overarching framework of California's GHG policies. *2022 Scoping Plan Update (ca.gov)*

VMT_{MDV}, $FE_{LDV,}$ and FE_{MDV} are the estimated fleet-average vehicle miles traveled and fuel economies in miles per gallon, respectively, given by the EMFAC2021 v1.0.2 model for gasoline-consuming vehicles.[18] The EMFAC2007 LDV categories[19] and EMFAC2007 medium-duty vehicle (MDV)[20] categories were used for classifying vehicle characteristics to calculate these averages.

Equation 1

$$D_G = S_{LDV,G} \times \frac{VMT_{LDV,G}}{FE_{LDV,G}} + S_{MDV,G} \times \frac{VMT_{MDV,G}}{FE_{MDV,G}} + D_{PW,G}$$

To estimate average annual VMT for LDVs, the DMV data were processed to select the subset of LDVs in the State, by Vehicle Identification Number (VIN), that had two or more odometer readings at different time periods. The age for each vehicle at the time of the odometer reading was used to aggregate VMT observations, and average annual VMTs were calculated between each odometer reading. Using this approach, California's total LDV fleet was estimated to have an average VMT of 12,443 miles per vehicle per year. For the baseline scenario, which is conservative in relation to goals to reduce statewide VMT, the LDV VMT is held constant through 2045. MDV VMT is assumed to follow trends in EMFAC. The LCFS Electric Vehicle VIN Decoder was used to separate Battery Electric Vehicles and non-Battery Electric Vehicles within the DMV database.[21]

b) Diesel Fuel Pool

Demand for California's diesel fuel pool has been estimated using the diesel vehicle stock for heavy-duty ($S_{HDV,D}$) and medium-duty ($S_{MDV,D}$) vehicles and the off-road diesel fuel demand ($D_{PW,D}$) outputs from EMFAC. The total diesel fuel pool demand (D_D) was determined using Equation 2, where VMT_{HDV}, VMT_{MDV}, $FE_{HDV,}$ and FE_{MDV} are the estimated fleet-average vehicle miles traveled and fuel economies in miles per gallon, respectively, given by the EMFAC2021 v1.0.2 model for diesel-consuming vehicles.[22] The vehicle weight categories for energy aggregation used the EMFAC2007 heavy-duty vehicle classification (HHDT) and EMFAC2007 MDV classification.

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[18] CARB. (2023). *EMFAC2017 (v1.0.3) Emissions Inventory: Results*. https://arb.ca.gov/emfac/emissions-inventory/3f0f3c7489b82ed889c6b740111452af6f718923

[19] LDA, LDT1, and LDT2

[20] LHDT1, LHDT2, MHDT, MH, OBUS, SBUS, and UBUS

[21] CARB (2023). *Methodology for Calculating Base Credits for Non-metered Plug-in Electric Vehicle (PEV) Charging*. https://ww2.arb.ca.gov/sites/default/files/2023-02/Non-meteredBaseCreditsMethodology_2023update.pdf

[22] See CARB. (2023). *EMFAC2017 (v1.0.3) Emissions Inventory: Results*.

Equation 2

$$D_D = D_{HDV} \times \frac{VMT_{HDV,D}}{FE_{HDV,D}} + S_{MDV} \times \frac{VMT_{MDV,D}}{FE_{MDV,D}} + D_{PW,D}$$

c) Compressed Natural Gas Fuel Pool

Compressed natural gas energy demand is calibrated to 2022 LCFS reported volumes and assumed to follow projections in the Scoping Plan Scenario from the 2022 Scoping Plan Update.

d) Light-Duty Zero Emission Vehicles

The October 2018 DMV snapshot suggests that the average California battery electric vehicle (BEV) has an average VMT of 10,400 miles per year (84% of internal combustion engine (ICE) vehicle VMT). By 2031, staff assumed that BEVs would no longer have a substantial range or charging-time disadvantage compared to gasoline-powered LDVs and would therefore achieve 100% of the ICE vehicle VMT. Staff assumed the electrical usage rate for BEVs is 3.3 mi/kWh, which is consistent with the combined city/highway EPA fuel economy value assigned to a Tesla Model Y AWD performance vehicle. Staff assumed the annual BEV stocks and plug-in hybrid electric vehicle (PHEV) stocks modeled for the Scoping Plan Scenario in the 2022 Scoping Plan Update. PHEV all-electric miles and energy use each year were assumed to follow EMFAC2021 values. Taken together, this allowed for an estimate of the total energy demand affiliated with light-duty electric vehicles in California each year through 2046.

For fuel demand associated with hydrogen fuel cell vehicles, staff incorporated the total LDV hydrogen fuel cell stock values modeled for the Scoping Plan Scenario in the 2022 Scoping Plan Update. Hydrogen fuel cell vehicles were assumed to have the same VMT as the average California vehicle fleet, with an average energy economy ratio of 2.5 from Table 5 of the LCFS regulation compared to the ICE vehicle fleet each year.

e) Heavy-Duty Zero Emission Vehicles

For the HDV fleet, vehicle stock numbers for electric vehicles were taken from EMFAC2021 v1.0.2. To estimate the split between electric and hydrogen vehicles, which are not distinguished in EMFAC, staff applied the adjustment factors used in the Initial Statement of Reasons for the ACF Regulation. The adjustments reflect the assumption in the Initial Statement of Reasons of the ACF regulation that 10% of day cab tractors will be hydrogen until 2027 and 25% afterwards, and that sleeper cabs are split equally between electric and hydrogen vehicles. All other vehicles are assumed to be electric until 2026, and starting in 2027, assumed to be 90% electric and 10% hydrogen. The electric vehicle energy use from EMFAC2021 for the HDV vehicle fleet as categorized by EMFAC2007 categories (HHDT) was used. The heavy-duty hydrogen vehicle energy economy ratio was assumed to be 1.9 from Table 5 of the LCFS regulation. Average VMT for HDVs as specified in EMFAC2021 was used for both hydrogen and electric vehicles.

f) Intrastate Jet Fuel

For intrastate jet fuel, demand was taken using jet fuel consumption volumes shown in the baseline/reference scenario in the 2022 Scoping Plan Update.

E. Comparison of Potential Compliance Responses under the Baseline and Proposed Amendments Scenario

In this section, staff provides a comparison of potential compliance responses under both the baseline and the proposed amendments scenario. Staff first describes potential compliance responses under the baseline and then describes differences between the expected compliance responses under the proposed amendments and the baseline.

As described earlier, the baseline assumes that compliance targets are held at a 20% reduction from 2030 through 2046. Figure 3 shows the estimated fuel mix for the baseline scenario, and Figure 4 shows the estimated fuel mix for the proposed amendments. Total transportation energy demand decreases in both scenarios despite constant vehicle miles traveled, due to adoption of battery-electric and hydrogen fuel cell vehicles, which are much more energy efficient than internal combustion engine vehicles.

Figure 3: Baseline Scenario – Fuel Mix

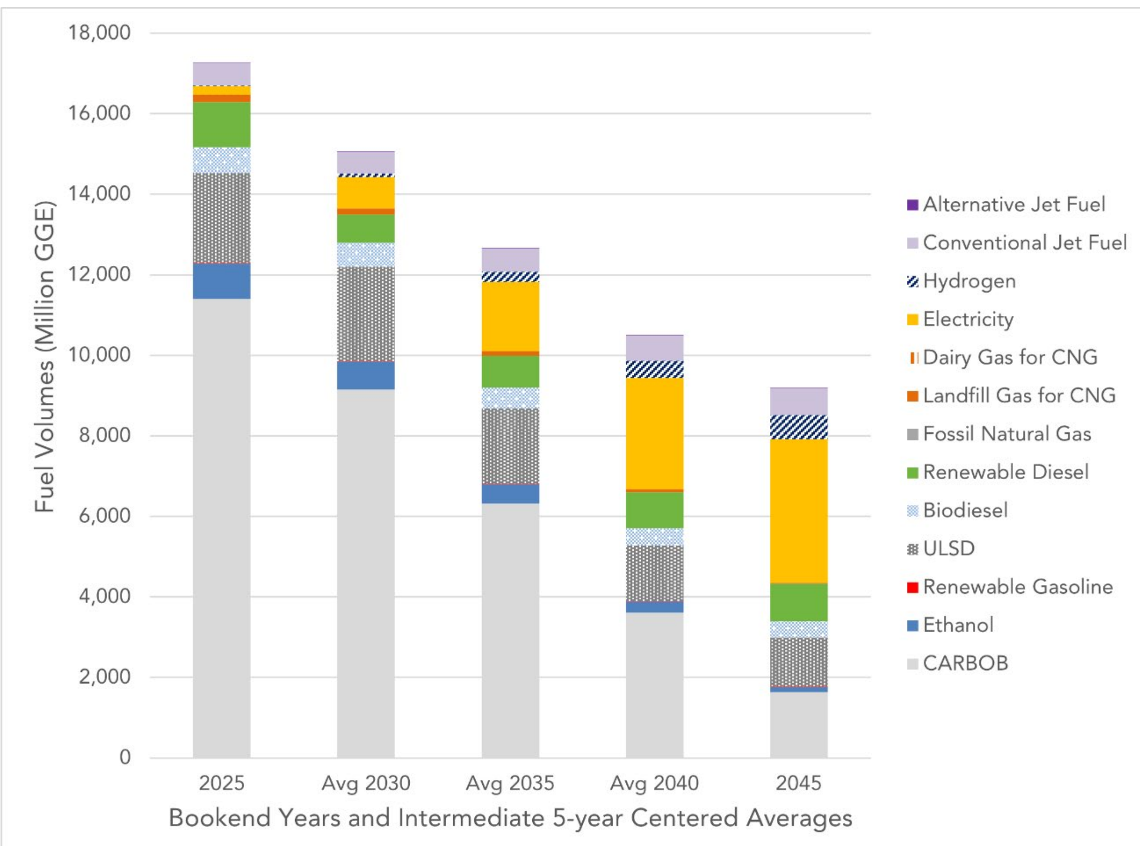
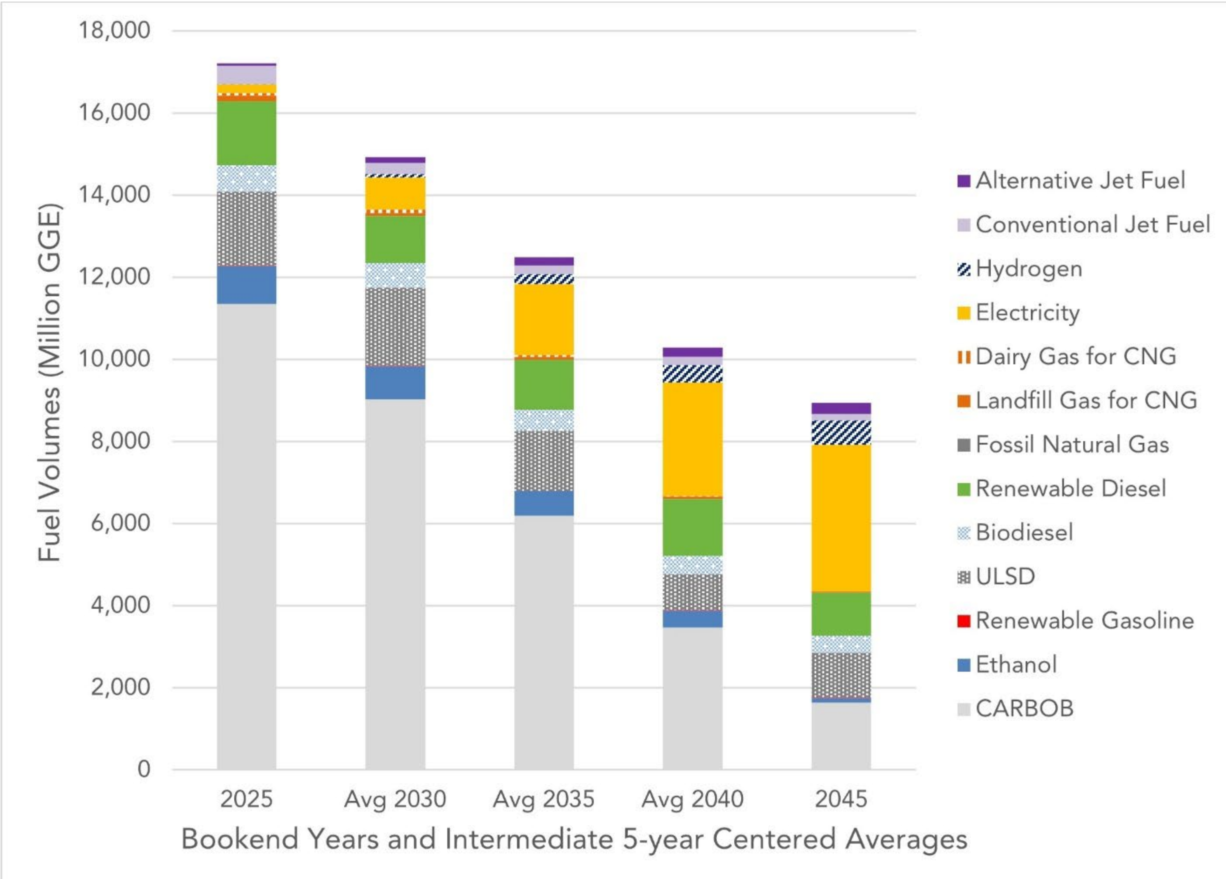


Figure 4: Proposed Amendments – Fuel Mix



The following general trends are observed from implementation of the Proposed Scenario, compared to the Baseline Scenario:

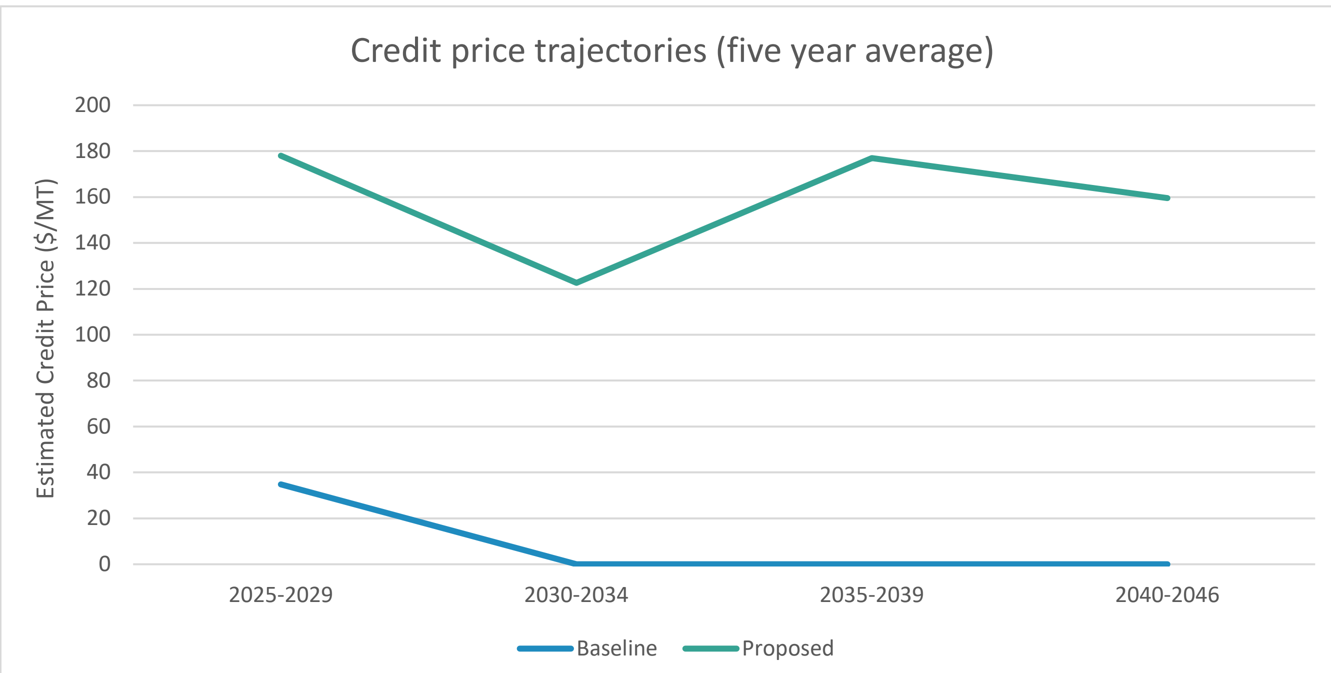
- Ultra-low sulfur diesel (fossil diesel or ULSD) consumption decreases more rapidly in the Proposed Scenario beyond the levels achieved by transitioning to ZEVs through the ACF regulation.
- Alternative jet fuel consumption in the Proposed Scenario grows significantly in response to adding fossil jet fuel as a deficit generating fuel in the program.
- The overall CI of electricity and hydrogen used in the transportation fuel pool declines as lower-carbon feedstocks and production methods come online through 2046, such as solar and wind sources and dairy biomethane used to produce electricity and hydrogen.
- The stronger credit price in the Proposed Scenario also supports more GHG reductions in the LDV fuel pool as carbon capture is deployed at ethanol facilities, further reducing the overall CI of ethanol in the Proposed Scenario.

In the proposed amendments scenario, total credits necessary for compliance in 2046, based on the 2045 calendar year, would increase from an estimated 7.2 MMT in the baseline to about

44 MMT in the proposed amendments scenario due to higher deficit generation from more stringent compliance targets. Because the proposed amendments require more credits for compliance, hydrogen production shifts from use of higher-CI feedstocks to low-CI electricity and biomethane from dairy digesters. Consumption of renewable diesel, renewable gasoline, ethanol, and biogas (used for biomethane, electricity, and hydrogen production) increases in the near-term, but declines in the later years as they eventually become deficit generating and are largely replaced by credits generated by electricity and hydrogen, in addition to direct air capture (DAC) paired with permanent sequestration.

As will be shown later in Sections III through V, the LCFS credit price plays a large role in the economic impact of the proposed amendments. The LCFS credit price is established by market participants as a function of supply and demand of credits. The LCFS credit price for each scenario was estimated based on the cost of obtaining the marginal, most expensive, credit in a given year to comply with the regulation.[23] Figure 5 shows the estimated credit price for each of the scenarios from 2025 through 2046.

Figure 5: Estimated Credit Price under Baseline and Proposed Amendments Scenarios



From 2025 to 2030, the LCFS CI reduction target increases gradually from 12.5% to 20% in the baseline scenario, whereas in the proposed amendments scenario the target increases more rapidly after a step-change in 2025 and reaches 30% reduction in 2030. In the baseline scenario, the LCFS is expected to generate significantly more credits than are needed for

[23] The method used by staff to estimate the LCFS credit price for the purpose of this analysis does not assume fully rational intertemporal pricing for the LCFS credit market. Instead, it shows possible market behavior under each scenario based on CARB staff's best estimate of LCFS market dynamics. Specifically, the LCFS credit price trajectories reflect the long-run marginal cost of reducing the carbon intensity of the transportation fuel pool. These prices should be treated as illustrative rather than predictive.

compliance with the existing carbon intensity targets. For this reason, the credit price drops to zero in the 2030 timeframe. Under the proposed amendments, the increase in compliance target stringency increases demand for credits and results in a likely increase in credit price, potentially to the maximum price of $221. The stringent post-2030 compliance targets continue to send a strong price signal to the market through the remainder of the modeled period, supporting investment in low-carbon fuels and bringing them online to achieve the LCFS benchmarks.

F. Public Outreach and Input

Staff has been engaging with the public on potential future changes to the LCFS program for several years. From October 2020 through August 2023, CARB staff conducted nine public workshops and two community meetings, in addition to numerous meetings with individual stakeholders to discuss concepts for potential proposed amendments to the LCFS regulation and address various concerns. Notices for the workshops were emailed to subscribers of the "Low Carbon Fuel Standard Program" and "Fuels (General)" listservs at least two weeks in advance of each workshop. About 11,500 individuals or companies were notified for each workshop/meeting through the existing LCFS subscription list. Details for public workshops and community meetings, including staff presentations, were posted to CARB's LCFS Meetings and Workshops webpage[24] prior to the workshops. During the workshops, staff presented concepts for public consideration and provided an opportunity for stakeholders to provide oral feedback, as well as an additional opportunity for stakeholders to provide written public feedback for at least two weeks following each workshop.[25] All written feedback is posted publicly on the LCFS Meetings and Workshop webpage. All workshops and community meetings were held virtually to allow for remote participation during the COVID-19 pandemic, which also allowed for wider participation. Staff also added community listening sessions, which has not been done previously for the LCFS. Meeting attendees included transportation fuel producers, providers, and importers; environmental justice groups; community members; academia; verification and certification bodies; consultants; and other interested persons.

These individuals participated by reviewing written material (i.e., preliminary draft regulations and other supporting documentation), providing data, and participating in workshops and meetings. Public input was used to inform and refine staff proposals, such as developing the acceleration mechanism and expanding the infrastructure crediting provision to the MHD sector. Staff also released the CATS model, which was used to evaluate the California fuel market and to assess the technological and economic feasibility of bringing low-carbon fuels to California under various scenarios, with associated technical information for public review and input. Public input through the pre-rulemaking public process assisted staff in developing the proposal. This also included input on alternative scenarios, as required under the SRIA process.

Staff's approach to public engagement follows the precedent of previous LCFS rulemakings. The previous Scoping Plan Update, approved in 2017, set the path of meeting California's

[24] *LCFS Meetings and Workshops.* https://ww2.arb.ca.gov/our-work/programs/low-carbon-fuel-standard/lcfs-meetings-and-workshops

[25] The August 16, 2023, workshop did not include a formal written comment period as it was a technical update.

2030 climate goals. In 2018, staff updated the LCFS to align with the 2017 Scoping Plan Update and the 2030 climate target. In May 2022, the draft 2022 Scoping Plan Update was released to identify a path and policies to achieve carbon neutrality and was brought to the Board for an informational Board Hearing in June 2022. This release provided a concrete goal and initiated a process with which staff could engage with the public to begin considering LCFS amendments such as the pre- and post-2030 targets. Although the 2022 Scoping Plan Update was not final at the time, staff used the draft document and Board comments to consider how the LCFS could support California's long-term carbon neutrality goal with stakeholders through workshops, while working closely with the Scoping Plan team to align the LCFS with policy direction provided by the final 2022 Scoping Plan Update. CARB approved the 2022 Scoping Plan Update in December 2022, providing high-level direction on changes needed in the LCFS. This direction played a role in developing and finalizing the proposed amendments discussed with stakeholders during public workshops and community meetings.

Table 4 lists dates for the public workshops to discuss potential future changes to the LCFS program.

Table 4: LCFS Public Workshops

Workshop	Date	Location	Time	Number of Feedback Letters Received
Workshop to discuss potential regulation revisions Day 1: Potential amendments to LCFS and potential revisions to OPGEE model Day 2: Stakeholder suggestions	Day 1: October 14, 2020 Day 2: October 15, 2020	Virtual via GoToWebinar	Day 1: 9am – 12pm Day 2: 9am – 1pm	135
Workshop to discuss guiding principles for potential future changes to LCFS program, including establishing post-2030 targets, phasing out petroleum projects, adding intrastate jet fuel, supporting hydrogen refueling infrastructure for MHD vehicles, and streamlining implementation	December 7, 2021	Virtual via GoToWebinar	9am – 12:30pm	106
Workshop to discuss potential changes to Crude Oil Carbon Intensity Estimation under the LCFS regulation	April 26, 2022	Virtual via GoToWebinar	9am – 10:30am	7
Workshop to discuss potential changes to the LCFS, including considerations for adjustments to compliance targets, MHD infrastructure crediting	July 7, 2022	Virtual via GoToWebinar	9am – 1pm	131

Workshop	Date	Location	Time	Number of Feedback Letters Received
Workshop to discuss potential opportunities to streamline implementation and potential updates to emission factors, verification, and electric vehicle base credit methodology	August 18, 2022	Virtual via GoToWebinar	9am – 12pm	76
Workshop to discuss options for increasing stringency of the carbon intensity targets for 2030 and beyond, MHD infrastructure crediting, biomethane policies, design of initial modeling scenarios, describe modeling approach, and soliciting alternatives	November 9, 2022	Virtual via GoToWebinar	9am – 1pm	155
Workshop to discuss potential credit generation opportunities that may affect carbon intensity targets, present preliminary fuel mix and cost outputs from CATS model, and present concepts related to streamlining implementation	February 22, 2023	Virtual via GoToWebinar	9am –3pm	154
Workshop to discuss ways to design an CI benchmark acceleration mechanism	May 23, 2023	Virtual via Zoom	9am – 12pm	45
Community meetings for community members to hear an overview of the LCFS program and provide input on potential future LCFS changes with CARB staff	May 31 and June 1, 2023	Virtual via Zoom	6pm – 8pm	17
Technical workshop to discuss modeling updates	August 16, 2023	Virtual via Zoom	9am – 11am	NA

In addition, CARB staff participated in numerous stakeholder meetings sponsored by other parties, presenting information on the implementation of the existing regulation and exploring potential amendments.

The LCFS website has been updated and improved since the beginning of the program to increase public participation and enhance the information flow between CARB staff and interested parties. Staff has consistently made available online materials related to this rulemaking, including meeting presentations, preliminary draft regulatory language, and LCA models and tools used in assessing fuel and feedstock availability to inform the proposed carbon intensity benchmarks. The website also provides background information on the LCFS, workshop and meeting notices and materials, other GHG-related information, and links to other websites with related information. The website also includes feedback letters from stakeholders in response to the public workshops and community meetings that informed the development of the proposed amendments.

CARB staff will continue to accept public feedback, including public comments that staff will invite on the rulemaking proposal, as well as engagement at public workshops and Board meetings, and will continue to consider changes to the rulemaking proposal based on stakeholder input. The updated estimated economic impact of a final proposal, if adopted (including any modifications to the current proposed amendments that occur during the regulatory process) will be analyzed in the Economic and Fiscal Impact Statement (STD 399) submitted to the Department of Finance and Office of Administrative Law with the final regulatory package.

II. Benefits

CARB anticipates that the proposed amendments, including the CI reductions outlined in Section I.B.1, will have the following general benefits to California businesses and individuals:

- Reduced GHG emissions near and long-term. The LCFS is specifically designed to reduce GHG emissions in the transportation sector, which is responsible for nearly half of GHG emissions in California. This will contribute to California’s efforts to address climate change.
- Increased use of lower CI fuels and alternative fueled vehicles including renewable diesel, biomethane, and lower CI electricity and hydrogen for ZEVs. In addition to reducing GHG emissions, this will in many cases lower levels of localized air pollutants, which are the cause of many deleterious health effects on California residents.
- Greater opportunities for California businesses to invest in the production of low-CI fuels and other credit generating opportunities.
- Reduced dependence on fossil fuels and support a diversified transportation fuel pool.

In the following sections, staff describes the estimated benefits of the proposed amendments to California businesses, small businesses, and individuals.

A. Emission Benefits

The proposed amendments will reduce GHG emissions and smog-forming and toxic air pollutants from the transportation sector by shifting to low-CI fuels which, in many cases, also release fewer pollutants when combusted than fossil fuels.

Reductions in GHG emissions and improvements in California air quality under the proposed amendments are anticipated to result in fewer damages due to climate change and in health benefits for California individuals. These health benefits result in cost savings to individuals, businesses, and government agencies due to fewer premature mortalities, fewer hospital and emergency room visits, and fewer lost days of work.

When combusted, transportation fuels emit harmful pollutants, which this proposal would help to eliminate. These pollutants include NOx and fine particulate matter (PM2.5). NOx is a precursor to ozone and secondary particulate matter formation. Exposure to ozone and to

PM2.5, which are inhalable particles with diameters that are generally 2.5 micrometers and smaller, is associated with increases in premature death, hospitalizations, visits to doctors, use of medication, and emergency room visits due to exacerbation of chronic heart and lung diseases and other adverse health conditions.

As noted earlier, the baseline includes the technology changes that are expected from implementation of on-road light-duty (ACC II), on-road heavy-duty (ACT and ACF), and off-road (At-Berth and TRU) regulations. In this SRIA, staff analyzed the benefits from the proposed changes to the LCFS regulation incremental to the baseline. Those benefits from the proposed changes to the LCFS regulation incremental to the baseline include quantification of the upstream emissions benefits of reduced California oil and gas extraction, which staff estimates will come from reduced demand for petroleum fuels in the future. During the COVID-19 pandemic and the stay-at-home orders, there was a drastic reduction in demand for petroleum fuels as residents stayed home. Data collected under the Regulation for the Mandatory Reporting of Greenhouse Gas Emissions for 2020 and 2021 show a reduction in oil and gas sector GHG emissions relative to previous years.[26] The most recent published AB 32 Annual GHG Inventory also shows a 13% reduction in oil and gas sector emissions from 2019 to 2020.[27] As such, a reduction in GHG, criteria, and toxic emissions from oil and gas extraction is expected to result from corresponding petroleum fuel demand reductions, further expanding the benefits of this regulation.

The methodology used to estimate the emissions impact and the incremental impacts of the proposed amendments (relative to the baseline) are detailed in the following section and in Appendix B.

1. Inventory methodology

In addition to fuel volumes, deficits, and credits generated by each fuel, the CATS model also provides the CI of each fuel pool in its outputs. Therefore, staff calculated GHGs associated with each scenario by multiplying fuel quantities by their respective CI. Staff also quantified upstream emission reductions that would result from reduced oil and gas extraction at California oil fields associated with reduced demand for transportation fuels, as projected by the CATS model.

The potential substitution from fossil fuels to low-CI electricity, hydrogen, natural gas, and liquid biofuels associated with the proposed amendments to the regulation may also result in changes in criteria pollutants and toxics due to expected emissions changes from 1) renewable feedstock transportation, 2) renewable fuel refining, 3) renewable fuel delivery, 4) tailpipe emissions, and 5) upstream oil and gas extraction. Criteria pollutants are estimated using a variety of tools including CARB's California Emissions Projection Analysis Model (CEPAM) 2019 Ozone SIP v.1.04, the on-road vehicle emission inventory tool EMFAC2021 v.1.02, CA-GREET 3.0, and CEIDARS 2020 Static.

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[26] *Mandatory Greenhouse Gas Reporting 2021 Emissions Year Frequently Asked Questions (ca.gov)*

[27] *California Greenhouse Gas Emissions for 2000 to 2020 Trends of Emissions and Other Indicators*

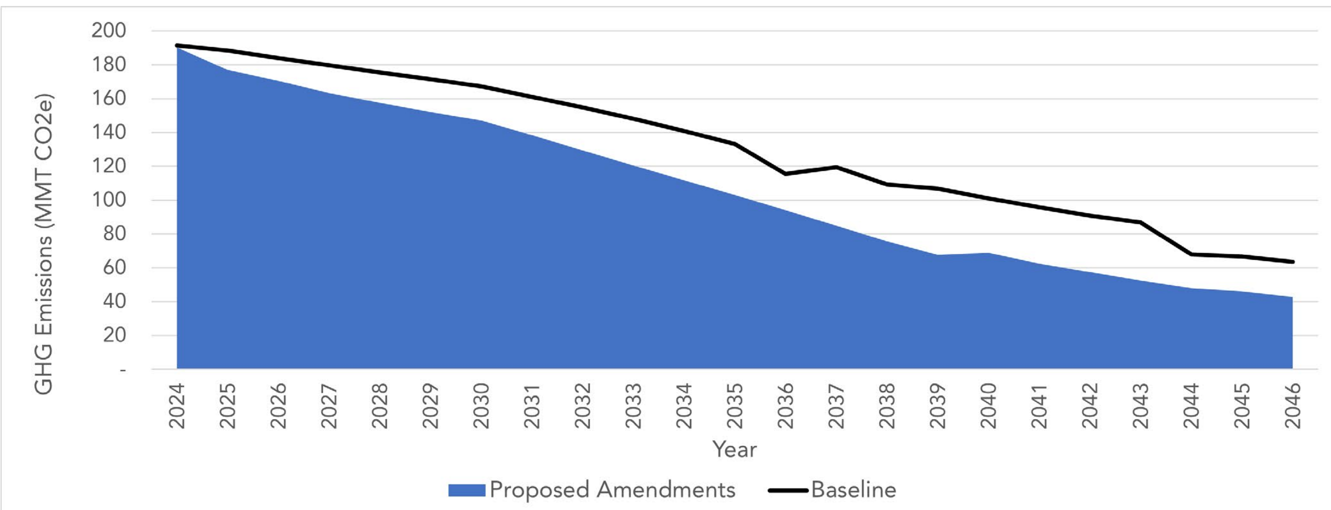
The full methodology used to estimate the changes in criteria emissions is detailed in Appendix B.

2. GHG Emissions Benefits of the Proposed Amendments

Figure 6 summarizes the annual life cycle GHG emissions reductions under the baseline and the proposed amendments scenario. Staff expects the proposed amendments to reduce GHG emissions relative to the baseline by 558 million metric tons in carbon dioxide equivalent ($MMTCO_2e$) from 2024 through 2046. It is important to note that because the LCFS calculates emission reductions on a full life cycle basis, the GHG emission reductions occur both in California and out-of-state.

These GHG reduction estimates are derived from CATS outputs of the fuel quantities and average annual CI associated with each fuel, as well as GHG reductions associated with oil and gas extraction emissions.

Figure 6: Annual GHG Emissions of Baseline and Proposed Amendments



3. Criteria Pollutant Emission Benefits of Proposed Amendments

The proposed amendments would affect air quality through four main categories: 1) changes in tailpipe emissions for on-road and off-road vehicles, 2) changes in aircraft emissions at airports, 3) changes in emissions at stationary sources from fuel production, and 4) changes in upstream emissions associated with oil and gas extraction where quantified (see Section II.A for more information on limited stationary source analysis).

Fossil fuels contain benzene, toluene, ethyl benzene, and xylenes (BTEX compounds), which can be emitted to the air and contaminate soil and water. Gasoline-engine exhaust contains benzene, 1,3-butadiene, formaldehyde, and acetaldehyde. Diesel-engine exhaust contains diesel particulate matter, which is a toxic air contaminant (TAC). Generally, all exhaust from the combustion of hydrocarbon fuels contains benzene as a product of incomplete combustion (PIC). Staff expects reductions in these criteria pollutants and toxics due to decreased use of fossil fuels in regions with heavy use of motor vehicles and diesel engines, such as big population centers (e.g., South Coast) and areas with heavy truck use (San Joaquin Valley).

Reducing criteria pollutants and toxic emissions from fuel combustion in line with California's air quality goals requires deploying ZEVs and ensuring the availability of fueling infrastructure to support ZEV deployment. In this SRIA, CARB staff estimated air quality benefits attributable to the proposed amendments. The emissions analysis includes expected reductions in emissions from upstream oil and gas extraction that would be expected to result from corresponding petroleum fuel demand reductions. First, staff estimated upstream extraction-based criteria pollutant emission changes associated with reduced petroleum demand. To estimate the emission benefits of reduced upstream oil extraction, staff focused on the proportion of demand reduction associated with fossil diesel declines expected from the LCFS proposal, given that staff expects diesel demand may persist longer than gasoline demand in California and future in-state extraction reductions may be limited by the pace of diesel demand reductions. The reductions shown in Tables 5 and 6 also include estimated changes in emissions that occur from changes in renewable fuel use in vehicles, feedstock transport, and changes in renewable fuel production.

In summary, the proposed amendments achieve reductions of PM2.5 and NOx through 2046, summarized in Table 5 and

Table 6. These emissions reductions are driven in part by increased use of renewable diesel and alternative jet fuel, which displace fossil diesel and fossil jet fuel. As noted earlier, emissions reductions from phasing down oil extraction and refining operations in tandem with petroleum demand reductions are included in this analysis. In total, the proposed amendments achieve reductions of 4,108 tons of PM2.5 and 17,397 tons of NOx in aggregate through 2046.

Table 5: NOx Emission Changes under the Proposed Amendment Scenario (tons per day)

Year	NOx (tpd)
2024	-0.214
2025	-0.923
2026	-0.968
2027	-0.980
2028	-1.108
2029	-1.154
2030	-1.385
2031	-1.660
2032	-1.786
2033	-1.850
2034	-1.928
2035	-2.093
2036	-2.209
2037	-2.360
2038	-2.525
2039	-2.615
2040	-2.823
2041	-2.907
2042	-2.988
2043	-3.097
2044	-3.210
2045	-3.377
2046	-3.471

Table 6: PM2.5 Emission Changes under the Proposed Amendment Scenario (tons per day)

Year	PM2.5 (tpd)
2024	-0.069
2025	-0.225
2026	-0.258
2027	-0.292
2028	-0.358
2029	-0.326
2030	-0.251
2031	-0.371
2032	-0.418
2033	-0.413
2034	-0.423
2035	-0.445
2036	-0.456
2037	-0.492
2038	-0.582
2039	-0.614
2040	-0.768
2041	-0.771
2042	-0.717
2043	-0.737
2044	-0.758
2045	-0.738
2046	-0.766

B. Benefits to Typical California Businesses

The proposed amendments will increase the demand for low-carbon fuels, which provides an opportunity for businesses, both in-state and out-of-state, to increase revenue from the sale of low-carbon fuels in California. Table 7 shows the potential LCFS credit revenue for several low-carbon fuels in 2025, 2030, 2035, 2040, and 2045. To allow comparison across fuels, the potential revenues are expressed as an equivalent gallon of either gasoline (GGE) or diesel (DGE) that the low-CI fuel displaces. The sale of LCFS credits provides an additional revenue stream for these firms, enabling them to increase their market share and increase their competitiveness against high-CI fuels such as fossil gasoline or diesel.[28] In Table 8, staff monetized the value of the revenues generated by both in-state and out-of-state low-CI fuels. The value will vary based on the actual credit price.

Table 7: Value Added from LCFS Credit for Low Carbon Fuels under the Proposed Amendments

Fuel	Average CI Value (gCO_2e/MJ)	2025	2030	2035	2040	2045	Units
*Proposed Amendments Estimated Credit Price**		*$221*	*$76*	*$138*	*$221*	*$105*	$/MT
Corn Ethanol	55	0.75	0.13	-0.01	-0.53	-0.55	$/gge
Hydrogen**	8	5.18	1.46	2.05	2.00	0.20	$/gge
Electricity**	64	5.68	1.52	1.93	1.36	-0.37	$/gge
Biodiesel	40	1.34	0.31	0.28	-0.15	-0.42	$/dge
Renewable Diesel	44	1.22	0.27	0.20	-0.27	-0.48	$/dge
Landfill NG	45	0.94	0.19	0.08	-0.41	-0.51	$/dge
Dairy NG	-293	10.98	3.64	6.35	NA***	NA	$/dge

* The following EERs were used for this calculation: 2.5 for hydrogen, 3.4 for electricity, and 0.9 for landfill NG and dairy NG.[29]

** Hydrogen CI shown is the average of all hydrogen pathways as of 2023 in the CATS model. Electricity CI is the average value from SP projections from 2023-2046.

*** Dairy NG is not a selected fuel starting in 2040, when avoided methane crediting is phased out.

Moreover, LCFS incentives may encourage California firms to invest early in innovative, low-CI fuel technologies and develop mature businesses earlier than firms outside of California, resulting in competitive advantages to these businesses as other state, federal, or international

[28] The LCFS incentive is incremental to incentives created by federal biofuel/low-carbon fuel policy, including the RFS.

[29] "Energy Economy Ratio (EER)" means the dimensionless value that represents the efficiency of a fuel as used in a powertrain as compared to a reference fuel. EERs are often a comparison of miles per gasoline gallon equivalent (mpge) between two fuels.

jurisdictions adopt similar carbon intensity standards.[30] The proposed amendments will also help promote a wider range of clean fuels and vehicles for California businesses to choose from, including vehicles operating on electricity, hydrogen, and biomethane.

The proposed amendments also benefit California fuel providers that have compliance obligations under the Cap-and-Trade Program. As the LCFS reduces the CI of fuels, it changes the composition of the State's transportation fuel mix and dependence on traditional petroleum-based fuels. CARB designed the LCFS and Cap-and-Trade Programs to complement one another. Investments made to comply with one of the programs will generally result in reduced compliance requirements for the other program. Increased use of low-carbon fuel due to the LCFS will reduce fuel suppliers' GHG emissions covered by the Cap-and-Trade Program, reducing the Cap-and-Trade Program compliance obligation of these firms. Similarly, selling cleaner fuels or investing in emission reduction projects at California refineries and oil fields to comply with the Cap-and-Trade Program may also generate credits under the LCFS.

Table 8 summarizes the estimated increase in revenue to small and typical credit generating California companies[31] from the sale of LCFS credits due to the proposed amendments. To apportion credits between in-state and out-of-state businesses, staff used an assumed percentage for production in-state and out-of-state for each fuel type, which is detailed in Table 48 in Appendix B. Cumulatively, from 2024 through 2046, the proposed amendments are estimated to increase total revenue for credit generating businesses as compared to the baseline scenario by $149 billion, of which approximately $128 billion is estimated to accrue to California businesses.

Table 8: Estimated Increase in Revenue from LCFS Credit Sales under the Proposed Amendments Relative to Baseline (million 2021$)

Year[32]	Typical California Businesses	California Small Business	Total California Businesses	Out-of-State Businesses	Total California and Out-of-State
2024	298	2	301	166	467
2025	4,108	19	4,127	1,326	5,454
2026	4,329	19	4,348	1,532	5,880
2027	4,019	15	4,034	1,290	5,325
2028	4,221	16	4,237	1,111	5,348
2029	4,016	15	4,031	951	4,982
2030	2,697	9	2,706	511	3,217

[30] Currently Oregon, Washington, British Columbia, Canada, Brazil, and the European Union have LCFS-like policies in place.

[31] "Typical credit generating California companies" are all California credit generators, excluding small businesses with less than 100 employees and earning less than 10 million in annual revenue.

[32] Years shown are samples from the regulatory period of 2024-2046. "Total" is the cumulative sum of revenues in all years from 2024 to 2046.

Year[32]	Typical California Businesses	California Small Business	Total California Businesses	Out-of-State Businesses	Total California and Out-of-State
2031	4,769	15	4,784	732	5,516
2032	5,681	16	5,697	819	6,516
2033	6,033	16	6,050	735	6,785
2034	6,215	16	6,232	731	6,963
2035	6,426	16	6,443	635	7,078
2036	6,633	16	6,649	500	7,149
2037	8,895	22	8,918	708	9,625
2038	9,304	24	9,328	724	10,052
2039	9,733	26	9,760	765	10,525
2040	8,041	26	8,067	-	8,067
2041	8,827	26	8,853	1,353	10,206
2042	7,158	22	7,180	1,286	8,466
2043	5,676	19	5,695	1,244	6,939
2044	4,346	15	4,361	1,195	5,556
2045	3,357	12	3,370	1,245	4,614
2046	3,234	12	3,246	1,064	4,310
Total	**128,017**	**399**	**128,416**	**20,623**	**149,040**

C. Benefits to Small Businesses

Staff defines small businesses as independently owned businesses located in California, with 100 employees or less and annual revenues under $10 million.

In addition to the benefits already discussed for California businesses, CARB estimates that small businesses will see benefits from the proposed amendments. Many of California’s biodiesel producers, hydrogen producers, electric charging stations, hydrogen stations, and natural gas stations are small businesses. Staff identified the following small businesses in California, which represented 8% of the LCFS parties registered in the LCFS in September 2021:

- Two biodiesel providers
- Six natural gas (CNG and LNG) fueling station operators
- 21 electric charging station operators
- One propane provider

In total, these small businesses generated approximately 119,000 LCFS credits in 2021, which provided an estimated $22 million in credit revenue as estimated using the 2021 average LCFS credit price of $188.

The proposed amendments will increase the demand for low-CI fuels and are anticipated to increase the prices for LCFS credits relative to the baseline, thereby increasing revenue to these small businesses. In addition, larger potential revenue resulting from the proposed amendments may allow other small businesses to enter the market. Therefore, staff kept the 2021 credit total of 119,000 as a static proxy for future small business credit generation.

D. Benefits to Individuals

The proposed amendments will benefit California residents mainly from reductions in GHG emissions and from improvements in California air quality.

1. Social Cost of Carbon

The benefit of GHG reductions achieved by the proposed amendments can be estimated using the social cost of carbon (SC- CO_2), 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.

The U.S. Council of Economic Advisors and the Office of Management and Budget convened an Interagency Working Group on the Social Cost of Greenhouse Gases (IWG) to develop a methodology for estimating the SC- CO_2. The methodology relies on a standardized range of assumptions and can be used consistently when estimating the benefits of regulations across agencies and around the world.[33] Staff used the current IWG-supported SC- CO_2 values to consider the social costs of actions taken to reduce GHG emissions. This is consistent with the approach presented in the 2022 Scoping Plan Update, is in line with U.S. Government Executive Orders including 13990 and the Office of Management and Budget Circular A-4 of September 17, 2003, and reflects the best available science in the estimation of the socio-economic impacts of carbon.[34,35]

The IWG describes the social cost of carbon as follows:

> “The social cost of carbon (SC- CO_2) 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 (CO_2) emissions into the atmosphere in that year, or equivalently, the benefits of reducing CO_2 emissions by the same amount in that year. The SC- CO_2 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 CO_2.

[33] Additional technical detail on the IWG process is available in the Technical Updates of the Social Cost of Carbon for Regulatory Impact Analysis – Under Executive Order 12866 (*Revised July 2015 version* and *August 2016 version*) by the Interagency Working Group on Social Cost of Greenhouse Gases, United States Government.

[34] CARB. (2022). *2022 Scoping Plan for Achieving Carbon Neutrality.* https://ww2.arb.ca.gov/sites/default/files/2022-12/2022-sp.pdf

[35] Office of Management and Budgets. (2003). *Circular A-4*. https://www.transportation.gov/sites/dot.gov/files/docs/OMB%20Circular%20No.%20A-4.pdf

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 CO_2 emissions today will affect economic outcomes throughout the next several centuries."[36]

The SC- CO_2 is year-specific and is highly sensitive to the discount rate used to adjust the value of the damages in the future due to CO_2. The SC- CO_2 increases over time as systems become more stressed from the aggregate impacts of climate change and future emissions cause incrementally larger damages. A higher discount rate decreases the value today of future environmental damages. This analysis uses the IWG standardized range of discount rates from 2.5 to 5% to represent varying valuation of future damages. Table 9 shows the range of IWG SC- CO_2 values (CPI adjusted) used in California's regulatory assessments which reflect the societal value of reducing carbon emissions by one metric ton.[37]

Table 9: SC- CO_2 Discount Rates (in 2021$ per Metric Ton of CO_2)

Year	5% Discount Rate	3% Discount Rate	2.5% Discount Rate
2020	$16	$57	$85
2025	$19	$63	$93
2030	$22	$68	$100
2035	$25	$75	$107
2040	$29	$82	$115
2045	$31	$88	$122
2050	$36	$94	$130

The GHG reductions due to the proposed amendments are calculated in CO_2e which includes reductions in carbon, methane, and other GHGs. As the CI of a fuel is based on a life cycle assessment of GHG emissions from the use of a fuel converted to CO_2e units, there is not a simple way to assess the breakdown of emissions reduction by GHG (i.e., CO_2, methane, or other GHG) due to the proposed amendments.

As there is no Social Cost of CO_2e, there is not a straightforward metric to estimate the benefits of the proposed amendments. If all GHG reductions under the proposed amendments are assumed to be carbon dioxide reductions, the cumulative estimated benefits from the proposed amendments would range from approximately $14 billion to $61 billion (in 2021$). In Table 10, staff calculated the avoided SC- CO_2 values (2021$) by applying values in Table 9 to the annual GHG emissions change.

[36] National Academies of Sciences, Engineering, Medicine. (2017). *Valuing Climate Damages: Updating Estimation of Carbon Dioxide.* 5-6. http://www.nap.edu/24651

[37] U.S. Government Interagency Working Group on Social Cost of Greenhouse Gases (2021). *Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under Executive Order 13990*. https://www.whitehouse.gov/wp-content/uploads/2021/02/TechnicalSupportDocument_SocialCostofCarbonMethaneNitrousOxide.pdf

Table 10: Avoided Social Cost of CO_2 from Proposed Amendments 2024-2046 (million 2021$)

Year	GHG Emission Reductions (MMT)	5% Discount Rate	3% Discount Rate	2.5% Discount Rate
2026	13	$254	$852	$1,250
2030	20	$438	$1,368	$1,997
2034	29	$716	$2,149	$3,065
2038	34	$921	$2,670	$3,775
2042	33	$1,008	$2,794	$3,939
2046	21	$680	$1,841	$2,550
Total	**558**	**$14,544**	**$43,045**	**$61,099**

It is important to note that the SC- CO_2, while intended to be a comprehensive estimate of the damages caused by carbon globally, does not represent the cumulative cost of climate change and air pollution to society. There are additional costs to society outside of the SC- CO_2, including costs associated with changes in co-pollutants and the social cost of other GHGs including methane and nitrous oxide. The IPCC has stated that the IWG SC- CO_2 estimates are likely underestimated due to the omission of significant impacts that cannot be accurately monetized, including important physical, ecological, and economic impacts.[38]

As mentioned, the SC- CO_2 calculation incorporates GHG emission reductions associated with methane reductions from the regulation. The LCFS supports CARB's work to meet Short Lived Climate Pollutant (SLCP) targets set by Senate Bill 1383 (Lara, Chapter 395, Statutes of 2016) by incentivizing dairies to capture and convert methane-rich biogas into transportation fuels (compressed natural gas, hydrogen, and electricity). Methane is a potent climate pollutant with a Global Warming Potential (GWP) 25 times higher than CO_2. CARB staff used the SC-CH4 values provided by the IWG, adjusted to 2021$, shown in Table 11 to estimate the avoided social cost of in-state methane converted to fuel. These values are consistent with the 2021 IWG interim numbers but adjust for inflation using California CPI. Staff use conversion factors from the Livestock Offset Protocol[39] and U.S. Energy Information Administration (EIA)[40] to calculate the methane emission reductions associated with in-state dairy biogas volumes from the CATS model outputs, resulting in a conversion factor of 0.020 metric tons of methane per British thermal unit (0.020MT/Btu).

[38] U.S. Environmental Protection Agency. (2016). *Social Cost of Carbon Fact Sheet*. https://www.epa.gov/sites/default/files/2016-12/documents/social_cost_of_carbon_fact_sheet.pdf

[39] CARB (2014). *Compliance Offset Protocol Livestock Projects*. https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2014/capandtrade14/ctlivestockprotocol.pdf

[40] U.S. Energy Information Administration (2023). *Energy Conversion Calculators* (updated June 1, 2023). https://www.eia.gov/energyexplained/units-and-calculators/energy-conversion-calculators.php. Accessed on 8/4/2023.

Table 11: Social Cost of Methane Discount Rates (in 2021$ per Metric Ton of CH_4)

Year	5% Discount Rate	3% Discount Rate	2.5% Discount Rate
2020	$739	$1,641	$2,188
2025	$889	$1,915	$2,462
2030	$1,039	$2,188	$2,735
2035	$1,231	$2,462	$3,146
2040	$1,368	$2,735	$3,556
2045	$1,641	$3,146	$3,830
2050	$1,778	$3,419	$4,240

Table 12 presents a sampling of years of avoided social cost of in-state methane, and the cumulative total avoided social cost in-state from 2024 to 2046, from the proposed amendments. The cumulative estimated benefits from the proposed amendments would range from approximately $3.8 billion to $9.7 billion (in 2021$).

Table 12: Avoided Social Cost of Methane from Proposed Amendments 2024-2046 (million 2021$)

Year	CH_4 Emission Reductions (MT)	5% Discount Rate	3% Discount Rate	2.5% Discount Rate
2026	196,000	$193	$402	$537
2030	140,000	$157	$325	$402
2034	210,000	$268	$547	$691
2038	268,000	$367	$734	$954
2042	0	0	0	0
2046	0	0	0	0
Total	**3,092,000**	**$3,767**	**$7,639**	**$9,663**

2. Health Benefits

The proposed amendments to the Low Carbon Fuel Standard regulation would reduce PM2.5 and NOx emissions, resulting in health benefits in California. CARB analyzed the value of health benefits associated with 12 health outcomes, most of which were added or updated through CARB's recent expansion of the health analysis[41]: cardiopulmonary mortality, acute myocardial infarction, lung cancer incidence, asthma onset, asthma symptoms, hospitalizations for cardiovascular illness, hospitalizations for respiratory illness, hospitalizations for Alzheimer's disease, hospitalizations for Parkinson's disease, cardiovascular emergency department (ED) visits, respiratory ED visits, and work loss days.

[41] CARB (2022). *California Air Resources Board Updated Health Endpoints Bulletin*. https://ww2.arb.ca.gov/sites/default/files/2022-11/California%20Air%20Resources%20Board%20Updated%20Health%20Endpoints%20Bulletin%20-%20Edited%20Nov%202022_0.pdf

These health outcomes have been identified by U.S. EPA as having a causal or likely causal relationship with exposure to PM2.5 based on a substantial body of scientific evidence.[42,43] U.S. EPA has determined that both long-term and short-term exposure to PM2.5 plays a causal role in premature mortality, meaning that a substantial body of scientific evidence shows a relationship between PM2.5 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. U.S. EPA has also determined a causal relationship between non-mortality cardiovascular effects (e.g., acute myocardial infarction) and short- and long-term exposure to PM2.5, a likely causal relationship between non-mortality respiratory effects (including worsening asthma) and short- and long-term PM2.5 exposure, and a likely causal relationship between non-mortality neurological effects and long-term PM2.5 exposure.

CARB staff evaluated health impacts associated with exposure to PM2.5 and NOx emissions from the proposed amendments. NOx includes nitrogen dioxide, a potent lung irritant, which can aggravate lung diseases such as asthma when inhaled.[44] However, the most serious quantifiable impacts of NOx emissions occur through the conversion of NOx to fine particles of ammonium nitrate aerosols through chemical processes in the atmosphere. PM2.5 formed in this manner is termed secondary PM2.5. Both directly emitted PM2.5 and secondary PM2.5 are associated with adverse health outcomes**.** As a result, reductions in PM2.5 and NOx emissions are associated with reductions in these adverse health outcomes.

Emission reductions from on-road vehicles and other sources were combined for health benefit quantification using the IPT method, described below. To estimate the reductions in primary PM2.5 from sources other than on-road vehicles, relative statewide potency factors were applied, derived from a CARB contract report that had evaluated exposures from multiple sources in California.[45] To account for the difference in population exposure of different sources of emissions compared to on-road vehicle emissions, emissions from Biofuel Production (Dairies), Biofuel Production (Refineries), Fuel Production from Fossil Natural Gas, and Alternative Jet Fuels were multiplied by 0.11, 0.63, 0.63, and 0.94, respectively. Emissions from these sources, released relatively further away from residential areas, are expected to result in lower impacts than emissions from motor vehicles on roadways that run through residential neighborhoods.

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[42] U.S. EPA. (2019). *Integrated Science Assessment for Particulate Matter* (Issue EPA/600/R-19/188). Center for Public Health and Environmental Assessment, Office of Research and Development. https://cfpub.epa.gov/ncea/isa/recordisplay.cfm?deid=347534

[43] U.S. EPA. (2021). *Estimating PM2.5- and Ozone-Attributable Health Benefits. (*Technical Support Document (TSD) for the Final Revised Cross-State Air Pollution Rule Update for the 2008 Ozone Season NAAQS). Office of Air and Radiation. https://www.epa.gov/sites/default/files/2021-03/documents/estimating_pm2.5-_and_ozone-attributable_health_benefits_tsd_march_2021.pdf

[44] U.S. EPA. (2016). *Integrated Science Assessment for Oxides of Nitrogen – Health Criteria* (EPA/600/R-15/068). https://www.epa.gov/isa/integrated-science-assessment-isa-oxides-nitrogen-health-criteria

[45] Apte, J. S., Chambliss, S. E., Tessum, C. W., & Marshall, J. D. (2019). A Method to Prioritize Sources for Reducing High PM2.5 Exposures in Environmental Justice Communities in California. CARB Contract Number 17RD006. https://ww2.arb.ca.gov/sites/default/files/classic/research/apr/past/17rd006.pdf

a) Incidence-Per-Ton Methodology

CARB uses the incidence-per-ton (IPT) methodology to quantify the health benefits of emissions reductions in cases where dispersion modeling results are not available. A description of this method is included on CARB's webpage.[46] CARB's IPT methodology is based on a methodology developed by U.S. EPA.[47,48,49]

Under the IPT methodology, it is assumed that changes in emissions are approximately proportional to changes in health outcomes. IPT factors are derived by calculating the number of health outcomes associated with exposure to PM2.5 for a baseline scenario using measured ambient concentrations and dividing by the emissions of PM2.5 or a precursor. The calculation is performed separately for each air basin using the following equation:

Equation 3: Incidence-per-ton calculation

$$IPT = \frac{number\ of\ health\ outcomes\ in\ air\ basin}{annual\ emissions\ in\ air\ basin}$$

Multiplying the emissions reductions from the proposed amendments in an air basin by the IPT factor then yields an estimate of the reduction in health outcomes achieved by the proposed amendments. For future years, the number of outcomes is adjusted to account for population growth. CARB's current IPT factors are based on a 2014-2016 baseline scenario, which represents the most recent data available at the time the current IPT factors were computed. IPT factors are computed for the two types of PM2.5: primary PM2.5 and secondary PM2.5 of ammonium nitrate aerosol formed from precursors.

b) Updated Information on Health Impact Analysis

CARB recently initiated an expanded health analysis to include additional health endpoints in order to provide a more comprehensive analysis of the benefits of the agency's plans and regulations. A description of the updated and new health outcomes was provided in CARB's Updated Health Endpoints Bulletin, released November 2022.[50] This expansion was based on U.S. EPA's Technical Support Document (TSD) for the Final Revised Cross-State Air Pollution

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[46] CARB. (2023). *CARB's Methodology for Estimating the Health Effects of Air Pollution* (Accessed August 4, 2023). https://ww2.arb.ca.gov/resources/documents/carbs-methodology-estimating-health-effects-air-pollution

[47] Fann N., Fulcher C.M., & Hubbell B.J. (2009). The influence of location, source, and emission type in estimates of the human health benefits of reducing a ton of air pollution. Air Quality, Atmosphere & Health, 2:169-176. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2770129/

[48] See Fann, N., Fulcher, C. M., & Hubbell, B. J. (2009). *The influence of location, source, and emission type in estimates of the human health benefits of reducing a ton of air pollution*.

[49] Fann, N., Baker, K. R., Chan, E. A., Eyth, A., Macpherson, A., Miller, E., & Snyder, J. (2018). *Assessing human health PM2. 5 and ozone impacts from US oil and natural gas sector emissions in 2025*. Environmental Science & Technology, 52(15), 8095-8103. https://pubs.acs.org/doi/full/10.1021/acs.est.8b02050

[50] CARB (2022). *California Air Resources Board Updated Health Endpoints Bulletin*. https://ww2.arb.ca.gov/sites/default/files/2022-11/California%20Air%20Resources%20Board%20Updated%20Health%20Endpoints%20Bulletin%20-%20Edited%20Nov%202022_0.pdf

Rule Update for the 2008 Ozone Season NAAQS and is associated with U.S. EPA's Environmental Benefit Mapping and Analysis Program – Community Edition (BenMAP-CE) version 1.5.8.[51]

To derive the IPT factors for each of the health endpoints, the number of health outcomes associated with exposure to PM2.5 were calculated by inputting PM2.5 concentrations from air monitoring data into U.S. EPA's BenMAP-CE version 1.5.8.4 (released April 16, 2021). The baseline incidence datasets embedded in the BenMAP-CE software were used; the incidence data for mortality, hospital admissions (including myocardial infarctions), and emergency department visits were at the county-level, while the incidence data for work loss days was provided at the national rate in the software.[52]

For most of the health endpoints, the U.S. EPA had identified one effect estimate derived from one study to be used in the respective health impact function. However, for myocardial infarction and respiratory ED visits, the U.S. EPA had identified multiple effect estimates; thus, EPA's health impact functions for these two endpoints were estimated using pooling methods. Pooling combines multiple risk estimates to determine a summary mean value estimate and associated confidence intervals.[53] For the myocardial infarction endpoint, the results were pooled from four different epidemiological studies using the random or fixed effects pooling and sum dependent pooling methods, as specified in the configuration file that U.S. EPA uses for PM quantification. For respiratory ED visits, the results were pooled from analyses across four different locations in the U.S. done in one study; this pooling using the random or fixed effects method, also as specified in U.S. EPA's configuration file.

c) Reduction in Adverse Health Impacts

CARB staff estimates that the total number of cases statewide that would be reduced (from 2024 to 2046) from implementation of the proposed amendments are as follows:

- 364 (201 - 519)[54] fewer cases of cardiopulmonary mortality;
- 74 (54 - 94) fewer cases of hospitalizations for cardiovascular illness;
- 97 (-37 - 227) fewer cases of cardiovascular ED visits;
- 41 (15 - 109) fewer cases of nonfatal acute myocardial infarction;
- 11 (0 - 22) fewer cases of hospitalizations for respiratory disease;
- 219 (43 - 457) fewer cases of respiratory ED visits;
- 27 (8 - 45) fewer cases of lung cancer incidence;
- 852 (818 - 884) fewer cases of asthma onset;

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[51] U.S. EPA. (2021). *Estimating PM2.5- and Ozone-Attributable Health Benefits. (*Technical Support Document (TSD) for the Final Revised Cross-State Air Pollution Rule Update for the 2008 Ozone Season NAAQS). Office of Air and Radiation. https://www.epa.gov/sites/default/files/2021-03/documents/estimating_pm2.5-_and_ozone-attributable_health_benefits_tsd_march_2021.pdf

[52] U.S. EPA. (2023). *Environmental Benefits Mapping and Analysis Program - Community Edition: User's Manual*. https://www.epa.gov/sites/default/files/2015-04/documents/benmap-ce_user_manual_march_2015.pdf

[53] See U.S. EPA. (2021). Estimating PM2.5- and Ozone-Attributable Health Benefits.

[54] The numbers in parentheses represent the 95% confidence intervals, which reflect the estimated variation in estimated associations between air pollutants (e.g., $PM_{2.5}$) and health endpoints from epidemiological literature.

- 73,433 (-35,816 – 178,171) fewer cases of asthma symptoms;
- 53,427 (45,055 – 61,482) fewer cases of work loss days;
- 174 (133 - 212) fewer cases of hospitalizations for Alzheimer's disease;
- 25 (13 - 36) fewer cases of hospitalizations for Parkinson's disease;

These reductions in adverse health cases are expected to be seen across all ages in the State. Children in particular will benefit from the reduced cases of asthma onset and symptoms due to the proposed amendments. This may lead to better health outcomes in these children when they become adults since studies have shown that childhood asthma puts individuals at greater risk for respiratory disease and lower respiratory function in adulthood.[55,56] Adults are also expected to benefit from the proposed amendments due to fewer lost work days, nonfatal acute myocardial infarctions (heart attacks), lung cancer incidences, and reduced cardiopulmonary mortality. Seniors may benefit from reduced cases of hospitalizations for not just cardiovascular and respiratory diseases, but also neurological conditions (Alzheimer's and Parkinson's diseases). And there will be fewer ED visits for both cardiovascular and respiratory diseases across all ages in the population.

Table 13 shows the air basin distribution of avoided health endpoints for the proposed amendments for 2024 through 2046 in California, relative to the baseline.

[55] Sears, M. R., Greene, J. M., Willan, A. R., Wiecek, E. M., Taylor, D. R., Flannery, E. M., Cowan, J.O., Herbison, G.P., Silva, P.A, & Poulton, R. (2003). *A longitudinal, population-based, cohort study of childhood asthma followed to adulthood*. New England Journal of Medicine, 349(15), 1414-1422. https://www.nejm.org/doi/full/10.1056/nejmoa022363

[56] McGeachie M.J., Yates K.P., Zhou X., Guo F., Sternberg A.L., Van Natta M.L., Wise R.A., Szefler S.J., Sharma S., Kho A.T., Cho M.H., Croteau-Chonka D.C., Castaldi P.J., Jain G., Sanyal A., Zhan Y., Lajoie B.R., Dekker J., Stamatoyannopoulos J., Covar R.A., Zeiger R.S., Adkinson N.F., Williams P.V., Kelly H.W., Grasemann H., Vonk J.M., Koppelman G.H., Postma D.S., Raby B.A., Houston I., Lu Q., Fuhlbrigge A.L., Tantisira K.G., Silverman E.K., Tonascia J., Weiss S.T., & Strunk R.C. (2016). *Patterns of growth and decline in lung function in persistent childhood asthma*. New England Journal of Medicine, 374(19), 1842-1852. https://www.nejm.org/doi/full/10.1056/nejmoa1513737

Table 13: Avoided Mortality and Morbidity Incidents per Air Basin from 2024 to 2046 under the Proposed Amendments*

Air Basin	SC	SCC	SJV	SFB	SD	Statewide
Cardiopulmonary Mortality	208 (115 - 296)	8 (5 - 12)	56 (31 - 79)	38 (21 - 54)	18 (10 - 26)	**364 (201 - 519)**
Hospitalizations for Cardiovascular Disease	42 (31 - 54)	2 (1 - 2)	11 (8 - 14)	8 (6 - 10)	5 (3 - 6)	**74 (54 - 94)**
Cardiovascular ED Visits	56 (-22 - 132)	2 (-1 - 5)	13 (-5 - 31)	11 (-4 - 26)	5 (-2 - 12)	**97 (-37 - 227)**
Acute Myocardial Infarction	24 (9 - 63)	1 (0 - 2)	6 (2 - 15)	5 (2 - 13)	2 (1 - 5)	**41 (15 - 109)**
Hospitalizations for Respiratory Disease	7 (0 - 13)	0 (0 - 0)	2 (0 - 3)	1 (0 - 2)	1 (0 - 1)	**11 (0 - 22)**
Respiratory ED Visits	119 (23 - 247)	4 (1 - 9)	36 (7 - 74)	28 (5 - 58)	9 (2 - 19)	**219 (43 - 457)**
Lung Cancer Incidence	15 (5 - 25)	1 (0 - 1)	3 (1 - 6)	4 (1 - 6)	2 (0 - 3)	**27 (8 - 45)**
Asthma Onset	471 (452 - 489)	21 (20 - 22)	102 (98 - 105)	134 (128 - 139)	45 (43 - 47)	**852 (818 - 884)**
Asthma Symptoms	40,494 (-19,758 – 98,213)	1,840 (-898 – 4,459)	9,106 (-4,447 – 22,068)	11,227 (-5,469 – 27,274)	3,798 (-1,850 – 9,226)	**73,433 (-35,816 – 178,171)**
Work Loss Days	29,258 (24,676 – 33,666)	1,251 (1,055 – 1,439)	6,991 (5,897 – 8,043)	7,677 (6,472 – 8,837)	3,110 (2,622 – 3,580)	**53,427 (45,055 – 61,482)**
Hospitalizations for Alzheimer's Disease	101 (78 - 123)	3 (2 - 4)	26 (20 - 32)	18 (13 - 22)	14 (11 - 18)	**174 (133 - 212)**
Hospitalizations for Parkinson’s Disease	14 (7 - 20)	1 (0 - 1)	3 (2 - 5)	3 (2 - 5)	2 (1 - 2)	**25 (13 - 36)**

* Numbers in parentheses throughout this table represent the 95% confidence interval.
** Air Basins listed: South Coast, South Coast Central, San Joaquin Valley, San Francisco Bay, San Diego County

Table 13 continued

Air Basin	SS	SV	NP	NC	NCC	Statewide
Cardiopulmonary Mortality	6 (4 - 9)	9 (5 - 14)	0 (0 - 1)	1 (0 - 1)	3 (2 - 4)	**364 (201 - 519)**
Hospitalizations for Cardiovascular Disease	1 (1 - 1)	2 (1 - 2)	0 (0 - 0)	0 (0 - 0)	1 (0 - 1)	**74 (54 - 94)**
Cardiovascular ED Visits	2 (-1 - 5)	2 (-1 - 5)	0 (0 - 0)	0 (0 - 0)	1 (0 - 2)	**97 (-37 - 227)**
Acute Myocardial Infarction	1 (0 - 2)	1 (0 - 3)	0 (0 - 0)	0 (0 - 0)	0 (0 - 1)	**41 (15 - 109)**
Hospitalizations for Respiratory Disease	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	**11 (0 - 22)**
Respiratory ED Visits	6 (1 - 12)	6 (1 - 12)	0 (0 - 1)	1 (0 - 1)	2 (0 - 5)	**219 (43 - 457)**
Lung Cancer Incidence	1 (0 - 1)	1 (0 - 1)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	**27 (8 - 45)**
Asthma Onset	16 (15 - 16)	22 (21 - 22)	1 (1 - 1)	2 (2 - 2)	10 (9 - 10)	**852 (818 - 884)**
Asthma Symptoms	1,414 (-688 – 3,436)	1,863 (-908 – 4,527)	96 (-47 - 233)	154 (-75 - 375)	827 (-403 - 2010)	**73,433 (-35,816 – 178,171)**
Work Loss Days	1,063 (896 - 1224)	1,449 (1221 - 1668)	58 (49 - 67)	117 (99 - 135)	577 (486 - 664)	**53,427 (45,055 – 61,482)**
Hospitalizations for Alzheimer's Disease	2 (2 - 2)	2 (2 - 3)	0 (0 - 0)	0 (0 - 0)	1 (1 - 1)	**174 (133 - 212)**
Hospitalizations for Parkinson's Disease	0 (0 - 1)	1 (0 - 1)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	**25 (13 - 36)**

* Air Basins listed: Salton Sea, Sacramento Valley, Northeast Plateau, North Coast, North Central Coast

Table 13 continued

Air Basin	MC	MD	LT	LC	GBV	Statewide
Cardiopulmonary Mortality	1 (1 - 2)	14 (8 - 20)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	**364 (201 - 519)**
Hospitalizations for Cardiovascular Disease	0 (0 - 0)	3 (2 - 4)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	**74 (54 - 94)**
Cardiovascular ED Visits	0 (0 - 1)	4 (-1 - 9)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	**97 (-37 - 227)**
Acute Myocardial Infarction	0 (0 - 0)	2 (1 - 4)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	**41 (15 - 109)**
Hospitalizations for Respiratory Disease	0 (0 - 0)	0 (0 - 1)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	**11 (0 - 22)**
Respiratory ED Visits	1 (0 - 2)	8 (2 - 16)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	**219 (43 - 457)**
Lung Cancer Incidence	0 (0 - 0)	1 (0 - 1)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	**27 (8 - 45)**
Asthma Onset	4 (4 - 4)	24 (23 - 25)	1 (1 - 1)	0 (0 - 0)	1 (0 - 1)	**852 (818 - 884)**
Asthma Symptoms	352 (-171 - 855)	2,140 (-1,042 – 5,199)	45 (-22 - 108)	28 (-14 - 68)	49 (-24 - 120)	**73,433 (-35,816 – 178,171)**
Work Loss Days	256 (216 - 295)	1,527 (1,287 – 1,758)	41 (35 - 48)	17 (14 - 20)	34 (29 - 40)	**53,427 (45,055 – 61,482)**
Hospitalizations for Alzheimer's Disease	0 (0 - 0)	6 (4 - 7)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	**174 (133 - 212)**
Hospitalizations for Parkinson's Disease	0 (0 - 0)	1 (0 - 1)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	**25 (13 - 36)**

* Air Basins listed: Mountain Counties, Mojave Desert, Lake Tahoe, Lake County, Great Basin Valleys

d) Uncertainties Associated with the Mortality and Illness Analysis

Although the estimated health outcomes presented in this report are based on a well-established methodology, they are subject to uncertainty. Uncertainty is reflected in the 95% confidence intervals included with the central estimates in Table 13. These confidence intervals take into account uncertainties in translating air quality changes into health outcomes.

Other sources of uncertainty include the following:

- The relationship between changes in pollutant concentrations and changes in pollutant or precursor emissions is assumed to be proportional, although this is an approximation.
- Emission reductions are reported at a State level and do not capture local variations.
- Future population estimates are subject to increasing uncertainty as they are projected further into the future.
- Baseline incidence rates can experience year-to-year variation.

e) Potential Future Evaluation of Additional Health Benefits

CARB is initiating an expanded health analysis to include additional health outcomes in order to provide a more comprehensive review of the health impacts of PM2.5 exposure for this regulation and upcoming regulations.[57] However, note that the current PM2.5 mortality and morbidity evaluation conducted by CARB staff still focuses on select air pollutants and only captures a portion of the health benefits of the proposed amendments. Further updates to the methodology may be made in the future to quantify additional benefits of reducing air pollution, such as by including additional pollutants and health outcomes. For instance, the current analysis considers the impact of NOx on the formation of secondary PM2.5 particles, but only includes a portion of the secondary PM2.5 particles. In addition, NOx can also react with other compounds to form ozone, which can cause respiratory problems. Ozone impacts are not included in this analysis. Also, CARB will continue to evaluate approaches to provide both quantitative and qualitative information on health outcomes based on the best available science, such as through current literature reviews and CARB funded research contracts. More information on CARB's research contracts can be found on *CARB's online research page* (https://ww2.arb.ca.gov/our-work/programs/research-planning/research-division-contracts).

3. Monetization of Health Impacts

The reductions in adverse health impacts described above can be assigned monetary values so the health benefits can be directly compared to other costs and savings associated with the proposed amendments. These values are derived from economics studies and are based on the expenses that an individual must bear for air pollution related health impacts such as medical bills and lost work, or willingness to pay metrics, which in addition to capturing the direct expenses of the health outcomes also capture the value that individuals place on pain and suffering, loss of satisfaction, and leisure time.

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[57] CARB. (2022). *CARB's Methodology for Estimating the Health Effects of Air Pollution*. *https://ww2.arb.ca.gov/resources/documents/carbs-methodology-estimating-health-effects-air-pollution*. Accessed August 4, 2023.

a) Methodology

Health outcomes are monetized by multiplying each incident by a value per incident that is consistent with the IPT method described above, using the standard economic studies and data as provided in U.S. EPA's Environmental Benefit Mapping and Analysis Program – Community Edition (BenMAP-CE).[58,59] The value per incident is derived from BenMAP-CE using the results for the total status-quo PM-related incidence for each health endpoint used to derive the IPT and dividing them by the total valuation (or cost) as estimated in BenMAP-CE using the standard studies and data as listed in Table 14 to derive a per incident dollar value for an avoided incident. These value per incident estimates are derived for each of the three years considered in the IPT air quality scenario (2014-2016); an average is taken across the three years to derive the final estimate.[60] The economic studies and data used are the same as those used in U.S. EPA's recent Revised Cross-State Air Pollution Rule Update.[61] The dollar values per incident therefore are equivalent to those evaluated in that rule, only varying due to California specific economic and demographic data.[62]

The value per incident for each endpoint derived by the methods described above are shown in Table 14. The value for avoided premature mortality is based on the value of statistical life (VSL),[63] a measure of willingness-to-pay (WTP) from economic theory, which when applied when to mortality risk provides a dollar estimate of benefits for an avoided premature death. The VSL 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, such that one death would be avoided in the year across the population.[64] Specifically, the U.S. EPA central estimate of $7.4 million (2006$) is used for VSL.[65] The estimate of VSL is adjusted for per capita income growth using U.S. EPA's central income elasticity estimate of 0.40 and the income growth forecast included in BenMAP-CE. This income elasticity estimate for VSL

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[58] U.S. EPA. (2022). *Environmental Benefit Mapping and Analysis Program – Community Edition (BenMAP-CE) version 1.5.8.5* (updated October 4, 2022). https://www.epa.gov/benmap

[59] U.S. EPA. (2023). *Environmental Benefits Mapping and Analysis Program - Community Edition: User's Manual*. https://www.epa.gov/sites/default/files/2015-04/documents/benmap-ce_user_manual_march_2015.pdf

[60] CARB. (2023). Valuation Estimates Spreadsheet Workbook.

[61] As documented in the U.S. EPA. (2021). *Estimating PM2.5- and Ozone-Attributable Health Benefits.* (Technical Support Document (TSD) for the Final Revised Cross-State Air Pollution Rule Update for the 2008 Ozone Season NAAQS). Office of Air and Radiation. https://www.epa.gov/sites/default/files/2021-03/documents/estimating_pm2.5-_and_ozone-attributable_health_benefits_tsd_march_2021.pdf

[62] The California specific data that cause variation from national estimates are the data on county-level median daily wages and the age distribution of the population residing in each air basin. Small variations may also arise due to BenMAP-CE's Monte Carlo simulation methods.

[63] U.S. EPA. (2000). *An SAB Report on EPA's White Paper Valuing the Benefits of Fatal Cancer Risk Reduction* (EPA-SAB-EEAC-00-013). *https://nepis.epa.gov/Exe/ZyPDF.cgi/P100JOK2.PDF?Dockey=P100JOK2.PDF*.

[64] U.S. EPA. (2000). *An SAB Report on EPA's White Paper Valuing the Benefits of Fatal Cancer Risk Reduction* (EPA-SAB-EEAC-00-013). *https://nepis.epa.gov/Exe/ZyPDF.cgi/P100JOK2.PDF?Dockey=P100JOK2.PDF*.

[65] U.S. EPA (2023). *Mortality Risk Valuation: What value of statistical life does EPA use?* (updated March 13, 2023). https://www.epa.gov/environmental-economics/mortality-risk-valuation. Accessed January 2023.

follows from empirical research and indicates that for every 1% increase in per capita income the VSL increases by 0.4%, consistent with health risk reduction being a normal good whose demand increases with income. Finally, the value for VSL is adjusted for California inflation to present the values in 2021 dollars. While the economic benefit associated with premature mortality is important to account for in the analysis, the valuation of avoided premature mortality does not directly correspond to changes in expenditures and is therefore not included in the macroeconomic modeling.

Unlike mortality valuation, the cost-savings for morbidity related endpoints such as avoided hospitalizations, emergency room visits, as well as disease onset and occurrence are based on the cost of illness (COI) methodology.[66] The COI methodology uses a combination of typical costs associated with hospitalization or disease occurrence to assign an economic value to avoidance of such outcomes. The types of cost that are included across the different valuation studies applied here include hospital charges, post-hospitalization medical care, out-of-pocket expenses, lost earnings for both individuals and family members, and lost household production (e.g., valuation of time-losses from inability to maintain the household or provide childcare).

Table 14: Valuation per Incident for Avoided Health Outcomes (2021$)

Endpoint	Value Per Incident (2021$)	Valuation Methodology	Notes
Premature Mortality			
Premature Mortality	$12,483,845	WTP	Shown at 2021 income levels. The estimate will grow annually proportional to income growth using U.S. EPA's central estimate for income elasticity of 0.40, and income growth forecast from BenMAP-CE.
Hospitalizations and ER Visits			
HA, Parkinson's Disease	$15,520	COI	Direct cost of hospitalization incident.
HA, Respiratory-2	$11,815	COI	Direct cost of hospitalization incident.
HA, Alzheimer's Disease	$14,539	COI	Direct cost of hospitalization incident.
HA, Cardio-, Cerebro- and Peripheral Vascular Disease	$18,696	COI	Direct cost of hospitalization incident.
ER visits, All Cardiac Outcomes	$1,403	COI	Direct cost of ER visit.
ER visits, respiratory	$1,057	COI	Direct cost of ER visit.

66 The WTP method is also used for valuation of one morbidity-related health endpoint: asthma symptoms.

Endpoint	Value Per Incident (2021$)	Valuation Methodology	Notes
Health Endpoint Onset/Occurrence			
Incidence, Asthma	$53,753	COI	Present value of lifetime healthcare cost and productivity losses using a 3% discount rate.
Asthma Symptoms, Albuterol use	$253	WTP for symptoms + COI for Albuterol use	Willingness to pay plus cost of albuterol.
Incidence, Lung Cancer	$30,377	COI	Direct medical cost of lung cancer. Cost discounted to present value at 3%.
Acute Myocardial Infarction, Nonfatal	$94,334	COI	Present value of 3 years medical cost and earnings lost over a 5-year period. Using a 3% discount rate.
Work Loss Days	$204	COI	Based on county-level median daily wages.

b) Results

The statewide valuation of health benefits from 2024-2046 are shown in Table 15. The total statewide health benefits derived from criteria emissions reductions is estimated to be approximately $5 billion, with $4.9 billion resulting from reduced premature cardiopulmonary mortality and $85 million resulting the reductions in other adverse health impacts. The spatial distribution of these benefits across the State follows the distribution of the health impacts by air basin as described in Table 13. These monetized benefits from all COI based endpoint valuations are included in the macroeconomic modeling.

Table 15: Statewide Valuation from Avoided Health Outcomes (million 2021$)

Year	Cardiopulmonary Mortality	Hospitalizations for Parkinson’s Disease	Respiratory ED Visits	Hospitalizations for Alzheimer's Disease	Hospitalizations for Cardiovascular Disease
2026	138	<1	<1	<1	<1
2030	127	<1	<1	<1	<1
2034	203	<1	<1	<1	<1
2038	279	<1	<1	<1	<1
2042	264	<1	<1	<1	<1
2046	268	<1	<1	<1	<1
Total	**4,892**	**<1**	**<1**	**3**	**1**

Table 15 continued.

Year	Cardiovascular ED Visits	ER visits, respiratory	Asthma Onset	Asthma Symptoms	Lung Cancer Incidence	Acute Myocardial Infarction	Work Loss Days	Valuation (Million 2021$)*
2026	<1	<1	2	1	<1	<1	0	**141**
2030	<1	<1	1	1	<1	<1	0	**129**
2034	<1	<1	2	1	<1	<1	0	**206**
2038	<1	<1	3	1	<1	<1	1	**284**
2042	<1	<1	2	1	<1	<1	1	**268**
2046	<1	<1	2	1	<1	<1	1	**273**
Total	**<1**	**<1**	**46**	**19**	**1**	**4**	**11**	**4,977**

*Note: Totals may differ due to rounding

III. Direct Costs

A. Direct Cost Inputs

Estimated direct costs of the proposed amendments include costs of obtaining LCFS credits, verification costs and impacts on fuel expenditures. Staff expects the more stringent CI targets in the proposed amendments to result in an increase in the costs to regulated parties of obtaining LCFS credits by: (1) increasing the total quantity of LCFS credits required to be in compliance with the rule for every gallon of high-carbon fuel sold, and (2) potentially increasing the price of LCFS credits.

1. Cost of Obtaining LCFS Credits

To comply with the LCFS, regulated parties must retire an equivalent number of credits to cover the deficits that they generate. As discussed earlier in Section I, the LCFS provides significant flexibility to regulated parties to obtain these credits. Broadly speaking, regulated parties that generate deficits may: (1) self-generate credits by blending low-CI fuels with hydrocarbon blendstocks, invest in refinery and oil field improvements that lower emissions, or use renewable hydrogen in refinery operations; (2) purchase credits from the LCFS open market or the Credit Clearance Market; or (3) use credits banked from previous years.

Since the LCFS allows regulated parties to pursue a variety of strategies to comply with the standard, it is difficult to precisely estimate the cost of obtaining the credits. To quantify the direct cost of obtaining LCFS credits in this analysis, CARB uses one annual uniform LCFS credit price for all firms. This methodology assumes that deficit generators will not pursue strategies themselves that cost more than the cost of obtaining credits from others through the LCFS market. However, some regulated entities may be able to generate LCFS credits at a cost lower than the assumed LCFS credit price, through producing and blending low-CI fuels themselves, investing in refinery and oil field projects, or producing renewable hydrogen for refinery use. Thus, using one annual LCFS market credit price as a proxy for the cost of compliance with the proposed amendments likely overstates the direct cost to deficit generating parties. Conversely, credit producers can sell their credits in the open market. The value of these credits is an important source of revenue to businesses producing and marketing low-carbon fuels and allows them to compete against high-carbon fuels. In this section, staff estimated the magnitude of these revenues to in-state and out-of-state businesses (see Appendix B for further details on in-state and out-of-state percentages).

As discussed in Section I.D, staff followed a multi-step process that uses the CATS model, refined through stakeholder input and external research, to produce estimates of the mix of fuels in California and credits that might be generated under each scenario. The estimated future LCFS credit price was then estimated for each year based on the cost of obtaining the most expensive (marginal) credit in that year, with an upper limit set by the maximum credit price as defined in the regulation. Table 16 shows the estimated LCFS price trajectory under the baseline and proposed amendments scenarios.

Table 16: Estimated Annual Credit Price for Baseline and Proposed Amendments (2021$)

Year	Baseline ($/MT)	Proposed Amendments ($/MT)	Incremental Change ($/MT)
2024	63	84	21
2025	58	221[67]	163
2026	58	221	163
2027	58	187	129
2028	0	138	138
2029	0	123	123
2030	0	76	76
2031	0	123	123
2032	0	138	138
2033	0	138	138
2034	0	138	138
2035	0	138	138
2036	0	138	138
2037	0	187	187
2038	0	201	201
2039	0	221	221
2040	0	221	221
2041	0	217	217
2042	0	184	184
2043	0	156	156

[67] Credit prices listed as $221 are rounded down from the 2021 maximum allowable LCFS credit price of $221.67. Source: CARB (2023). *LCFS Credit Clearance Market* (updated 2023). https://ww2.arb.ca.gov/resources/documents/lcfs-credit-clearance-market. Accessed April 17, 2023.

Year	Baseline ($/MT)	Proposed Amendments ($/MT)	Incremental Change ($/MT)
2044	0	129	129
2045	0	105	105
2046	0	105	105

Under the proposed amendments, regulated entities supplying high-carbon fuels in aggregate are expected to generate more deficits, and therefore are required to obtain more credits. Table 17 summarizes the number of deficits, annual price, and resulting cost that California companies are expected to generate as compared to the baseline. Cumulatively, approximately 545 million additional deficits are expected to be generated in California under the proposed amendments as compared to the baseline. The cost of compliance for the proposed amendments was calculated by multiplying the credit price in a given year by the projected number of deficits in that year and subtracting the same product from the baseline scenario deficits and credit price.

Table 17: Proposed Amendment Scenario - Estimated Annual Incremental Cost

Year	Deficits (Baseline Scenario) (MMT)	Credit Price (Baseline Scenario) ($/MT)	Credit Purchasing Cost (Baseline Scenario) ($M)	Deficits (Proposed Scenario) (MMT)	Credit Price (Proposed Scenario) ($/MT)	Credit Purchasing Cost (Proposed Scenario) ($M)	Incremental Credit Purchasing Cost ($M)
2024	22.7	63	1,430	22.6	84	1,898	467
2025	24.1	58	1,395	31.8	221	7,027	5,631
2026	25.4	58	1,473	34.4	221	7,595	6,122
2027	27.0	58	1,564	36.8	187	6,889	5,325
2028	28.1	0	-	38.8	138	5,348	5,348
2029	28.7	0	-	40.3	123	4,955	4,955
2030	29.0	0	-	42.1	76	3,201	3,201
2031	27.4	0	-	44.8	123	5,516	5,516
2032	25.8	0	-	47.2	138	6,516	6,516
2033	24.2	0	-	49.2	138	6,785	6,785
2034	22.4	0	-	50.5	138	6,963	6,963
2035	20.6	0	-	51.3	138	7,078	7,078
2036	18.8	0	-	51.5	138	7,111	7,111
2037	17.1	0	-	50.8	187	9,506	9,506
2038	15.4	0	-	48.7	201	9,785	9,785
2039	13.9	0	-	46.9	221	10,369	10,369
2040	12.5	0	-	45.6	221	10,076	10,076

Year	Deficits (Baseline Scenario) (MMT)	Credit Price (Baseline Scenario) ($/MT)	Credit Purchasing Cost (Baseline Scenario) ($M)	Deficits (Proposed Scenario) (MMT)	Credit Price (Proposed Scenario) ($/MT)	Credit Purchasing Cost (Proposed Scenario) ($M)	Incremental Credit Purchasing Cost ($M)
2041	11.1	0	-	43.6	217	9,470	9,470
2042	9.9	0	-	43.2	184	7,949	7,949
2043	8.9	0	-	41.4	156	6,457	6,457
2044	8.0	0	-	39.7	129	5,123	5,123
2045	7.2	0	-	40.7	105	4,274	4,274
2046	6.5	0	-	37.9	105	3,977	3,977
Total	**435**		**5,863**	**980**		**153,867**	**148,004**

Table 18 summarizes the change in the aggregate cost of obtaining LCFS credits for California and out-of-state businesses due to the proposed amendments. Out-of-state businesses are expected to generate 26.5 million deficits, translating to approximately $4.4 billion in costs, and resulting in a total cost of approximately $152 billion to in- and out-of-state businesses combined (see Appendix B for further details on in-state and out-of-state percentages).

Table 18: Estimated Direct Cost of Purchasing LCFS Credits to cover Deficits under the Proposed Amendments Relative to Baseline (million 2021$)

Year	California Credit Purchasing Cost	Out of State Credit Purchasing Cost	Total Credit Purchasing Cost
2024	467	-	467
2025	5,631	-	5,631
2026	6,122	-	6,122
2027	5,325	-	5,325
2028	5,348	-	5,348
2029	4,955	-	4,955
2030	3,201	-	3,201
2031	5,516	-	5,516
2032	6,516	-	6,516
2033	6,785	-	6,785
2034	6,963	-	6,963
2035	7,078	-	7,078
2036	7,111	39	7,149
2037	9,506	120	9,625
2038	9,785	266	10,052
2039	10,369	451	10,820

Year	California Credit Purchasing Cost	Out of State Credit Purchasing Cost	Total Credit Purchasing Cost
2040	10,076	707	10,783
2041	9,470	736	10,206
2042	7,949	517	8,466
2043	6,457	481	6,939
2044	5,123	433	5,556
2045	4,274	340	4,614
2046	3,977	333	4,310
Total	**148,004**	**4,423**	**152,427**

2. Cost of Third-Party Verification to Electricity and Hydrogen Credit Generating Companies

There will also be direct costs faced by regulated entities that operate Fueling Supply Equipment (FSE) dispensing electricity and hydrogen due to expansion of the third-party verification provisions of the proposed amendments. Staff estimated third-party verification costs for these additional fuel transaction types by surveying potential verifiers using a survey methodology similar to that used for the 2018 Amendments to the LCFS, in which verification was required for most fuel pathways and fuel transactions. The third-party verification cost estimates are comprised of contract costs for verification services obtained from qualified parties that regularly carry out third-party verifications or "audits." Total costs per year are expected to average $324 million. More details on the methodology used to estimate verification costs are presented in Appendix A. Because the majority of the entities that would incur these verification costs are opt-in entities, for whom participation in the LCFS is optional, it is assumed that the credit revenue gained from participating in the program will exceed the costs of verification.

3. Fuel Expenditures

The proposed amendments will increase the volume of low-CI fuels in the California market, which tend to be higher cost than fossil fuels. As such, the proposed amendments will impact the volumes of low-carbon and fossil fuels sold, which affects the overall expenditures on fuels in California. The statewide change in expenditures based on fuel changes forecasted by the CATS model is included in Table 19. Changes in fuel volumes were multiplied by California Energy Commission's Integrated Energy Policy Report (IEPR) Transportation Fuel Price forecasted fuel prices to calculate the changes in fuel expenditures (see Macroeconomics Chapter and Macroeconomic Appendix for further details).[68]

[68] California Energy Commission. (2023). 2022 Transportation Fuel Price Forecasts Workbook (updated January 5, 2023). Transportation Energy Forecasting Unit.

4. Total Costs

The total direct cost to the proposed amendments is the summation of the cost of compliance to in-state deficit generators (e.g., petroleum refiners) to purchase credits and the cost of third-party verification for electric and hydrogen FSE, which were not previously subject to verification before these proposed amendments. The proposed amendments will also result in changes to statewide fuel expenditures. Table 19 provides a breakdown of the estimated annual direct costs and changes in fuel expenditures.

The proposed amendments are projected to go into effect in 2024. From 2024 through 2046, the proposed amendments are estimated to result in direct costs of about $162 billion. The highest annual cost occurs in 2039 with an estimated direct cost of about $11.2 billion. In addition, the proposed amendments are estimated to increase expenditures on fuels by $7 billion due to changes in the volumes and types of fuels delivered to California.

Table 19: Estimated Total Direct Costs to California of the Proposed Amendments to Deficit Generators and on Statewide Fuel Expenditures Relative to Baseline (million 2021$)

Year	Verification Cost	Cost of Obtaining Credits	Statewide Fuel Expenditures	Total Cost
2024	26	467	3	496
2025	35	5,631	131	5,798
2026	46	6,122	200	6,368
2027	63	5,325	273	5,661
2028	83	5,348	358	5,789
2029	107	4,955	353	5,415
2030	134	3,201	226	3,561
2031	166	5,516	315	5,997
2032	198	6,516	372	7,085
2033	232	6,785	374	7,391
2034	270	6,963	377	7,610
2035	310	7,078	379	7,767
2036	350	7,111	383	7,843
2037	390	9,506	387	10,283
2038	429	9,785	400	10,614
2039	467	10,369	404	11,240
2040	502	10,076	403	10,981
2041	536	9,470	398	10,404
2042	569	7,949	377	8,895
2043	597	6,457	377	7,432
2044	624	5,123	377	6,124
2045	649	4,274	66	4,989

Year	Verification Cost	Cost of Obtaining Credits	Statewide Fuel Expenditures	Total Cost
2046	675	3,977	66	4,718
Total	**7,457**	**148,004**	**7,001**	**162,462**

5. Cost Effectiveness

The cost effectiveness for the proposed amendments is based on the GHG reductions as compared to the total net cost (Table 20).

Table 20: Cost-Effectiveness

	Revenue from LCFS Credit Sales (Million 2021$)	Total Costs (Million 2021$)	Net Costs (Million 2021$)	Total GHG Reduction (MMT CO_2e)	CE ($/MT CO_2e)
Proposed Amendments	128,416	162,462	34,046	558	61

B. Direct Costs on Typical Businesses

Businesses involved in the LCFS vary greatly by size, geographic location, and even by industry, and there is no easily defined typical business. However, staff expects that the costs of complying with the proposed amendments would fall initially on crude oil refineries which would then likely pass these costs to consumers of high-carbon fossil fuels such as gasoline and diesel. In this section, staff estimated the annual costs for a typical California refinery to comply with the proposed amendments, detailed in Table 21. Section III.D.1 discusses how these costs may be passed to consumers in the form of increased retail prices for both gasoline and diesel.

California has nine crude refining companies that currently produce transportation fuel, five of which represent approximately 96% of California's crude oil refining capacity and therefore can be considered typical businesses.[69] The direct cost of the proposed amendments on a typical crude oil refinery consists of increased cost of obtaining LCFS credits. While a typical refinery might elect to invest in projects that generate credits (for example, direct production of low-carbon fuels or energy-efficiency refinery projects to generate credits), they are only likely to do so if the cost of the project is less than the cost of obtaining the LCFS credits through credit purchase. Therefore, estimating refinery costs using the market credit price may overestimate the costs of the proposed amendments on a typical refinery.

To calculate the average compliance cost for the typical refinery, staff divided the total annual compliance cost (total number of deficits multiplied by the LCFS credit price) by the five major

[69] California Energy Commission (2023). *California's Oil Refineries* (updated February 7, 2023). https://www.energy.ca.gov/data-reports/energy-almanac/californias-petroleum-market/californias-oil-refineries. Accessed March 21, 2023.

refineries (refineries with a capacity greater than 75,000 barrels a day).[70] In the first few years, the difference in direct cost is relatively small under the proposed amendments due to small changes in LCFS credit prices and compliance target stringency. In later years, the more stringent LCFS standard under the proposed amendments will lead to higher cost of obtaining LCFS credits due to increased demand and quantity needed by the typical refinery.

Table 21: Estimated Direct Cost for a Typical Refinery under the Proposed Amendments Relative to Baseline (million 2021$)

Year	Cost
2024	93
2025	1,126
2026	1,224
2027	1,065
2028	1,070
2029	991
2030	640
2031	1,103
2032	1,303
2033	1,357
2034	1,383
2035	1,383
2036	1,366
2037	1,792
2038	1,807
2039	1,880
2040	1,782
2041	1,626
2042	1,324
2043	1,042
2044	798
2045	661
2046	601
Total	**27,419**

[70] Since the credit price is expected to represent the marginal costs of producing the last credit needed to achieve compliance in the system (i.e., the marginal GHG abatement needed to achieve the targeted CI benchmarks), each refiners' compliance cost is certain to be lower than staff's estimated value (because most abatement comes at a cost lower than the marginal abatement cost). These estimates therefore represent an upper bound estimate.

C. Direct Costs on Small Businesses[71]

Staff estimated the number of small businesses in California that could be impacted by the proposed amendments: two biodiesel producers, nine fossil gas and propane fueling station owners, and 23 electric charger owners. No producers of fossil fuels (petroleum refiners) are considered small businesses. While fueling station owners that currently dispense fossil gas or propane would eventually earn deficits as the compliance targets become more stringent in future years, the LCFS credit value provides substantial incentive for these stations to switch to lower-CI biomethane and renewable propane and earn LCFS credits instead of deficits. Biodiesel will also eventually generate deficits in the later years of the program due to the increased stringency of the CI targets, but fuel suppliers could dispense biodiesel with carbon capture or other technological advancements to avoid deficit generation. Some small businesses could also incur indirect costs related to facility expansion and higher feedstock purchases to meet the higher demand for their products due to the more stringent LCFS. Any cost of expansion is assumed to be balanced by increased revenues from increased sales of LCFS credits. Under this assumption, a new small business would enter the market, or an existing small business would expand, only if the increased revenue from credit generation made the decision profitable.

The addition of electricity and hydrogen fuel transactions verification may affect some low-carbon fuel providers that are small businesses. Staff is evaluating a threshold that would be appropriate for verification deferral and/or exemption for electricity and hydrogen transactions which could significantly reduce costs of verification for small businesses.

D. Direct Costs on Individuals

There are no direct regulatory costs incurred by individuals as a result of the proposed amendments. Businesses that incur costs may pass on costs to consumers, which could result in increased prices for gasoline and diesel. This indirect impact is discussed in the following section.

1. Estimated Cost Pass-Through

The proposed amendments would likely increase the costs to producers and importers of high-carbon intensity fuels, while producers of low-carbon intensity fuels would likely see revenue increases. This could indirectly affect individuals in California that purchase transportation fuel, as staff assumes some portion of increased costs associated with production or import of high-carbon intensity fuels is likely to be passed on to consumers in the form of higher prices for these fuels. This section details the assumptions and methods used by staff to quantify the portion of the costs and revenues that may be passed to transportation fuel consumers.

The potential portion of the cost or revenue passed through to consumers can be approximated using bounding assumptions. To reflect an upper-bound, staff assumed that cost increases faced by petroleum fuel producers and importers are completely passed through to

[71] Staff defines small businesses as independently owned businesses that are located in California, with less than 100 employees and which have annual revenue of less than $10 million.

consumers. Revenues generated by low-carbon fuels are assumed to be passed through to fuel consumers only if the credits are generated by the consumer or dispenser of the fuel. When LCFS credit revenue is generated by a fuel producer, staff assumes that the producer may not share any of the revenue with fuel consumers, but rather use this revenue to cover the higher cost of producing these lower carbon fuels or retain this value to improve their firm’s profitability. For example, in the case of biodiesel, producers receive the LCFS credits, thus staff assumes none of the value of the LCFS credit would be passed to consumers in the form of lower fuel prices. On the other hand, in the case of electricity used by a transit agency, the transit agency is the generator of credits, and thus the LCFS credits will represent cost savings to the transit agency and effectively reduce the price of electricity used to power battery-electric buses.

Staff expects that cost increases may fall exclusively on producers of high-carbon intensity fuels, as discussed in Section 0. The producers/importers of the California gasoline blendstock (CARBOB), fossil diesel (CARB diesel or ULSD), and fossil jet fuel (under the proposed amendments) generate deficits under the LCFS. Fuel producers must obtain credits to cover each deficit for compliance with the LCFS. Therefore, the quantity of deficits generated per gallon of fuel multiplied by the LCFS credit price can be used to estimate the increase in production cost of fossil fuels, which is assumed to be passed to consumers.

As discussed previously, this calculation assumes that all credits acquired by the high-carbon intensity fuel producers are obtained at the price of the marginal LCFS credit (shown for the period 2024 through 2046 in Table 16). This represents a reasonable upper bound of the cost to consumers at a given credit price, as the proposed amendments provide flexibility for regulated parties to meet the CI targets through a variety of compliance strategies (for example, increased blending of low-CI fuels or generating credits at production facilities). Regulated parities will therefore pursue actions that generate credits with costs less than or equal to the LCFS market price.

To estimate the LCFS credit price pass-through for diesel, staff used the following formula:

$$Diesel\ pass\ through\ (\frac{\$}{gal})_t = \frac{CARB\ diesel\ deficits_t \times credit\ price_t}{gallons\ of\ CARB\ diesel\ sold_t}$$

where t indexes the year. This formula assumes that the cost of the deficit on diesel is fully passed through to consumers. It also assumes that biodiesel and renewable diesel producers price their retail products at the same price as fossil diesel.

To estimate the LCFS credit cost pass through for gasoline, staff assumes the current blend of gasoline, called E10, which is 90% CARBOB (which generates deficits) and 10% ethanol (which generates credits), persists through 2046.

To estimate the LCFS credit price pass through for CARBOB, staff used the following formula:

$$Gasoline\ pass\ through\ (\frac{\$}{gal})_t = \frac{0.9 \times CARBOB\ deficits_t \times credit\ price_t}{gallons\ of\ CARBOB\ sold_t}$$

Staff assumed that CARBOB costs associated with the LCFS may be fully passed through to consumers of gasoline and that the ethanol credit value is not passed to consumers but rather kept by the ethanol producer.

To estimate the LCFS credit cost pass through for fossil jet fuel, staff used the following formula:

$$Fossil\ jet\ pass\ through\ (\frac{\$}{gal})_t = \frac{Fossil\ jet\ deficits_t \times credit\ price_t}{gallons\ of\ fossil\ jet\ sold_t}$$

Table 22 presents a range of potential LCFS credit price pass-through for gasoline, diesel, and fossil jet due to the proposed amendments relative to the baseline. The range is based on staff's analysis described in the sections above. Once the proposed amendments are implemented in 2024, they are projected to potentially increase the price of gasoline by an average of $0.37 per gallon, potentially increase the price of diesel by an average of $0.47 per gallon, and fossil jet fuel $0.35 per gallon based on the average change in estimated annual LCFS credit price and annual deficits from 2024 through 2030. On average, from 2031 through 2046 the proposed amendments are projected to potentially increase the price of gasoline by $1.15 per gallon, potentially increase the price of diesel by $1.50 per gallon and fossil jet fuel by $1.21 per gallon.

Table 22: Gasoline, Diesel, and Fossil Jet Fuel Pass-through Cost

Year	Gasoline ($/gal)	Diesel ($/gal)	Fossil jet fuel ($/gal)
2024	0.12	0.14	0.00
2025	0.47	0.59	0.44
2026	0.52	0.66	0.50
2027	0.49	0.62	0.47
2028	0.39	0.50	0.38
2029	0.38	0.48	0.38
2030	0.25	0.32	0.25
2031	0.47	0.60	0.47
2032	0.59	0.76	0.60
2033	0.66	0.85	0.68
2034	0.72	0.94	0.75
2035	0.79	1.03	0.82
2036	0.86	1.12	0.89
2037	1.25	1.63	1.31
2038	1.44	1.88	1.51
2039	1.69	2.21	1.78
2040	1.80	2.35	1.90
2041	1.83	2.40	1.94

Year	Gasoline ($/gal)	Diesel ($/gal)	Fossil jet fuel ($/gal)
2042	1.61	2.12	1.71
2043	1.42	1.86	1.50
2044	1.21	1.59	1.29
2045	1.02	1.34	1.09
2046	1.02	1.34	1.09

Retail fuel prices are strongly influenced by many factors beyond LCFS credit prices (e.g., global events, holiday weekends, seasonal fluctuations, refinery disruptions, seasonal fuel blends, taxes) and fuel producer pricing strategies are complex and reflect local and regional market conditions.[72] Predicting how LCFS credit price changes impact these complex pricing strategies is beyond the scope of this work. Instead, staff provides the analysis above as an estimate of the upper bound of possible consumer price impacts based on the carbon content of fuel.

The proposed amendments scenario estimates consumption of CARBOB and ULSD will decrease by about 68% by 2046. Decreased fossil fuel use is expected due to increased vehicle efficiency (better miles per gallon efficiency) and alternative fuel vehicles. While, as discussed above, there may be a higher potential cost pass through to those still using high-carbon fuels in later years due to the proposed amendments, the reduction in total demand for these high-carbon fuels over time, driven by the LCFS and other GHG reduction policies, is expected to at least partially cover these costs to high-carbon fuel consumers. For example, if vehicle efficiency improves significantly, consumers of fossil fuels can travel much further on the same gallon of gasoline and diesel. Therefore, total household expenditure on fossil fuel may not rise as much as the result of California's suite of GHG policies, even if the price per gallon of those fossil fuels increases due to the proposed amendments.

Many transportation fuels will generate increased revenues from LCFS credit sales under the proposed amendments. In some cases, producers or fuel importers will generate the LCFS credits, as is the case for liquid biofuels. In other cases, the LCFS credits are generated by the fuel end user or the fuel dispenser, such as fleet owners that own and operate their own electricity charging or hydrogen refueling stations.

In the case where LCFS credits are generated by the fuel producer or importer (primarily for liquid biofuels such as renewable diesel and ethanol, and biomethane), staff assumes that the value of these credits is not passed on to consumers but is instead used to compensate these producers for creating low-carbon fuels (either to cover the costs of producing more expensive low-carbon fuels or to boost low-carbon fuel producer profitability). This analysis assumes that low-CI fuels for which LCFS credits are generated by the fuel producer or importer are generally more costly to produce than fossil fuels. In the future, it may be possible that alternative fuel producers might pass the value of the LCFS credit value to discount the price

[72] Between 2017 and 2022, the retail price of gasoline fell as low as $3.08 and rose as high as $5.41, and similarly for diesel, the retail price ranged between $3.07 and $6.02. Source: United States Energy Information Administration. *Annual Retail Gasoline and Diesel Prices* (updated July 31, 2023). https://www.eia.gov/dnav/pet/pet_pri_gnd_dcus_sca_a.htm. Accessed August 7, 2023.

of their product to increase market share. If this were to occur, it could reduce the impact of the estimated price increase to consumers. As it is difficult to predict future marketing behavior, staff elected to use the conservative assumption that LCFS credit revenue for most biofuels was not passed on to consumers.

E. Equity Considerations

The LCFS program aims to benefit all vehicle owners by displacing fossil fuels and supporting deployment of ZEVs and the use of alternative fuels. However, as stated in Section III.D.1, the proposed amendments are likely to indirectly result in increases to the retail price of fossil fuels at the pump, due to cost pass-through by fossil fuel producers and importers. This potential price increase may impact low-income, disadvantaged, and rural communities more than other consumers of fossil fuels, because individuals living in these communities traditionally spend a larger share of their income on transportation fuels. In addition, it is possible that individuals in these communities may lack the means to effectively make use of ZEV technology as quickly as wealthier individuals, and therefore would rely on more expensive fossil fuels for longer. Low-income and disadvantaged communities are also more likely to be communities of color that face on-going exposure to the highest concentrations of toxic air pollutants from vehicles using fossil fuels because these communities are often located near congested roadways, including near warehouses, ports, and distribution centers. Reducing emissions and exposure in these communities is a priority for CARB, and while a recent report from the Office of Health Hazard Assessment found that communities of color and disadvantaged communities have been the greatest beneficiaries of reduced emissions from heavy duty vehicles, there is still more to do to reduce the burdens faced by these communities.[73] By supporting continued reductions of fossil fuel use, particularly for medium- and heavy-duty vehicles, the emission reductions that will result from implementation of the LCFS proposal and other complimentary vehicle regulations will result in greater health benefits in these communities and help reduce the health impacts these communities face.

The LCFS regulation includes several provisions that aim to improve access of low-income, disadvantaged, and rural communities to zero-emission transportation. Specifically, the program requires that an increasing proportion of LCFS credit revenue from residential electric vehicle charging issued to electrical distribution utilities be directed toward electrification in priority communities. The program also supports a point of purchase rebate called the California Clean Fuel Reward, which has provided up to $1,500 off the price of a new EV, for a total of $416 million in support.[74]

At this time and for the purposes of this SRIA, staff is initially proposing to increase the proportion of residential electric vehicle charging credits that must be used to support transportation electrification in low-income, disadvantaged, or rural communities. Staff requested feedback in several LCFS workshops and community meetings in 2022 and 2023

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[73] Office of Environmental Health Hazard Assessment. (2022). *Benefits and Impacts of Greenhouse Gas Limits on Disadvantaged Communities- Findings from the Second Examination* (updated February 3, 2022). https://oehha.ca.gov/environmental-justice/report/ab32-benefits. Accessed August 8, 2023.

[74] California Clean Fuel Reward. (2023). *Reporting: Customer Overview* (updated June 29, 2023). https://cleanfuelreward.com/reporting. Accessed August 7, 2023.

on this topic and have incorporated specific areas in need of funding into the list of eligible spending categories. Based on the credit prices estimated in this SRIA and the total electric vehicle crediting modeled, the value provided by these residential credits will range from $500 million to $1.2 billion per year through 2030, and $600 million to $1.4 billion per year from 2031-2046. This significant funding pool is intended to support individuals in low-income, disadvantaged, or rural communities as they seek to transition to ZEV technology, which in turn would avoid the potential pass-through cost assigned by fuel producers on fossil fuels. Second, staff is proposing to expand the ZEV refueling infrastructure provisions in the LCFS with a focus on equity. Under these proposed amendments, fast chargers and hydrogen stations supported with ZEV infrastructure credits must be located in low-income, disadvantaged or rural communities to qualify. This requirement is expected to incentivize buildout of ZEV refueling stations in these communities and improve refueling access for residents. In addition, staff is proposing to add a ZEV infrastructure provision for the trucking sector, with a requirement that the equipment be located within a particular range of freight corridors. This provision will provide significant support to implement the State's regulations such as ACF by providing ZEV refueling where it is needed most and ensuring that clean trucks can use these corridors.

While priority populations currently have lower levels of ZEV ownership, the LCFS, CARB vehicle regulations, and Clean Transportation[75] investments provide health benefits to priority populations while subsidizing and minimizing the cost to transition to cleaner transportation. Of the State's investment in renewable fuels and ZE transportation, a proportion is dedicated toward low-income consumer vehicle purchase incentives, affordable and convenient ZEV infrastructure access in low-income neighborhoods, and to support sustainable community-based transportation equity projects that increase access to ZE mobility in disadvantaged and low-income communities.

CARB's incentive and regulatory programs work together. There is a natural progression of support for technologies starting in the pre-commercial demonstration phase all the way through to financing assistance for small businesses who are unable to qualify for conventional financing for cleaner trucks. As technologies become more established and demand continues to grow, CARB is beginning to shift from broad purchase incentives to more targeted strategies that support lower-income consumers and small fleets. CARB anticipates this shift will continue to accelerate in the coming years, helping to create an equitable transition to a clean transportation future. To date, 56% of CARB's Low Carbon Transportation funding has supported projects benefiting priority populations. For some heavy-duty solicitations, all of the projects benefit priority populations. Projects include pilots of large-scale deployments of ZE drayage trucks, deployments of ZE transit and school buses in urban and rural settings, and projects to support ZE technologies at freight facilities.

The LDV regulation ACC II works in tandem with incentives and other programs to advance access to ZEVs for lower-income Californians. In that regulation, staff included a suite of minimum standards for ZEVs to ensure that emissions benefits are realized and long-lasting, while supporting more reliable ZEVs both in the new and used vehicle market, where the cost

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[75] CARB. *Clean Transportation Equity Incentives webpage*. https://ww2.arb.ca.gov/clean-transportation-equity-incentives. Accessed August 9, 2023.

of ZEVs must become more affordable to lower-income households. Additionally, ACC II includes optional environmental justice vehicle values under the ZEV regulation that are awarded to manufacturers who help increase affordable access and exposure to ZEV technologies. These actions include providing ZEVs and PHEVs at a discount to community clean mobility programs; retaining used ZEVs after leases in the California market for low-income vehicle purchasing and finance assistance programs; and offering lower-priced new ZEVs to the market. These provisions encourage supporting community carshare programs, producing ZEVs at lower price points, and keeping used vehicles in California to support CARB's complementary equity incentive programs.

The lower total cost of ownership for both light- and heavy-duty ZEVs, combined with CARB's actions to direct resources and incorporate regulatory provisions to support priority populations, should help mitigate potential impacts that would be associated with cost pass-through to ICE vehicle owners who have limited access to renewable diesel and gasoline.

IV. Fiscal Impacts

Three separate impacts related to the proposed amendments affect local and State government finances: revenue generated from the sale of credits from transit fleets that use low-CI fuels, change in local tax revenues due to the change in the fuel mix, and the change in the expenditure on fuels for government fleets.

The proposed amendments are anticipated to generate an additional $1.65 billion in local government revenue while fuel costs are expected to total $52.5 million, as shown in Table 23. The proposed amendments are anticipated to generate an additional $379 million in State government revenue while fuel costs are expected to increase $17.5 million.

Table 23: Change in Local and State Total Revenues and Costs (2021M$)

Year	Local Tax Revenue	Local LCFS Credit Revenue	Local Fuel Cost	Local Total Revenue	Local Total Cost	State Tax Revenue	State LCFS Credit Revenue	State Fuel Cost	State Total Revenue	State Total Cost
Total	(20.67)	1,670.60	52.47	1,649.92	52.47	139.69	239.33	17.49	379.02	17.49

A. Local Government

1. Revenue from LCFS Credits

Many local governments are already generating credits from the LCFS program, which generate revenue. As discussed above, the proposed amendments will increase the demand, and subsequently the price, for LCFS credits relative to the baseline scenario, which can increase local government revenues.

In 2021, local governments earned 280,000 credits from the LCFS, which were largely generated from low-CI fuel use in government vehicle fleets and public transit systems. This sum does not include credits generated by public-owned utilities (POU) for the use of electricity in electric vehicles, since the utilities are obligated to pass the value of these credits to the electric vehicle owners. Of the credits generated by local governments, 15% were generated from the use of natural gas, from either fossil or renewable sources, and 85% were generated from the use of electricity, or PHEVs for transportation from non-POU sources. The average price of LCFS credits in 2021 was $188, and thus the LCFS program is estimated to have contributed over $53 million to local governments. Under the proposed LCFS updates, staff estimate that local governments will generate approximately $1.67 billion in additional LCFS credit revenue between 2024 and 2046.

2. Changes in Local Tax Revenue

Tax revenue for local governments would be affected by the proposed amendments.

Ethanol Taxes

The State sales tax rates are applied to sales of ethanol fuel. The State sales tax varies across the State from a minimum of 7.25% up to 10.5% in some municipalities. For this analysis, staff used a value of 8.7%, which is a weighted average based on county-level output with 4.76% going to local governments and the remaining 3.94% going to the State General Fund.[76]

Gasoline Taxes

Taxes on gasoline include a 51.1 cents per gallon State excise tax, of which 21.5 cents goes towards local governments, and a State and local sales tax that averages 3.76% across California. Of the 3.76%, 1% is under State jurisdiction but goes towards various local revenue funds and is therefore included with the impacts to local government. The 3.76% sales tax revenue collected from gasoline sales goes to a variety of funds, some of which support transportation and local government operations, and others which support programs such as local criminal justice activities, local health, and social services programs.

Diesel Taxes

Taxes on diesel include a 38.9 cents per gallon State excise tax, of which 6.2 cents goes towards local governments, and a local sales tax that averages 4.76% across California.

Total Change in Tax Revenue

Cumulatively over the period from 2024 through 2046, local government tax revenue is estimated to decrease by $20.67 million. The decrease in tax revenue is due to lower gasoline excise taxes collected from reduced sales. Gasoline fuel sales are partially replaced by higher fuel volumes of ethanol sold, which is not subject to excise tax.

3. Change in Costs to Local Government from Fuel Purchases

Cumulatively over the period from 2024 through 2046, local government agencies are estimated to have additional fuel expenditures of $52.5 million. The proportion of diesel and its substitutes used by local government is estimated using fuel combustion volumes by sector

[76] California Department of Tax and Fee Administration. (2023). *California City and County Sales and Use Tax Rates* (updated January 1, 2023). https://www.cdtfa.ca.gov/taxes-and-fees/Archive-Rates-01-01-23-03-31-23.pdf.

from the CARB Greenhouse Gas Emission Inventory.[77] The proportion of gasoline and its substitutes used by local governments is estimated based on the proportion of LDVs owned by local governments (See Macroeconomic Appendix for further details). The additional fuel costs are due to increased liquid fuel volumes purchased. It is assumed that the consumption of gasoline and diesel by local government fleets will change proportionally with the overall statewide change in gasoline and diesel consumption.

B. State Government

1. Revenue from LCFS Credits

In 2021, State government earned 1,733 credits from the LCFS, which were largely generated from low-CI fuel use in government and university vehicle fleets. Of the credits generated by State government, 90% were generated from the use of electricity or plug-in hybrid electric vehicles for transportation, and 10% were generated from the use of hydrogen. The average price of LCFS credits in 2021 was $188, and thus the LCFS program is estimated to have contributed over $326,000 to State government. Under the proposed modifications, staff estimate that cumulatively, between 2024 and 2045, incremental State government revenue from LCFS credit sales will be approximately $239 million.[78]

2. Change in Sales Taxes

The primary factor affecting fuel tax revenue is an increase in volume of renewable gasoline, ethanol, and renewable diesel fuel sold in the State. The additional volume of fuel is subject to ethanol, gasoline, and diesel sales and excise taxes resulting in an additional $140 million in State sales tax revenue.[79]

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[77] CARB. (2022). *Greenhouse Gas Emission Inventory* [Fuel combustion activity data]. https://ww2.arb.ca.gov/applications/greenhouse-gas-emission-inventory-0

[78] Staff used the following assumptions for this analysis: Staff used 2021 DMV data to estimate the ratio of transit buses owned by local governments compared to the State. This ratio was then applied to the total electricity and hydrogen demand associated with urban buses obtained from EMFAC 2021 v.1.02 and used to calculate credits associated with use of ZE buses for both local government and State government. As compared to the REMI model's values for local and State government's share of the California economy (0.75% and 0.25%, respectively), the transit bus calculation resulted in an average of 4% more credits going to local governments, and 1% less credits going to State government.

REMI's ratios for local and State government were applied to electricity and hydrogen for fleets.

[79] Staff used the following assumptions for this analysis:

Ethanol Taxes

California sales tax at 8.7% was used in this analysis with 3.94% going to State government.

Gasoline Taxes

Gasoline is exempt from the portion of State sales tax that supports the State General Fund and 2011 Realignment. Of the 51.1 cents per gallon State excise tax, 39.6 cents go towards State governments.

Diesel Taxes

Taxes on diesel include a 38.9 cents per gallon State excise tax, of which 32.7 cents goes towards State government, and a State sales tax of 3.94%.

Natural Gas Surcharge

Natural gas has a State excise tax of $0.0887 per gallon.

3. Change in Costs to State Government Fuel Purchases

The proportion of diesel and its substitutes used by State government is estimated using fuel combustion volumes by sector from the CARB Greenhouse Gas Emission Inventory.[80] The proportion of gasoline and its substitutes used by State governments is estimated based on the proportion of LDVs owned by the State government (See Macroeconomic Appendix for further details). It is assumed that the consumption of gasoline and diesel by the State's fleet will change by the same rate as the assumed overall statewide change in gasoline and diesel consumption.

Based on these assumptions, staff estimated the additional costs of gasoline and diesel fuel purchases from 2024 through 2046 for State fleets to be an additional $17.5 million over the lifetime of these amendments.

V. Macroeconomic Impacts

A. Methods for determining economic impacts

This section estimates the total impact of the proposed amendments on the California economy. The proposed amendments are expected to have a broad impact on the California economy. For example, the direct impacts to alternative and fossil fuel producing industries will lead to indirect changes in employment, output, and investment in sectors that supply goods and services to the fuel-producing industries. Costs and benefits that are borne by directly affected industries will also affect the personal income of individuals in California. These changes in personal income will lead to additional induced effects, like the change in consumer expenditures across other spending categories. The following analysis focuses on the resulting incremental changes in major macroeconomic indicators including employment, growth, and California gross State product (GSP).

The direct costs discussed in section III are input into Regional Economic Models, Inc. (REMI), Policy Insight Plus Version 3.0.0 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.[81] REMI Policy Insight Plus provides year-by-year estimates of the total impacts of the proposed amendments, pursuant to the requirements of the California Administrative Procedure Act and the California Department of Finance (DOF).[82] Staff used the REMI single region, 156 sector model with the model reference case adjusted to reflect California Department of Finance's most current publicly available economic and demographic projections. Specifically, the REMI model's National and Regional Control (i.e., the model's default forecast of National and California economic conditions) was updated to

[80] CARB. (2022). *Greenhouse Gas Emission Inventory* [Fuel combustion activity data]. https://ww2.arb.ca.gov/applications/greenhouse-gas-emission-inventory-0

[81] For further information and model documentation see: *https://www.remi.com/model/pi/*

[82] See title 1, California Code of Regulations, sections 2000-2004. California Department of Finance. (2013). *Chapter 1: Standardized Regulatory Impact Analysis for Major Regulations - Order of Adoption*. https://dof.ca.gov/wp-content/uploads/sites/352/Forecasting/Economics/Documents/Order_of_Adoption-1.pdf

conform to the most recent California Department of Finance economic forecasts which include U.S. Real Gross Domestic Product, income, and employment, as well as California civilian employment by industry. [83,84,85] These forecasts were released with the 2023-2024 May Revision to the Governor's Budget on May 12, 2023. In addition, the REMI model was adjusted to incorporate the Department of Finance demographic forecasts for California population, last updated in July 2021.[86] The Department of Finance economic forecasts extend through 2026; therefore, CARB staff assumed that post-2026, economic variables would continue to grow at the same rate projected in the REMI baseline forecasts.

B. Inputs and assumptions 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 macroeconomic impacts of the proposed amendments. The direct and indirect costs and benefits of the proposed amendments estimated in previous sections are translated into REMI policy variables and used as inputs for the macroeconomic analysis.[87]

The inputs to the model include: the cost of acquiring credits to cover deficits generated by high-CI fuels, credit revenue generated by producers of low-CI fuels, and changes in demand and fuel expenditures for fuels. The proposed amendments will increase the number of deficits and credits generated. Industries that generate deficits will incur costs in acquiring credits to cover those deficits, while industries that generate credits will obtain revenue. These impacts are input into REMI as a change in production cost by industry as classified in the North American Industry Classification System (NAICS).

As the volumes and types of fuels in California change, there would be corresponding changes in State and local tax revenues (described in Section IV – Fiscal Impacts). These are input into the model as changes in State and local government spending. In addition, there would be reduced spending on healthcare-related services from health benefits (described in Section II – Benefits). The model uses the inputs to calculate additional indirect and induced effects. The additional indirect effects are the changes in sales, income, or employment within California that supplies goods or services to the directly affected industries. Induced effects capture changes within California that result from changes in household spending. The following two

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[83] California Department of Finance (2023). *National Economic Forecast – Annual & Quarterly* (updated April 2023). https://dof.ca.gov/Forecasting/Economics/economic-forecasts-u-s-and-california/. Accessed August 7, 2023.

[84] California Department of Finance (2023). Economic Research Unit. *California Economic Forecast – Annual & Quarterly* (updated April 2023). https://dof.ca.gov/Forecasting/Economics/economic-forecasts-u-s-and-california/. Accessed August 7, 2023.

[85] California Department of Finance (2023). *National Deflators: Calendar Year averages* (updated April 2023). https://dof.ca.gov/forecasting/economics/economic-indicators/inflation/. Accessed August 7, 2023.

[86] California Department of Finance (2022). *Report P-3: Population Projections, California, 2010-2060* (Baseline 2019 Population Projections; Vintage 2023 Release). Updated July 19, 2023. Demographic Research Unit. https://dof.ca.gov/forecasting/demographics/projections/. Accessed July 2023.

[87] Refer to the Macroeconomic Appendix for a full list of REMI inputs.

sections provide an overview of the REMI inputs. Additional detailed methodology and full REMI input data tables are included in the Macroeconomic Modeling Appendix.

Table 24 summarizes the value of deficits and credits generated for each fuel type categorized by NAICS code to illustrate the pre-netted impacts of transfers of costs and revenues. Deficits represent costs and credits represent revenues from credit generation. California producers of fossil fuels such as gasoline and diesel will generate deficits and incur $148 billion in costs, of which $128.4 billion are transferred to California producers of low-CI fuels such as renewable diesel, biodiesel, hydrogen, and electricity. Approximately $20 billion in credit generation associated with hydrogen and corn ethanol fuel is assumed to be claimed outside of California and is not included in the table.

Table 24: Estimated Incremental Value of Deficits or Credits for California Facilities by Fuel Type for 2024 through 2046 Relative to the Baseline (Million 2021$) [CATS model Credit and Deficit Count multiplied by Credit Price]*

NAICS Industry	Category	Credits	Deficits	Net Cost by NAICS Industry
Petroleum and coal products manufacturing (324)	Petroleum Projects	63	0	-147,941
Petroleum and coal products manufacturing (324)	Incremental Deficits	0	-11	
Petroleum and coal products manufacturing (324)	Fossil Gasoline (CARBOB)	0	-105,088	
Petroleum and coal products manufacturing (324)	Fossil Diesel	0	-27,799	
Petroleum and coal products manufacturing (324)	Fossil Gas	0	0	
Petroleum and coal products manufacturing (324)	Fossil Jet Fuel	0	-4,198	
Petroleum and coal products manufacturing (324)	Biobased Diesel/Gas/Jet	0	-10,908	
Basic chemical manufacturing (3251)	Hydrogen (0-CI)	937	0	21,337
Basic chemical manufacturing (3251)	Hydrogen (Dairy)	3,050	0	
Basic chemical manufacturing (3251)	Hydrogen (Fossil)	0	0	
Basic chemical manufacturing (3251)	Hydrogen (Grid)	0	0	
Basic chemical manufacturing (3251)	Hydrogen (Landfill)	0	0	
Basic chemical manufacturing (3251)	LDV HRI Fast Charging	3,332	0	

NAICS Industry	Category	Credits	Deficits	Net Cost by NAICS Industry
Basic chemical manufacturing (3251)	MHDV HRI Fast Charging	4,317	0	
Basic chemical manufacturing (3251)	Corn Ethanol	0	0	
Basic chemical manufacturing (3251)	Biobased Diesel/Gas/Jet	9,699	0	
Natural gas distribution (2212)	Direct Air Capture	7,387	0	9,832
Natural gas distribution (2212)	Biomethane (Dairy)	2,446	0	
Natural gas distribution (2212)	Biomethane (Landfill)	0	0	
Electric power generation, transmission, and distribution (2211)	Electricity	86,426	0	92,707
Electric power generation, transmission, and distribution (2211)	Electricity (Dairy)	5,445	0	
Electric power generation, transmission, and distribution (2211)	Fixed Guideway	836	0	
Various Sectors**	Forklift	1,627	0	1,627
Truck transportation (484)	Electricity used in Truck Transportation Refrigeration Units	750	0	750
Scenic and sightseeing transportation and support activities for transportation (487, 488)	Electricity Used in Cargo Handling Equipment and Ocean-Going Vessels at-berth	2,100	0	2,100
Total		**128,416**	**-148,004**	**-19,588**

* Positive values represent costs in the Deficits column and revenue in the Credit column. Negative values represent cost savings in the Deficits column and lost revenue in the Credit column.

** Forklift credits were distributed across 156 NAICS sectors in REMI using the same spread as in the Proposed Zero-Emission Forklift Regulation SRIA[88]

The proposed amendments are designed to increase penetration of low-CI fuels in the California market and support the transition to ZEVs. As such, the proposed amendments will impact the volumes of high- and low-CI fuels sold which affects the output of fuel-producing

[88] CARB (2023). *Proposed Zero-Emission Forklift Regulation SRIA*. https://dof.ca.gov/wp-content/uploads/sites/352/2023/04/ZE-Forklift-SRIA-to-DOF.pdf

industries and revenue for the fuel-producing industries.[89] In general, fossil fuel demand is expected to decline as consumption of these fuels is replaced by low-CI fuels on top of the existing transition to ZEVs, which is included in the baseline. Changes in fuel volumes were multiplied by IEPR forecasted fuel prices to calculate the fuel revenue (see Macroeconomic Appendix). The changes in revenue for fuel producers and are modeled in REMI as a change in exogenous final demand to affected NAICS industries. Table 25 summarizes the change in revenue by fuel type between the baseline and proposed scenarios based on demand and subsequent volume changes forecasted by the CATS model.

Table 25: Change in Revenue to California Industries by Fuel Type 2024 through 2046 Relative to the Baseline (Million 2021$) [CATS model Estimated Fuel Volumes multiplied by Forecasted IEPR Fuel Price]

NAICS Industry	Category	Change in Revenue	Revenue Change by NAICS Industry
Petroleum and coal products manufacturing (324)	Fossil Gasoline (CARBOB)	-11,714.2	-70,191.2
Petroleum and coal products manufacturing (324)	Fossil Jet Fuel	-20,545.9	
Petroleum and coal products manufacturing (324)	Fossil Diesel	-37,931.1	
Basic chemical manufacturing (3251)	Alternative Jet Fuel	21,323.0	77,197.7
Basic chemical manufacturing (3251)	Biodiesel	0.0	
Basic chemical manufacturing (3251)	Renewable Diesel	39,341.3	
Basic chemical manufacturing (3251)	Renewable Gasoline	0.0	
Basic chemical manufacturing (3251)	Ethanol/E85	16,536.5	
Basic chemical manufacturing (3251)	Hydrogen for HDV (0-CI)	10,331.8	
Basic chemical manufacturing (3251)	Hydrogen for HDV (Dairy)	4,287.0	
Basic chemical manufacturing (3251)	Hydrogen for HDV (Fossil)	-23,783.2	
Basic chemical manufacturing (3251)	Hydrogen for HDV (Grid)	0.0	

89 Revenue generated by a fuel producer is defined as the price of the fuel multiplied by the volume sold.

NAICS Industry	Category	Change in Revenue	Revenue Change by NAICS Industry
Basic chemical manufacturing (3251)	Hydrogen for HDV (Landfill)	9,161.3	
Basic chemical manufacturing (3251)	Hydrogen for LDV (0-CI)	2,888.4	
Basic chemical manufacturing (3251)	Hydrogen for LDV (Dairy)	3,521.0	
Basic chemical manufacturing (3251)	Hydrogen for LDV (Fossil)	-10,815.8	
Basic chemical manufacturing (3251)	Hydrogen for LDV (Grid)	0.0	
Basic chemical manufacturing (3251)	Hydrogen for LDV (Landfill)	4,406.3	
Natural gas distribution (2212)	Landfill RNG	-2,797.1	-5.1
Natural gas distribution (2212)	Biodiesel	0.0	
Natural gas distribution (2212)	Dairy Gas for CNG	2,792.0	
Electric power generation, transmission, and distribution (2211)	Electricity for HDV	-697.6	0.0
Electric power generation, transmission, and distribution (2211)	Electricity for HDV (Dairy)	697.6	
Electric power generation, transmission, and distribution (2211)	Electricity for LDV	-3,066.2	
Electric power generation, transmission, and distribution (2211)	Electricity for LDV (Dairy)	3,066.2	

As a result of the changes in fuel volumes, proposed amendments are anticipated to change expenditures on fuels for households, businesses, and government agencies. The reduced demand for petroleum-based fuels replaced by low-CI fuels is modeled by a change in exogenous demand in REMI. Impacts to households are input in REMI as a change in consumer spending on motor vehicle fuels, electricity, or natural gas. Impacts to businesses that consume fuel, electricity, or natural gas are input in REMI as a change in production cost by industry.

Third-party verification requirements will increase operating costs for fuel producing industries. Higher verification costs are modeled as an increase in production cost to the two industry NAICS codes anticipated to bear these costs: basic chemical manufacturing (3251) and electric power generation, transmission, and distribution (2211). Demand for verification services is also expected to grow because of the proposed verification requirements. This demand is modeled as an increase in exogenous final demand for management, scientific, and technical consulting services (NAICS 5416).

Impacts to government agencies are input into REMI as changes to State or local government spending. State and local agencies collect taxes and fees on transportation fuels which will be impacted by the proposed amendments. Taxes and fees are considered revenue. Local and state governments also obtain revenue through credit sales. State and local agencies purchase fuel for their fleets which is a cost. Changes to revenues and costs are input into REMI as a change in State or local government spending. Changes in State and local revenue is estimated in IV - Fiscal Impacts.

As described in Section II, the proposed amendments are also anticipated to result in an overall reduction in a variety of adverse health outcomes because of reductions in PM2.5 and NOx emissions. The cost-savings of the proposed amendments from reduced medical costs, hospital admissions, and emergency room visits from 2024 through 2046 is $73.9 million and the annual costs or cost-savings are input into REMI as a change in consumer spending on hospitals. The impacts of lost work days are modeled as changes in labor productivity.

The proposed amendments also provide benefits in the form of avoided climate damages from reduced GHG emissions and avoided deaths from the reductions in PM2.5 and NOx emissions. Benefits from avoided deaths are estimated based on how much people are willing to pay for small reduction in their risks of dying. These valuations are not direct expenditures that would result in further macroeconomic impacts. Therefore, they are omitted from the macroeconomic analysis.

C. 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 proposed amendments are expected to decrease Gross State Product (GSP), output, employment, and personal income for the Proposal timeline. The proposed amendments require investments in technology and infrastructure to create a marketplace for low-CI fuels which provide a smaller energy equivalent to traditional fuels and would not be purchased otherwise. Additionally, after 2040, direct air capture and carbon sequestration (DACS) becomes cost competitive and shifts investment away from other low-CI fuel industries. It’s important to note that deployment of CCS and DAC must happen towards the end of this decade to be on track for achieving AB 1279 as demonstrated in the 2022 Scoping Plan Update. The results are reported here in tables for every four years from 2026 through 2046.

1. California Employment Impacts

Table 26 presents the impact of the proposed amendments on total employment in California across all industries. Employment comprises estimates of the number of jobs, full-time and part-time, by place of work for all industries. Full-time 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, which consist of positive impacts for some industries and negative impacts for others. The statewide employment impacts of the proposed amendments are estimated to have a positive impact on employment through 2027, followed by a mostly negative impact on employment through 2046 (Figure 7). The positive impacts on employment primarily result from the credits generated by low-CI fuels. The demand for these credits leads to expansion in the industries producing these fuels. After 2040, the CATS model predicts the costs for DAC will be lower than the costs of obtaining credits directly from low-CI fuel producers. As a result, the latter years of the assessment are characterized by high production costs for high-CI fuel producers, but overall less benefits for low-CI fuel producers. Increases in production costs and reductions in credit revenue for low-CI fuel producers negatively affect employment projections, as producers must cut employment to compensate for overall profit losses. The changes in employment do not exceed 0.04% of baseline California employment in any one year during the regulatory horizon.

Table 26: Total California Employment Impacts

Year	California Employment	Change in Total Jobs	% Change
2026	25,901,827	4,087	0.02%
2030	26,129,917	-4,659	-0.02%
2034	26,444,013	-2,612	-0.01%
2038	27,003,553	205	0.00%
2042	27,531,082	-7,608	-0.03%
2046	28,105,659	-10,991	-0.04%
Average	**26,714,238**	**-3,099**	**-0.01%**

The services and manufacturing sectors receive the majority of job increases until 2040 when all sectors show a decrease in job growth. The services and manufacturing sectors are projected to have initial increases in employment as resources are invested in development of low-CI fuel technologies, and then decrease in employment over the baseline after the first five years. The pronounced decrease in employment after 2040 corresponds to the more stringent CI targets that increase operational costs without increasing output. To counteract increased operational costs, other costs are often lowered in the form of reduced employment and wages for related industries which then impacts indirect industries such as the service industry.

Figure 7: Employment Impacts by Major Sector

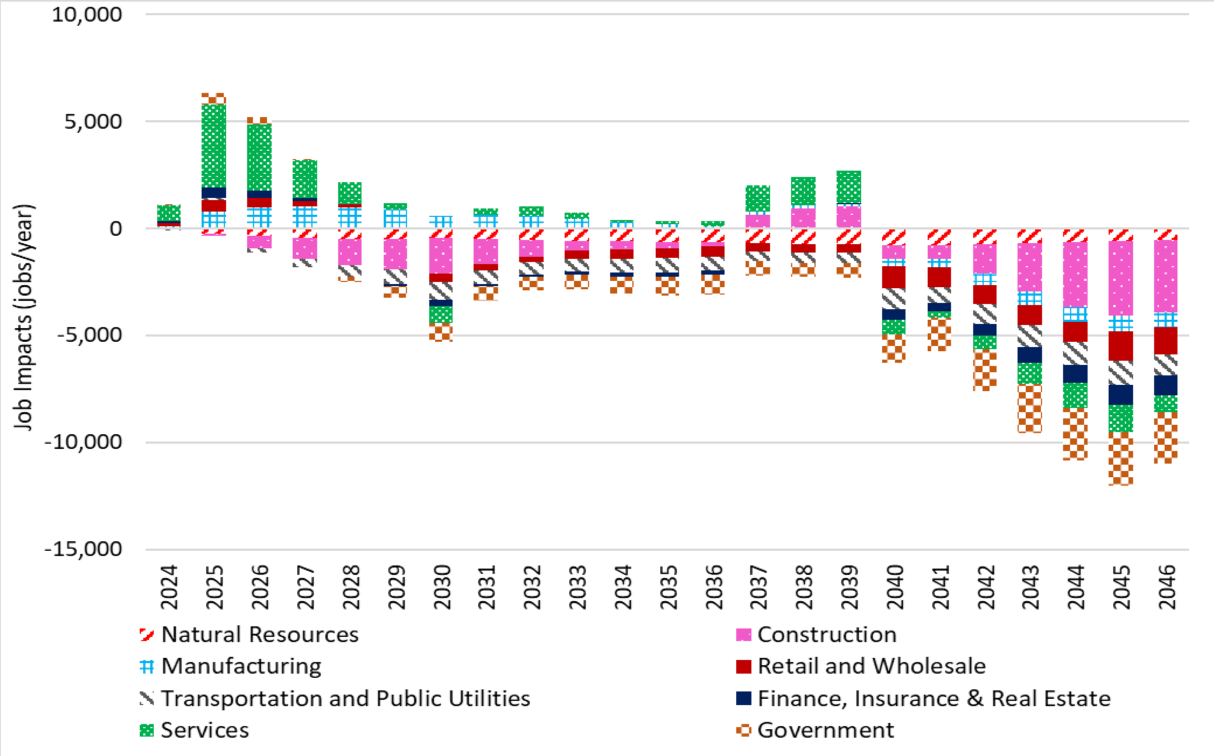


Table 27 Table presents changes in employment for industries directly impacted by the proposed amendments. Losses in jobs are largest in the petroleum and coal products manufacturing industry and are caused by reduced demand for these high-CI fuels as demand increases for low-CI fuels and increased production costs from the deficits generated by fossil gasoline and diesel fuels. The impacts to the petroleum and coal products manufacturing industry reaches its peak in 2040 with a 13.7% reduction in employment under the proposed amendments relative to the baseline. Overall California's employment continues to grow and averages 26.7 million jobs between 2024 and 2046. On average, the petroleum and coal products manufacturing industry is estimated to create 1,167 fewer jobs when compared to the baseline. On average, across all industries the estimated job impacts are approximately 3,099 fewer jobs created when compared to the baseline. The decreases in employment for high-CI fuel producers is countered by increases in employment growth in industries that include producers of low-CI fuels. For example, between 2026 and 2046, California employment grows by 2.2 million jobs, going from 25.9 million jobs in 2026 to 28.1 million jobs in 2046.

Table 27: Employment Impacts by Industry

	Petroleum and coal products manufacturing (324)	Petroleum and coal products manufacturing (324)	Basic chemical manufacturing (3251)	Basic chemical manufacturing (3251)	Natural gas distribution (2212)	Natural gas distribution (2212)	Electric power generation, transmission, and distribution (2211)	Electric power generation, transmission, and distribution (2211)
Year	**Change in Jobs**	**% Change**	**Change in Jobs**	**% Change**	**Change in Jobs**	**% Change**	**Change in Jobs**	**% Change**
2026	-664	-5.12%	417	6.35%	38	0.28%	296	0.73%
2030	-863	-6.77%	409	6.06%	29	0.22%	351	0.91%
2034	-1,229	-9.80%	487	6.96%	23	0.18%	881	2.40%
2038	-1,562	-12.58%	537	7.45%	0	0.00%	1,359	3.87%
2042	-1,593	-12.84%	376	5.12%	234	1.97%	1,020	3.04%
2046	-1,179	-9.45%	250	3.33%	289	2.52%	405	1.26%
Average	**-1,167**	**-9.31%**	**430**	**6.15%**	**84**	**0.70%**	**734**	**2.07%**

2. California Business Impacts

Gross output is used as a proxy for business impacts because it is principally a measure of an industry's sales or receipts and tracks the quantity of goods or services produced in a given time period. Output growth is the sum of output of each private industry and State and local government as it contributes to the State's GSP and is affected by production cost and demand changes. As production costs increase and demand decreases for high-CI fuel, output is expected to contract. Likewise, as production costs decreases and demand increases for low-CI fuels, the associated industries will likely experience output growth.

Table 28 presents the estimated changes to output growth resulting from the proposed amendments. The proposed amendments have a minimal impact on overall growth. California output is expected to increase through 2046 but at a slower rate than the baseline prediction, with the largest decrease occurring in 2043 of $12.5 billion, or 0.16%, when compared to the baseline. Under the proposed amendments, California's estimated average annual decrease in output of $7 billion results in an annual output average of $6.8 trillion. This estimated annual decrease is small in comparison to overall growth; for example, from 2026 and 2046, California output is estimated to still grow by almost $2.5 trillion going from $5.9 trillion in 2026 to $8.3 trillion in 2046.

Table 28: Change in California Output

Year	Output (2021M$)	Change (2021M$)	% Change
2026	5,859,728	-1,405	-0.02%
2030	6,155,055	-4,647	-0.08%
2034	6,554,673	-6,418	-0.10%
2038	7,096,044	-8,180	-0.12%
2042	7,673,337	-12,174	-0.16%
2046	8,300,731	-11,472	-0.14%
Average	**6,806,804**	**-6,972**	**-0.10%**

The output impacts by major sector are illustrated in Figure 8. Major sectors of the economy experience different output changes. Most sectors are projected to experience decreases in output over the lifetime of the proposed amendments. Similar to the employment impacts, the negative impact to output grows over time as the CI target requirements become more stringent, leading to increased operational costs. To counteract increased operational costs, other costs are often lowered in the form of reduced output.

Figure 8: Change in California Output Growth by Major Sector

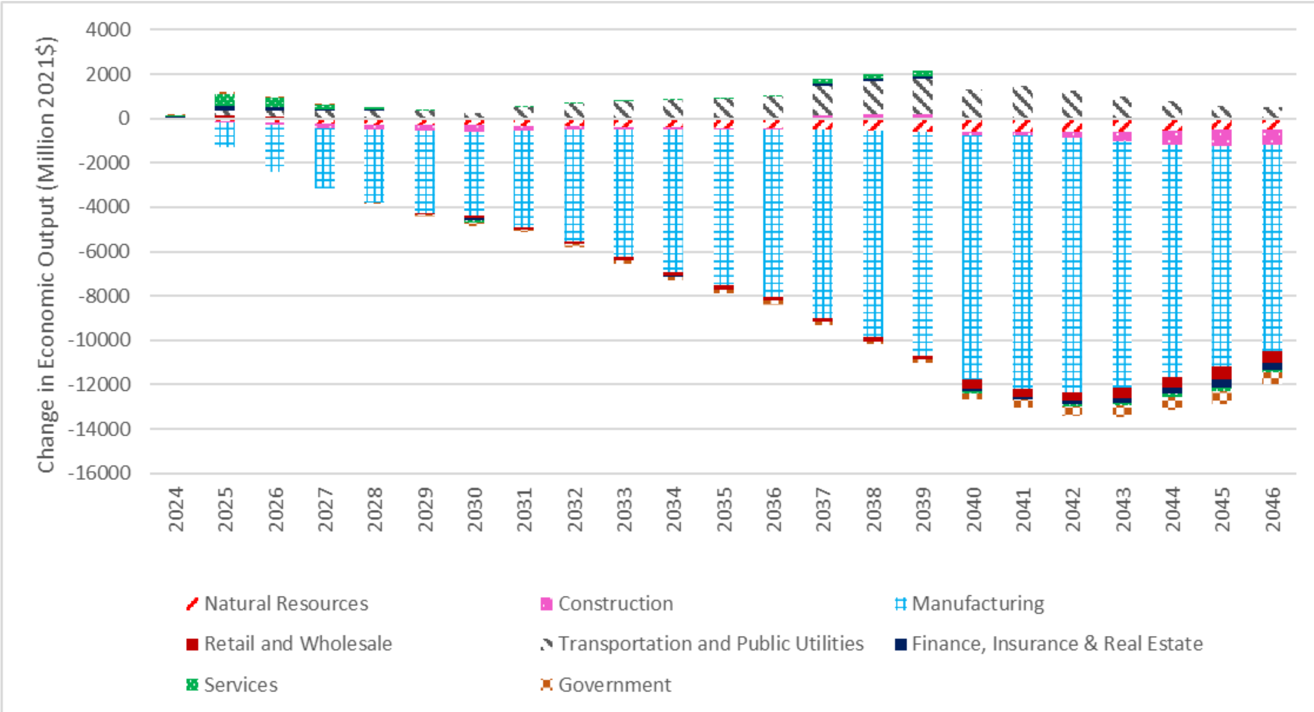


Table 29 illustrates the impacts to output by directly regulated industry.

Table 29: Change in California Output by Regulated Industry

	Petroleum and coal products manufacturing (324)	Petroleum and coal products manufacturing (324)	Basic chemical manufacturing (3251)	Basic chemical manufacturing (3251)	Natural gas distribution (2212)	Natural gas distribution (2212)	Electric power generation, transmission, and distribution (2211)	Electric power generation, transmission, and distribution (2211)
Year	**Change in Jobs**	**% Change**	**Change in Jobs**	**% Change**	**Change in Jobs**	**% Change**	**Change in Jobs**	**% Change**
2026	-4,960	-5.13%	2,195	6.38%	14	0.28%	334	0.73%
2030	-6,712	-6.79%	2,270	6.12%	12	0.22%	419	0.92%
2034	-10,017	-9.84%	2,860	7.03%	13	0.19%	1,116	2.42%
2038	-13,441	-12.63%	3,342	7.52%	16	0.00%	1,845	3.90%
2042	-14,522	-12.90%	2,498	5.19%	13	1.99%	1,493	3.08%
2046	-11,373	-9.52%	1,762	3.38%	8	2.54%	643	1.29%
Average	**-9,967**	**-9.35%**	**2,574**	**6.21%**	**12**	**0.71%**	**988**	**2.09%**

3. 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.

As modeled, the proposed amendments result in slight private investment increases of $4 million on average. The beginning and end of the regulatory period experience decreases in investment when compared to the baseline while the mid years see an increase. The difference in private investment for the proposed amendments is modest and does not exceed 0.09% of baseline investment across the analytical time period for any one year and averages no percentage change over the regulatory horizon (Table 30).

Table 30: Change in Private Investment

Year	Private Investment (2021M$)	Change (2021M$)	% Change
2026	565,257	-28	0.00%
2030	609,113	-325	-0.05%
2034	656,228	102	0.02%
2038	719,011	616	0.09%
2042	781,017	119	0.02%
2046	845,246	-653	-0.08%
Average	**680,505**	**4**	**0.00%**

4. Impacts on Individuals in California

The proposed amendments do not directly regulate individuals in California. However, the costs incurred by affected businesses could indirectly be passed on to individuals and the changes in fuels provided to California would result in changes in consumer spending on fuels. One measure of the resulting impact to individuals is the change in real personal income, which is income received from all sources, including compensation of employees and government and business transfer activity, adjusted for inflation. This is an aggregate statewide measure of personal income change, representing a net of income lost from jobs foregone in some sectors and jobs gained in other sectors. Personal income mostly decreases when compared to the baseline in the early years of the proposed amendment until 2032, followed by increases over the baseline in mid years of the proposed amendments, and then decreases again towards the end of the regulatory horizon from 2043 to 2046.

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. The change in per capita personal income growth is, on average, positive over the lifetime of the proposed amendments with a maximum increase in per capita income of $41 in 2039 and maximum decrease in per capita income of $23 in 2045. The average per capita income change between 2024 and 2046 is an annual increase of $5 (Table 31).

Table 31: Change in Personal Income

Year	Personal Income (2021M$)	Change (2021M$)	% Change	Personal Income Per Capita (2021$)	Per Capita Change (2021$)
2026	2,993,750	-287	-0.01%	72,966	-8
2030	3,292,669	-699	-0.02%	78,664	-11
2034	3,624,804	215	0.01%	85,164	10
2038	4,019,017	1,796	0.04%	93,190	39
2042	4,438,728	121	0.00%	101,930	7
2046	4,884,559	-2,098	-0.04%	111,421	-18
Average	**3,779,481**	**-24**	**0.00%**	**88,589**	**5**

5. 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 of economic growth. It is calculated as the sum of the dollar value of consumption, investment, net exports, and government spending.

Table 32: Change in Gross State Product shows the estimated annual change in GSP because of the proposed amendments. GSP is estimated to grow at a slower rate than the baseline, with the largest decrease to GSP growth in 2045 of $4.7 billion corresponding to a 0.09% decrease compared to the baseline GSP.

Table 32: Change in Gross State Product

Year	GSP (2021M$)	Change (2021M$)	% Change
2026	3,493,557	-24	0.00%
2030	3,723,135	-1,685	-0.05%
2034	4,003,924	-2,014	-0.05%
2038	4,324,107	-2,262	-0.05%
2042	4,652,494	-4,151	-0.09%
2046	5,007,198	-4,339	-0.09%
Average	**4,119,839**	**-2,240**	**-0.05%**

6. Creation or Elimination of Businesses

The REMI model cannot directly estimate the creation or elimination of businesses. However, changes in jobs and output for the California economy described above can be used to understand some potential impacts. Reductions in output could indicate elimination of businesses. Conversely, increased output within an industry could signal the potential for additional business creation if existing businesses cannot accommodate all future demand. There is no threshold that identifies the creation or elimination of business.

The Statewide jobs and output impacts of the proposed amendments are small relative to the total California economy. The largest employment increase is estimated to be 0.02% for 2025 compared to the baseline. The largest employment decrease is estimated to be 0.04% for 2044 through 2046 compared to the baseline. Output is expected to decrease for the lifetime of the regulation compared to the baseline. The largest output decrease in the State is estimated to be 0.16% for 2043. However, impacts to specific industries are larger or smaller as described in previous sections.

The trend of increased demand for low-CI fuels will cause petroleum-based businesses to shift away from production and consumption of fossil fuel sources and pave the way for cleaner fuel sources to be manufactured and used. There is potential for elimination of businesses focused primarily on high-CI fuels unless innovations are made to reduce the CI of these fuels. The proposed amendments have the potential to incentivize new businesses that produce low-CI fuels such as producers of renewable diesel, biomethane, and low-CI hydrogen and electricity.

7. Incentives for Innovation

The proposed amendments require implementing processes that substitute low-carbon sources of energy, such as waste oils and renewable electricity, in place of fossil fuel sources. The proposed amendments will lead to an overall higher price for LCFS credits relative to the baseline, which will send a signal for research, development, and deployment of innovative technologies and fuels that support California’s long-term GHG emissions reduction goals.

All fuel producers will have an increased incentive to innovate and deploy new methods that reduce the CI of their fuels. The proposed amendments will additionally provide long term price stability for LCFS credits, which is essential for low-CI fuel producers to make investments in long-term capital projects and research and development.

8. Competitive Advantage or Disadvantage

Because the proposed amendments are designed to increase the competitiveness of low-CI fuels in California, California businesses that produce low-CI fuels may become more competitive. Petroleum fuel producers will face increased compliance costs under the proposed amendments. California sectors that rely heavily on transportation fuel may also face higher prices, resulting in a potential competitive disadvantage relative to out-of-state entities that are not subject to the LCFS. However, any potential impact of the proposed amendments on the competitiveness of California businesses will likely be reduced as more low-carbon fuel policies similar to California’s LCFS are adopted across North America. Oregon, Washington, and British Columbia all have similar clean fuels programs to California’s program, and several other states are considering their own programs.

D. Summary and Agency Interpretation of the Assessment Results

Overall, California output, employment, private investment, and personal income all continue to grow between 2024 and 2046 under the analysis conducted for the proposed amendments. LCFS credits generation provides fuel producers with incentive to innovate and deploy new methods that reduce the CI of their fuels. This incentive for low-CI fuels and innovation will drive investments in long-term capital projects, research and development, and creation and expansion of businesses focused on production of low-CI fuels both within and outside of California. Compared to the baseline, the analysis shows the proposed amendments have a minimal impact on this overall growth and are estimated to result in an average annual reduction of output by $7 billion. As mentioned earlier, the economic analysis used the REMI model that may not fully capture the innovation incentives, research and development support, competitive advantage, or business creation outcomes from LCFS credit generation; however, it does provide valuable insight to the potential macroeconomic effects of the proposed amendments. Nevertheless, the REMI analysis shows that, as compared to the baseline no action alternative, output declines throughout the lifetime of the analysis as production costs increase. Personal income grows overall between 2024 and 2046 but, relative to the baseline, is lower on average under the proposed amendments. This is the same with employment, which grows between 2024 and 2046, but at reduced levels under the proposed amendments. Overall, private investment values show very little variance compared to the baseline and total impacts to the economy are expected to be minimal. No California economic indicator varied by more than 0.16% from the baseline value in any given year (Table 33).

Table 33: Summary of Impacts of the Proposed Amendments

	GSP	GSP	Personal Income	Personal Income	Employment	Employment	Output	Output	Private Investment	Private Investment
Year	**Change (2021M$)**	**% Change**	**Change (2021 M$)**	**% Change**	**Change (Jobs)**	**% Change**	**Change (2021 M$)**	**% Change**	**Change (2021 M$)**	**% Change**
2026	-24	0.00%	-287	-0.01%	4,087	0.02%	-1,405	-0.02%	-28	-0.01%
2030	-1,685	-0.05%	-699	-0.02%	-4,659	-0.02%	-4,647	-0.08%	-325	-0.05%
2034	-2,014	-0.05%	215	0.01%	-2,612	-0.01%	-6,418	-0.10%	102	0.02%
2038	-2,262	-0.05%	1,795	0.04%	205	0.00%	-8,180	-0.12%	616	0.09%
2042	-4,151	-0.09%	121	0.00%	-7,608	-0.03%	-12,174	-0.16%	119	0.02%
2046	-4,339	-0.09%	-2,099	-0.04%	-10,991	-0.04%	-11,472	-0.14%	-653	-0.08%
Average	**-2,240**	**-0.05%**	**-24**	**0.00%**	**-3,099**	**-0.01%**	**-6,972**	**-0.10%**	**4**	**0.00%**

VI. Alternatives

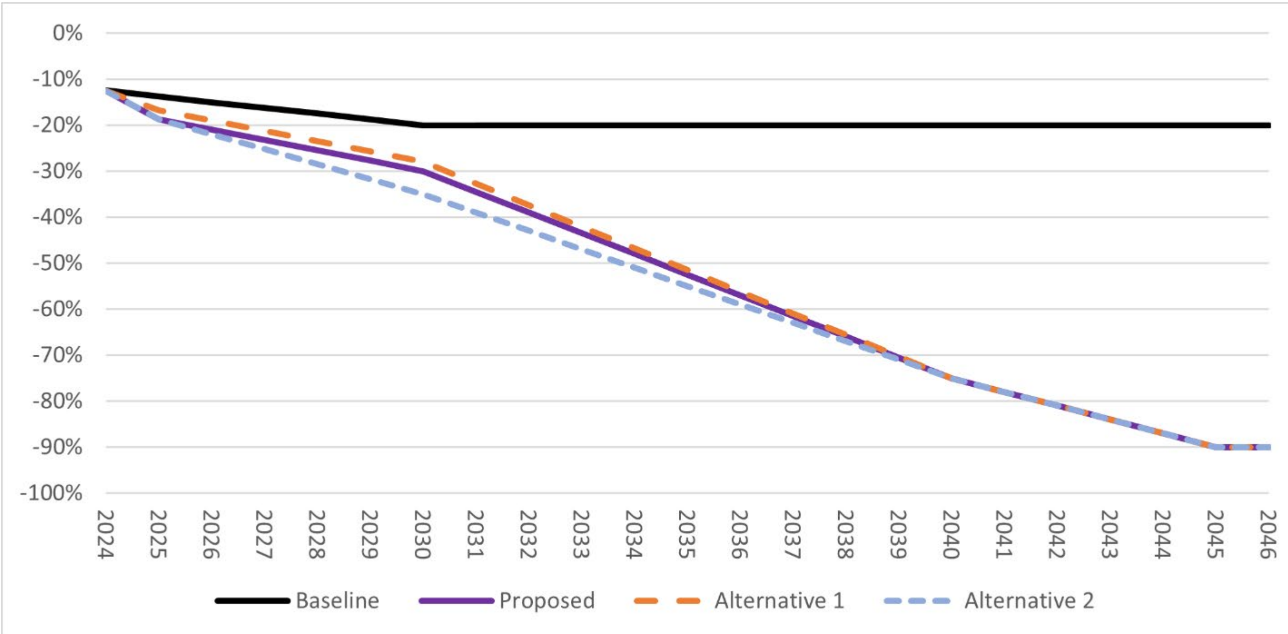
CARB solicited public input regarding alternatives to the proposed amendments. This solicitation was presented and discussed at a workshop held on November 9, 2022.[90] In the solicitation, staff requested that alternatives be submitted by December 2, 2022. Several stakeholders responded to the solicitation by proposing alternatives.

Staff analyzed two alternatives to the proposed amendments. Both alternatives increase the stringency of benchmarks beyond the baseline since more low-CI fuels are entering the market than previously expected, and CI reductions are outpacing the current benchmark schedule. They both reach a 90% benchmark reduction in 2045 but have different rates of change in the interim years in order to provide analysis on the comparative cost and benefits of more rapidly declining benchmarks in early years as compared to later years.

While the overall benchmark schedule of the first alternative (based off proposals and stakeholder feedback) is more stringent than the baseline, it is less stringent than the proposed amendments and has a 3% step-down, achieving a 28% CI reduction in 2030. The second alternative (based off proposals and stakeholder feedback) is more aggressive than the proposed amendments and achieves a CI reduction target of 35% by 2030, after a 5% step-down and a linear compliance trajectory from 2025 to 2030. Both alternatives reach the same 90% CI reduction in 2045 as the proposed amendments but have different compliance curves from 2025-2045 to account for the difference in their 2030 targets, as shown in Figure 9. Although the scenarios reach the same end-goal of 90% CI reduction in 2045, Alternative 1 is the least stringent through 2030, while Alternative 2 reflects the higher costs of front-loading the stringency of the CI targets through 2030.

[90] CARB (2022). *Low Carbon Fuel Standard Public Workshop: Concepts and Tools for Compliance Target Modeling*. https://ww2.arb.ca.gov/sites/default/files/2022-11/LCFSPresentation.pdf

Figure 9: Carbon Intensity Compliance Curves for Each Alternative



A. Alternative 1

Compared to the proposed amendments, Alternative 1 has a less stringent CI compliance curve before 2030. It then accelerates to meet the same 90% carbon reduction in 2045 but is more stringent than the baseline (Figure 9 and

Table 34). Compared to the proposed amendments, this scenario is less stringent in the early years when aggressive CI reductions are expected to be more expensive and challenging to meet because some renewable fuel production has yet to reach economies of scale. Figure 10 shows the resultant low-CI fuel volumes.

Alternative 1 is more easily attainable given current supplies of low-CI fuels and requires fewer additional low-CI fuels in early years. Accordingly, Alternative 1 includes several policy mechanisms that have the effect of limiting the number of credits created from existing low-CI pathways. For example, Alternative 1 includes a complete phase out of light-duty battery electric forklifts from the program. Alternative 1 also includes a limit on total credits from diesel fuels or sustainable aviation fuel produced from virgin oil feedstocks. Figure 11 depicts the fuel mix for Alternative 1.

Table 34: Alternative 1 - CI Target Benchmarks

Year	Percent Reduction
2024	12.4%
2025	16.8%
2026	19.0%
2027	21.3%
2028	23.5%
2029	25.8%
2030	28.0%
2031	32.7%
2032	37.4%
2033	42.1%
2034	46.8%
2035	51.5%
2036	56.2%
2037	60.9%
2038	65.6%
2039	70.3%
2040	75.0%
2041	78.0%
2042	81.0%
2043	84.0%
2044	87.0%
2045	90.0%
2046	90.0%

Figure 10: Low-CI Fuel Volumes in the Alternative 1 Scenario

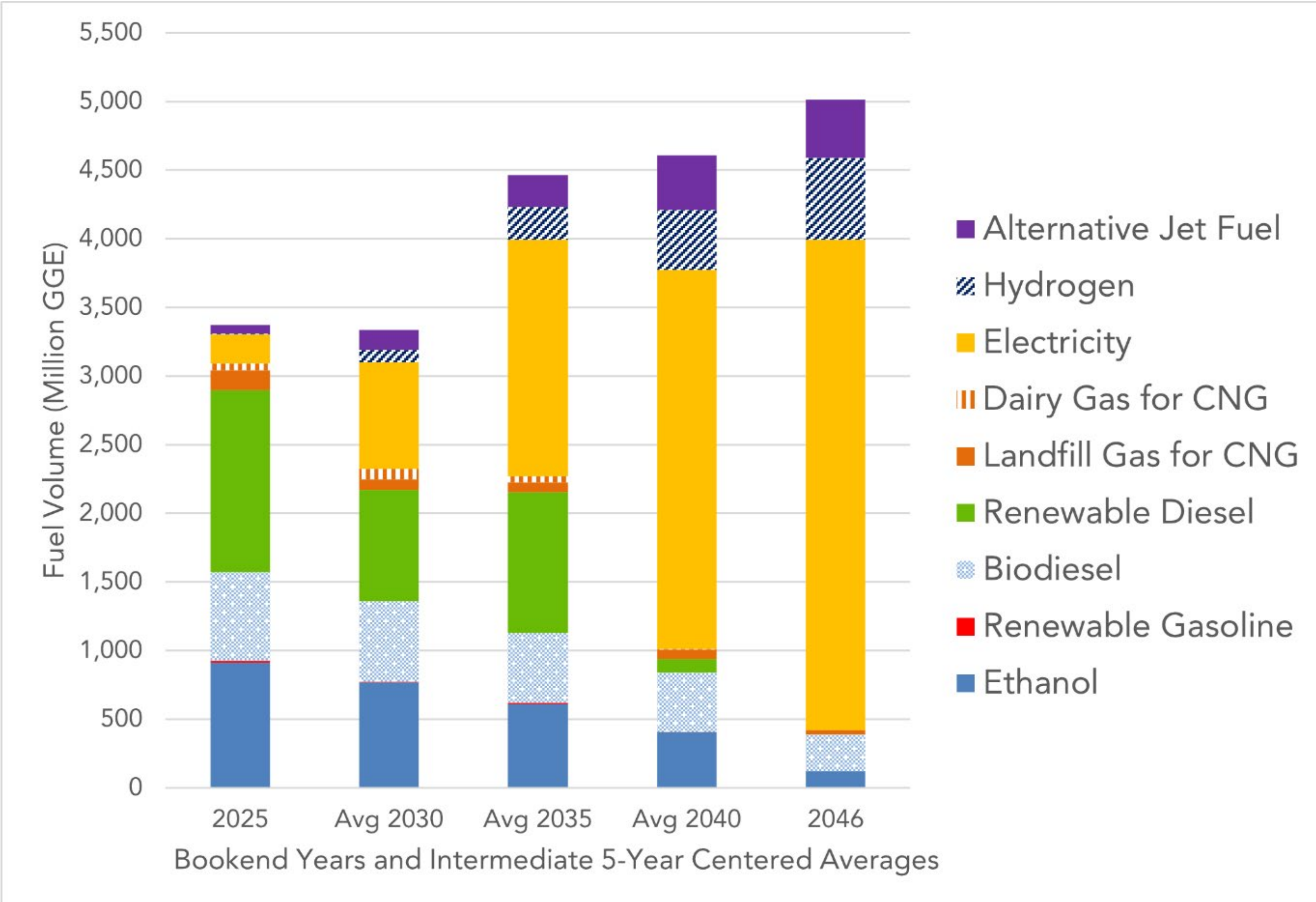
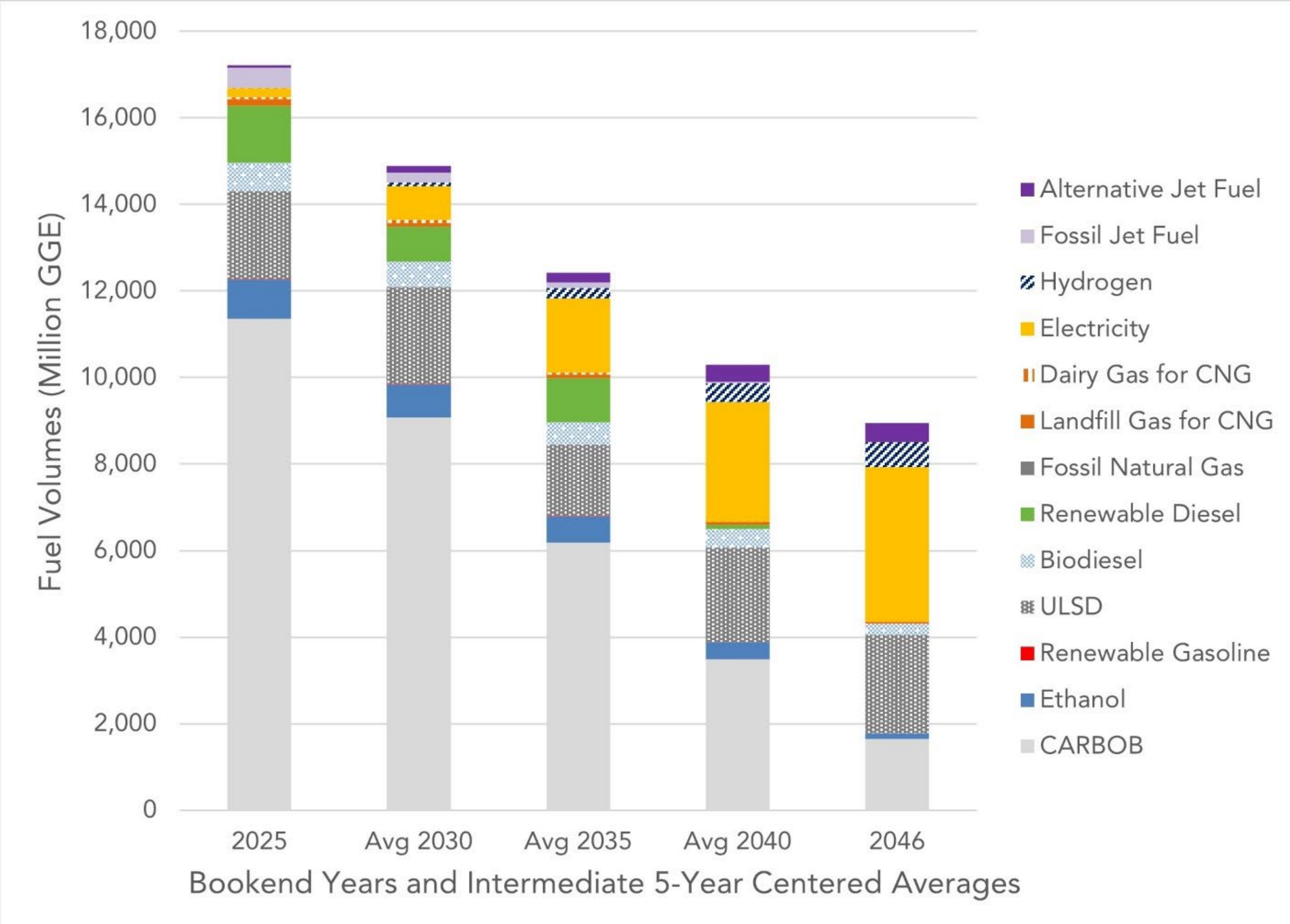


Figure 11: Fuel Mix – Alternative 1 Scenario



1. Costs

Alternative 1 costs $164 billion, approximately 1% more than the proposed amendments. The main reason is that diesel fuel is a larger part of the fuel mixture and continues generating large amounts of in-state deficits through 2046. This is because renewable diesel produced from virgin oil feedstock is phased out, waste oil feedstocks are used to produce alternative jet fuel, and more fossil diesel is needed to fuel the remaining vehicles with internal combustion engines. Credit revenues in California are $126 billion, 2% less than the proposed amendments.

2. Benefits

a) Emissions

Alternative 1 reduces GHG emissions by 461 MMTCO_2e compared to the baseline scenario (as shown in Figure 12). This is approximately 18% fewer reductions than the proposed amendments. Accordingly, the social cost of carbon benefits for Alternative 1 from reduced CO_2e range from approximately $12 to $50 billion, values approximately 18% lower than the proposed amendments. Table 35 and

Table 36 show the change in NOx and PM2.5 as compared to the baseline. Alternative 1 results in a reduction in cumulative NOx emissions by 18,728 tons and a decrease in PM2.5 emissions by 1,573 tons. Compared to the proposed amendments, Alternative 1 reduces NOx emissions by an additional 1,331 tons and increases PM2.5 emissions by 2,535 tons. Alternative 1 has more PM2.5 emissions than the proposed amendments because this scenario uses less renewable diesel than the proposed amendments. Alternative 1 has fewer NOx emissions than the proposed amendments because there is less in-state renewable fuel production needed to meet on-road alternative fuel demand, and because roughly two billion more gallons of alternative jet fuel are used in this scenario compared to the proposed amendments, which results in substantially reduced engine NOx emissions in the aviation sector.

Figure 12: Alternative 1 - GHG Emissions

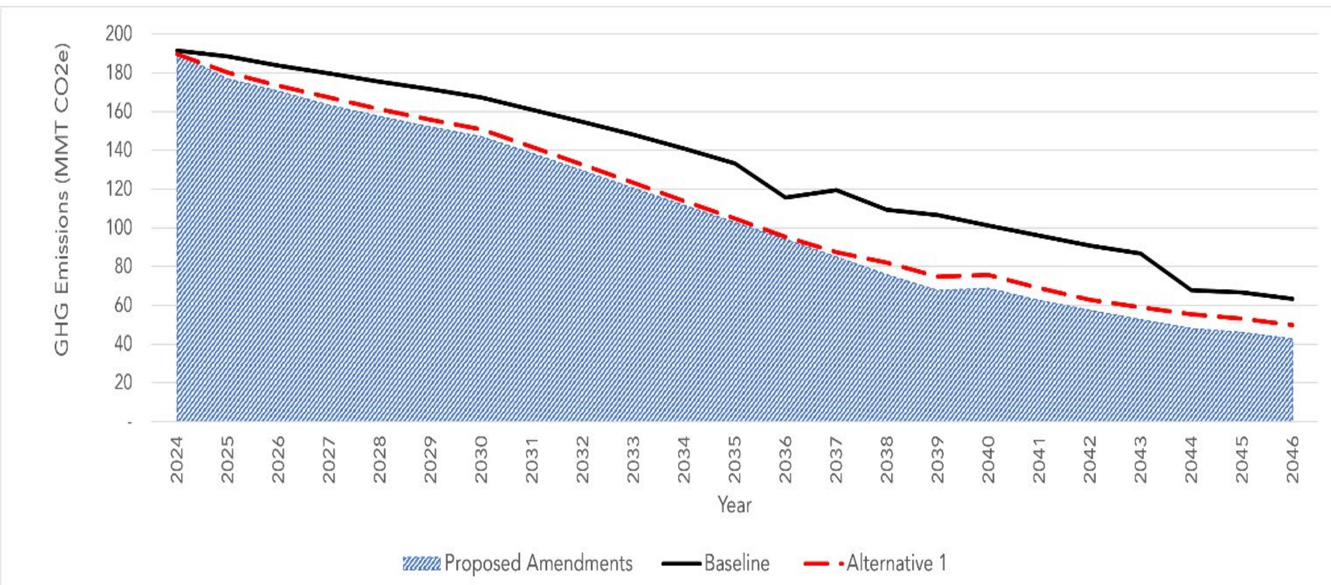


Table 35: Alternative 1 - NOx Emission Changes (tons per day)

Year	NOx (tpd)
2024	-0.232
2025	-0.575
2026	-0.576
2027	-0.859
2028	-1.023
2029	-0.981
2030	-1.059
2031	-1.160
2032	-1.598
2033	-1.883
2034	-2.018
2035	-2.094
2036	-2.282
2037	-2.288
2038	-2.315
2039	-2.486
2040	-2.753
2041	-2.946
2042	-3.306
2043	-4.184
2044	-4.632
2045	-4.945
2046	-5.079

Table 36: Alternative 1 - PM2.5 Emission Changes (tons per day)

Year	PM2.5 (tpd)
2024	-0.070
2025	-0.119
2026	-0.056
2027	-0.260
2028	-0.309
2029	-0.178
2030	-0.097
2031	-0.050
2032	-0.178
2033	-0.285
2034	-0.388
2035	-0.427
2036	-0.463
2037	-0.265
2038	-0.101
2039	-0.065
2040	-0.145
2041	-0.156
2042	-0.200
2043	-0.118
2044	-0.108
2045	-0.116
2046	-0.154

b) Health Benefits

Staff used the methods described in Section II.D.2 to estimate avoided cardiopulmonary mortality, hospitalizations for cardiovascular illness and respiratory illness, and emergency room visits for respiratory illness and asthma that would be expected to result from implementing Alternative 1 when compared to the Baseline scenario. The results are presented in Table 37 for each California air basin. As shown in

Table 38, Alternative 1 has a valuation of health benefits at $1.58 billion compared to the proposed amendments with a valuation at $4.98 billion, a difference of $3.4 billion less in health benefits. The negative health impacts of Alternative 1 are primarily associated with increases in PM2.5 over the baseline due to lower utilization of renewable diesel.

Table 37: Alternative 1 - Avoided Mortality and Morbidity Incidents from 2024 to 2046

Air Basin	SC	SCC	SJV	SFB	SD	Statewide
Cardiopulmonary Mortality	48 (27 - 67)	6 (3 - 8)	30 (17 - 43)	12 (6 - 17)	13 (7 - 18)	**119 (66 - 168)**
Hospitalizations for Cardiovascular Disease	9 (7 - 12)	1 (1 - 2)	6 (4 - 7)	2 (2 - 3)	3 (2 - 4)	**24 (17 - 30)**
Cardiovascular ED Visits	14 (-5 - 32)	1 (-1 - 3)	7 (-3 - 17)	4 (-1 - 8)	3 (-1 - 8)	**32 (-12 - 75)**
Acute Myocardial Infarction	6 (2 - 15)	1 (0 - 2)	3 (1 - 8)	1 (1 - 4)	1 (0 - 4)	**13 (5 - 36)**
Hospitalizations for Respiratory Disease	1 (0 - 3)	0 (0 - 0)	1 (0 - 2)	0 (0 - 1)	0 (0 - 1)	**4 (0 - 7)**
Respiratory ED Visits	29 (6 - 59)	3 (1 - 6)	20 (4 - 41)	9 (2 - 18)	6 (1 - 13)	**74 (14 - 153)**
Lung Cancer Incidence	3 (1 - 5)	0 (0 - 1)	2 (1 - 3)	1 (0 - 2)	1 (0 - 2)	**9 (3 - 14)**
Asthma Onset	105 (102 - 109)	14 (13 - 14)	55 (53 - 57)	42 (40 - 43)	31 (29 - 32)	**270 (260 - 280)**
Asthma Symptoms	10,221 (-5,020 – 24,634)	1,248 (-610 – 3,021)	5,059 (-2,476 – 12,235)	3,585 (-1,749 – 8,695)	2,619 (-1,276 – 6,359)	**24,920 (-12,197 – 60,258)**
Work Loss Days	7,117 (6,012 – 8,176)	833 (703 - 959)	3,847 (3,247 – 4,423)	2,402 (2,025 – 2,763)	2,140 (1,804 – 2,463)	**17,862 (15,077 – 20,538)**
Hospitalizations for Alzheimer's Disease	15 (13 - 16)	2 (2 - 2)	12 (10 - 15)	5 (4 - 6)	9 (7 - 12)	**47 (38 - 55)**
Hospitalizations for Parkinson’s Disease	2 (1 - 3)	0 (0 - 1)	2 (1 - 2)	1 (1 - 1)	1 (1 - 2)	**7 (4 - 10)**

Table 37 continued

Air Basins	SS	SV	NP	NC	NCC	Statewide
Cardiopulmonary Mortality	3 (2 - 5)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	1 (1 - 2)	**119 (66 - 168)**
Hospitalizations for Cardiovascular Disease	1 (0 - 1)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	**24 (17 - 30)**
Cardiovascular ED Visits	1 (0 - 2)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0 (0 - 1)	**32 (-12 - 75)**
Acute Myocardial Infarction	0 (0 - 1)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	**13 (5 - 36)**
Hospitalizations for Respiratory Disease	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	**4 (0 - 7)**
Respiratory ED Visits	3 (1 - 6)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	1 (0 - 3)	**74 (14 - 153)**
Lung Cancer Incidence	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	**9 (3 - 14)**
Asthma Onset	9 (8 - 9)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	5 (5 - 5)	**270 (260 - 280)**
Asthma Symptoms	785 (-382 – 1,908)	59 (-29 - 141)	-27 (13 - -67)	-30 (15 - -74)	425 (-207 – 1,032)	**24,920 (-12,197 – 60,258)**
Work Loss Days	583 (491 - 671)	13 (11 - 15)	-19 (-16 - -22)	-30 (-26 - -35)	293 (247 - 337)	**17,862 (15,077 – 20,538)**
Hospitalizations for Alzheimer's Disease	1 (1 - 1)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0 (0 - 1)	**47 (38 - 55)**
Hospitalizations for Parkinson’s Disease	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	**7 (4 - 10)**

Table 37 continued

Air Basin	MC	MD	LT	LC	GBV	Statewide
Cardiopulmonary Mortality	-1 (0 - -1)	7 (4 - 10)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	**119 (66 - 168)**
Hospitalizations for Cardiovascular Disease	0 (0 - 0)	1 (1 - 2)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	**24 (17 - 30)**
Cardiovascular ED Visits	0 (0 - 0)	2 (-1 - 4)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	**32 (-12 - 75)**
Acute Myocardial Infarction	0 (0 - 0)	1 (0 - 2)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	**13 (5 - 36)**
Hospitalizations for Respiratory Disease	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	**4 (0 - 7)**
Respiratory ED Visits	0 (0 - -1)	4 (1 - 8)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	**74 (14 - 153)**
Lung Cancer Incidence	0 (0 - 0)	0 (0 - 1)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	**9 (3 - 14)**
Asthma Onset	-1 (-1 - -2)	12 (11 - 12)	1 (1 - 1)	0 (0 - 0)	0 (0 - 0)	**270 (260 - 280)**
Asthma Symptoms	-126 (61 - -305)	1,069 (-521 – 2,597)	40 (-20 - 98)	-2 (1 - -6)	-4 (2 - -10)	**24,920 (-12,197 – 60,258)**
Work Loss Days	-103 (-87 - -118)	757 (638 - 871)	37 (32 - 43)	-2 (-2 - -3)	-4 (-3 - -5)	**17,862 (15,077 – 20,538)**
Hospitalizations for Alzheimer's Disease	0 (0 - 0)	3 (2 - 3)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	**47 (38 - 55)**
Hospitalizations for Parkinson’s Disease	0 (0 - 0)	0 (0 - 1)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	**7 (4 - 10)**

Table 38: Alternative 1 Valuation by Health Outcome (Million 2021$)

	Cardiopulmonary Mortality	Hospitalizations for Parkinson' s Disease	Respiratory ED Visits	Hospitalizations for Alzheimer's Disease	Hospitalizations for Cardiovascular Disease	Cardiovascular ED Visits	ER visits, respiratory	Asthma Onset	Asthma Symptoms	Lung Cancer Incidence	Acute Myocardial Infarction	Work Loss Days	Valuation
2026	68	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	69
2030	48	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	49
2034	184	<1	<1	<1	<1	<1	<1	1.74	<1	<1	<1	<1	187
2038	26	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	26
2042	8	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	8
2046	2	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	2
Total	**1,555**	**0.11**	**0.04**	**0.68**	**0.45**	**0.05**	**0.08**	**14.5**	**6.3**	**0.3**	**1.3**	**3.7**	**1,583**

3. Economic Impacts

Alternative 1 is less stringent than the proposed amendments since Alternative 1 uses less stringent CI targets, which in turn result in a smaller credit market overall and lower compliance costs. Lower compliance costs translate to a smaller overall effect on the California economy, but at the cost of not achieving as many GHG emissions reductions.

The macroeconomic impact analysis results shown in

Table 39 indicate that Alternative 1 would result in more positive impacts on GSP, personal income, employment (Figure 13), output (Figure 14) and private investment when compared to the proposed amendments, but that the impacts would still on average be negative for GSP, employment, and output. This trend is expected, as Alternative 1 is the least stringent in the earlier years of the program and makes up for this early lag by accelerating the rate of CI reductions in the later years of the program to achieve the same endpoint as the proposed amendments, 90% CI reduction in 2046. In general, the California economic indicators decline more in later years as achieving higher CI targets becomes more difficult and costly.

Table 39: Summary of Economic Impacts of Alternative 1

	GSP	GSP	Personal Income	Personal Income	Employment	Employment	Output	Output	Private Investment	Private Investment
Year	**Change (2021M$)**	**% Change**	**Change (2021 M$)**	**% Change**	**Change (Jobs)**	**% Change**	**Change (2021 M$)**	**% Change**	**Change (2021 M$)**	**% Change**
2026	210	0.01%	119	0.00%	3,631	0.01%	-336	-0.01%	66	0.01%
2030	-903	-0.02%	-83	0.00%	-779	0.00%	-2,875	-0.05%	-32	-0.01%
2034	-1,608	-0.04%	795	0.02%	-265	0.00%	-5,598	-0.09%	308	0.05%
2038	-1,760	-0.04%	2,797	0.07%	5,499	0.02%	-7,503	-0.11%	1,097	0.15%
2042	-4,067	-0.09%	1,104	0.02%	-4,012	-0.01%	-12,455	-0.16%	583	0.07%
2046	-4,248	-0.08%	-1,151	-0.02%	-8,020	-0.03%	-11,688	-0.14%	-188	-0.02%
Average	**-1,925**	**-0.04%**	**636**	**0.02%**	**-451**	**0.00%**	**-6,379**	**-0.09%**	**297**	**0.04%**

Figure 13: Alternative 1- Employment Impacts by Major Sector (Jobs)

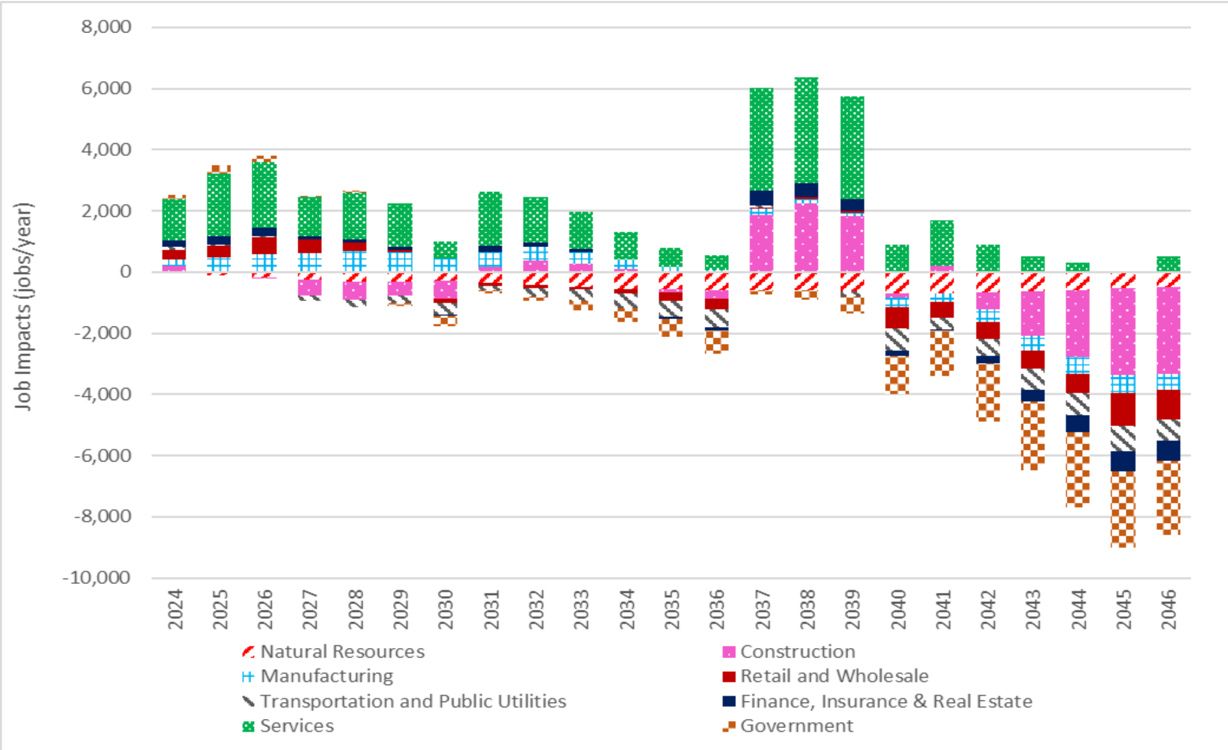
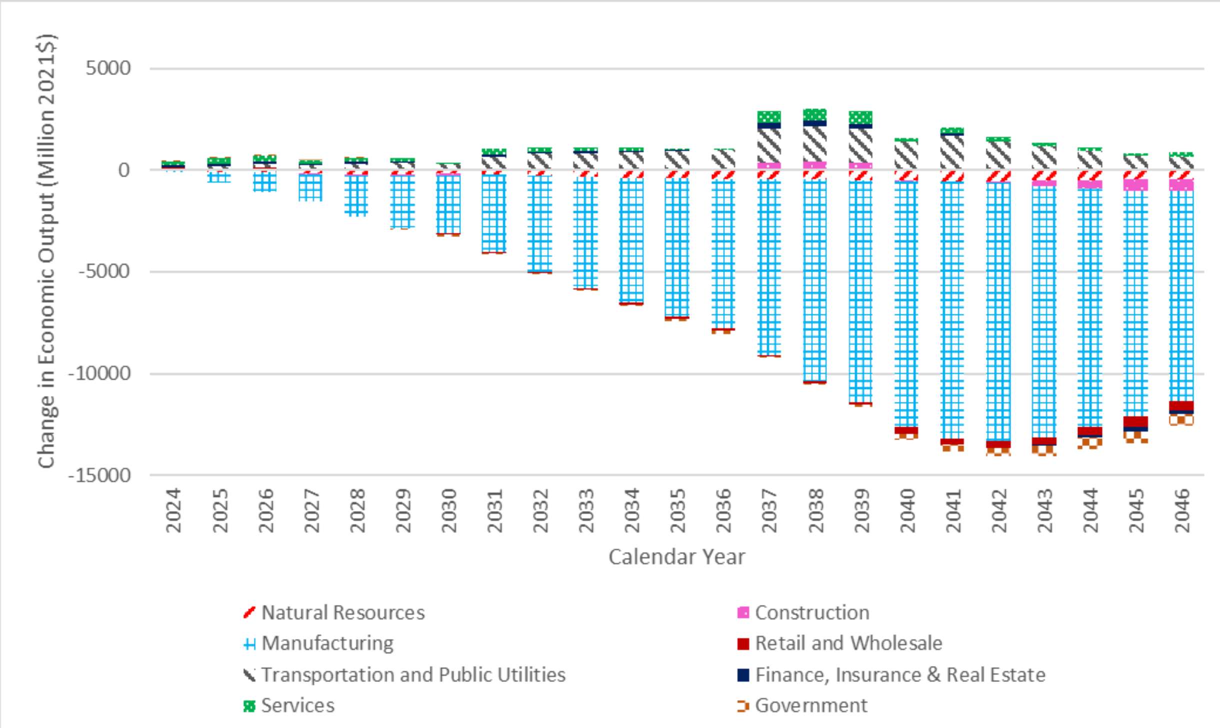


Figure 14: Alternative 1 - Change in Output by Major Sector (2021M$)



4. Cost-Effectiveness

Alternative 1 has a cost effectiveness of $83 per metric ton CO_2e, calculated as the net cost to California (relative to baseline) divided by the cumulative GHG reductions (relative to baseline). This is $22 more per metric ton CO_2e than the proposed amendments, and results in 17% fewer GHG reductions.

5. Reason for Rejecting

Alternative 1 is rejected for several reasons. While all scenarios will ultimately achieve a 90% CI reduction by 2045, the Alternative achieves the fewest emissions reductions of the scenarios considered over the duration of the program, particularly in the near-term through 2030. As described in the 2022 Scoping Plan Update, near-term action is critical to achieving the Statewide 2030 GHG emissions reductions target, and this scenario does not support this goal. Alternative 1 also relies more heavily on fossil fuels and carbon dioxide removal technology than the proposed amendments. As a result, this Alternative does not achieve the same level of NOx and PM2.5 emissions reductions as the proposed amendments and potentially exacerbates existing air quality challenges in the State.

B. Alternative 2

Alternative 2 has more stringent CI reduction targets from 2025 to 2030, then smaller increments until reaching 90% reduction in 2045, as compared to the proposed amendments (Table 40). As a result of the more stringent near-term CI targets, Alternative 2 results in higher credit prices and greater credit generation.

Increasing the pace of CI reductions in early years would require additional policies for credit generation to incentivize near-term investment. Alternative 2 does not include several of the credit limitations in the proposed amendments in order to free up supplies of low-carbon fuels to balance the market. Alternative 2 keeps the existing requirements for forklifts that are now commonplace and allows electric forklifts to continue to generate more credits into the future. In addition, Alternative 2 does not include a deliverability requirement for biomethane, which would maintain high supplies of biomethane for credit generation in the LCFS while the vehicle fleet is moving towards non-combustion technologies. Lastly, Alternative 2 does not phase out the avoided methane credit for dairy and swine manure biomethane pathways – allowing those credits to continue to be generated for transportation use when the State is moving away from combustion technologies in the sector. While these policy inputs potentially allow for more credit generation, they do not align with the State's goal (per the 2022 Scoping Plan Update) of focusing the LCFS program on sectors in most need of support and continue to send policy signals for biomethane as a primary fuel in the transportation sector.

Table 40: Alternative 2 - CI Reduction Targets

Year	Percent Reduction
2024	12.4%
2025	18.6%
2026	21.9%
2027	25.2%
2028	28.5%
2029	31.7%
2030	35.0%
2031	39.0%
2032	43.0%
2033	47.0%
2034	51.0%
2035	55.0%
2036	59.0%
2037	63.0%
2038	67.0%
2039	71.0%
2040	75.0%
2041	78.0%
2042	81.0%
2043	84.0%
2044	87.0%
2045	90.0%

Year	Percent Reduction
2046	90.0%

1. Costs

Alternative 2 costs approximately $206 billion as compared to the baseline and 127% the cost of the proposed amendments. Credit prices in Alternative 2 are expected to be at the maximum allowable level for many years under this scenario. Credit revenues in California are $167 billion as compared to the baseline and approximately 130% of the benefit of the proposed amendments, due to the increased stringency of the Alternative and the additional credits needed for compliance.

2. Benefits

a) Emissions

Social cost of carbon benefits of Alternative 2 from the scenario's 643 $MMTCO_2e$ reduction (Figure 15) range from approximately $17B to $71B, as compared to the baseline. This is an average 16% greater valuation than the proposed amendments, since GHG reductions occur earlier and are valued more highly in the near term, as shown by the discount values in Section II.D.1. Alternative 2 results in decreased cumulative NOx emissions by 17,691 tons (Table 41) and a decrease in PM2.5 emissions by 4,145 tons (

Table 42). As compared to the proposed amendments, Alternative 2 results in additional reductions of 294 tons of NOx and 37 tons of PM2.5. PM2.5 emissions decrease further than the proposed amendments before 2040 since more renewable diesel enters the market.

Figure 15: Alternative 2 - GHG Emissions

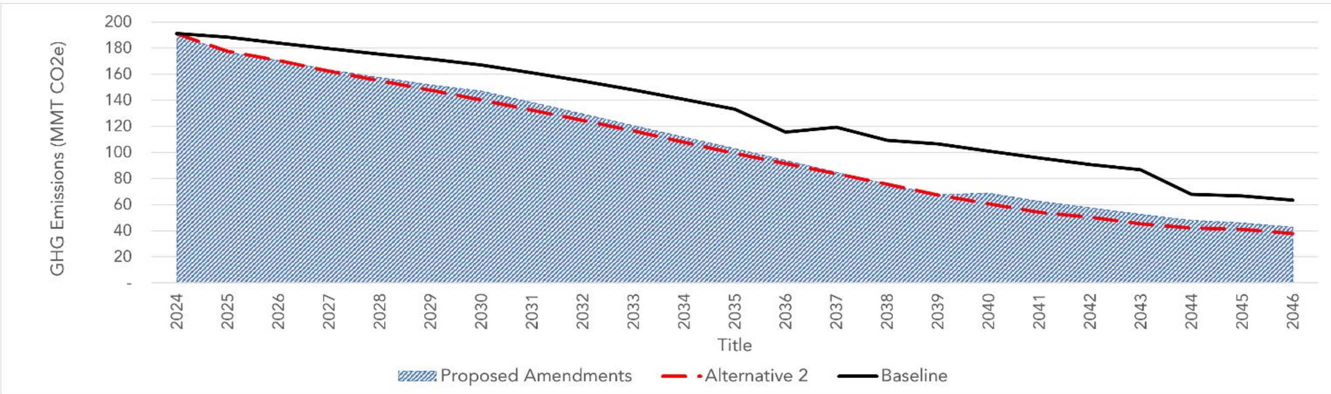


Table 41: Alternative 2 - NOx Emission Changes (tons per day)

Year	NOx (tpd)
2024	-0.069
2025	-0.744
2026	-0.969
2027	-1.130
2028	-1.303
2029	-1.357
2030	-1.807
2031	-1.896
2032	-1.951
2033	-2.007
2034	-2.075
2035	-2.237
2036	-2.279
2037	-2.387
2038	-2.514
2039	-2.614
2040	-2.702
2041	-2.787
2042	-2.867
2043	-2.978
2044	-3.105
2045	-3.278
2046	-3.380

Table 42: Alternative 2 - PM2.5 Emission Changes (tons per day)

Year	PM2.5 (tpd)
2024	-0.019
2025	-0.155
2026	-0.259
2027	-0.378
2028	-0.471
2029	-0.451
2030	-0.464
2031	-0.478
2032	-0.491
2033	-0.504
2034	-0.520
2035	-0.540
2036	-0.510
2037	-0.519
2038	-0.575
2039	-0.613
2040	-0.634
2041	-0.636
2042	-0.582
2043	-0.602
2044	-0.645
2045	-0.634
2046	-0.670

b) Health Benefits

Staff used the methods described in Section II.D.2 to estimate avoided cardiopulmonary mortality, hospitalizations for cardiovascular illness and respiratory illness, and emergency room visits for respiratory illness and asthma that would be expected to result from implementing Alternative 2 when compared to the Baseline scenario. The results are presented in Table 43.

Alternative 2 has approximately a 11% higher valuation of health benefits at $5.5 billion more than the baseline (Table 44), as compared to the proposed amendment at $4.9 billion. The positive health impacts of Alternative 2 are associated with additional decreases in both NOx and PM2.5 over the baseline.

Table 43: Alternative 2 - Avoided Mortality and Morbidity Incidents from 2024 to 2046

Air Basin	SC	SCC	SJV	SFB	SD	Statewide
Cardiopulmonary Mortality	236 (131 - 337)	9 (5 - 13)	56 (31 - 80)	42 (23 - 60)	20 (11 - 29)	**405 (224 - 578)**
Hospitalizations for Cardiovascular Disease	48 (35 - 61)	2 (1 - 2)	11 (8 - 14)	9 (7 - 11)	5 (4 - 6)	**83 (60 - 104)**
Cardiovascular ED Visits	64 (-25 - 150)	2 (-1 - 5)	13 (-5 - 31)	12 (-5 - 29)	5 (-2 - 13)	**109 (-42 - 253)**
Acute Myocardial Infarction	27 (10 - 72)	1 (0 - 2)	6 (2 - 16)	5 (2 - 14)	2 (1 - 6)	**46 (17 - 122)**
Hospitalizations for Respiratory Disease	7 (0 - 14)	0 (0 - 0)	2 (0 - 3)	1 (0 - 2)	1 (0 - 1)	**12 (0 - 24)**
Respiratory ED Visits	135 (27 - 281)	5 (1 - 9)	36 (7 - 75)	31 (6 - 65)	10 (2 - 21)	**244 (48 - 509)**
Lung Cancer Incidence	17 (5 - 28)	1 (0 - 1)	4 (1 - 6)	4 (1 - 7)	2 (1 - 3)	**30 (9 - 50)**
Asthma Onset	538 (517 - 558)	22 (21 - 23)	104 (100 - 108)	149 (143 - 155)	49 (47 - 51)	**954 (917 - 990)**
Asthma Symptoms	46,196 (-22,537 – 112,061)	1,950 (-952 – 4,727)	9,287 (-4,534 – 22,511)	12,529 (-6,103 – 30,438)	4,165 (-2,029 – 10,118)	**82,175 (-40,074 – 199,409)**
Work Loss Days	33,357 (28,132 – 38,385)	1,326 (1,119 – 1,526)	7,118 (6,004 – 8,189)	8,554 (7,211 – 9,847)	3,408 (2,873 – 3,923)	**59,701 (50,345 – 68,704)**
Hospitalizations for Alzheimer's Disease	116 (89 - 140)	3 (2 - 4)	27 (20 - 32)	20 (15 - 24)	16 (12 - 19)	**194 (148 - 236)**
Hospitalizations for Parkinson’s Disease	16 (8 - 22)	1 (0 - 1)	3 (2 - 5)	4 (2 - 5)	2 (1 - 2)	**28 (15 - 40)**

Table 43 continued

Air Basins	SS	SV	NP	NC	NCC	Statewide
Cardiopulmonary Mortality	7 (4 - 10)	12 (6 - 17)	0 (0 - 1)	1 (0 - 1)	3 (2 - 5)	**405 (224 - 578)**
Hospitalizations for Cardiovascular Disease	1 (1 - 2)	2 (2 - 3)	0 (0 - 0)	0 (0 - 0)	1 (0 - 1)	**83 (60 - 104)**
Cardiovascular ED Visits	2 (-1 - 5)	3 (-1 - 7)	0 (0 - 0)	0 (0 - 1)	1 (0 - 2)	**109 (-42 - 253)**
Acute Myocardial Infarction	1 (0 - 2)	1 (1 - 4)	0 (0 - 0)	0 (0 - 0)	0 (0 - 1)	**46 (17 - 122)**
Hospitalizations for Respiratory Disease	0 (0 - 0)	0 (0 - 1)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	**12 (0 - 24)**
Respiratory ED Visits	6 (1 - 13)	7 (1 - 15)	0 (0 - 1)	1 (0 - 2)	3 (1 - 5)	**244 (48 - 509)**
Lung Cancer Incidence	1 (0 - 1)	1 (0 - 1)	0 (0 - 0)	0 (0 - 0)	0 (0 - 1)	**30 (9 - 50)**
Asthma Onset	18 (17 - 18)	26 (25 - 27)	1 (1 - 1)	2 (2 - 3)	10 (10 - 11)	**954 (917 - 990)**
Asthma Symptoms	1,576 (-767 - 3,830)	2,269 (-1105 - 5,512)	122 (-59 - 297)	195 (-95 - 475)	899 (-438 - 2186)	**82,175 (-40,074 – 199,409)**
Work Loss Days	1,181 (995 - 1,359)	1,764 (1,487 - 2,031)	74 (63 - 86)	149 (125 - 171)	626 (528 - 721)	**59,701 (50,345 – 68,704)**
Hospitalizations for Alzheimer's Disease	2 (2 - 3)	3 (2 - 4)	0 (0 - 0)	0 (0 - 0)	1 (1 - 1)	**194 (148 - 236)**
Hospitalizations for Parkinson's Disease	1 (0 - 1)	1 (0 - 1)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	**28 (15 - 40)**

Table 43 continued

Air Basin	MC	MD	LT	LC	GBV	Statewide
Cardiopulmonary Mortality	2 (1 - 2)	16 (9 - 22)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	**405 (224 - 578)**
Hospitalizations for Cardiovascular Disease	0 (0 - 0)	3 (2 - 4)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	**83 (60 - 104)**
Cardiovascular ED Visits	0 (0 - 1)	4 (-2 - 10)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	**109 (-42 - 253)**
Acute Myocardial Infarction	0 (0 - 0)	2 (1 - 5)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	**46 (17 - 122)**
Hospitalizations for Respiratory Disease	0 (0 - 0)	0 (0 - 1)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	**12 (0 - 24)**
Respiratory ED Visits	1 (0 - 3)	9 (2 - 18)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	**244 (48 - 509)**
Lung Cancer Incidence	0 (0 - 0)	1 (0 - 2)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	**30 (9 - 50)**
Asthma Onset	5 (5 - 5)	27 (26 - 28)	1 (1 - 1)	0 (0 - 0)	1 (1 - 1)	**954 (917 - 990)**
Asthma Symptoms	457 (-222 - 1110)	2,387 (-1,162 – 5,800)	47 (-23 - 115)	36 (-17 - 86)	59 (-29 - 145)	**82,175 (-40,074 – 199,409)**
Work Loss Days	333 (281 - 384)	1,703 (1,436 – 1,960)	44 (37 - 51)	22 (18 - 25)	41 (35 - 48)	**59,701 (50,345 – 68,704)**
Hospitalizations for Alzheimer's Disease	0 (0 - 1)	6 (5 - 8)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	**194 (148 - 236)**
Hospitalizations for Parkinson’s Disease	0 (0 - 0)	1 (0 - 1)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	**28 (15 - 40)**

Table 44: Alternative 2 - Valuation by Health Outcome

Year	Cardiopulmonary Mortality	Hospitalizations for Parkinson’ s Disease	Respiratory ED Visits	Hospitalizations for Alzheimer's Disease	Hospitalizations for Cardiovascular Disease	Cardiovascular ED Visits	ER visits, respiratory	Asthma Onset	Asthma Symptoms	Lung Cancer Incidence	Acute Myocardial Infarction	Work Loss Days	Valuation (Million 2021$)
2026	139	<1	<1	<1	<1	<1	<1	1.54	<1	<1	<1	<1	142
2030	250	<1	<1	<1	<1	<1	<1	2.54	1.04	<1	<1	<1	255
2034	261	<1	<1	<1	<1	<1	<1	2.49	<1	<1	<1	<1	266
2038	274	<1	<1	<1	<1	<1	<1	2.50	1.00	<1	<1	<1	279
2042	256	<1	<1	<1	<1	<1	<1	2.25	<1	<1	<1	<1	260
2046	262	<1	<1	<1	<1	<1	<1	2.22	<1	<1	<1	<1	267
Total	**5,429**	**0.43**	**0.15**	**2.82**	**1.54**	**0.15**	**0.26**	**51.3**	**20.8**	**0.93**	**4.30**	**12.19**	**5,524**

3. Economic Impacts

Alternative 2 is more stringent than the proposed amendments since Alternative 2 includes more stringent CI targets, which in turn result in a larger credit market overall and greater deficit generation, leading to higher compliance costs. Higher compliance costs would lead to a larger overall effect on the California economy.

The macroeconomic impact analysis results shown in shown in

Table 45 indicate that Alternative 2 would result in more negative impacts on GSP, personal income, employment (Figure 16), output (Figure 17), and private investment growth when compared to the proposed amendments and the baseline due to the more stringent requirements.

Table 45: Summary of Economic Impact Indicators for Alternative 2

	GSP	GSP	Personal Income	Personal Income	Employment	Employment	Output	Output	Private Investment	Private Investment
Year	**Change (2021M$)**	**% Change**	**Change (2021 M$)**	**% Change**	**Change (Jobs)**	**% Change**	**Change (2021 M$)**	**% Change**	**Change (2021 M$)**	**% Change**
2026	-681	-0.02%	-1,128	-0.04%	-1,095	0.00%	-2,513	-0.04%	-317	-0.06%
2030	-2,783	-0.07%	-945	-0.03%	-7,179	-0.03%	-8,044	-0.13%	-400	-0.07%
2034	-3,785	-0.09%	-49	0.00%	-7,704	-0.03%	-11,273	-0.17%	40	0.01%
2038	-4,803	-0.11%	-827	-0.02%	-11,920	-0.04%	-13,422	-0.19%	-182	-0.03%
2042	-5,607	-0.12%	-2,210	-0.05%	-15,077	-0.05%	-14,910	-0.19%	-527	-0.07%
2046	-5,350	-0.11%	-4,231	-0.09%	-16,163	-0.06%	-13,238	-0.16%	-1,132	-0.13%
Average	**-3,656**	**-0.08%**	**-1,315**	**-0.03%**	**-9,313**	**-0.03%**	**-10,173**	**-0.14%**	**-360**	**-0.05%**

Figure 16: Alternative 2 - Employment Impacts by Major Sector (jobs)

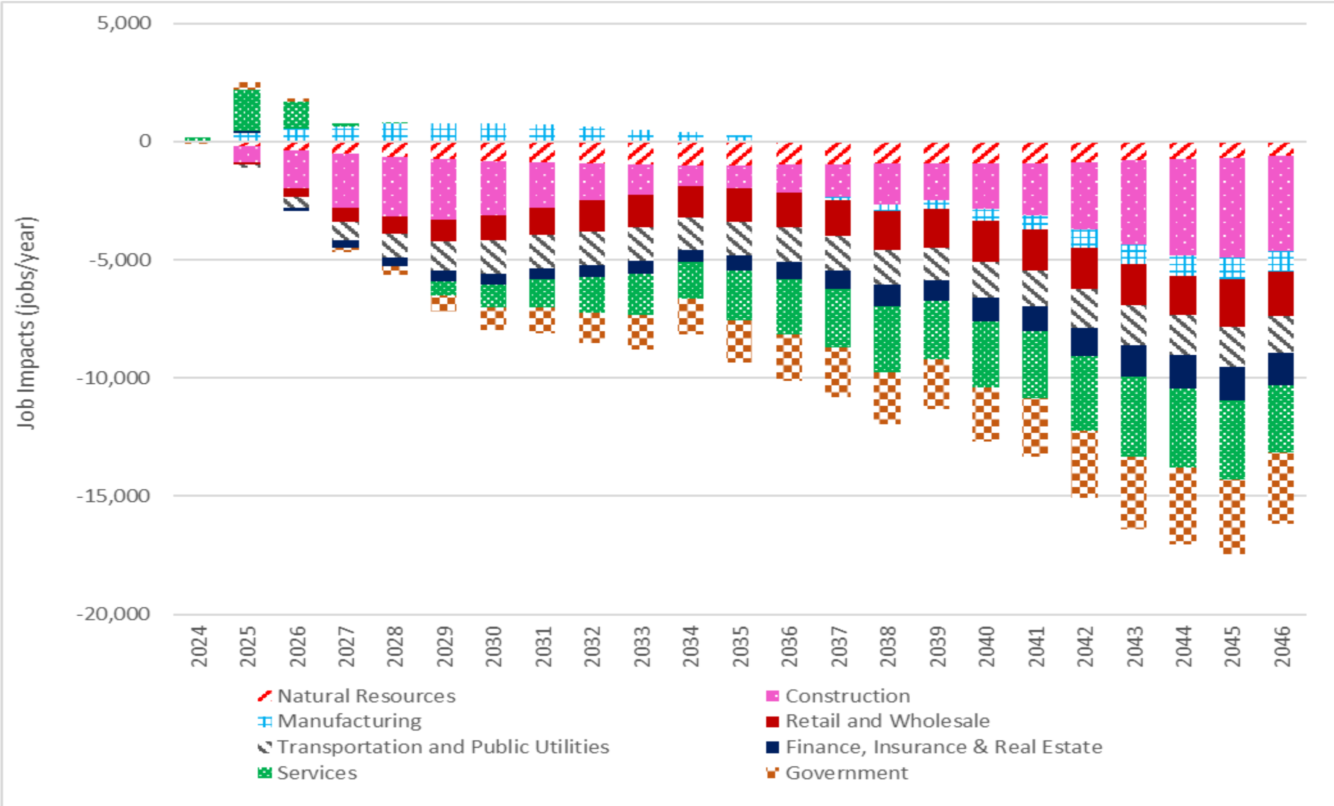
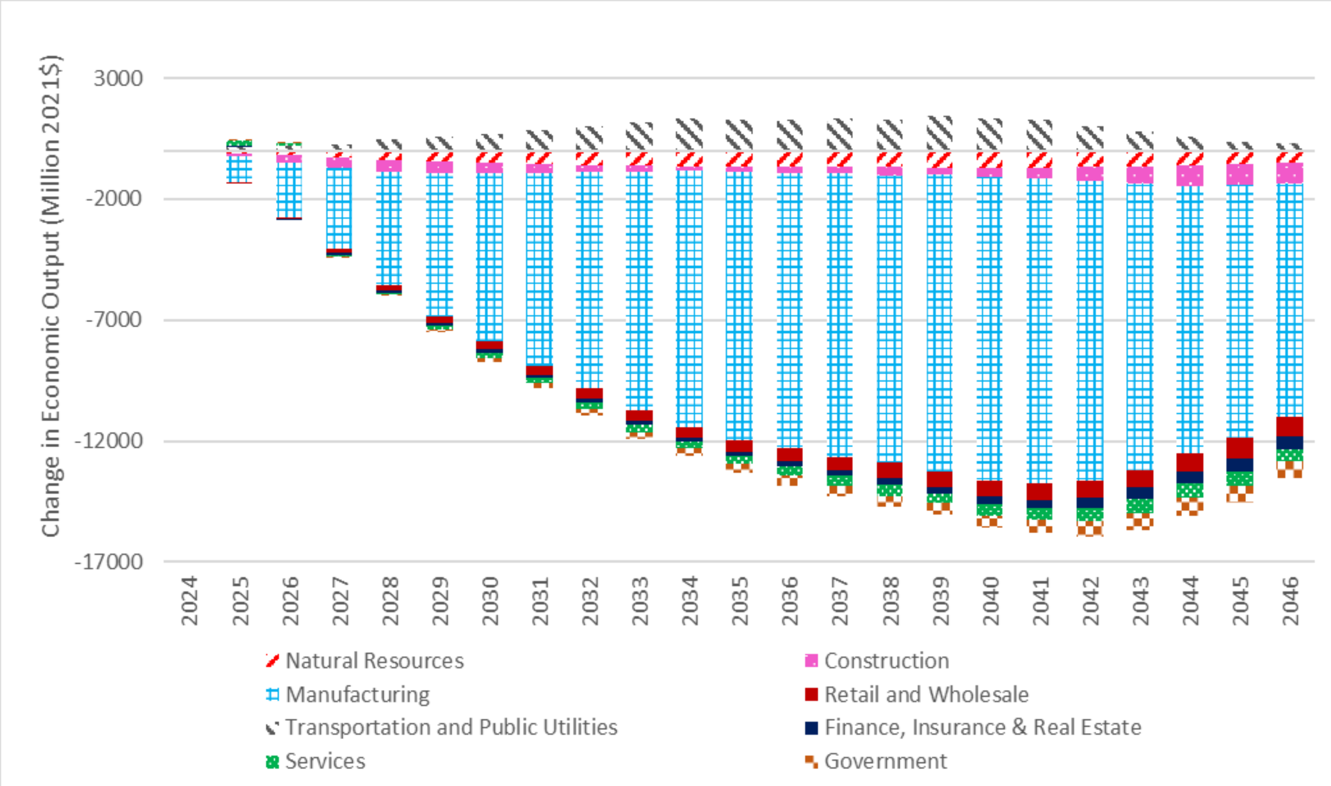


Figure 17: Alternative 2 - Change in Output by Major Sector (2021M$)



4. Cost-Effectiveness

Alternative 2 has a cost effectiveness of $60 per metric ton CO_2e. This is similar to the proposed amendments due to higher GHG reductions balanced against higher overall cost.

5. Reason for Rejecting

Alternative 2 was rejected for several reasons. First, the scenario is less feasible to achieve than the proposed amendments due to the more stringent near-term CI targets through 2030. Credit prices in this scenario are projected to be at or near the maximum and would quickly trigger advanced crediting requirements if low-carbon fuels are not produced at projected volumes. To achieve these near-term emission reductions, Alternative 2 also necessitates removing several important policy inputs in the proposed amendments, such as updates to the forklift crediting methodology and alignment of deliverability requirements for biomethane. Pursuing faster CI target reductions at the expense of these and other provisions would counteract the broader energy transition that the program is designed to support. Lastly, the credit prices in Alternative 2 are higher than the proposed amendments and may place additional near-term burden on consumers of fossil fuels at the retail level.

Appendix A: Methodology for Estimating Costs

Cost Modeling

See California Transportation Supply (CATS) Technical Documentation.[91]

Verification Methodology

Staff conducted a draft survey of registered LCFS third-party verification parties to estimate the cost of verification for hydrogen and electric fuel supply equipment (FSE) owners of different sizes and technology types. Staff broke companies into bins with 1 to 10, 11 to 50, 51 to 100 and more than 100 FSE, then created categories for non-residential electric vehicle (EV) charging, residential incremental charging, electric cargo handling equipment (eCHE), electricity provided to ocean-going vessels at-berth (eOGV), electric forklifts (eforklift), fixed guideways, hydrogen fuel cell vehicles, and electric transport refrigeration units (eTRU) FSE. Survey respondents provided cost estimates based on these categories, and staff subsequently calculated the average cost of verification based on company size. Using 2022 market data of total energy demand and quantity of FSE per existing company, staff estimated the number of FSE needed per year to meet the projected hydrogen and electricity demand, assuming no changes to output per FSE. Lastly, staff removed the energy demand and costs by multiplying the total values by the proportion of companies with more than 10 FSE in the 2022 market data, and then calculated the average expected cost per kg and kilowatt hour (see Table 46). Small companies (those with 10 or fewer FSE) were excluded because low credit producers will likely be eligible for verification deferrals and/or exemption provisions in recognition of their smaller revenues.

Table 46: Average Estimated Verification Cost per Unit Energy Dispensed

Fuel Type	Cost per unit energy
Hydrogen	\$0.023/kg
Electricity	\$0.006/kWh

[91] CARB (2022). *California Transportation Supply (CATS) Model - Technical Documentation*. https://ww2.arb.ca.gov/sites/default/files/2022-11/CATS%20Technical.pdf.

Appendix B: Methodologies for Estimating Criteria Pollutant Emission Changes due to the Proposed LCFS Amendments

I. Methodology for Estimating PM2.5 and NOx Reductions from Crude Oil Extraction

Background

The Low Carbon Fuel Standard (LCFS) program is expected to reduce transportation emissions in California through fuels. It is reasonable to expect that the supply of crude oil extracted in California may ramp down in tandem with declining demand for finished petroleum products. Staff included the criteria emissions benefits of ramping down oil extraction in California using the following approach.

Methodology and Underlying Assumptions

Assumption 1: Oil extraction operations in California decline at the same rate that demand for petroleum products declines.

- California refines the crude it extracts and imports additional crude to meet current petroleum demand.
- Extraction and refinement of California crude is generally more expensive than other crude because of the cost of operating in California and California crude is “heavy,” meaning it is process-intensive to refine. California is reducing its demand for fossil fuel refining; therefore, as alternative fuel production in California increases, less crude will be refined and there will be less demand for California crude.

Assumption 2: Both gasoline and diesel demand reductions will drive oil extraction ramp-downs.

- LCFS modeling shows an 83% decline in petroleum gasoline and diesel by 2046, as compared to 2024.
- The LCFS supports both the light-duty and heavy-duty vehicle transition.
- However, to conservatively estimate the emission benefits of reduced upstream oil extraction, staff looks at only the proportion of demand reduction associated with fossil diesel declines expected from the LCFS proposal, given staff expects diesel demand will persist longer than gasoline demand in California and future in-state extraction reductions may be limited by the pace of diesel demand reductions.

Methodology:

- Use CEIDARS data from 2019[92] as the baseline inventory for NOx and PM emissions from oil extraction operations in California by air basin (Bnox, Bpm).
- Calculate the percent decrease in petroleum demand using CATS modeling outputs 2024-2046 (x%).
- Estimate % crude demand due to diesel vs. gasoline (y%) using EIA data.
- Estimate the 2046 NOx and PM emissions associated with diesel demand reduction as modeled by LCFS. ((1-x%*y%)*Bnox, (1-x%*y%)*Bpm)
- Using the base year and 2046, interpolate the annual emissions reductions from LCFS per air basin.

II. Estimated Emissions from the Increase in Production of Alternative Fuel in California

Staff expects the proposed amendments will increase the production of low-carbon fuels in California, which will result in increased emissions at these production facilities. To estimate the increase in volume of in-state low carbon fuel production (Table 47), staff multiplied the estimated change in total production for each fuel attributable to LCFS (relative to the baseline) by the assumed proportion of low-CI production that will occur in-state (Table 48). Note that total quantities of electricity and hydrogen are assumed to be the same between the baseline and proposed scenarios but differ in volumes associated with particular fuel pathway types (feedstock, production method, CI, etc.).

[92] CARB (2023). *CARB Pollution Mapping Tool*. https://www.arb.ca.gov/carbapps/pollution-map/. Accessed February 7, 2023.

Table 47: Change in In-State Low Carbon Fuels Production for 2024-2046 Relative to Baseline

Fuel	Units	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Renewable Gasoline	mm gal	1	4	4	5	6	5	3	4	5	4	4	4
Hydrogen (Fossil)	mm kg	0	0	0	0	0	-9	-26	-49	-73	-94	-123	-155
Hydrogen (0-CI)	mm kg	0	0	0	0	0	0	-2	0	0	0	0	0
Hydrogen (Dairy)	mm kg	0	0	0	0	8	14	17	20	25	27	30	33
Electricity (Dairy)	1000 MWH	0	979	563	766	433	321	193	0	17	331	462	450
Renewable Diesel	mm gal	67	401	385	488	530	453	250	389	429	414	399	384
Alternative Jet Fuel	mm gal	0	106	140	174	208	241	275	289	303	318	332	346
Dairy Biomethane	mm DGE	0	22	22	42	34	38	34	31	26	23	20	17

Table 47 continued.

Fuel	Units	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046
Renewable Gasoline	mm gal	4	4	5	5	5	4	3	3	3	1	1
Hydrogen (Fossil)	mm kg	-186	-218	-251	-283	-313	-343	-377	-397	-417	-436	-462
Hydrogen (0-CI)	mm kg	0	0	41	88	128	180	237	256	276	295	322
Hydrogen (Dairy Biomethane)	mm kg	35	38	42	45	0	0	0	0	0	0	0
Electricity (Dairy Biomethane)	1000 MWH	573	696	696	696	0	0	0	0	0	0	0
Renewable Diesel	mm gal	369	403	481	465	445	410	278	263	247	121	121
Alternative Jet Fuel	mm gal	360	375	357	354	362	385	446	460	475	489	489
Dairy Biomethane	mm DGE	14	11	7	3	0	0	0	0	0	0	0

Table 48: Assumed Percentage of New Alternative Fuels Production in California

Fuel	Percentage of New Production in California	Notes
Ethanol and E85	0	All volumes in excess of currently dispensed amounts are produced by out-of-state producers
Biodiesel	0	All volumes in excess of currently dispensed amounts are produced out-of-state.
Renewable Diesel/Renewable Gasoline/Alt Jet Fuel	87-100	Renewable Diesel in-state percentage is defined as the net annual demand in each scenario as compared to the baseline, divided by the total in-state supply above baseline. Staff defines in-state supply capacity as the cumulative volume reported in LCFS in plus additional capacity announced by Marathon Martinez and Phillips 66 Rodeo; any additional demand is met by out-of-state production. Renewable gasoline, renewable diesel, Alternative Jet Fuel in-state percentages of Alternative Jet Fuel (AJF) and renewable gasoline are assumed equal to the in-state percentage of renewable diesel, as renewable diesel, renewable gasoline, and AJF are all produced at the same facilities that hydrotreat fats, oils, and greases.
Hydrogen (Grid and 0-CI)	0-100	Staff assumption of linear increase from 0 to 100 between 2024 and 2030, as electrolysis facilities are built in California.
Hydrogen (CNG)	100	Hydrogen from fossil natural gas is assumed to be produced in-state.
Hydrogen (Dairy Biomethane)	Variable	Based on CATS model results.
Electricity (Dairy Biomethane)	Variable	Based on CATS model results.
Fossil CNG	100	Assumed in-state production.
Biomethane from Landfill Gas	0	Based on observed LCFS data.
Biomethane from Dairy Gas	Variable	Annual value provided in CATS outputs.
DAC	50	Staff assumption.

Staff calculated increases in criteria pollutant emissions associated with the production increases by multiplying facility emission factors, summarized in Table 49, by the estimated increases of in-state production.

Table 49: Estimated Alternative Fuel Production Facility Emission Factors

Fuel Production	NOx	PM2.5	Units
Renewable Diesel/Renewable Gasoline/ Alternative Jet Fuel	0.058	0.022	tons/million DGE
Dairy gas flaring to produce biomethane/purified dairy gas	0.4347	0.634	tons/million DGE
Hydrogen production from steam methane reforming	0.281	0.102	tons/million kg
Electricity from purified dairy gas (fuel cell conversion)	0.00085	0	tons/GWh

The methods for determining the estimated emission factors for production of each alternative fuel are described below.

- **Renewable Diesel, Renewable Gasoline, and Alternative Jet Fuel:** Staff assumed the production facility for these fuels to have similar emissions to a simple oil refinery. Staff divided the 2020 emissions of Kern Oil & Refining Co.[93] by the 2020 production volume for this facility obtained from LCFS data.
- **Dairy biomethane:** Staff modeled a dairy farm with 5,000 head of cows to estimate on-site (local) emissions from dairy biogas production and upgrading. Staff assumed a covered lagoon to capture methane from manure followed by upgrading in a pressure swing adsorption unit. The covered lagoon does not require heating and electricity is used for upgrading. Electricity use requirements for upgrading were estimated using the vendor's design specifications for pressure swing adsorption. Tail gas is produced from the upgrading unit which is sent to a thermal oxidizer for flaring. Staff assumed that about 10% of methane produced is flared. Hence, flaring is the only source of local emissions used in estimating emissions from dairy biomethane. The emission factors for NOx from flaring is from the San Joaquin Valley Air Pollution Control District Rule 4311,[94] and for PM2.5 is derived from CA-GREET3.0.[95]
- **Hydrogen SMR:** CEIDARS 2016.[96]

[93] CARB. (2023). *Facility Search Engine – Kern Oil & Refining, 2021 Criteria & Toxic plus Risk Data*. https://www.arb.ca.gov/app/emsinv/facinfo/facinfo.php?dd=. Accessed July 2023.

[94] San Joaquin Valley Air Pollution Control District. (2020). *Rule 4311*. https://www.valleyair.org/rules/currntrules/r4311.pdf.

[95] CA-GREET3.0 model, 2018.

[96] Derived from emissions in *CARB Pollution Mapping Tool*. https://www.arb.ca.gov/carbapps/pollution-map/, Energy Independence Now, *Renewable Hydrogen Roadmap*. https://einow.org/rh2roadmap, and U.S. Energy Information Administration, 2016. *Refinery Utilization and Capacity*. https://www.eia.gov/dnav/pet/pet_pnp_unc_a_(na)_YUP_pct_m.htm.

- **Electricity from purified dairy gas (fuel cell conversion):** Staff assumed the NOx emission factor to match the factor reported by Bloom Energy's 300 kW, ES-5 Fuel Cell that uses digester gas.[97]

III. Methodology for Estimating Changes in Criteria Pollutant Emissions from Feedstock and Finished Fuel Transport

As discussed in the previous section, staff expects the proposed amendments will increase the production of low carbon fuels in California, which will increase the transport and distribution of biofuel feedstocks and finished fuels.

The amount of feedstock required to produce the low carbon fuels was calculated using the increased production volume and production yield of each biofuel. Assumptions regarding average production yields per fuel type were obtained from the CATS Technical Documentation[91] and converted into volumes using energy densities for each fuel, found on the Notes tab of LCFS' Quarterly Data Spreadsheet, and are tabulated in Table 50.[98]

Table 50: Assumed Production Yield of Low Carbon Fuels

Fuel	Feedstock	Yield
Ethanol	Corn	21.4 gal/wet ton
Renewable Gasoline	Used cooking oil, tallow, vegetable oil	295 gal/ton
Biodiesel	Used cooking oil, tallow, vegetable oil	274 gal/ton
Renewable Diesel	Used cooking oil, tallow, vegetable oil	295 gal/ton
Alternative Jet Fuel	Used cooking oil, tallow, vegetable oil	284 gal/ton

Staff estimated emission factors for on-road biomass and biofuel transportation (Table 51) using EMFAC 2021.[99]

[97] Bloom Energy (2002). *The Bloom Energy Server 5 Data Sheet*. https://www.bloomenergy.com/wp-content/uploads/es5-300kw-datasheet-2022.pdf.

[98] CARB (2023). *LCFS Quarterly Data Spreadsheet* (Updated July 31, 2023). https://ww2.arb.ca.gov/resources/documents/low-carbon-fuel-standard-reporting-tool-quarterly-summaries.

[99] CARB (2023). EMFAC 2021 – adjusted for adopted regulations including advanced clean fleets (ACF). Accessed July 19, 2023.

CARB (2022). *Advanced Clean Fleets Regulation Appendix F: Emissions Inventory and Results*. *https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/acf22/appf.pdf*.

Table 51: Emission Factors of Heavy-Duty Diesel Trucks (g/mi/truck)

Year	NOx	PM2.5
2024	1.911	0.063
2025	1.382	0.062
2026	1.225	0.062
2027	1.076	0.061
2028	0.939	0.060
2029	0.848	0.060
2030	0.770	0.058
2031	0.698	0.057
2032	0.636	0.056
2033	0.586	0.055
2034	0.539	0.054
2035	0.496	0.052
2036	0.479	0.051
2037	0.446	0.049
2038	0.418	0.047
2039	0.394	0.045
2040	0.380	0.044
2041	0.369	0.043
2042	0.360	0.042
2043	0.352	0.042
2044	0.345	0.041
2045	0.340	0.041
2046	0.335	0.041

Staff estimated the emission factors for rail transportation of biomass and imported alternative fuels (Table 52) by multiplying line-haul locomotive emission factors, per Tier, by the forecasted distribution of locomotives by Tier.[100,101] This value was then converted to a ton*mile basis by dividing by an assumed fuel efficiency for freight locomotives of 470 ton*mi/gal.[102]

Table 52: Estimated Emission Factors for Transportation by Freight Locomotives (10g/ton*mi)

Year	NOx	PM2.5
2024	0.231	0.005
2025	0.226	0.005
2026	0.217	0.005
2027	0.209	0.004
2028	0.200	0.004
2029	0.192	0.004
2030	0.102	0.002
2031	0.092	0.001
2032	0.088	0.001
2033	0.084	0.001
2034	0.081	0.001
2035	0.059	0.001
2036	0.046	0.001
2037	0.031	0.000
2038	0.030	0.000
2039	0.029	0.000
2040	0.028	0.000
2041	0.027	0.000
2042	0.026	0.000
2043	0.026	0.000
2044	0.025	0.000
2045	0.024	0.000
2046	0.024	0.000

[100] U.S. EPA (2009). *Emission Factors for Locomotives*. Office of Transportation and Air Quality. https://nepis.epa.gov/Exe/ZyPDF.cgi/P100500B.PDF?Dockey=P100500B.PDF

[101] CARB (2022). *CARB's 2022 In Use Locomotive Emission Inventory: Regulation Proposal and Scenarios*. *Air Quality Planning and Science Division, Mobile Source Analysis Branch. https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/locomotive22/appg.pdf.*

[102] *U.S. DOT (2023). Class I Rail Freight Fuel Consumption and Travel Workbook.*

These emission factors were used to estimate emissions for feedstock and finished fuel transport using the following assumptions.

- **In-State Feedstock Transportation:** Used cooking oil is assumed to travel within a 100-mile radius of a refinery by 7,500-gallon capacity trucks. Tallow and vegetable oil are assumed to travel within a 300-mile radius of a refinery by rail, which is consistent with the transportation scenario of AltAir's biorefinery in Paramount, California.[103]
- **In-State Biofuel Distribution:** In-state biodiesel is assumed to travel by 7,500-gallon tanker trucks from a biorefinery to blending terminals. The average roundtrip distance traveled per truck is assumed to be 200 miles. Renewable diesel, AJF, and renewable propane are assumed to travel 20 miles roundtrip by 7,500-gallon tanker trucks to the blending facility, which is consistent with the distribution distance of renewable diesel from AltAir's biorefinery in Paramount, California.[103]
- **Out-of-State Biofuel Transportation and Distribution:** Imported biofuel is assumed to travel by unit train from the U.S. into California railyards located within a 300-mile radius from the state border. Biofuel is assumed to then travel 100 miles in 7,500-gallon tanker trucks to blending terminals.
- **Empty Returns of Truck and Train:** Staff adjusted the emission factors for empty returns to reflect the difference in environmental impacts from loaded and empty mileage. The differences in emissions are assumed to be proportional to the energy savings from weight reduction during empty returns. The Institute for Energy and Environmental Research (IFEU) suggests that commercial trucks and freight rail can achieve 3.1%and 5% of relative energy savings per 10% weight reduction, respectively.[104] Therefore, it is estimated that emissions from empty trucks are 21% lower than loaded trucks, and emissions from empty rail cars are 36.5% lower than loaded cars.

IV. Methodology for Estimating Changes in Criteria Pollutant Emissions from Use of Alternative Jet Fuel

International Civil Aviation Organization (ICAO) is responsible for setting emission measurement procedures and compliance standards, which are based on a standardized landing and take-off (LTO) cycle developed to address ground level air quality issues. The LTO cycle is comprised of taxi-out, take-off, climb-out, approach, landing, and taxi-in modes. Emissions between ground level up to 3,000 feet in altitude are included.

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[103] AltAir Fuels. (2015). *Paramount, CA GreenJet Refinery*. https://www.smgov.net/uploadedFiles/Departments/Airport/Sustainability/20150126_AltAir_Presentation.pdf

[104] IFEU (2004). *Energy savings by light-weighting – II*. https://transport.world-aluminium.org/fileadmin/_migrated/content_uploads/1274789761IFEU2003_Energy_savings_by_light-weighting_-_I.pdf

NASA[105] tested a variety of AJF fuel mixtures from January 19 to February 3, 2009, to assess changes in the aircraft's CFM-56 engine performance and emission parameters relative to operation with standard JP-8. The experiment results of JP-8 and Fischer Tropsch (FT)/JP-8 fuel blend are shown in Table 53.

Table 53: NOx of Fossil Jet Fuels (JP-8) and AJF Blend at Different Engine Thrusts

Fuel Type (gNOx/kg-fuel)	4%	7%	30%	45%	65%	85%	100%
JP-8	15.36	20.21	52.10	73.89	107.95	151.39	174.31
FT/JP-8 Blend	14.24	16.38	47.63	66.44	95.90	134.80	159.01

The NOx emission reductions of an AJF blend during the LTO cycle were calculated based on the NASA experiment results shown above. Similarly, staff estimated the PM emission reductions of an AJF blend based on a study burning conventional and AJF blend fuels in a CFM56-7B commercial jet engine.[106] The calculated ratios of NOx and PM emissions for AJF blend fuels relative to fossil jet fuels are tabulated in Table 54.

- **Alternative Jet Fuel:** Alternative jet fuel emits 87.4% the NOx and 55% the PM2.5 that fossil jet fuel emits. Staff divided the estimated NOx and PM2.5 emissions for 2024-2030 by the estimated yearly volume of fuel and the energy density of jet fuel from CA-GREET3.0 fuel specifications. Since emission factors were consistent across 2024 through 2030, staff assumes the emissions factors do not change through 2046.

Table 54: NOx and PM Emissions of AJF Blend Normalized to Fossil Jet Fuels

Mode	NOx	PM
Taxi (7% thrust)	0.81	0.35
Approach (30% thrust)	0.91	0.37
Climb (85% thrust)	0.89	0.64
Take-Off (100% thrust)	0.91	0.6

Staff estimated the percentages of fuel consumed during each phase of the LTO cycle assuming that fuel flow is proportional to engine thrust, which is corroborated by a study

[105] Anderson, B. E., Beyersdorf, A. J., Hudgins, C. H., Plant, J. V., Thornhill, K. L., Winstead, E. L., Ziemba, L. D., Howard, R., Corporan, E., Miake-Lye, R.C., Herndon, S.C., Timko, M., Woods, E., Doods, W., Lee, B., Santoni, G., Whitefield, P., Hagen, D., Lobo, P… Bhargava, A. (2011). Alternative Aviation Fuel Experiment (AAFEX) (No. NASA/TM-2011-217059). https://ntrs.nasa.gov/api/citations/20110007202/downloads/20110007202.pdf

[106] Lobo, Prem, Hagen, D.E., & Whitefield, P.D. (2011). *Comparison of PM Emissions from a Commercial Jet Engine Burning Conventional, Biomass, and Fischer-Tropsch Fuels*. Environmental Science & Technology, 45 (24),10744–10749. https://pubmed.ncbi.nlm.nih.gov/22043875/

examining fuel combustion in six jet engines.[107] Using information from Table 54 and Table 55, staff estimates that replacing conventional jet fuels with AJF blend fuels can achieve reductions of 12.6% and 45% for NOx and PM, respectively, for fuels consumed within the California air basin.

Table 55: Power Setting, Time, and Fuel Consumption in LTO Cycle

Mode	Engine Thrust	Duration (mins)	LTO Fuel Consumption
Taxi (7% thrust)	7%	26	32.56%
Approach (30% thrust)	100%	0.7	12.52%
Climb (85% thrust)	85%	2.2	33.45%
Take-Off (100% thrust)	30%	4	21.47%

Approximately 1.69%, 32.29%, and 0.97% of jet fuels are consumed by intrastate, interstate and international flights, respectively, during the LTO cycle, while the remainder are consumed during cruise.[108] Intrastate flights consume all LTO fuels within the California air basin, while outbound interstate and international flights consume 62.25% of LTO fuels within the California air basin (during taxi-out, take-off, and climb). Therefore, staff estimates that approximately 22.4% of total jet fuels loaded onto aircraft at California airports are combusted within the California air basins.

Combustion of jet fuels also contributes to CO and unburned hydrocarbon (UHC) emissions. However, studies on AJF combustion show conflicting results for emissions of these two criteria pollutants relative to conventional jet fuel. Studies show that CO and UHC emissions are very low at higher power settings and only significant at the lowest power setting.[109] Reductions in these two pollutants when using AJF are most pronounced at near-idle settings.[16] One study shows that 100% FT fuels result in 21% and 31% reduction in CO at ground idle (3% engine thrust) and at 7% idle respectively, while 50% FT fuel blends result in 4% and 18% reduction in CO at ground idle and at 7% idle, respectively.[110] Another study

[107] Carter, Nicholas A., Stratton, R.W., Bredehoeft, M.K., & Hileman, J.I. (2011). *Energy and Environmental Viability of Select Alternative Jet Fuel Pathways*. Massachusetts Institute of Technology. http://web.mit.edu/aeroastro/partner/reports/proj28/altfuelpathways.pdf

[108] CARB (2017). 2016 Vision 2.1 (updated February 15, 2017). https://www.arb.ca.gov/planning/vision/downloads.html. Accessed November 30, 2017.

[109] Boeing Company, UOP, & United States Air Force Research Laboratory (2011). Research Report D02-1739: Evaluation of Bio-Derived Synthetic Paraffinic Kerosenes (Bio-SPKs). UOP, U.S. Air Force Research Laboratory. Committee D02 on Petroleum Products and Lubricants, Subcommittee D02.J0.06 on Emerging Turbine Fuels, ASTM International.

[110] Timko, M.T., Herndon, S.C., Blanco, d.E., Wood, E.C., Yu, Z., Miake-Lye, R.C., Knighton, W.B., Shafer, L., DeWitt, M.J., Corporan, E. (2011). *Combustion Products of Petroleum Jet Fuel, a Fischer-Tropsch Synthetic*

concluded that AJF use results in 10 to 25 and 20 to 30% reduction in CO and UHC during idle, respectively.[111] In contrast to the reductions discussed above, ASTM research reports concluded that CO and UHC emissions were highly variable because of the low emission level, but the AJF blend showed an increase in CO (5 to 9%) and UHC (20 to 45%), which might be explained by a reduction in flame temperature and combustion efficiency.[18,112]

V. Methodology for Estimating Changes in Criteria Pollutant Emissions from use of Biodiesel and Renewable Diesel

The use of diesel fuel generates diesel exhaust, which is comprised of a large number of pollutants, including NOx and PM. The combustion of biomass-based diesel, either as 100% biodiesel (B100), 100% renewable diesel (R100), or blended in various mixtures with conventional diesel, results in similar chemical species, including criteria pollutant emissions. However, the level of those emissions is different for biodiesel and renewable diesel compared to conventional diesel. Both biodiesel and renewable diesel generally emit less PM than conventional diesel. However, biodiesel use can emit more NOx than conventional diesel, depending on feedstock saturation level and engine type,[113] while renewable diesel use generally emits less NOx than conventional diesel.[114,115] The emissions levels vary depending

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Fuel, and a Biomass Fatty Acid Methyl Ester Fuel for a Gas Turbine Engine. Combustion Science and Technology,183:10, 1039-1068. https://www.tandfonline.com/doi/abs/10.1080/00102202.2011.581717?journalCode=gcst20

111 Corporan, E., Edwards, T., Shafer, L., DeWitt, M.J., Klingshirn, C.D., Zabarnick, S., West, Z., Striebich, R., Graham, J., Klein, J. (2011). *Chemical, Thermal Stability, Seal Swell, and Emissions Studies of Alternative Jet Fuels*. Energy & Fuels, 25, 955-966. https://pubs.acs.org/doi/pdf/10.1021/ef101520v

112 Edwards, T., Meyer, D., Johnston, G., McCall, M., Rumizen, M., Wright, M. (2016). Research Report D02-1828: Evaluation of Alcohol to Jet Synthetic Paraffinic Kerosenes (ATJ-SPKs). Committee D02 on Petroleum Products, Liquid Fuels, and Lubricants, Subcommittee D02.J0 on Aviation Fuels, ASTM International.

113 The use of biodiesel in non-NTDEs results in an increase in NOx emissions relative to use of conventional diesel. Consistent with past rulemakings, staff assumed the use of biodiesel in NTDEs results in no change in NOx emissions relative to use of conventional diesel. CARB staff is continuing to study biodiesel emission rates in NTDEs.

114 CARB. (2015). *Proposed Regulation on the Commercialization of Alternative Diesel Fuels – Staff Report: Initial Statement of Reasons*. Industrial Strategies Division, Oil and Gas and GHG Mitigation Branch & Transportation Fuels Branch. https://www.arb.ca.gov/regact/2015/adf2015/adf15isor.pdf

115 NOx emissions test data for renewable diesel in NTDEs were not available (Durbin et al., 2011). Based on test data for biodiesel in NTDEs, staff conservatively assumed use of renewable diesel in NTDEs results in no change in NOx emissions relative to conventional diesel. Source: Durbin, T.D., Miller, J.W., Johnson, K., Hajbabaei, M., Kado, N.Y., Kobayashi, R., Lui, X., Vogel, C.F., Matsumura, F. Wong, P.S., & Cahill, T. (2011). *Final Report - CARB Assessment of the Emissions from the Use of Biodiesel as a Motor Vehicle Fuel in California "Biodiesel Characterization and NOx Mitigation Study".* https://ww2.arb.ca.gov/sites/default/files/classic/isd/fuels/diesel/altdiesel/20111013_carb%20final%20biodiesel%20report.pdf?_ga=2.58437354.1525227723.1691423115-350507302.1675712467

on the blend levels,[116] and the engine type in which the fuels are used. The changes in NOx and PM emissions for different blend levels of biodiesel and renewable diesel relative to conventional diesel are shown in Table 56 and Table 57, and Table 58 and Table 59, respectively. The values in tables generally represent conservative estimates of NOx and PM emissions changes (i.e., estimates that result in high NOx emissions changes and low PM emissions changes) for biodiesel and renewable diesel relative to conventional diesel when used in non-NTDE (new technology diesel engines).[117]

Table 56: Biodiesel NOx Emissions Relative to Conventional Diesel[118]

Engine Type	Biodiesel Saturation Level	B5	B10	B20
Non- NTDE	Low	1.1%	1.8%	4.0%
Non- NTDE	High	-0.2%	0.1%	1.5%
NTDE	Low	0.0%	0.0%	0.0%
NTDE	High	0.0%	0.0%	0.0%

Table 57: Biodiesel PM Emissions Change Relative to Conventional Diesel[119]

Engine Type	Biodiesel Saturation Level	B5	B10	B20
Non- NTDE	Low	-4.7%	-8.9%	-19%
Non- NTDE	High	-4.7%	-8.9%	-19%

[116] Biodiesel blends are named according to the percentage of biodiesel in the blend. For example, B20 biodiesel contains 20% biodiesel. Similarly, renewable diesel blends are named according to the percentage of renewable diesel in the blend. For example, R5 renewable diesel contains 5% renewable diesel.

[117] NOx and PM emissions changes relative to conventional diesel were provided for on-road heavy-duty vehicles. Biodiesel use in on-road light-duty and medium-duty vehicles has been found not to result in changes in NOx emissions relative to conventional diesel. Biodiesel use in heavy-duty non-road engines has been found to result in NOx emissions increases that are lower than the increases for on-road heavy- duty engines and PM emissions decreases that are higher than the decreases for on-road heavy-duty engines. Source: CARB. (2015). *Proposed Regulation on the Commercialization of Alternative Diesel Fuels – Staff Report: Initial Statement of Reasons*. Industrial Strategies Division, Oil and Gas and GHG Mitigation Branch & Transportation Fuels Branch. https://www.arb.ca.gov/regact/2015/adf2015/adf15isor.pdf

[118] CARB. (2015). *Proposed Regulation on the Commercialization of Alternative Diesel Fuels – Staff Report: Initial Statement of Reasons*. 41-45. https://www.arb.ca.gov/regact/2015/adf2015/adf15isor.pdf.

[119] PM emissions changes for biodiesel relative to conventional diesel were based on testing using pre- 2007 engines without diesel filters. CARB (2015) indicates that, for 2007 and later engines equipped with PM filters, there were no meaningful differences in PM emissions between conventional diesel and biodiesel. However, Durbin et al. (2011) indicates that PM emissions for these engines were essentially at the limit of detection, and the level of efficiency of the diesel particulate factor would have masked any fuel differences. For these reasons, staff believes that PM emissions changes for biodiesel use in pre-2007 engines without diesel particulate filters relative to conventional diesel use was also applicable to 2007 and later engines with diesel filters.

Engine Type	Biodiesel Saturation Level	B5	B10	B20
NTDE	Low	-4.7%	-8.9%	-19%
NTDE	High	-4.7%	-8.9%	-19%

Table 58: Renewable Diesel NOx Emissions Relative to Conventional Diesel [120,121,122,123]

Engine Type	R20	R100
Non-NTDE	-2.9%	-10%
NTDE	0.0%	0.0%

Table 59: Renewable Diesel PM Emissions Relative to Conventional Diesel[124]

Engine Type	R20	R100
Non-NTDE	-4.0%	-30%
NTDE	-4.0%	-30%

A. EMFAC's diesel emissions factors

EMFAC (Emission Factors and Activity Data) is a database and model developed by CARB that contains emission factors for various types of vehicles and equipment. These factors are used when modeling the environmental impacts of regulations and policies. Emission factors are determined by measuring the pollutants emitted from a vehicle or piece of equipment while operating under a standard test cycle designed to simulate real-world driving conditions, such as the Federal Test Procedure. These measurements are used to calculate the quantity of

[120] Changes in NOx and PM emissions for renewable diesel relative to conventional diesel are assumed to be linearly related to renewable diesel blend level based on the results of Durbin et al. (2011).

[121] See CARB. (2015). Proposed Regulation on the Commercialization of Alternative Diesel Fuels – Staff Report: Initial Statement of Reasons. 41-45.

[122] Durbin, T.D., Miller, J.W., Johnson, K., Hajbabaei, M., Kado, N.Y., Kobayashi, R., Lui, X., Vogel, C.F., Matsumura, F. Wong, P.S., & Cahill, T. (2011). *Final Report - CARB Assessment of the Emissions from the Use of Biodiesel as a Motor Vehicle Fuel in California "Biodiesel Characterization and NOx Mitigation Study".* https://ww2.arb.ca.gov/sites/default/files/classic/isd/fuels/diesel/altdiesel/20111013_carb%20final%20biodiesel%20report.pdf?_ga=2.58437354.1525227723.1691423115-350507302.1675712467

[123] NOx emissions test data for renewable diesel in NTDEs were not available (Durbin et al., 2011). Based on test data for biodiesel in NTDEs, staff conservatively assumed use of renewable diesel in NTDEs results in no change in NOx emissions relative to conventional diesel.

[124] PM emissions test data for renewable diesel in NTDEs were not available (Durbin et al., 2011). Similar to biodiesel, staff assumed that PM emissions changes for renewable diesel use relative to conventional diesel use in pre-2007 engines are applicable for estimating PM emissions reductions associated with renewable diesel use in diesel-fueled mobile sources.

pollutants emitted per unit of fuel consumed (e.g., grams per mile, grams per gallon, or grams per kilowatt-hour/brake horsepower-hour).

As alternative diesel fuels have become more common in California, fuel blends are more diverse than the certification fuel used to develop EMFAC's default emissions factors. For instance, CARB and federal policies have substantially incentivized the use of biodiesel and renewable diesel. These fuels have different emissions profiles compared to conventional petroleum-derived diesel. Therefore, regulations like the LCFS and other policies that potentially impact the amount of biodiesel or renewable blended into California's diesel pool adopt different emission factors to reflect the real-world environmental impacts of the regulation. To do this, the EMFAC emission factors are modified using fuel test data from specific fuel blends that are more representative of the fuel blends incentivized by fuel regulation.

B. Assessing emissions from biodiesel and renewable diesel blends

CARB regularly conducts fuel emissions research to assess the potential impacts of new or emerging fuels on air quality. CARB also collects data from a variety of other sources, including CARB-sponsored research studies, academic studies, industry technical information, and literature reviews to understand the properties and characteristics of the fuel, vehicle, or technology being evaluated.

Emissions affiliated with the use of biodiesel and renewable diesel were estimated using the percent change in emissions listed in Table 60 and Table 61 to alter default emissions factors for on-road and off-road non-NTDE and NTDE vehicle classes. For instance, NOx emissions affiliated with the use of biodiesel in non-NTDE engines resulted in an increase of 4% for each B20-equivalent volume of biodiesel, or 20% for each B100 volume of biodiesel used instead of ULSD.

Table 60: Percent Change in NOx and PM emissions from using B100 relative to ULSD

Engine Type	NOx (B100)	PM (B100)
NTDE		
on-road	0%	-95%
off-road	0%	-95%
Non-NTDE		
on-road	20%	-95%
off-road	20%	-95%

Table 61: Percent Change in NOx and PM emissions from using RD100 relative to ULSD

Engine Type	NOx (R100)	PM (R100)
NTDE		
on-road	0%	-30%
off-road	0%	-30%

Engine Type	NOx (R100)	PM (R100)
Non-NTDE		
on-road	-10%	-30%
off-road	-10%	-30%

Fleet composition and baseline PM and NOx emissions associated with the use of ULSD for NTDE and non-NTDE vehicles were determined using EMFAC model results and considerations associated with the vehicle model year and type. EMFAC2021 v1.0.2 was used for on-road vehicle fleet estimates while the off-road EMFAC v1.0.3 model was used for off-road estimates. Vehicle fleet characteristics were used to estimate total emissions for each gallon of ULSD, biodiesel, and renewable diesel used in the state.

Appendix C - Macroeconomics

Table 62 summarizes the various sources of costs and savings associated with the proposed amendments and the methods used to model the impacts in REMI. The subsequent subsections provide additional information on these methods and includes the inputs to REMI. All costs or savings are input into REMI as millions of dollars and are adjusted to a 2020 value using the CPI index to correspond to the dollar value of the REMI policy variables. All values presented in the SRIA are presented in 2021 dollar values.

Table 62: Summary of Methods for Modeling the Macroeconomic Impacts of the Proposed Amendments in REMI

Source of Cost or Savings	Method for Modeling Costs or Savings	Method for Modeling Changes in Final Demand
Costs from deficit generation	Production cost increase to producers of high CI fuels	n/a
Revenues from credit generation	Producers of low CI fuels: Production cost decrease eTRU credits: Production cost decrease to truck transportation Forklift credits: Production cost decrease allocated amongst 156 REMI industries, farm proprietors income, and state and local government spending Credits generated by state and local government: increase in state and local government spending	n/a

Source of Cost or Savings	Method for Modeling Costs or Savings	Method for Modeling Changes in Final Demand
Changes in expenditures on fuels	Based on household, business, and government shares of fuel use. Households: change in consumer spending on motor vehicle fuels and lubricants, natural gas distribution, and electricity Businesses: change in production costs allocated to all 156 REMI industries Government: change in state and local government spending	Households: included in the consumer spending policy variable Businesses and government: change in exogenous final demand for petroleum and coal products manufacturing (324), basic chemical manufacturing (3251), natural gas distribution (2212), and electric power generation, transmission and distribution (2211)
3rd Party Verification Costs	Production cost increases to petroleum and coal products manufacturing (324), basic chemical manufacturing (3251), and electric power generation, transmission and distribution (2211)	Exogenous final demand increase for management, scientific, and technical consulting services (5416)
Changes in tax revenue	Impacts to state and local government spending	n/a
Avoided adverse health impacts	Decrease in consumer spending on hospitals and change in labor productivity	Savings from hospital expenditures are allocated to all other consumer goods

I. Changes in Costs and Revenues from Deficit and Credit Generation

Conventional and alternative fuel producers will either face costs associated with deficit generation or realize increased revenues from credit generation. REMI's production cost policy variable is used to account for the change in operating costs for industries that generate LCFS deficits or credits.

The direct cost and cost savings associated with credit or deficit generation are modeled as a change in production costs by industry. The NAICS code representing petroleum and coal products manufacturing (324) is used to represent deficits generated by CARBOB gasoline, diesel, and jet fuel.

Low-CI fuel producers that generate credits are grouped into three NAICS codes: basic chemical manufacturing (3251), natural gas distribution (2212), and electric power generation, transmission, and distribution (2211).

Changes in the production costs to basic chemical manufacturing industry is used to represent credits generated from renewable gasoline, ethanol, hydrogen, biodiesel, renewable diesel, and alternative jet fuel. Changes in the production costs to the natural gas distribution industry is used to represent credits generated from conventional natural gas and dairy natural gas. Changes in the production costs to the electric power generation, transmission, and distribution industry is used to represent credits generated from electricity used in transportation and derived from dairy production.

In some instances, operators of equipment generate LCFS credits. Credits generated by operators of eTRU equipment are modeled as a change in production costs for the truck transportation industry (484). Credits generated by eCargo handling equipment and ocean-going vessel shorepower equipment are modeled as a change in production costs for the scenic and sightseeing transportation and support activities for transportation industry (487,488). The revenue generated by forklift operators are modeled in the same way as in the Forklift Standardized Regulatory Impact Assessment Table 60, where industry shares are estimated based on forklift data from CARB's DOORS database, which are then matched to industry classification of the businesses operating fleets according to NAICS of the businesses owning the forklifts.[125] The credit revenue generated by state and local governments are modeled as changes in state and local government spending.

Table 63 shows the value of credits and deficits generated by the primarily impacted industries.

[125] California Air Resources Board, Proposed Zero-Emission Forklift Regulation Standardized Regulatory Impact Assessment. Date of Release: April 5, 2023 *https://dof.ca.gov/wp-content/uploads/sites/352/2023/04/ZE-Forklift-SRIA-to-DOF.pdf*

Table 63: Value of Credits and Deficits Generated by Primarily Impacted Industries

REMI Category	**Production Cost**	**Production Cost**	**Production Cost**	**Various**	**State and Local Government Spending**	**State and Local Government Spending**
Explanation	**Deficits from fuel production and refinery credits**	**Credit generation**	**Credit generation**	**Credits generated from electricity**	**Local revenue from credit generation**	**State revenue from credit generation**
Industry (NAICS)	**Petroleum and coal products manufacturing (324)**	**Basic chemical manufacturing (3251)**	**Natural gas distribution (2212)**	**Electric power generation, transmission and distribution (2211) and others[126]**	**Local Government**	**State Government**
2024	1438.55	-714.29	0.00	-568.54	16.94	1.10
2025	1844.77	-691.94	0.00	-576.52	16.38	1.06
2026	4335.84	-1502.71	0.00	-1674.80	39.25	3.73
2027	5856.15	-1959.66	0.00	-2862.40	53.32	5.94
2028	6305.59	-2035.07	0.00	-3504.34	58.00	7.33
2029	6631.47	-1968.73	0.00	-4056.41	62.53	8.85
2030	8696.59	-1978.97	0.00	-5690.91	84.83	11.70
2031	9395.13	-1889.26	0.00	-6680.13	94.58	13.79
2032	9850.92	-1678.59	0.00	-7459.29	100.28	15.46
2033	9692.04	-1381.84	0.00	-7821.79	100.03	16.09
2034	9553.08	-1142.31	0.00	-8080.89	99.31	16.65
2035	9819.23	-1032.89	0.00	-8570.70	105.46	18.07
2036	10075.66	-1052.85	0.00	-8967.69	108.69	19.03
2037	10208.12	-1123.49	0.00	-9206.13	111.18	19.68
2038	11303.17	-1268.76	0.00	-10130.94	124.05	22.09
2039	11466.55	-1307.99	-204.99	-10138.30	123.68	21.90
2040	11854.80	-759.99	-1163.39	-9307.79	112.33	18.66

[126] Also includes the value of credits generated by operators of forklifts, electric cargo handling equipment, and eTRUs.

REMI Category	Production Cost	Production Cost	Production Cost	Various	State and Local Government Spending	State and Local Government Spending
Explanation	Deficits from fuel production and refinery credits	Credit generation	Credit generation	Credits generated from electricity	Local revenue from credit generation	State revenue from credit generation
Industry (NAICS)	Petroleum and coal products manufacturing (324)	Basic chemical manufacturing (3251)	Natural gas distribution (2212)	Electric power generation, transmission and distribution (2211) and others[126]	Local Government	State Government
2041	11856.76	-679.41	-1630.36	-8626.56	105.04	16.91
2042	10614.05	-535.23	-2036.60	-6032.19	84.01	12.85
2043	9247.21	-459.77	-2244.96	-4429.62	65.06	9.18
2044	8091.59	-400.85	-2438.13	-2994.10	48.41	5.98
2045	6988.35	-344.75	-2525.71	-1800.87	33.85	3.29
2046	6801.66	-335.31	-2393.58	-1722.20	34.28	3.43

II. Changes in Expenditures on Fuels

This section describes the method for modeling the changes in household, business, and government expenditures on fuels that are associated with the shifts in the types and volumes of fuels provided to California as a result of the Proposed Amendments. The changes in expenditures on fuels enter the model in two ways: 1) as a change in household, business, and government expenditures on fuels to illustrate the costs or savings to purchasers of fuels in California and 2) as a change in exogenous final demand for the industries that manufacture and deliver fuels to illustrate the supply side impacts of the Proposed Amendments.

A. Proportioning Fuel Expenditures to Households, Businesses, and Government

To allocate fuel expenditures across the different California users, staff first split changes in total fuel expenditures into expenditures on gasoline and its substitutes, diesel and its substitutes, and jet fuel. This is because these fuels are used in different applications. For example, gasoline is more often used in light-duty vehicles and is used in higher proportion by households. In contrast, diesel is more often used in medium and heavy-duty vehicles and is used in higher proportion by businesses.

Fuels that are classified as gasoline substitutes are renewable gasoline, ethanol, hydrogen used for light duty vehicles, and electricity used for light duty vehicles. Fuels that are classified as diesel substitutes are biodiesel, renewable diesel, alternative and conventional jet fuels, conventional and renewable natural gas, hydrogen used in heavy duty vehicles, and electricity used in heavy duty vehicles.

Next, staff derived splits of household, government, and business shares of fuel use for gasoline and its substitutes and diesel and its substitutes.

The proportion of gasoline and its substitutes used among households, businesses, and government is based on their shares of light-duty vehicle ownership and rentals.[127] The proportion of diesel and its substitutes used by household and business is estimated using 2022 fuel combustion volumes by sector from the CARB Greenhouse Gas Emission Inventory.[128] The State and local government split for both gasoline and diesel use was based on State government's share of government employment of 25% and Local government's share of government employment of 75% for 2020.[129]

Table 64 illustrates the splits for household, government, and business expenditures used in the analysis.

Table 64: Household, Business, and Government Share of Fuel Use

Entity	Gasoline and its substitutes	Diesel and its substitutes
Household Fuel Expenditures	92.0%	2.0%
Local Government Fuel Expenditures	0.75%	0.75%
State Government Fuel Expenditures	0.25%	0.25%
Business Fuel Expenditures	7.0%	97.0%

1. Household and Government Fuel Expenditures

Changes in household expenditures for fuels are input into REMI using the consumer spending policy variable in the categories of motor vehicle fuels, lubricants, and fluids. Changes in

127 California Energy Commission (CEC), 2021, July 1, Light Duty ZEV Uptake in Government and Rental Segments. *https://www.energy.ca.gov/sites/default/files/2021-07/Light-Duty%20ZEV%20Uptake%20in%20Government%20and%20Rental%20Segments_ADA.pptx*

128 CARB, 2022. 2022 Edition of CARB's GHG Emission Inventory, fuel combustion activity data.

129 REMI Policy Insight Plus (v 3.0), State and Local government share of Employment

government expenditures on fuels are input into REMI using the state and local government spending policy variables.

Table 65: Consumer and Government Change in Fuel Expenditures

REMI Category	Consumer Spending	State and Local Government Spending	State and Local Government Spending
Explanation	**Change in consumer fuel expenditures**	**Change in fuel expenditures for fleets**	**Change in fuel expenditures for fleets**
Industry (NAICS)	**Motor vehicle fuels and lubricants**	**State Government**	**Local Government**
2024	-35.8	0.05	0.02
2025	18.4	-0.04	-0.41
2026	47.7	-0.24	-0.88
2027	93.4	-0.53	-1.58
2028	66.7	-0.74	-1.73
2029	30.1	-0.81	-1.70
2030	123.1	-1.16	-2.72
2031	182.1	-1.36	-3.22
2032	217.9	-1.51	-3.50
2033	240.6	-1.54	-3.70
2034	255.2	-1.52	-3.72
2035	276.2	-1.53	-3.83
2036	279.6	-1.50	-3.87
2037	279.2	-1.46	-3.98
2038	279.9	-1.47	-4.19
2039	278.5	-1.41	-4.23
2040	277.9	-1.37	-4.11
2041	277.3	-1.37	-4.10

REMI Category	Consumer Spending	State and Local Government Spending	State and Local Government Spending
Explanation	Change in consumer fuel expenditures	Change in fuel expenditures for fleets	Change in fuel expenditures for fleets
Industry (NAICS)	Motor vehicle fuels and lubricants	State Government	Local Government
2042	275.3	-1.27	-3.82
2043	275.2	-1.27	-3.74
2044	274.9	-1.22	-3.56
2045	3.1	-0.45	-1.21
2046	2.9	-0.44	-1.13

2. Allocating Business Fuel Expenditures to Various Industries

Total business expenditures on fuels were then further split across all REMI's 156 industries based on each industries relative use of gasoline, diesel, and jet fuel. The expenditures are then input into the model as a change in production costs.

To estimate each industry's relative use of gasoline, diesel, and jet fuel, staff used the REMI input-output (IO) table. The REMI model's IO table describes the value of intermediate inputs needed to create one dollar of output for each industry. For example, the IO table includes the value of petroleum that is needed to produce one dollar of output. The intermediate input is then multiplied by the total output for each industry to get the total expenditure on petroleum by industry. The sum of all industries gives the total value of petroleum used by all 156 industries, and the relative proportion used by each industry can be calculated.

Petroleum as an intermediate input, which is not restricted to transportation fuels, is used as a proxy for gasoline and its substitutes. Truck transportation as an intermediate input is used as a proxy diesel and its substitutes. Air transportation as an intermediate input is used as a proxy for jet fuel.

Specifically, each industry's change in expenditures on fuels is then estimated as:

$$E_{i,t} = P_{i,petroleum} \times EF_{1,t} + P_{i,truck} \times EF_{2,t} + P_{i,air} \times EF_{3,t}$$

Where $E_{i,t}$ is the change in expenditures on fuels by industry i at time t, $P_{i,petroleum}$ is industry i's percent of total spending on petroleum relative to all 156 industries, $P_{i,truck}$ is industry i's percent of total spending on truck transportation relative to the all 156 industries, $P_{i,air}$ is industry i's percent of total spending on air transportation relative to all 156 industries,

$EF1,t$ is the total change in expenditures by all businesses on gasoline and its substitutes, $EF2,t$ is the total change in expenditures by all businesses on diesel and its substitutes, and $EF3$ is the statewide change in expenditures on conventional and alternative jet fuel.

The percentage splits used in the analysis are illustrated in Table 66Table 66.

Table 66: Estimated Proportion of fuel expenditures by industry

NAICS Industry	Gasoline and substitutes	Diesel and substitutes	Jet fuel
Forestry; Fishing, hunting, trapping (1131, 1132, 114)	0.04%	0.10%	0.16%
Logging (1133)	0.08%	0.05%	0.00%
Support activities for agriculture and forestry (115)	0.05%	0.38%	0.02%
Oil and gas extraction (211)	0.70%	0.23%	0.03%
Coal mining (2121)	0.05%	0.02%	0.00%
Metal ore mining (2122)	0.17%	0.07%	0.00%
Nonmetallic mineral mining and quarrying (2123)	0.24%	0.10%	0.03%
Support activities for mining (213)	0.13%	0.04%	0.05%
Electric power generation, transmission, and distribution (2211)	4.49%	1.41%	0.48%
Natural gas distribution (2212)	0.00%	0.01%	0.07%
Water, sewage, and other systems (2213)	0.10%	0.35%	0.03%
Construction (23)	21.61%	14.25%	1.05%
Sawmills and wood preservation (3211)	0.01%	0.09%	0.01%

NAICS Industry	Gasoline and substitutes	Diesel and substitutes	Jet fuel
Veneer, plywood, and engineered wood product manufacturing (3212)	0.03%	0.07%	0.01%
Other wood product manufacturing (3219)	0.16%	0.41%	0.10%
Clay product and refractory manufacturing (3271)	0.01%	0.05%	0.01%
Glass and glass product manufacturing (3272)	0.05%	0.27%	0.04%
Cement and concrete product manufacturing (3273)	0.06%	0.66%	0.15%
Lime, gypsum and other nonmetallic mineral product manufacturing (3274, 3279)	0.03%	0.24%	0.04%
Iron and steel mills and ferroalloy manufacturing (3311)	0.07%	0.27%	0.02%
Steel product manufacturing from purchased steel (3312)	0.01%	0.06%	0.01%
Alumina and aluminum production and processing (3313)	0.02%	0.11%	0.01%
Nonferrous metal (except aluminum) production and processing (3314)	0.01%	0.31%	0.01%
Foundries (3315)	0.01%	0.05%	0.01%
Forging and stamping (3321)	0.02%	0.21%	0.05%
Cutlery and hand-tool manufacturing (3322)	0.00%	0.02%	0.01%
Architectural and structural metals manufacturing (3323)	0.03%	0.37%	0.13%

NAICS Industry	Gasoline and substitutes	Diesel and substitutes	Jet fuel
Boiler, tank, and shipping container manufacturing (3324)	0.01%	0.15%	0.02%
Hardware manufacturing (3325)	0.01%	0.03%	0.02%
Spring and wire product manufacturing (3326)	0.00%	0.04%	0.01%
Machine shops; turned product; and screw, nut, and bolt manufacturing (3327)	0.06%	0.39%	0.25%
Coating, engraving, heat treating, and allied activities (3328)	0.06%	0.15%	0.07%
Other fabricated metal product manufacturing (3329)	0.03%	0.27%	0.05%
Agriculture, construction, and mining machinery manufacturing (3331)	0.01%	0.13%	0.04%
Industrial machinery manufacturing (3332)	0.02%	0.29%	0.08%
Commercial and service industry machinery manufacturing, including digital camera manufacturing (3333)	0.38%	0.15%	0.07%
Ventilation, heating, air-conditioning, and commercial refrigeration equipment manufacturing (3334)	0.01%	0.12%	0.02%
Metalworking machinery manufacturing (3335)	0.00%	0.08%	0.03%
Engine, turbine, power transmission equipment manufacturing (3336)	0.05%	0.67%	0.09%
Other general purpose machinery manufacturing (3339)	0.06%	0.29%	0.06%

NAICS Industry	Gasoline and substitutes	Diesel and substitutes	Jet fuel
Computer and peripheral equipment manufacturing, excluding digital camera manufacturing (3341)	0.10%	0.93%	0.05%
Communications equipment manufacturing (3342)	0.02%	0.27%	0.06%
Audio and video equipment manufacturing (3343)	0.00%	0.07%	0.00%
Semiconductor and other electronic component manufacturing (3344)	0.04%	0.54%	0.04%
Navigational, measuring, electromedical, and control instruments manufacturing (3345)	0.04%	0.60%	0.12%
Manufacturing and reproducing magnetic and optical media (3346)	0.00%	0.01%	0.00%
Electric lighting equipment manufacturing (3351)	0.07%	0.07%	0.01%
Household appliance manufacturing (3352)	0.00%	0.02%	0.00%
Electrical equipment manufacturing (3353)	0.05%	0.09%	0.00%
Other electrical equipment and component manufacturing (3359)	0.20%	0.26%	0.03%
Motor vehicle manufacturing (3361)	0.03%	1.41%	0.05%
Motor vehicle body and trailer manufacturing (3362)	0.00%	0.05%	0.01%
Motor vehicle parts manufacturing (3363)	0.05%	0.76%	0.10%
Aerospace product and parts manufacturing (3364)	0.05%	0.48%	0.10%
Railroad rolling stock manufacturing (3365)	0.00%	0.09%	0.02%

NAICS Industry	Gasoline and substitutes	Diesel and substitutes	Jet fuel
Ship and boat building (3366)	0.01%	0.08%	0.08%
Other transportation equipment manufacturing (3369)	0.00%	0.25%	0.03%
Household and institutional furniture and kitchen cabinet manufacturing (3371)	0.06%	0.38%	0.10%
Office furniture (including fixtures) manufacturing; Other furniture related product manufacturing (3372, 3379)	0.06%	0.33%	0.10%
Medical equipment and supplies manufacturing (3391)	0.25%	0.50%	0.30%
Other miscellaneous manufacturing (3399)	0.12%	0.51%	0.12%
Animal food manufacturing (3111)	0.02%	0.48%	0.05%
Grain and oilseed milling (3112)	0.09%	2.08%	0.07%
Sugar and confectionery product manufacturing (3113)	0.31%	0.37%	0.03%
Fruit and vegetable preserving and specialty food manufacturing (3114)	0.13%	0.96%	0.05%
Dairy product manufacturing (3115)	0.25%	3.00%	0.14%
Animal slaughtering and processing (3116)	0.02%	2.20%	0.10%
Seafood product preparation and packaging (3117)	0.00%	0.06%	0.00%
Bakeries and tortilla manufacturing (3118)	0.10%	0.35%	0.17%
Other food manufacturing (3119)	0.19%	1.68%	0.16%

NAICS Industry	Gasoline and substitutes	Diesel and substitutes	Jet fuel
Beverage manufacturing (3121)	0.63%	2.86%	0.37%
Tobacco manufacturing (3122)	0.01%	0.05%	0.01%
Textile mills and textile product mills (313, 314)	0.02%	0.23%	0.03%
Apparel, leather and allied product manufacturing (315, 316)	0.08%	0.90%	0.18%
Pulp, paper, and paperboard mills (3221)	0.06%	0.15%	0.01%
Converted paper product manufacturing (3222)	0.07%	0.62%	0.09%
Printing and related support activities (323)	0.50%	0.33%	0.28%
Petroleum and coal products manufacturing (324)	14.34%	6.97%	0.61%
Basic chemical manufacturing (3251)	2.52%	1.96%	0.32%
Resin, synthetic rubber, and artificial synthetic fibers and filaments manufacturing (3252)	0.79%	0.45%	0.08%
Pesticide, fertilizer, and other agricultural chemical manufacturing (3253)	0.26%	0.32%	0.02%
Pharmaceutical and medicine manufacturing (3254)	0.30%	1.14%	0.14%
Paint, coating, and adhesive manufacturing (3255)	0.13%	0.19%	0.04%
Soap, cleaning compound, and toilet preparation manufacturing (3256)	0.34%	0.44%	0.04%
Other chemical product and preparation manufacturing (3259)	0.22%	0.17%	0.03%

NAICS Industry	Gasoline and substitutes	Diesel and substitutes	Jet fuel
Plastics product manufacturing (3261)	0.16%	0.53%	0.22%
Rubber product manufacturing (3262)	0.03%	0.18%	0.03%
Wholesale trade (42)	2.48%	4.31%	8.61%
Retail trade (44-45)	1.97%	7.46%	1.14%
Air transportation (481)	4.86%	0.75%	0.39%
Rail transportation (482)	0.94%	0.10%	0.03%
Water transportation (483)	0.63%	0.17%	0.34%
Truck transportation (484)	7.94%	3.97%	2.16%
Couriers and messengers (492)	4.32%	0.33%	0.10%
Transit and ground passenger transportation (485)	2.15%	0.34%	0.11%
Pipeline transportation (486)	0.00%	0.00%	0.00%
Scenic and sightseeing transportation and support activities for transportation (487, 488)	3.34%	2.21%	1.48%
Warehousing and storage (493)	0.05%	0.31%	0.07%
Newspaper, periodical, book, and directory publishers (5111)	0.03%	0.24%	0.35%
Software publishers (5112)	0.18%	0.23%	0.81%
Motion picture, video, and sound recording industries (512)	0.24%	0.86%	2.68%

NAICS Industry	Gasoline and substitutes	Diesel and substitutes	Jet fuel
Data processing, hosting, related services, and other information services (518, 519)	0.44%	0.80%	4.00%
Broadcasting (except internet) (515)	0.31%	2.05%	4.99%
Telecommunications (517)	0.03%	0.38%	0.20%
Monetary authorities, credit intermediation, and related activities (521, 522)	0.57%	1.30%	3.75%
Funds, trusts, and other financial vehicles (525)	1.73%	0.14%	2.69%
Securities, commodity contracts, and other financial investments and related activities (523)	1.53%	0.15%	4.99%
Insurance carriers (5241)	0.00%	0.04%	0.01%
Agencies, brokerages, and other insurance related activities (5242)	0.01%	0.03%	0.33%
Real estate (531)	3.04%	1.20%	11.27%
Automotive equipment rental and leasing (5321)	0.45%	0.07%	0.60%
Consumer goods rental and general rental centers (5322, 5323)	0.10%	0.03%	0.23%
Commercial and industrial machinery and equipment rental and leasing (5324)	0.36%	0.16%	0.56%
Lessors of nonfinancial intangible assets (except copyrighted works) (533)	0.03%	0.07%	0.04%
Legal services (5411)	0.02%	0.13%	1.90%

NAICS Industry	Gasoline and substitutes	Diesel and substitutes	Jet fuel
Accounting, tax preparation, bookkeeping, and payroll services (5412)	0.04%	0.10%	1.12%
Architectural, engineering, and related services (5413)	0.51%	0.61%	2.16%
Specialized design services (5414)	0.01%	0.15%	0.14%
Computer systems design and related services (5415)	0.57%	0.38%	5.64%
Management, scientific, and technical consulting services (5416)	0.08%	0.76%	2.70%
Scientific research and development services (5417)	0.43%	1.32%	1.91%
Advertising, public relations, and related services (5418)	0.03%	0.32%	1.00%
Other professional, scientific, and technical services (5419)	0.06%	0.25%	0.57%
Management of companies and enterprises (55)	0.47%	0.21%	0.42%
Office administrative services; Facilities support services (5611, 5612)	0.10%	0.23%	1.29%
Employment services (5613)	0.03%	0.07%	3.87%
Business support services; Investigation and security services; Other support services (5614, 5616, 5619)	0.33%	0.44%	3.44%
Travel arrangement and reservation services (5615)	0.01%	0.06%	1.19%
Services to buildings and dwellings (5617)	2.09%	0.62%	1.45%

NAICS Industry	Gasoline and substitutes	Diesel and substitutes	Jet fuel
Waste management and remediation services (562)	0.63%	0.48%	0.67%
Educational services; private (61)	0.20%	0.26%	0.72%
Offices of health practitioners (6211-6213)	0.26%	0.59%	3.12%
Outpatient, laboratory, and other ambulatory care services (6214, 6215, 6219)	0.22%	0.69%	1.16%
Home health care services (6216)	0.02%	0.07%	0.20%
Hospitals; private (622)	0.70%	0.75%	0.42%
Nursing and residential care facilities (623)	0.21%	0.26%	0.43%
Individual and family services; Community and vocational rehabilitation services (6241-6243)	0.31%	0.64%	0.94%
Child day care services (6244)	0.05%	0.06%	0.11%
Performing arts companies; Promoters of events, and agents and managers (7111, 7113, 7114)	0.01%	0.06%	0.10%
Spectator sports (7112)	0.01%	0.01%	0.06%
Independent artists, writers, and performers (7115)	0.00%	0.03%	0.02%
Museums, historical sites, and similar institutions (712)	0.01%	0.03%	0.01%
Amusement, gambling, and recreation industries (713)	0.39%	0.43%	0.31%
Accommodation (721)	0.32%	0.26%	0.25%

NAICS Industry	Gasoline and substitutes	Diesel and substitutes	Jet fuel
Food services and drinking places (722)	1.45%	1.64%	1.59%
Automotive repair and maintenance (8111)	0.25%	0.29%	0.19%
Electronic and precision equipment repair and maintenance (8112)	0.01%	0.09%	0.05%
Commercial and industrial machinery and equipment (except automotive and electronic) repair and maintenance (8113)	0.03%	0.11%	0.12%
Personal and household goods repair and maintenance (8114)	0.01%	0.03%	0.01%
Personal care services (8121)	0.03%	0.09%	0.12%
Death care services (8122)	0.00%	0.10%	0.00%
Drycleaning and laundry services (8123)	0.10%	0.09%	0.07%
Other personal services (8129)	0.02%	0.05%	0.16%
Religious organizations; Grantmaking and giving services, and social advocacy organizations (8131-8133)	0.44%	0.13%	0.30%
Civic, social, professional, and similar organizations (8134, 8139)	0.20%	0.11%	0.24%

B. Changes in Final Demand

The changes in expenditures by households, businesses, and government entities are mirrored by changes in demand for the fuel producing industries. The consumer spending policy variable that is used for modeling household expenditures also captures for the subsequent supply side impacts. For business and government expenditures, the supply side impacts are modeled using REMI's exogenous final demand policy variable.

Petroleum and coal products manufacturing (324) is used for changes in expenditures on CARBOB gasoline, diesel, and conventional jet fuel. Basic chemical manufacturing (3251) is used for changes in alternative jet fuel, biodiesel, renewable diesel, renewable gasoline, ethanol, and hydrogen. Within the natural gas distribution industry (2212) and electric power generation, transmission, and distribution (2211), there is a transfer of production value from conventional natural gas and electricity producers to dairy natural gas and dairy electricity producers. However, these effects net to zero when combined in the same NAICS code. Table 67 shows the values input into REMI.

Table 67: REMI Inputs to Model Changes in Demand for Fuels

REMI Category	Exogenous Final Demand	Exogenous Final Demand
Industry (NAICS)	**Petroleum and coal products manufacturing (324)**	**Basic chemical manufacturing (3251)**
2024	-960.10	992.87
2025	-863.17	896.64
2026	-1472.90	1537.93
2027	-2389.11	2498.36
2028	-3430.76	3584.36
2029	-4119.96	4306.36
2030	-4785.76	5010.45
2031	-4902.21	5132.51
2032	-4935.54	5165.76
2033	-4882.61	5115.05
2034	-4461.07	4682.15
2035	-4185.71	4400.14
2036	-4191.39	4407.43
2037	-4571.73	4802.39
2038	-5235.60	5491.79
2039	-5429.60	5692.61
2040	-5059.86	5308.69

REMI Category	Exogenous Final Demand	Exogenous Final Demand
Industry (NAICS)	**Petroleum and coal products manufacturing (324)**	**Basic chemical manufacturing (3251)**
2041	-5041.74	5289.41
2042	-4133.64	4347.01
2043	-4002.11	4205.92
2044	-3452.69	3633.57
2045	-3302.78	3453.18
2046	-3176.35	3317.45

III. Third Party Verification Costs

As outlined in Section C - Direct Costs, third-parity verification requirements will increase operating costs for fuel producing industries. Higher verification costs are modeled as an increase in production cost to the three industry NAICS codes anticipated to bear these costs: petroleum and coal products manufacturing (324), basic chemical manufacturing (3251), and natural gas distribution (2212). Demand for verification services will also grow as a result of the proposed verification requirements. This demand is modeled as an increase in exogenous final demand for management, scientific, and technical consulting services (NAICS 5416). Aggregated costs for third-party verification services, and the corresponding increase in demand, are outlined in Table 68Table 68.

Table 68: REMI Inputs to Simulate Third-Party Verification Requirements

REMI Category	**Production Cost**	**Production Cost**	**Exogenous Final Demand**
Explanation	**3rd Party Verification Costs**	**3rd Party Verification Costs**	**Demand for 3rd Party Verification Costs**
Industry (NAICS)	**Basic chemical manufacturing (3251)**	**Electric power generation, transmission, and distribution (2211)**	**Management, Scientific, and Technical Consulting Services (5416)**
2024	0.02	26.03	-26.05
2025	0.02	32.78	-32.80
2026	0.05	41.07	-41.11
2027	0.08	53.86	-53.95
2028	0.13	69.21	-69.34
2029	0.19	87.31	-87.50
2030	0.49	108.45	-108.94
2031	0.57	132.90	-133.46
2032	0.80	157.87	-158.67
2033	0.89	185.38	-186.27
2034	1.14	214.62	-215.77
2035	1.26	245.59	-246.85
2036	1.26	276.08	-277.34
2037	1.53	306.20	-307.72
2038	1.54	335.56	-337.10

REMI Category	Production Cost	Production Cost	Exogenous Final Demand
Explanation	3rd Party Verification Costs	3rd Party Verification Costs	Demand for 3rd Party Verification Costs
Industry (NAICS)	Basic chemical manufacturing (3251)	Electric power generation, transmission, and distribution (2211)	Management, Scientific, and Technical Consulting Services (5416)
2039	1.82	364.02	-365.85
2040	2.17	391.41	-393.58
2041	2.33	417.65	-419.97
2042	2.48	442.47	-444.95
2043	2.63	465.82	-468.45
2044	2.78	487.62	-490.40
2045	2.91	507.58	-510.49
2046	3.05	528.06	-531.12

IV. State and Local Government Tax Revenue

The Proposed Amendments will impact state and local government revenues through impacts to sales tax. A detailed discussion of the fiscal impacts of the proposed amendments is included in Section IV: Fiscal Impacts. The state tax rates for each fuel type are listed in Table 69. All fuel types were converted from their native units to a gasoline gallon equivalent using the fuel conversion rates published by the CEC[130]. Table 70Table 69 reports the inputs for state and local government tax revenue impacts that are input into REMI.

[130] CEC, Transportation Fuel Price Forecasts, Final Revision 5 January 2023

Table 69: Rates used to Calculate Government Taxes (per gallon of fuel purchased)

Entity	Gasoline	Diesel	E85	Natural Gas
Local Government Portion of Sales Tax	3.7%	4.76%	4.76%	
State Government Portion of Sales Tax	0.0%	9.69%	3.94%	
Total Sales Tax	3.70%	14.5%	8.70%	
Local Government Portion of State Excise Tax	$0.215	$0.062		
State Government Portion of State Excise Tax	$0.296	$0.327		
CA State Excise Tax	$0.511	$0.389		$0.089

Table 70: State and Local Government Tax Revenues Input into REMI

REMI Category	State and Local Government Spending	State and Local Government Spending
Industry (NAICS)	**State Government**	**Local Government**
Explanation	**Sales, Excise, and ERF Tax**	**Sales, Excise, and UU Tax**
2024	6.63	3.11
2025	4.01	1.08
2026	7.49	1.67
2027	12.45	2.36
2028	20.65	5.78

REMI Category	State and Local Government Spending	State and Local Government Spending
Industry (NAICS)	**State Government**	**Local Government**
Explanation	**Sales, Excise, and ERF Tax**	**Sales, Excise, and UU Tax**
2029	27.39	8.89
2030	29.45	7.75
2031	28.56	6.38
2032	27.35	5.38
2033	27.20	4.99
2034	25.29	4.16
2035	23.99	3.40
2036	24.75	3.73
2037	27.02	4.48
2038	31.13	5.89
2039	32.18	6.20
2040	30.08	5.45
2041	29.96	5.42
2042	24.58	3.53
2043	23.13	3.02

REMI Category	State and Local Government Spending	State and Local Government Spending
Industry (NAICS)	**State Government**	**Local Government**
Explanation	**Sales, Excise, and ERF Tax**	**Sales, Excise, and UU Tax**
2044	19.72	1.86
2045	23.56	8.23
2046	22.16	7.75

V. Avoided Adverse Health Impacts

The *Consumer Spending* and *Labor Productivity* variables are used to model health benefits due to the proposed amendments' contributions to reduced PM2.5 emissions. The reductions in PM2.5 emissions largely outweigh adverse health impacts that result from increased NOx emissions.

The decrease in acute respiratory, cardiovascular, and asthma related hospital and emergency room visits results in less household spending in the healthcare industry and allows for an increase in spending in all other consumption categories.

Costs associated with work loss days are modeled as the implied necessary increase in employment using REMI's baseline employment and compensation values. The implied increase in employment and REMI's baseline output is used to recalculate labor productivity under the Proposed Regulation. The percentage change in labor productivity is input into REMI's *Labor Productivity* policy variable for the support activities for all 156 industries. Changes to labor productivity related to positive health impacts are negligible. Table 71 shows the inputs into the REMI model.

Table 71: REMI Inputs to simulate Monetized Health Benefits

REMI Category	Consumer Spending on Hospitals	Labor Productivity
Industry (NAICS)	**Hospitals**	**All 156 Sectors**
2024	-0.45	0.000003

REMI Category	Consumer Spending on Hospitals	Labor Productivity
Industry (NAICS)	Hospitals	All 156 Sectors
2025	-2.43	0.000016
2026	-2.34	0.000015
2027	-2.74	0.000018
2028	-2.96	0.000019
2029	-2.64	0.000017
2030	-1.95	0.000012
2031	-2.70	0.000017
2032	-2.94	0.000018
2033	-2.93	0.000018
2034	-2.95	0.000018
2035	-3.04	0.000018
2036	-3.08	0.000017
2037	-3.33	0.000018
2038	-3.93	0.000021
2039	-4.06	0.000021
2040	-4.20	0.000022
2041	-4.11	0.000021

REMI Category	Consumer Spending on Hospitals	Labor Productivity
Industry (NAICS)	**Hospitals**	**All 156 Sectors**
2042	-3.58	0.000018
2043	-3.62	0.000018
2044	-3.66	0.000017
2045	-3.41	0.000016
2046	-3.51	0.000016