



Driving California Forward

Public Health and Societal Economic Benefits
of California's AB 32 Transportation Fuel Policies

LCFS AND CAP-AND-TRADE REGULATIONS

Environmental Defense Fund / American Lung Association in California / Tetra Tech

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Environmental Defense Fund

Environmental Defense Fund is dedicated to protecting the environmental rights of all people, including the right to clean air, clean water, healthy food and flourishing ecosystems. Guided by science, we work to create practical solutions that win lasting political, economic and social support because they are nonpartisan, cost-effective and fair.

American Lung Association in California

The American Lung Association in California saves lives and improves the health of Californians and their lungs. Through research, education and advocacy, we fight to reduce smoking, keep the air we breathe clean, prevent and treat lung diseases such as asthma and chronic obstructive pulmonary disease, and eliminate lung cancer.

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The complete report is available online at edf.org/ and lung.org/california.

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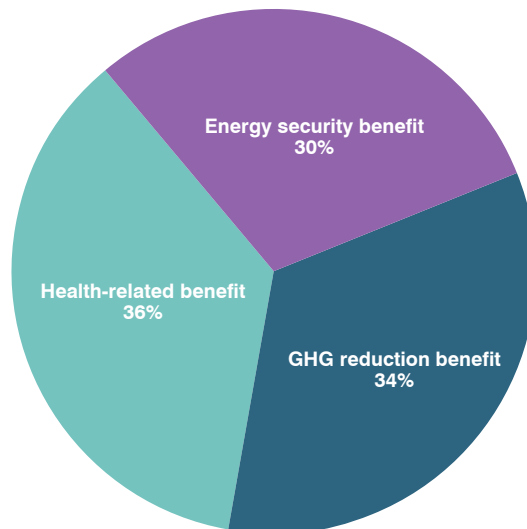
Executive summary

The transportation sector is the largest source of pollution in California, contributing close to 70% of smog-forming gases and 40% of the state's climate change pollution every year. Consequently, the current transportation system is responsible for a significant portion of the adverse health impacts that citizens suffer from, in addition to causing energy vulnerability that threatens economic stability and contributing to climate change that threatens the future of our state and planet.

California can reduce these severe negative impacts by cutting the overall system's rate of pollution that endangers public health (e.g. NO_x, SO_x, and PM_{2.5}), growing the volume of domestically produced clean fuels, and cutting carbon pollution from fuels. Among the many policies being pursued to drive this transformation are the state's AB 32 Low Carbon Fuel Standard (LCFS) and cap-and-trade regulation (C&T).

This analysis calculates the economic benefit of the LCFS and C&T by evaluating the societal benefits of full implementation in 2020 and 2025, which include 1) avoided public health costs and incidents of illness, 2) avoided fossil fuel dependence costs, and 3) avoided climate change-related costs (see Figure E-1 below for the proportion of the total societal economic benefit attributed to these three components). These benefits are compared to a baseline that does not factor in those policies to show that by 2025, the LCFS and C&T will incentivize the shift to a cleaner transportation fleet that will save the state and its citizens money.

FIGURE E-1
Breakdown of net societal economic benefit by component (2025)



Combined benefits of LCFS and C&T fuel regulations

Modeling conducted for this report shows that without the LCFS and C&T, the California transportation system is expected to result in cumulative societal economic impacts of \$274 billion by 2020 and \$387 billion by 2025. The transition to a cleaner and more diverse vehicle fleet will require investments in alternative fuel production and infrastructure. According to modeling conducted in this analysis, the LCFS and C&T regulations will result in cumulative benefits from avoided health, energy insecurity, and climate change costs of \$10.4 billion by 2020 and \$23.1 billion by 2025. The model used in this report includes benefits from both the light-duty (e.g. passenger cars and light trucks) and heavy-duty (e.g. on- and off-road trucks and buses) sectors. Each of the three components studied in this report are described in further detail below.

Health effects of the current transportation system and benefits of new fuel regulations

Among the many documented impacts of air pollution generated from cars and trucks is increased risk of asthma attacks, heart attacks, cardiovascular disease, respiratory ailments, and cancer, as well as shortened lifespan. This pollution is particularly detrimental to more vulnerable populations, such as infants, children, and the elderly; low-income and disadvantaged individuals who are already exposed to increased amounts of pollutants; and people with pre-existing lung and heart diseases. All told, air pollution has been estimated by the California Air Resources Board to cause 9,200 deaths in California per year,¹ with more recent research indicating that approximately 21,000 deaths per year in California are caused by roadway pollution.²

A 2011 American Lung Association in California report entitled *The Road to Clean Air*,³ which this report builds on, demonstrates that a reduction in transportation pollution from increasing cleaner and more efficient passenger vehicles will improve the quality of the air and reduce the incidence of observed health impacts. This transition will not only directly improve health, but also create billions of dollars in annual economic benefits in the form of fewer missed work days and fewer expensive hospital visits.⁴

Pursuant to the analysis presented in this report, the increased use of cleaner fuels through implementation of the LCFS and C&T program will substantially improve air quality and reduce climate pollution generated in California leading up to 2020 and beyond. By 2025, when a significant part of the vehicle and fuel mix will have been influenced by the LCFS and C&T, communities can expect a cumulative benefit from the LCFS and C&T that includes:

- Savings of \$8.3 billion in pollution-related health costs
- Prevention of 600 heart attacks and 880 premature deaths caused by air pollution
- Prevention of 38,000 asthma attacks and almost 75,000 lost work days
- Reduction of criteria pollutant emissions by almost 180,000 tons

Energy security benefits of transportation fuel regulations

California's reliance on imported oil for transportation energy is documented to be a major factor that contributes to the state's economic vulnerability.⁵ According to research on the U.S. economy-wide impact of energy dependence on imported oil, the cumulative cost was more than \$2 trillion from 2007 to 2011.⁶

By creating a regulatory signal to diversify the state's fuel mix with a portfolio of lower carbon fuels, many of which are produced domestically in California or in other parts of the U.S., the LCFS and C&T will decrease costs associated with energy dependence (including associated supply vulnerability costs) on imported oil. By 2025, petroleum use and import

reductions that lead to greater energy independence will produce significant cumulative fiscal and societal benefits, including:

- Savings of approximately \$6.9 billion from increased energy independence
- Reduced consumption of gasoline by 21.4 billion gallons
- Reduced consumption of diesel by 11.8 billion gallons

Climate change-related benefits (known as the “social cost of carbon”) of transportation fuel regulations

Global climate change is linked to significant economic costs because of its causal connection to disruptive impacts such as extreme weather events, higher temperatures, changing precipitation patterns, and sea level rise. The social cost of carbon therefore takes into account climate change damages like changes in net agricultural productivity, human health, and property damages from increased flood risk, as well as drought and higher than normal temperatures.

By decreasing greenhouse gas pollution through the LCFS and C&T, California will contribute to reduced social costs associated with climate change. By 2025, regulating transportation fuels through the LCFS and C&T is expected to produce significant cumulative benefits, including:

- Savings of \$7.9 billion in social cost of carbon damages
- Reduction of CO₂ equivalent emissions by almost 165 million metric tons

Background and overview



All results of the model used in this report are calculated in 2013 U.S. dollars.

California is in the process of transitioning the statewide economy into one that is more diverse, more resilient to economic downturns, and better for the environment. This transition necessarily includes a shift in the transportation sector away from over-reliance on a single fuel source, most of which is imported, and towards a system that is based on a mix of lower emitting, domestically produced, more sustainable fuels. This process also includes a shift towards more highly efficient modes of transportation, as well as land use and transportation planning initiatives that promote healthier alternatives to driving.

Over the next decade, two landmark policy drivers—California’s AB 32 Low Carbon Fuel Standard (LCFS) and cap-and-trade regulation (C&T)—will be at the heart of the continued overhaul of the transportation system. As shown by this and other analyses,⁷ these policies reduce harmful air pollution and cut overall fossil fuel use. Furthermore, compliance with these regulations will result in investments that will save billions of dollars over the next decade.

In this report, a transportation fleet modeling platform was developed to better understand the impact of the LCFS and C&T regulations between 2010 and 2025. The model was first run to predict what the statewide vehicle fleet would be composed of assuming the LCFS and C&T regulations were not in place (the “no-regulation scenario”). The model was then used to predict what the statewide vehicle fleet would look like assuming full compliance with the LCFS and C&T regulations as planned (the “deployment scenario”). The two modeling outputs were then compared to calculate the **societal economic benefit** of the transition in the statewide vehicle fleet associated with the regulations. The societal economic benefit aggregates impacts from the following three categories: 1) avoided air pollution-related public health impacts, 2) avoided fossil fuel dependence impacts, and 3) avoided climate change impacts.

Societal economic benefit is the main metric of this report and refers to the total economic benefit that will come from implementation of the LCFS and C&T in California. This number is a sum of three components: 1) avoided public health costs, 2) avoided fossil fuel dependence costs, and 3) avoided climate change-related costs.

Costs of maintaining a transportation system in the no-regulation scenario

California is home to more than 30 million vehicles, with drivers consuming about 17 billion gallons of gasoline and diesel each year and approximately 3,000 trillion Btus of energy. Of all fifty states, California ranks first in terms of the amount of energy used for transportation, as shown in Table 1-1. This high rate of consumption causes drivers to spend between \$60 and \$80 billion annually with gasoline prices between \$3 and \$4 per gallon.

Reliance on conventional motor vehicles that run on the combustion of fossil fuels comes at a high economic and public health cost. The health costs of air pollution are real—Californians are suffering from missed work days, asthma attacks, respiratory and cardiac hospitalizations, and premature deaths.⁸ The reason for this is that California’s air pollution remains among the worst in the country, with 30 million Californians, or roughly 80% of the state’s population, living in

TABLE 1-1
Transportation sector energy use (2011)

State	Ranking	Btu/year (in trillions)
California	1	3000
Texas	2	2818
Florida	3	1538
New York	4	1015
Illinois	5	979

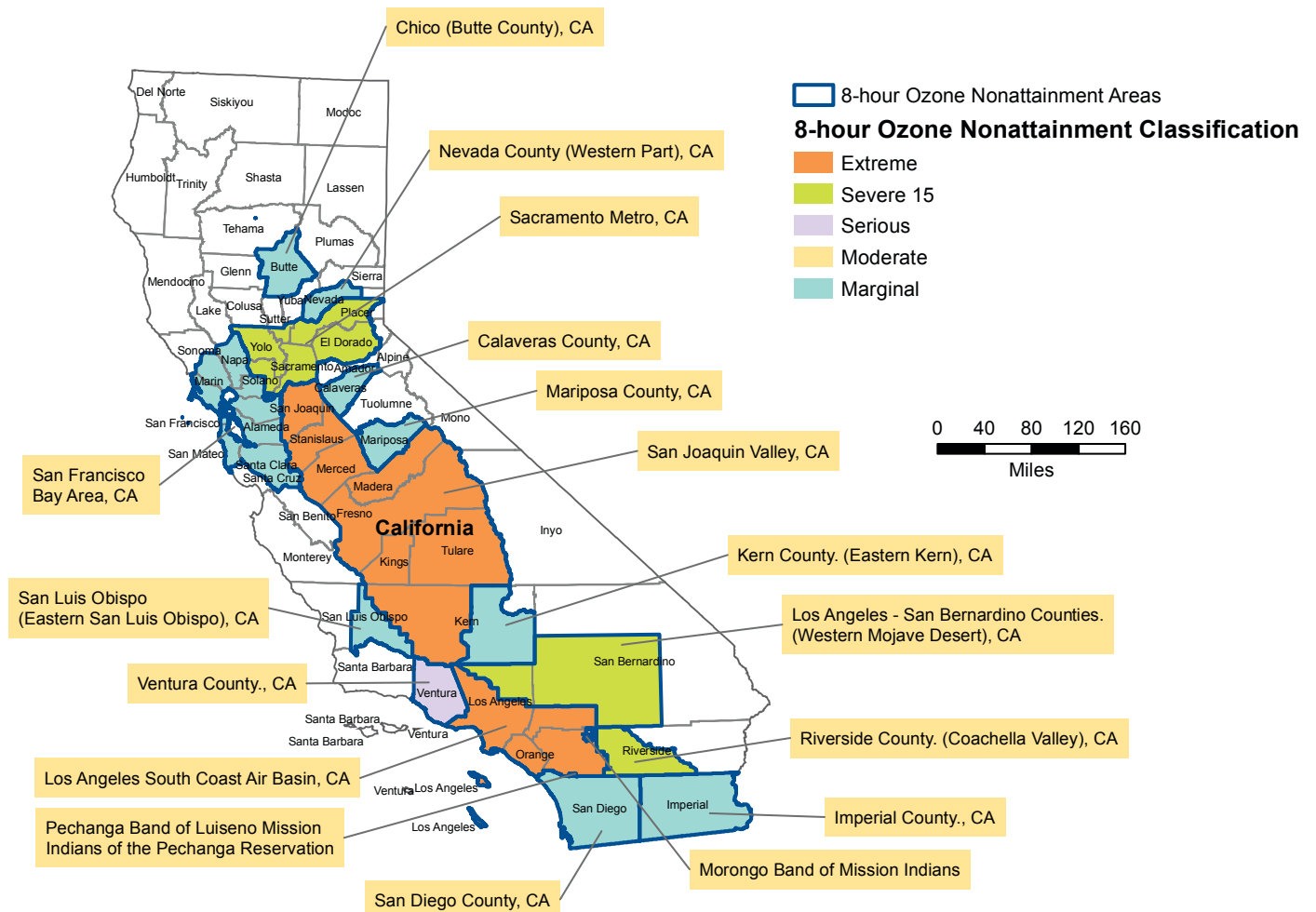
Source: U.S. Energy Information Administration⁹

counties with unhealthy air.¹⁰ Of great concern are particulate matter and ground-level ozone. Ozone is formed when nitrogen oxide, hydrocarbons, or carbon monoxide from tailpipes or other polluting sources react with sunlight. Motor vehicles are among the biggest contributors of these pollutants.¹¹ Particle pollution is made up of microscopic specks of soot, metals, acids, dirt, pollen, molds, and aerosols that are tiny enough to inhale. Key sources of particle pollution in California include cars, diesel engines in trucks, buses, and freight vehicles, equipment, and other combustion sources.

Pollution is especially acute in the many California counties that fail to meet federal health-based air quality standards for ozone and PM_{2.5}, including most urbanized areas in California, especially the San Joaquin Valley and Southern California regions. A map of these regions is displayed in Figure 1-1.

Exposure to dirty air can cause or worsen a variety of severe health problems, including respiratory diseases like asthma, pulmonary inflammation, and cardiovascular disease, as well as increased risk of heart attack, increased infant mortality, and increased cancer risk. Vulnerable populations such as children and infants, the elderly, anyone with existing respiratory and heart illnesses, and disadvantaged communities who are already

FIGURE 1-1
Air quality by county
 California 8-hour ozone nonattainment areas (2008 standard)



Source: Environmental Protection Agency¹²

burdened with degraded air quality are especially at risk. Table 1-2, characterizes many of these impacts.

Furthermore, the current transportation sector contributes almost 40% of California's climate change-causing greenhouse gas pollution (see Figure 1-2, page 5). As documented, climate change adversely affects communities across the state, from farmers in the Central Valley dealing with drought to coastal communities confronting sea level rise. Transportation contributes nearly twice the amount of climate pollution as California's industrial sector, and disproportionately impacts environmental justice communities.¹³ These communities are made up of predominantly low-income residents who are especially vulnerable to climate change and other environmental hazards.¹⁴

In addition, California's dependence on liquid fossil fuels produced from crude oil, over 60% of which is imported from out-of-state (50% from foreign countries, 12% from Alaska),¹⁵ results in energy insecurity and subjects California's economy to fluctuations in oil prices and import volume availability. In 2012, nearly 45% of foreign imports originated from the Middle East, with Saudi Arabia accounting for the largest portion at 27.2% (see Figure 1-3, page 5), although increasing volumes of crude oil have started being imported from Canada into California by rail.

Based on modeling analysis conducted for this paper and described in *Methodology* (page 11) and *Model results and analysis* (page 15), the societal economic costs of California's transportation system are divided into three main categories:

1. Cost of the public health impacts from air pollution (NO_x, SO_x, PM_{2.5})
2. Cost of energy insecurity from fossil fuel dependency
3. Cost of climate change from greenhouse gas pollution (social cost of carbon)

TABLE 1-2
Health impacts of air pollution from motor vehicles

Tailpipe pollutant	What is it?	What does it do?
Nitrogen oxides (NO _x)	Generated from fuel combustion. Harmful gas when emitted. Reacts with volatile organic compounds (VOCs), carbon monoxide (CO), and sunlight to create ozone smog. Forms PM _{2.5} in the atmosphere.	NO _x triggers asthma and increases the risk of infections. NO _x also recognized as a key marker of near-roadway pollution . Ozone smog poses a variety of health threats, including premature death, respiratory harm (e.g. worsened asthma), and is linked to cardiovascular harm.
Sulfur oxides (SO _x)	Generated from combustion of fuel containing sulfur. Harmful gas when emitted. Forms PM _{2.5} in the atmosphere.	SO _x exacerbates asthma and increases risk of hospitalization. See below for effects of PM _{2.5} .
Particulate matter (PM _{2.5} , PM ₁₀)	Tiny airborne liquid and solid particles generated by fuel combustion and by friction on tires, brakes, and road dust. Smaller than 2.5 microns in diameter and 10 microns in diameter, respectively.	Causes premature death, cardiovascular harm (e.g. heart attacks, strokes, heart disease), increased risk of respiratory harm (e.g. worsened asthma, worsened COPD), increased lung cancer.
Volatile organic compounds (VOCs)	Highly reactive gases generated from fuel combustion. Include benzene, formaldehyde, and other carcinogens. Reacts with NO _x , carbon monoxide (CO), and sunlight to create ozone smog.	VOCs can cause a variety of health problems including respiratory harm and cancer. See above for effects of ozone smog.
Carbon monoxide (CO)	Generated from fuel combustion. Reacts with NO _x , VOCs, and sunlight to create ozone smog.	Reduces oxygen flow in bloodstream. See above for effects of ozone smog.

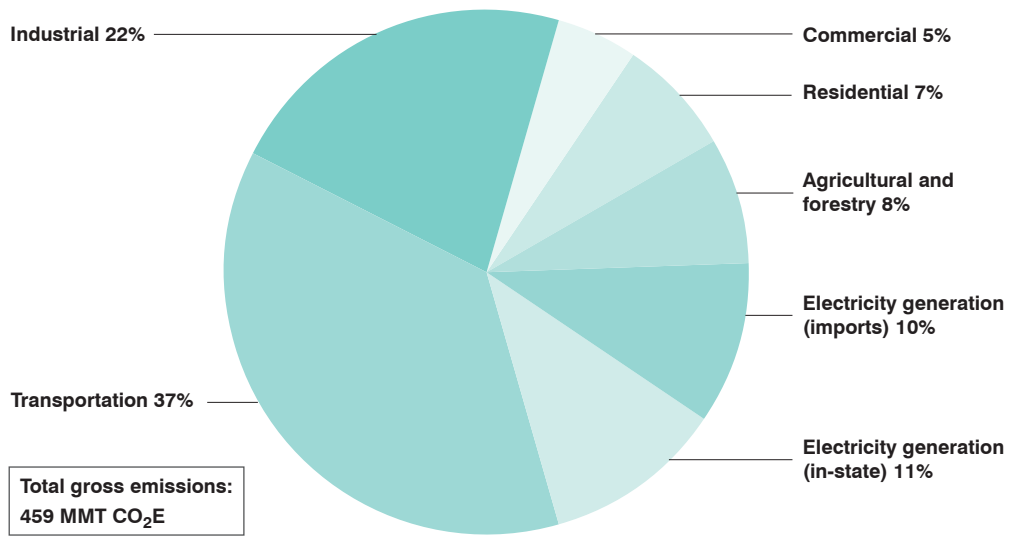
Source: American Lung Association in California, American Lung Association, Health Effects Institute, U.S. Environmental Protection Agency¹⁶

Near-roadway pollution hazards:
Growing evidence shows pollution levels near highways or busy roads are higher than in the community, and people who live or work nearby are at increased risk for respiratory and cardiovascular harm.

This report quantifies the combined societal cost associated with these three categories at approximately \$25 billion in 2014.

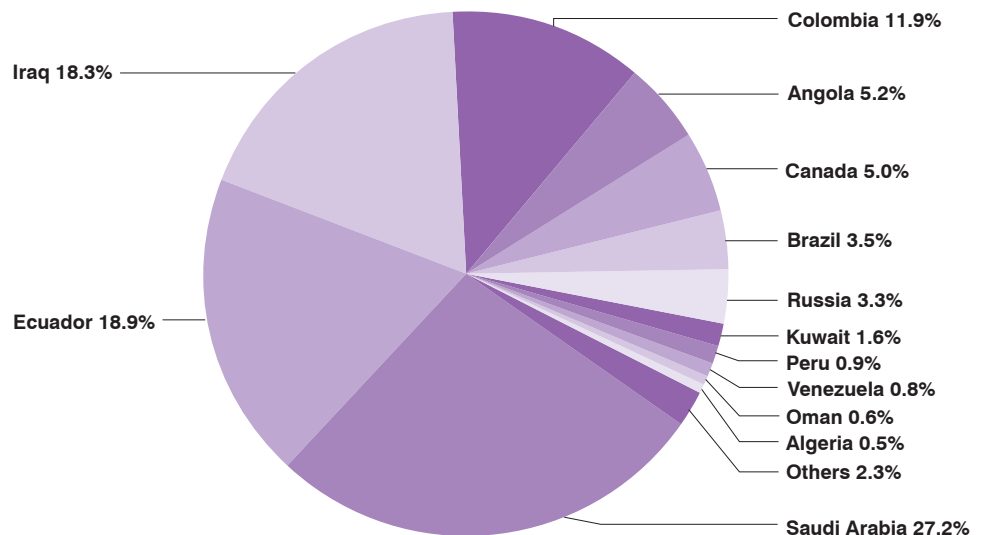
The modeling conducted for this report also constructs a hypothetical fleet mix that would result from having no LCFS or C&T regulation in place between present day, 2020, and 2025. As described in *Analysis assumptions* (page 7), *Methodology* (page 11), and *Model results and analysis* (page 15) the cumulative costs of maintaining the transportation system without the LCFS and C&T reach \$274 billion by 2020 and \$387 billion by 2025 due to public health impacts, energy insecurity, and greenhouse gas pollution (see *Methodology*, page 11, and Appendix D).

FIGURE 1-2
California greenhouse gas inventory by sector (2012)



Source: California Air Resources Board¹⁷

FIGURE 1-3
Foreign sources of crude oil imports to California (2012)



Source: California Energy Commission, Energy Almanac¹⁸

Benefits of transitioning the California transportation system through the LCFS and C&T

California vehicle and fuel policies are creating durable market signals to incentivize the transformation of the state's transportation system. These health protective policies are driving the deployment and availability of new, cleaner fuels and vehicles and will continue to do so in the future. Based on current and forecasted deployment trends, it is apparent that California's fuel market is becoming more diverse and shifting towards more domestically-produced, lower-carbon fuels that will result in dramatically reduced emissions of traditional air pollutants, criteria pollutants, and toxic air contaminants.

Aggregate estimates of alternative fuel penetration resulting from implementation of all transportation fuel policies by 2020 range from 11.3–18.8% of the total fuel mix (see Table 1-3). This amounts to approximately 1.7–2.8 billion gallons of alternative fuel in gasoline gallon equivalents.

As detailed in *Analysis assumptions* (page 7) and *Model results and analysis* (page 11), the benefits of LCFS and C&T implementation include reduced public health impacts, improved energy security, and reduced greenhouse gas pollution. By comparing a no-regulation scenario to one which models full implementation of the LCFS and C&T, the combined benefits of these policies can be determined. As shown through this comparison, the LCFS and C&T will provide a benefit of almost \$2 billion in the year 2020, and cumulative benefits of \$10.4 billion by 2020 and \$23.1 billion by 2025.

TABLE 1-3

Estimated volumes of future alternative fuel penetration in California

Alternative fuel type	Year 2020 projected volume	Volume of displaced gasoline gallons in CA in 2020	% of fuel market share of cars and trucks (gasoline and diesel) in CA in 2020
Natural gas (cars)	95 MM therms sold ¹⁹	76 million gallons per year	0.50%
Natural gas (trucks)	15–35% new heavy duty trucks ²⁰	199 million–221 million gallons per year	1.3%–1.5%
Biofuel (ethanol)	1.6 billion–2.4 billion gallons ²¹	1.1–1.6 billion gallons per year	7.2%–10.8%
Biofuel (biodiesel)	5%–15% aggregate blend into diesel ²²	200 million–600 million gallons per year	1.3%–4.0%
Electricity and hydrogen passenger vehicles	500,000–1,000,000 vehicles on the road ²³	160 million–321 million gallons per year	1.0%–2.0%
		Total displaced gallons: 1.7–2.8 billion	Market share of alt. fuels: 11.3%–18.8%

Source: Environmental Defense Fund²⁴

Note: These volumes are taken from current estimates of market share, but increased volumes are expected in some categories, including electricity and hydrogen.

Analysis assumptions



Assessment of the “no-regulation scenario”

To change the dynamics of California’s fossil fuel-intensive transportation system, the state and federal government have, over the years, adopted a series of regulations and initiatives. These include mandatory car and truck efficiency and mileage standards, in addition to alternative fuels and vehicle grant programs. Additionally, California has adopted strategies to reduce the harm caused by vehicle pollution through efforts like truck and bus regulations, SB 375 Sustainable Communities Strategies, and mass transit programs. In this study, the LCFS and C&T regulations were considered separately from the suite of other transportation policies that California has implemented in order to isolate their impacts.

Although these two programs do not currently include provisions for declining targets past the year 2020, the vehicles and fuels in place to meet the targets in 2020 will remain on the road post-2020, and will continue to accrue benefits when compared to the no-regulation scenario. The model used in this study assumes continuation of the LCFS and C&T regulations after 2020 at constant stringency levels after that year. This is a conservative estimation given the executive order signed by Governor Schwarzenegger setting a 2050 target of 80% reduction cuts below 1990 levels of emission in California. Post-2020 reduction targets for these two programs are being actively discussed to help the state get closer to achieving this ambitious goal.²⁵

Modeling transportation system impacts without the LCFS or C&T (the “no-regulation scenario”) was performed by Tetra Tech and analyzes the hypothetical lifecycle emissions from the projected business-as-usual motor vehicle fleet in 2015, 2020, and 2025 (see Appendix A for fleet inputs) using two emissions models. First, upstream “well-to-tank” emissions for both light- and heavy-duty vehicles were derived with Argonne National Laboratory’s Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) model, using the carbon intensities of the default fuel pathways for California. These emissions were then added to the downstream “tank-to-wheel” emissions derived using a modified version of the California Air Resources Board’s Emissions Factor (EMFAC) model.^{26,27} From the combined GREET and EMFAC results, the societal economic impact of the fleet mix was quantified using the methodology described in the sections below.

Assessment of the LCFS and C&T “deployment scenario”

To assess the effect of the implementation of the LCFS and C&T, a vehicle and fuel deployment scenario was developed based on available literature associated with potential deployment patterns in California (see Appendix C for fleet inputs). This scenario was then run through both the GREET model and modified EMFAC model in the same manner as the “no-regulation scenario.”

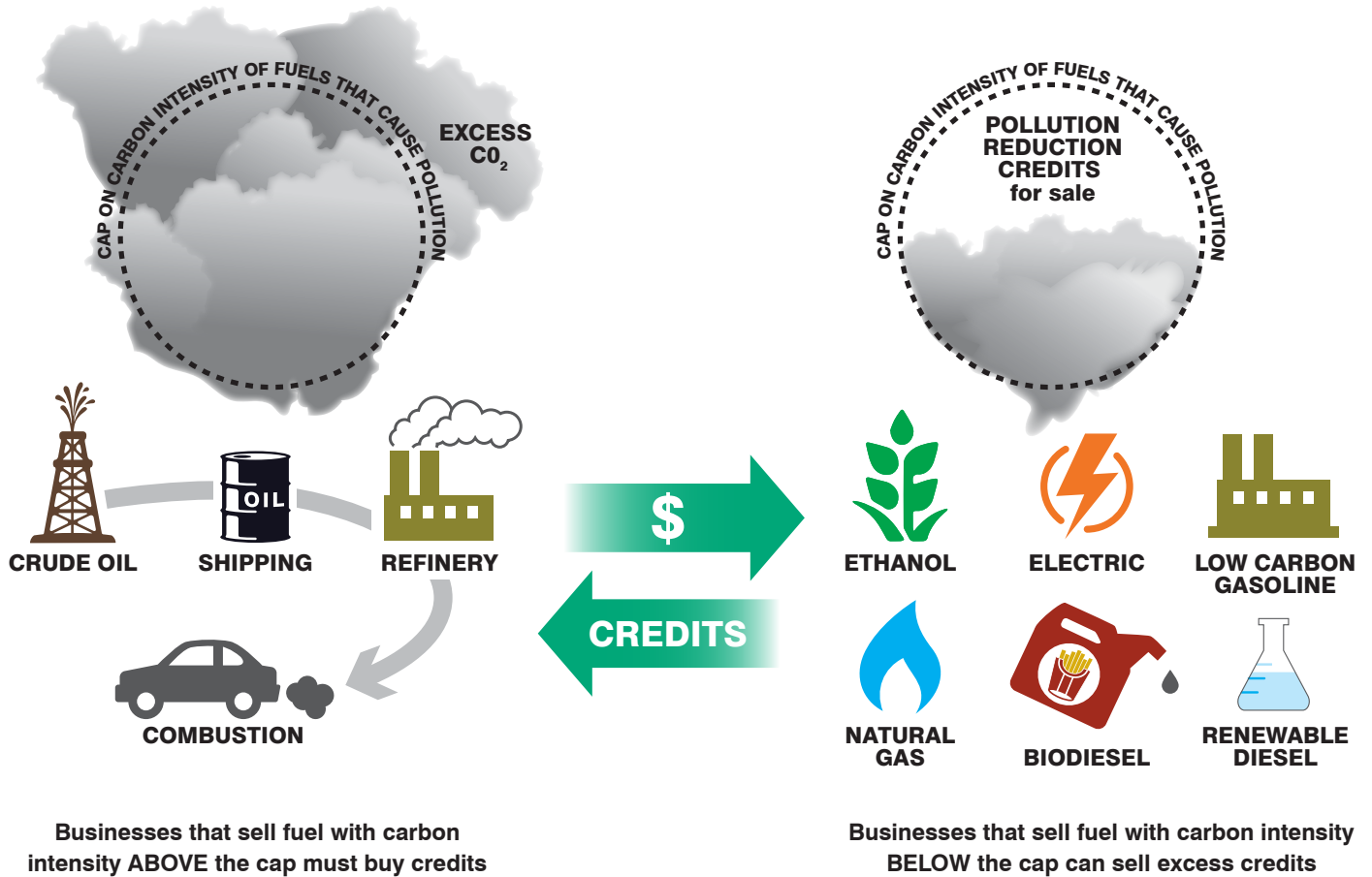
As described above, the LCFS and C&T regulation create a durable market signal for investment and innovation within the transportation fuel system. However, since these regulations work synergistically to incentivize investments and pollution reductions throughout the California transportation system, the effect of one was determined to be indiscernible from the effect of the other. Further, neither regulation can incentivize deployment of technology beyond the capabilities of fuel and vehicle developers. As a result, this analysis modeled the combined effect of the LCFS and C&T, and the deployment scenario constructed was set at a level which represents feasible deployment figures discussed in publicly available literature and which closely resemble compliance with the LCFS regulation.

California Low Carbon Fuel Standard (LCFS)

The LCFS is a market-based mechanism directly applied to the transportation fuel mix. The first-in-the-nation LCFS was established under Executive Order S-1-07 and implemented pursuant to an early action regulatory effort under California’s AB 32, the Global Warming Solutions Act of 2006. As written, the LCFS requires a phased reduction in the carbon intensity of transportation fuels in the state, leading to a 10% reduction by 2020.²⁸ Achieving this target

FIGURE 2-1

Operation of California's Low Carbon Fuel Standard



An LCFS limits the amount of carbon emissions from fuels and allows clean fuel producers to sell their carbon credits to businesses that have trouble meeting the carbon intensity requirement.

has been forecasted to result in a reduction of approximately 16 million metric tons (MMT) of greenhouse gas emissions annually from the transportation sector, thus achieving roughly 10% of the AB 32 reduction goal.²⁹ Fuel producers achieve the standards by reducing the carbon intensity of the fuel they sell or by purchasing credits from other fuel producers.³⁰ The LCFS helps to promote the increased use of fuel from cleaner, renewable sources with lower carbon scores, such as plant-based fuels (biodiesel, advanced ethanol, etc.), natural gas and biogas, electricity, and hydrogen, to name a few. As alternatives to gas and diesel are incentivized, California's vehicle fleet will come to rely more on vehicles powered by these cleaner fuels.

The LCFS is already proving itself effective: according to a University of California, Davis study, alternative fuels have grown to approximately 6.8% of the fuel mix, displacing more than a billion gallons of gasoline and diesel.³¹ This resulted in a reduction in carbon dioxide emissions equivalent to taking half a million cars off the road.

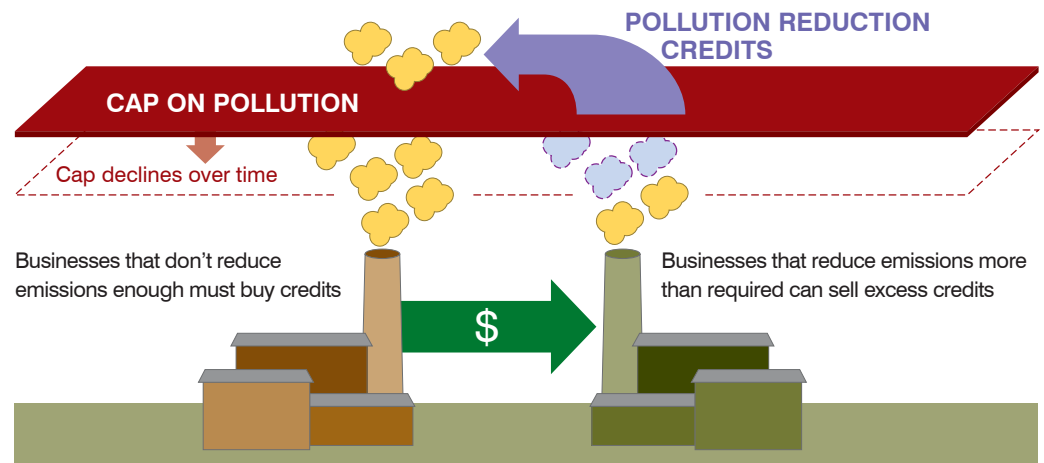
California cap-and-trade regulation (C&T)

Since January 2013, pollution from a range of sources in California has been subject to the C&T program, a market-based pollution reduction program. During the first phase of the program from 2013 to 2014, pollution from utilities and other large industrial sources is subject to

emission reduction requirements. Beginning in 2015, pollution from the combustion of transportation fuels in motor vehicles will also be included under the cap. Accordingly, fuel producers will become responsible for emissions from transportation fuels, creating a new market signal for investments in lower emitting, less carbon intensive fuels, as well as in investments that reduce the amount of fuel combusted. Over time, the program will produce about 20% of the pollution cuts required under AB 32, with the inclusion of transportation fuels accounting for more than half of the total emissions covered by the program.³²

FIGURE 2-2

General operation of California's cap-and-trade regulation



A cap-and-trade system limits the amount of carbon emissions (the cap) and allows clean technology users to sell their carbon credits to businesses that do not meet their targets (the trade).

Methodology



Comparing the costs of the current transportation system to the deployment scenario made possible by the LCFS and C&T

Environmental Defense Fund and the American Lung Association in California worked with Tetra Tech³³ to model the benefits of implementing the LCFS and C&T. To model the economic impact of these cutting-edge transportation policies, a theoretical vehicle fleet was constructed between 2010 and 2025 that assumes no implementation of the LCFS and C&T (the “no-regulation scenario”). In addition, a scenario representing the effect of implementing the LCFS and C&T was also developed and run through 2025 (the “deployment scenario”). The difference in emissions between the scenarios is calculated as the benefit of the implementation of these two policies.

Establishing a hypothetical no-regulation scenario fleet

The no-regulation scenario of the motor vehicle fleet uses projections from the California Energy Commission (CEC) to model the vehicle fleet through 2025 in the absence of the LCFS and C&T. The baseline incorporates existing transportation policies in California, including fuel economy standards and emissions standards as specified in *Analysis assumptions* (page 7). Fuel consumption levels and associated greenhouse gas and lifecycle criteria pollutant emissions from the fleet mix were estimated using EMFAC 2011 and GREET1.³⁴ Fleet characteristics associated with the no-regulation scenario are included in Appendix A.

Developing the deployment scenario for modeling

The modeled compliance scenario for the LCFS and C&T program was developed using a literature review of published and unpublished estimates from industry, state and federal government, academia, and non-profit organizations associated with alternative fuels and vehicle technologies. The sources used to model the motor vehicle fleet under LCFS and C&T is detailed in Appendix C.

Vehicle and fuel deployment numbers were compiled into Table 3-1 shown below. These numbers were then run through an LCFS compliance calculation using carbon intensity values published by the California Air Resources Board to compare combined penetration levels to LCFS compliance.

TABLE 3-1
On-road vehicle and fuel use in the deployment scenario³⁵

Fuel type	Fuel/vehicle detail	Year	Deployment scenario
Conventional liquid fossil fuel	Gasoline	2020	23,112,152 vehicles
		2025	20,715,007 vehicles
	Diesel	2020	286,610 vehicles
		2025	139,750 vehicles
Natural gas	Light-duty sector	2020	35,347 vehicles
		2025	37,027 vehicles
	Heavy-duty sector	2020	32,205 vehicles
		2025	38,249 vehicles
Hydrogen and electrification (ZEVs)	Hydrogen, plug-in hybrid and battery electric	2020	1,074,299 vehicles
		2025	1,610,744 vehicles
Biofuels	Ethanol	2020	1.74 billion gal/year
		2025	2.87 billion gal/year
	Biodiesel*	2020	326 million gal/year
		2025	518 million gal/year

*The biodiesel fleet average blend starts at B5 and increases to B20 by the year 2025.

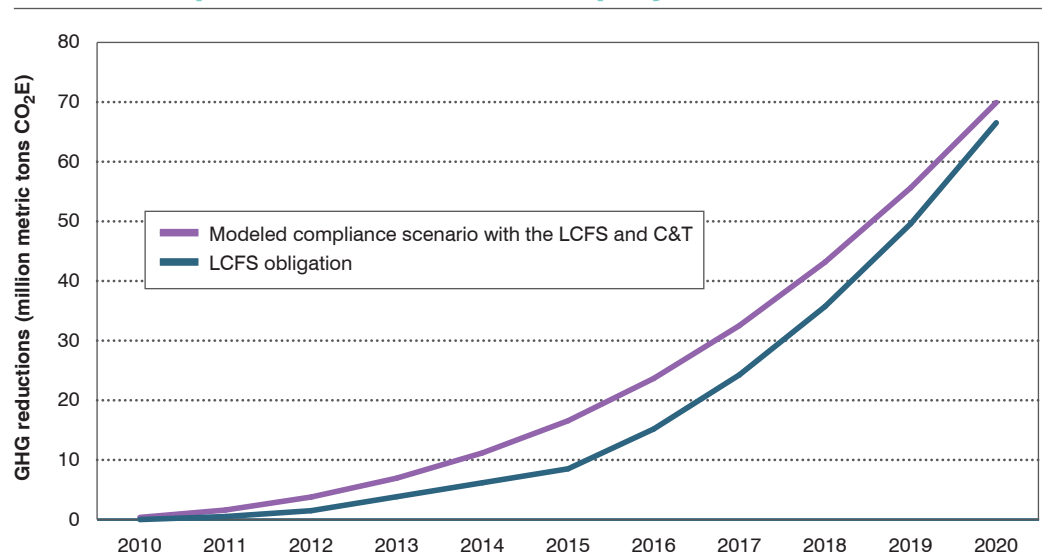
The reductions of greenhouse gas pollution that result from the modeled vehicle deployment numbers are shown in Table 3-2. This table then compares these reductions against the carbon reductions required in the LCFS to determine whether the modeled scenario would achieve existing regulatory requirements through the year 2020. In essence, Table 3-2 represents a check of the modeled scenario to ensure modeled deployment figures were sufficiently close to what is needed pursuant to the LCFS regulation. As shown, the aggregate reductions associated with the modeled scenario are within 0.5% of required aggregate reductions in the LCFS. Figure 3-1 is a graphical representation of the values in Table 3-2.

TABLE 3-2
Aggregate GHG reductions achieved by LCFS compliance vs. model deployment scenario

Year	LCFS obligation (aggregate million metric tons reduced)	Model compliance scenario (aggregate million metric tons reduced)
2010	0	0.36
2011	0.51	1.60
2012	1.49	3.78
2013	3.83	6.95
2014	6.17*	11.18
2015	8.51*	16.57
2016	15.19	23.66
2017	24.25	32.52
2018	35.72	43.16
2019	49.59	55.62
2020	66.53	69.93

*Assumes LCFS stringency remains the same for 2013, 2014 and 2015

FIGURE 3-1
Aggregate GHG reductions achieved by LCFS compliance vs. modeled deployment scenario



Metrics used to compare the no-regulation and deployment scenarios

Monetizing societal impacts and benefits

The reduction in societal harm that results from the displacement of gasoline and diesel by cleaner alternative fuels was modeled in the deployment scenario to calculate the benefits of reduced emissions and lower petroleum dependence. By finding the difference between the impact of the no-regulation scenario and that of the deployment scenario, the model calculates the societal benefit (in dollars) of implementing the combined policies. The benefits to air quality, energy security, and climate change are monetized using the factors presented in Appendix B to determine the equivalent economic benefits attributable to the two policies.

The monetization factor for the energy security component was applied only to the imported fraction of petroleum fuel. For each gallon of petroleum fuel avoided/displaced as a result of these two policies, it is estimated that imported fuel is reduced by approximately half a gallon.³⁶ Due to this adjustment, the monetization estimate of the energy security component is conservative; it is likely that some savings attributed to increased petroleum independence also come from reducing the number of domestically produced gallons of petroleum fuel in addition to imports. This is due to the fact that the politics and pricing surrounding domestic fuel and imported fuel are inextricably intertwined.

The societal impacts measured and the source of data for the associated costs are shown in Table 3-3 below and also included in Appendix B.

TABLE 3-3
Societal costs and source data

Societal cost measured	Source of societal cost correlation data (correlation data is included in Appendix B)
Public health costs: the impacts of the emissions of air pollutants PM _{2.5} , NO _x , and SO _x , including cases of mortality; respiratory-related emergency room visits; upper, lower and acute respiratory symptoms; exacerbated asthma attacks; heart attacks; hospitalization from respiratory and cardiovascular illness; and lost work days. ³⁷	US EPA, <i>Benefits Per Ton PM_{2.5} Reduced, Environmental Benefits Mapping and Analysis Program (BENMAP)</i> , also see N. Fann, <i>et al.</i> , <i>The influence of location, source, and emission type in estimates of the human health benefits of reducing a ton of air pollution</i> , 2 <i>Air Quality, Atmosphere & Health Volume 169</i> (2009).
Energy security costs: the impact of being dependent on petroleum, including the price and supply vulnerability and the associated security risks. ³⁸	40 CFR §§85, 86, and 600, <i>2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards, Final Rule</i> (Oct. 15, 2012).
Climate change-related costs (the “social cost of carbon”): the impacts of climate change on agricultural businesses, human health, property, ecosystem services, and more. ^{39,40}	Interagency Working Group on the Social Cost of Carbon (includes the Council of Economic Advisors, the Departments of Agriculture, Energy, Commerce, Transportation and the Treasury, the Environmental Protection Agency, the Office of Management and Budget and several other agencies), <i>Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis under Executive Order No. 12,866</i> (Nov. 2013).

Model results and analysis



No-regulation scenario: societal costs of California's transportation system without the LCFS and C&T

Using the GREET and modified EMFAC models, societal economic costs associated with health impacts from modeled pollutants (NO_x, SO_x, and PM_{2.5}), energy security impacts from petroleum demand, and social costs associated with climate change were modeled in a scenario lacking both the LCFS and C&T policies. Annual as well as cumulative costs were calculated for the time frame between 2010 and 2025.

As shown in Figure 4-1, in 2020, the total cost (for all years between 2010 and 2020, inclusive) associated with the fleet in a no-regulation scenario is approximately \$274 billion. By 2025, the cumulative economic impact grows to approximately \$387 billion. Figure 4-2 shows how the

FIGURE 4-1

Cumulative societal economic costs from transportation system without the LCFS and C&T

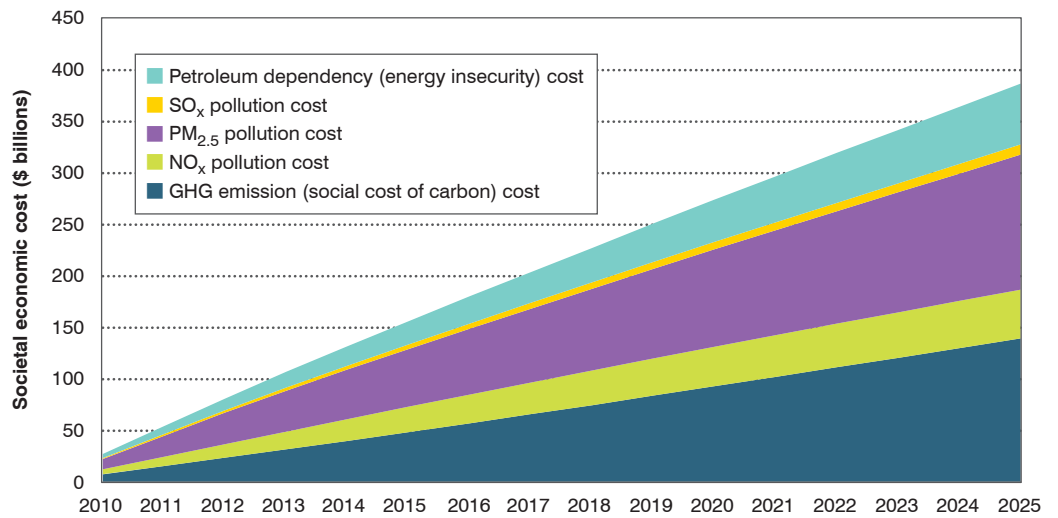
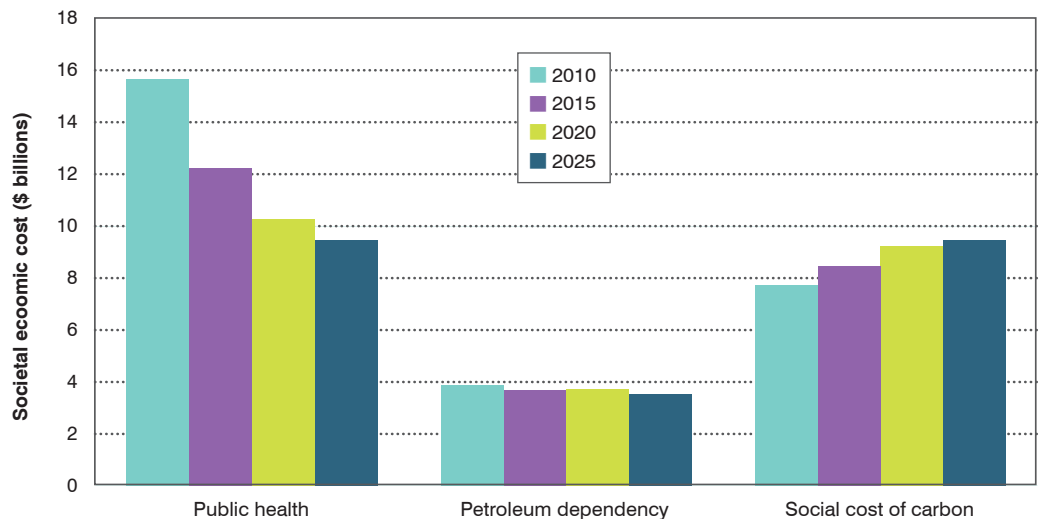


FIGURE 4-2

Annual societal economic cost of transportation system without the LCFS and C&T



annual cost associated with each contributing factor (public health, petroleum dependency, or climate change) varies from 2010 to 2025. Over time, the public health and petroleum dependency costs are expected to decrease, while the climate change “social cost of carbon” is expected to increase slightly. When the three factors are compared against one another, it is clear that the public health costs are the biggest contributor to overall societal costs from the transportation sector without the implementation of the LCFS or C&T policies until the year 2020. In 2025, the annual climate change effects become more costly than the public health costs.

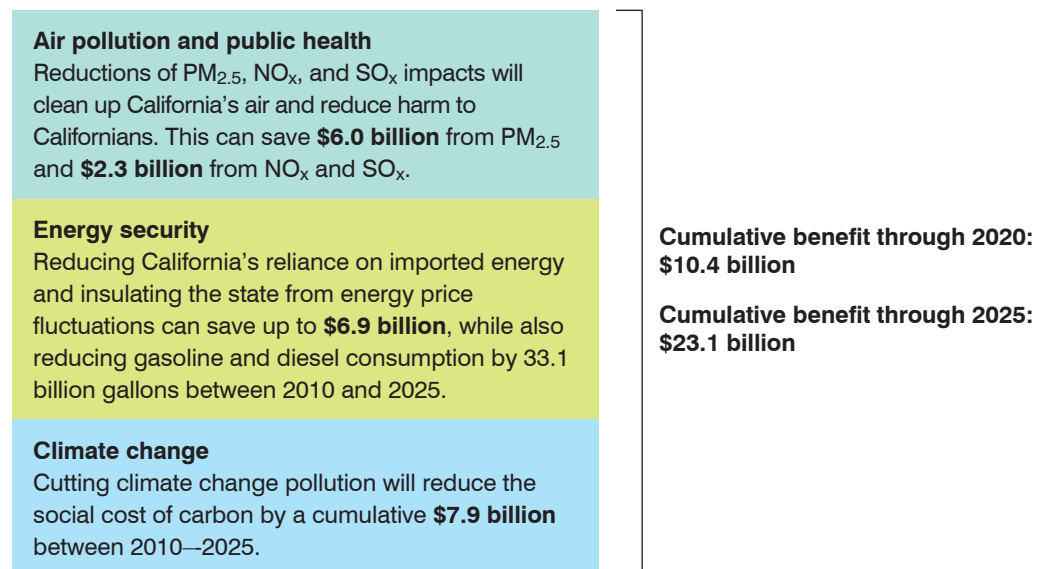
Deployment scenario results: the benefits of the transition to a cleaner transportation fuel system through implementation of the LCFS and C&T

Cleaning up California’s transportation system with diversified and lower carbon sources of energy will provide an economic benefit by addressing challenges associated with air pollution, energy dependence, and climate change. Based on results from the modeled compliance scenario, implementation of California’s LCFS and C&T will result in the necessary transition to a cleaner fuel mix that is estimated to produce economic benefits, as shown below in Figure 4-3.

Benefits from the LCFS and C&T deployment scenario can be reported as a cumulative benefit that accrues across all model years (see Figure 4-4, page 18) or as an annual benefit (see Figure 4-5, page 18). While a cumulative benefit assessment can provide great insight into the societal economic benefits over time through increasing deployment of alternative fuels and vehicles, the annual benefit is also relevant.

According to the annual numbers shown in Figure 4-5, the year-over-year benefit of the LCFS and C&T implementation increases over time as expanded vehicle and fuel deployment occur throughout the California transportation system. The modeled benefits of the vehicle and

FIGURE 4-3
Benefit of implementing the LCFS and C&T transportation fuel policies between 2010 and 2025
 Overall public health and societal economic benefits



fuel transition stemming from LCFS and C&T are expected to reach \$1.9 and \$3.0 billion annually in 2020 and 2025, respectively. These benefits are a result of a combination of better health outcomes due to reduced pollution, improved energy security achieved through a diversified fuel mix, and avoided negative impacts of climate change. The cumulative benefits of these policies reach up to \$10.4 and \$23.1 billion by 2020 and 2025, respectively (see Figure 4-4).

These results show that, although existing California fuel and vehicle policies (excluding the LCFS and C&T) are contributing to long-term improvements in the transportation system, the

FIGURE 4-4
Cumulative societal economic benefits from the implementation of the LCFS and C&T

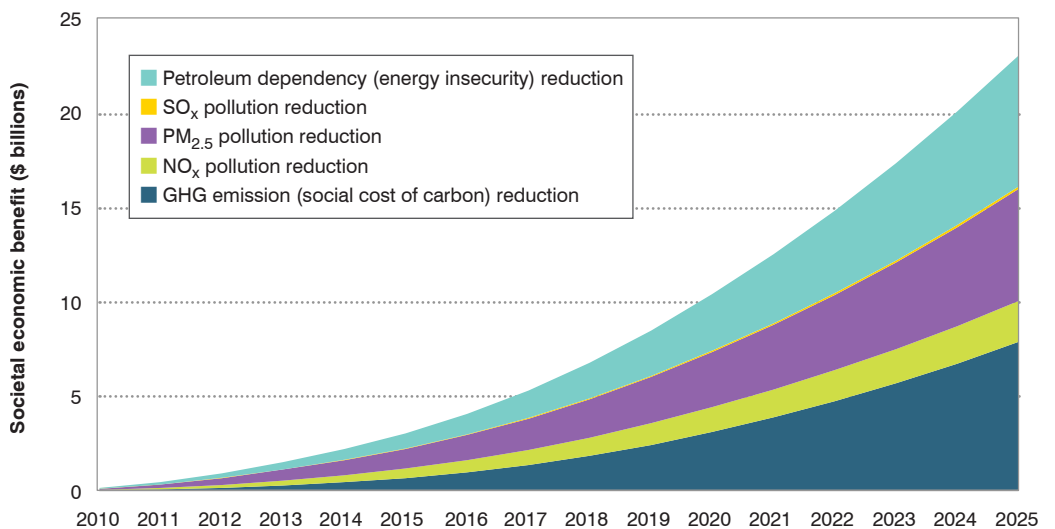


FIGURE 4-5
Annual societal economic benefits from the implementation of the LCFS and C&T

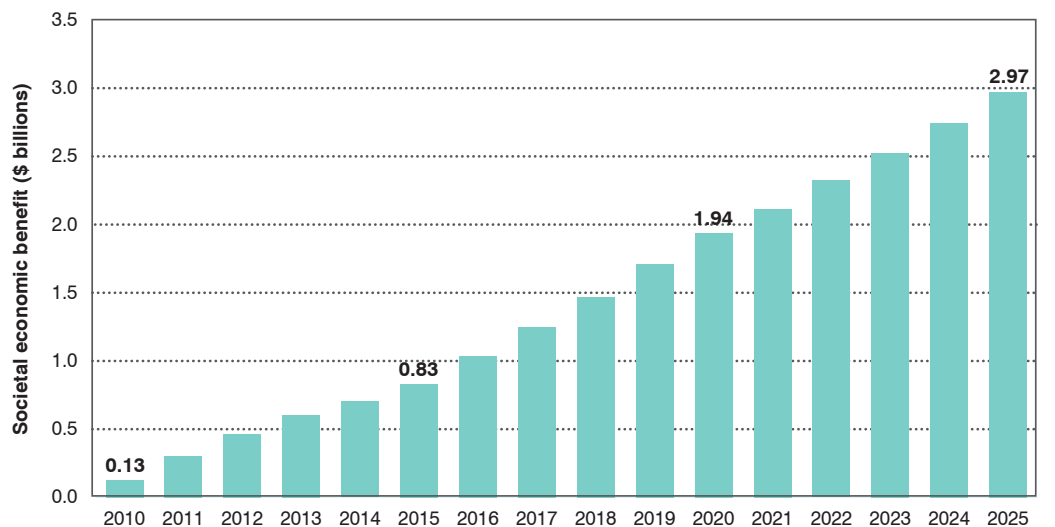


TABLE 4-2

Societal economic benefit of the LCFS and C&T by 2020 and 2025

Benefit type	Total societal benefit (billions) 2010–2020	Total societal benefit (billions) 2010–2025
Overall societal economic benefit	\$10.4	\$23.1
Avoided health impact (PM _{2.5} , NO _x , SO _x)	\$4.3	\$8.3
Avoided energy security impact (petroleum dependence)	\$3.0	\$6.9
Avoided climate change impact (GHG)	\$3.1	\$7.9

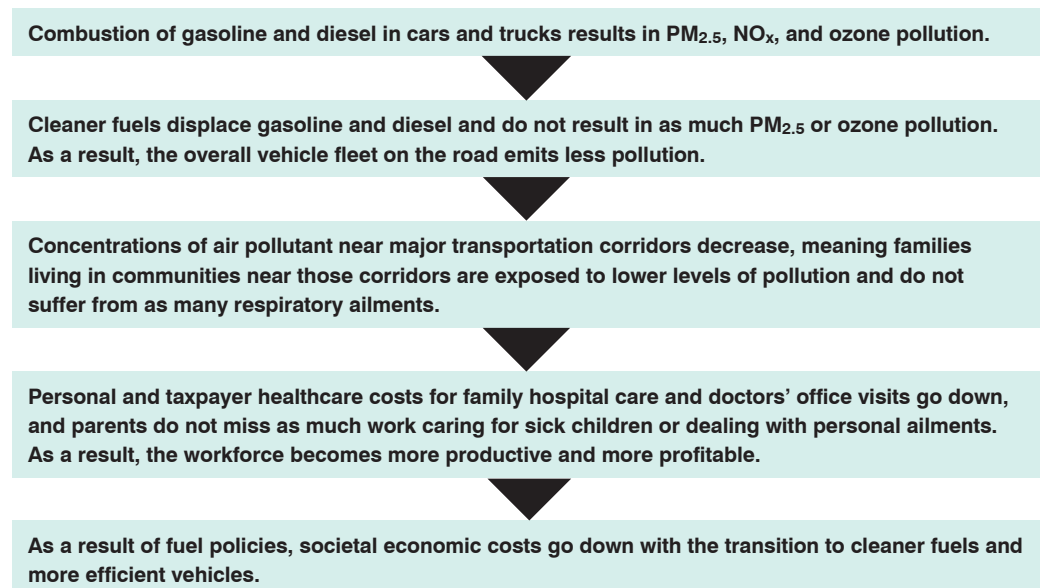
LCFS and C&T, when fully implemented, will have significant additional benefits on top of those. These policies will result in even broader and deeper reductions of air pollution (PM_{2.5}, NO_x, and SO_x), petroleum use, and climate change pollution (lifecycle greenhouse gases). Accordingly, the LCFS and C&T programs will expedite fleet improvements and speed the improvement of air quality.

Air pollution and public health benefits assessment

Transitioning to a cleaner and more efficient vehicle and fuel mix will result in reduced combustion of fossil fuels throughout California. This transition will necessarily result in reduced pollution in communities and air basins where those fuels would otherwise be combusted. One example of how the societal economic benefits are achieved from these reduced emissions can be seen in the causal chain shown in Figure 4-6.

FIGURE 4-6

Causal chain of the transition to cleaner fuels and vehicles yielding lower societal costs



The AB 32 LCFS and C&T programs will expedite fleet improvements and speed the trajectory toward cleaner air.

TABLE 4-3

Modeled NO_x, SO_x, and PM_{2.5} emissions reductions from LCFS and C&T implementation

Pollutant	Total emissions avoided (tons) 2010–2020	Total emission avoided (tons) 2010–2025
NO _x	106,664	166,940
PM _{2.5}	4,767	9,037
SO _x	2,038	3,849

TABLE 4-4

Modeled health benefits of LCFS and C&T implementation⁴¹
(also included in Appendix E)

Modeled impacts	Total health benefit (number of cases) 2010-2020	Total health benefit (number of cases) 2010-2025
Avoided premature deaths	470	882
Avoided cases of upper and lower respiratory symptoms	14,415	26,759
Avoided cases of acute respiratory symptoms	238,675	439,629
Avoided cases of acute bronchitis	464	861
Avoided asthma attacks	20,645	38,321
Avoided hospitalizations (cardiac and respiratory related)	338	643
Avoided heart attacks	311	597
Avoided lost work days	40,316	74,339

Using the deployment scenario for the LCFS and C&T (see Section 3.1b), the GREET and EMFAC models discussed in *Assessment of the “no-regulation scenario”* (page 8), were applied for the years 2010 through 2025. Results of this modeling for decreased air pollution from the transportation sector due to LCFS and C&T are displayed in Table 4-3 above.

As a result of LCFS and C&T implementation, the transition in the vehicle and fuel mix will result in significant improvements in public health. The modeled benefits are displayed in Table 4-4 above.

Energy security benefits assessment associated with petroleum demand⁴²

California’s LCFS and C&T implementation reduce gasoline and diesel consumption—resulting in increased energy security for the state. The consumption of fossil fuel (gasoline and diesel) in California in the no-regulation scenario and the LCFS and C&T implementation scenario is displayed in Figure 4-7 (page 21).

By facilitating the transition away from a dependence on oil and greatly reducing the money that the state spends on imported energy, the LCFS and C&T can result in a significant increase in energy security. As shown in Figure 4-8 (page 21), by 2025, the decreased petroleum dependency resulting from LCFS and C&T can result in a cumulative avoided cost of nearly \$6.9 billion.

FIGURE 4-7

California gasoline and diesel consumption in no-regulation scenario vs. deployment scenario

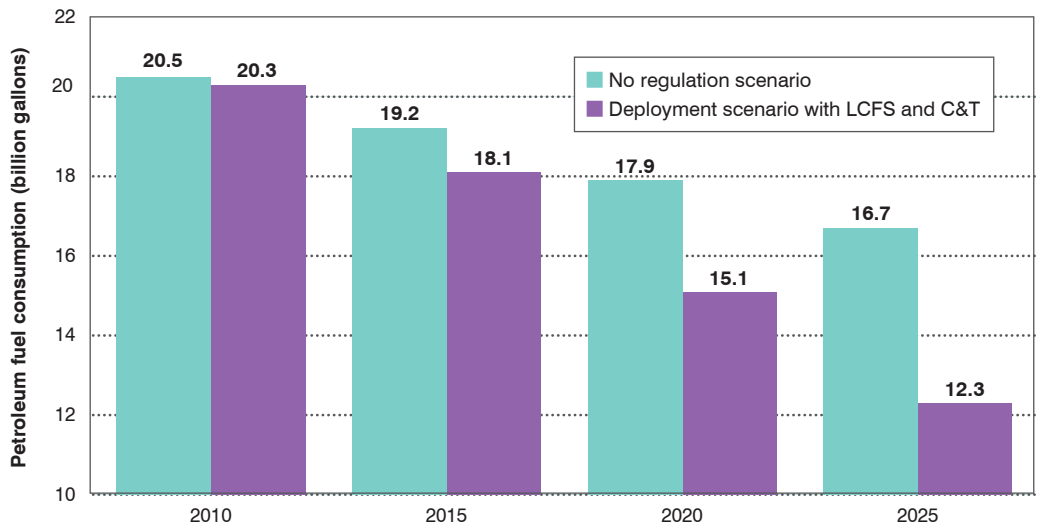
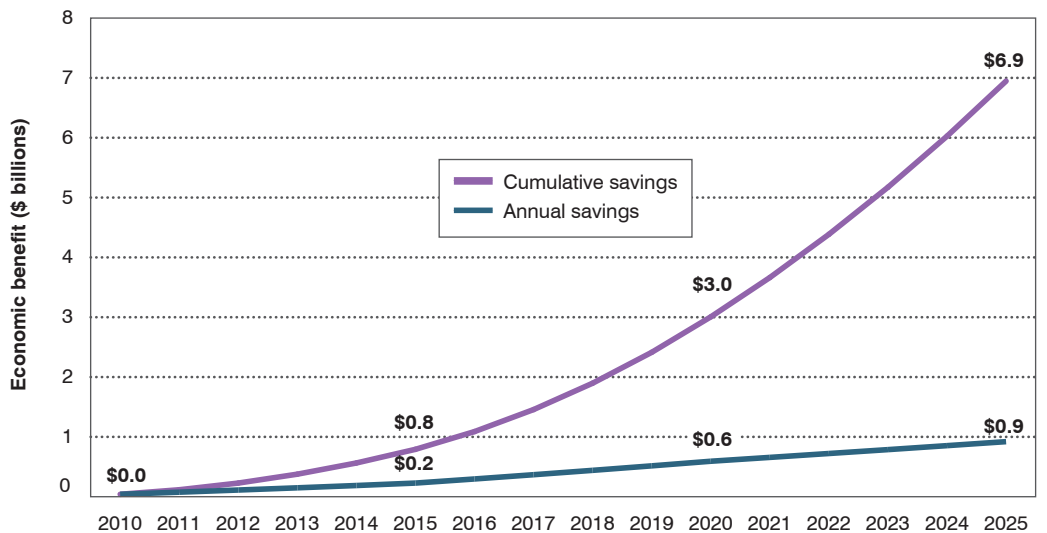


FIGURE 4-8

Economic benefits of LCFS and C&T implementation resulting from decreased petroleum dependency



Climate change benefits assessment and the social cost of carbon

The transition to lower carbon fuels modeled in this scenario leads to reduced levels of greenhouse gas emissions on a well-to-wheel (WTW) basis—in other words, a reduction in harmful pollutants from the set of operations that includes the lifecycle of the fuel (i.e. feedstock extraction, processing/refining, distribution, fuel consumption, vehicle refueling, and fuel evaporation). The difference in emissions of the no-regulation scenario versus the deployment scenario is shown in Figure 4-9 (page 22).

When determining emissions reductions, it is necessary to look at the entire WTW lifecycle. Focusing exclusively on tailpipe emissions captures only part of the story—for instance, while

FIGURE 4-9

Climate pollution reductions from implementation of the LCFS and C&T

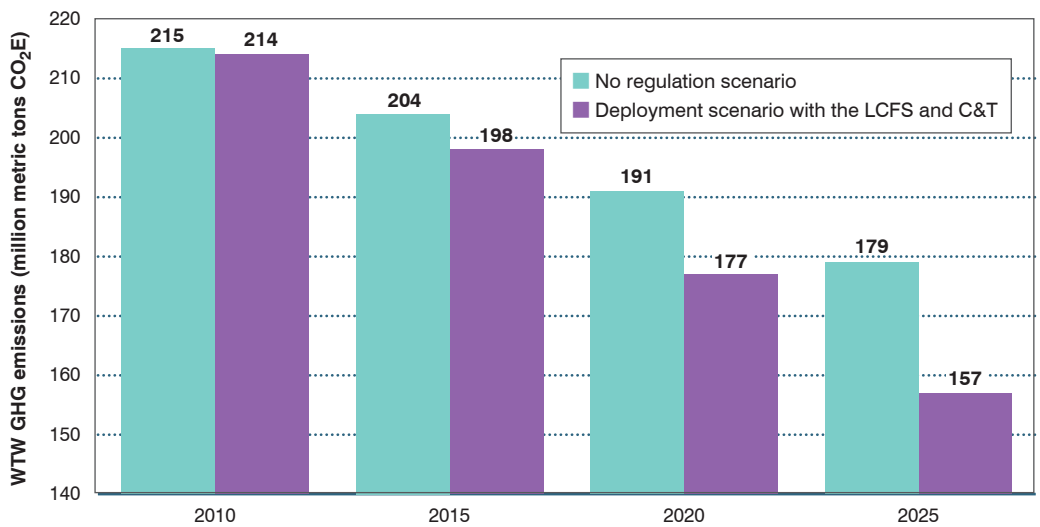
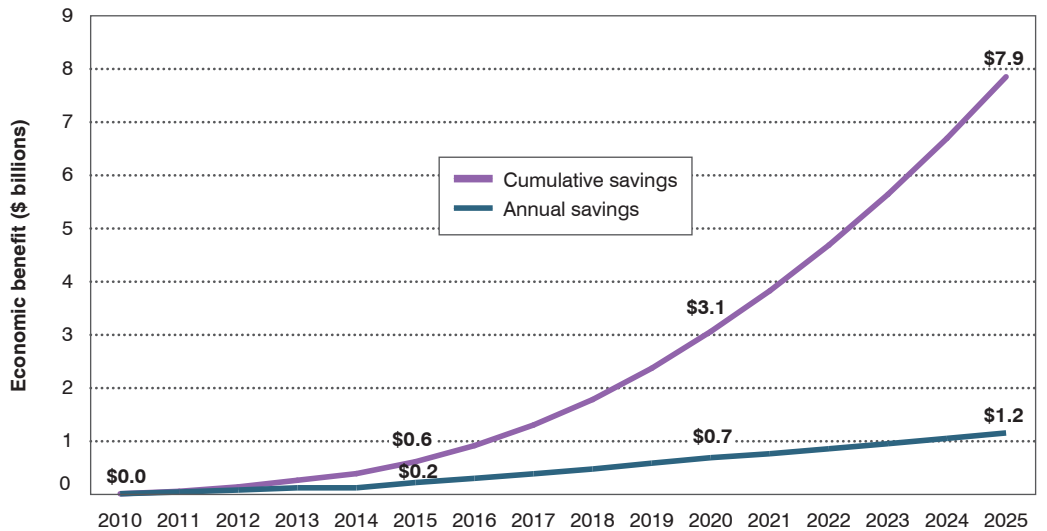


FIGURE 4-10

Economic benefits of LCFS and C&T implementation resulting from decreased carbon pollution (social cost of carbon)



electric vehicles might lead to fewer emissions on the road, production of electricity via fossil fuels can partially offset such a benefit. Thus, the reductions and subsequent benefits shown are only significant to the extent that they look at the full picture, and not just at a piece of the puzzle.

A reduction in harmful greenhouse gas emissions that contribute to climate change will result in fewer adverse health impacts, such as certain types of cancer, respiratory ailments, and cardiovascular disease. As explained in the health benefits analysis in *Air pollution and public health benefits assessment* (page 19), this results in avoided costs related to missed

work days and hospital visits. The reductions in greenhouse gas emissions will also prevent costs of up to \$1.2 billion annually by 2025, amounting to cumulative savings of \$7.9 billion, as shown in Figure 4-10 (page 22). These savings were calculated by applying published climate change-related cost multipliers (the “social cost of carbon”) to the projected amount of avoided greenhouse gas emissions, providing an estimate of the economic benefit of reducing climate pollution from the LCFS and C&T. The modeling in this report uses the most recent social cost of carbon estimated by the 2013 Interagency Working Group on the Social Cost of Carbon. A recent study showed that this estimate is actually too low due to many omitted climate change impacts.⁴³ Thus, this climate change benefits assessment is conservative and the positive impact of the LCFS and C&T is likely greater than presented here.

By leading the nation in addressing climate change, California is benefitting the health of its citizens and the economy.

Conclusion

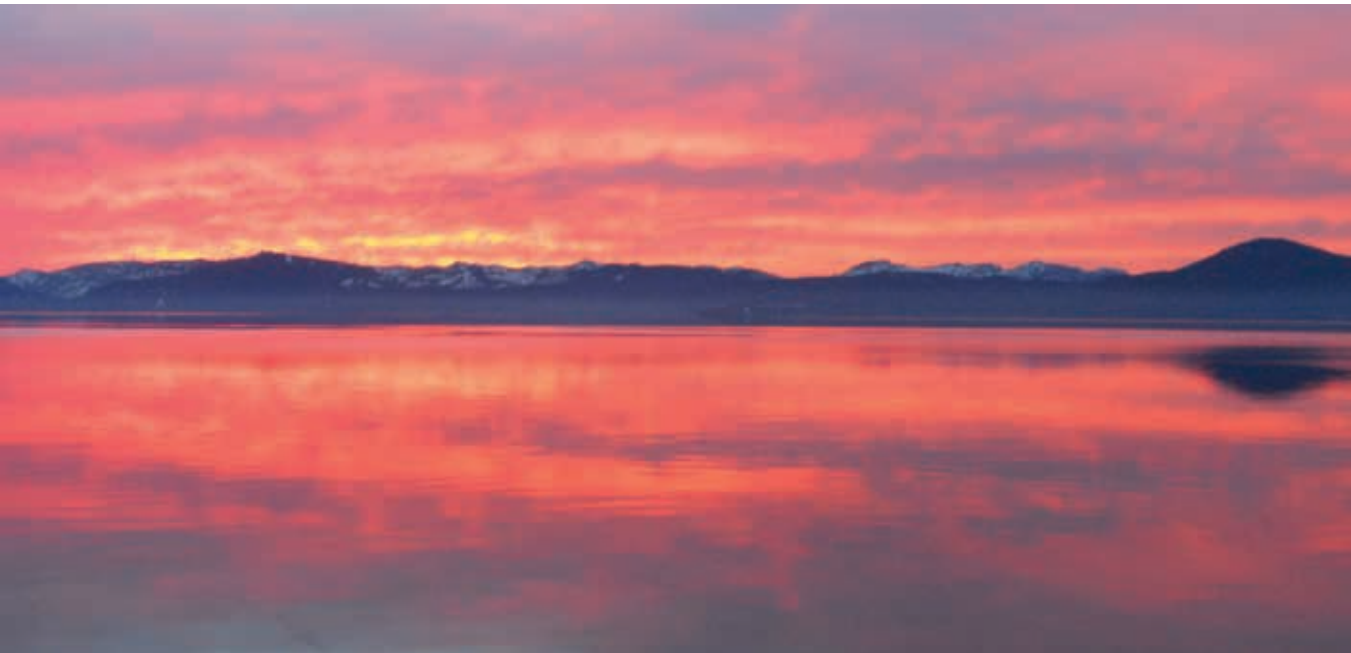
Moving California's vehicle fleet forward

California's innovative clean transportation policies are putting communities on a path to save billions of dollars in avoided costs of pollution, climate change, and energy insecurity each year. As the LCFS and C&T policies move forward, California will see significant economic benefit, and this suite of transportation fuels policies will pay dividends for years to come.

The transition to cleaner fuels and a more diverse vehicle fleet will result in cleaner air and better health for Californians, increased energy security, and mitigation of climate change impacts. A monetization of these avoided consequences—measured in terms of fewer missed work days and hospital visits, reduced detriment to key economic sectors, and reduced energy insecurity—show that in addition to direct benefits, implementation of the LCFS and C&T will save the state billions of dollars.

This report demonstrates how advantageous these policies can be for the people across the state. By leading the nation in addressing climate change, California is improving the health of its citizens and the economy.

Appendices



APPENDIX A

No-regulation scenario input for model

The theoretical no-regulation scenario (without LCFS and C&T) fleet of conventional gasoline and diesel vehicles is characterized by:

- Light-duty vehicle (LDV) and heavy-duty vehicle (HDV) populations, as projected by the California Energy Commission (CEC) 2011 Transportation Energy Forecasts and Analysis for the 2011 Integrated Energy Policy Report (IEPR).
- LDV and HDV upstream “well-to-tank” greenhouse gas (GHG) and criteria pollutant emissions, using emission factors from GREET1 2012.
- LDV and HDV tailpipe “tank-to-wheels” GHG and criteria pollutant emissions, using emission factors from EMFAC2011 and the current California Air Resources Board (CARB) Greenhouse Gas Inventory – 2020 Emissions Forecast for Transportation.⁴⁴
- LDV and HDV petroleum consumption based on EMFAC2011 and included the national Clean Car regulation for new light duty vehicles to model year 2025 (assumed 3% GHG reduction scenario via Pathway B which represents an approach where advanced gasoline vehicles and mass reduction are utilized).

The California fleet of vehicles is allocated into the LDV and HDV categories by weight class, with lighter vehicles that generally operate on gasoline placed into the LDV category and heavier vehicles that generally operate on diesel placed into the HDV category. From this allocation of vehicles into either the LDV or HDV category, the analysis examines the average characteristics of that category, weighted by vehicle population and including annual mileage, fuel economy, and emissions.

APPENDIX B

Societal impact monetization factors

Societal impact	Monetized value (2013\$)	Source
Air quality:		
NO _x	\$9,919/ton in 2010 to \$14,687/ton in 2025	Communication with Neal Fann, U.S. Environmental Protection Agency (EPA) Office of Air Quality Planning & Standards, Air Benefit and Cost Group. July 2013. (Using the updated model that also produced the benefits per ton results for EPA's Environmental Benefits Mapping and Analysis Program website: http://www.epa.gov/oaqps001/benmap/bpt.html)
PM _{2.5}	\$506,094/ton in 2010 to \$734,831/ton in 2025	Communication with Neal Fann, EPA. July 2013.
SO _x	\$33,770/ton in 2010 to \$40,440/ton in 2025	Communication with Neal Fann, EPA. July 2013.
Climate change		
GHG	\$36/metric ton in 2010 to \$53/metric ton in 2025 ⁴⁵	U.S. Government. "Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866." Interagency Working Group on Social Cost of Carbon, United States Government. November 2013.
Petroleum dependency:		
Macroeconomic disruption and monopsony	\$0.415/gal in 2010 to \$0.488/gal in 2025	U.S. Federal Register, Volume 77, No. 199, [40 CFR Parts 85, 86, and 600]. "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards, Final Rule." October 15, 2012.

APPENDIX C

Sources for alternative fuel vehicle population and fuel consumption projections

Projection	Sources
BEV (LDV and HDV)	California Energy Commission. "California Energy Demand 2012-2022 Final Forecast, Volume 1: Statewide Electricity Demand and Methods, End-User Natural Gas Demand, and Energy Efficiency." CEC-200-2012-001. June 2012.
	California Energy Commission. "Transportation Energy Forecasts and Analyses for the 2011 Integrated Energy Policy Report." CEC-600-2011-007-SD. August 2011.
	TIAX LLC. "California Low Carbon Fuel Standard (LCFS) Electric Pathway—On-Road and Off-Road." Presentation to California Electric Transportation Coalition. http://www.caletc.com/wp-content/uploads/2012/12/TIAX_CalETC_LCFS_Electricity_Potential_FINAL.pdf . November 14, 2012.
BEV and PHEV	Governor's Interagency Working Group on Zero-emission Vehicles, "2013 ZEV Action Plan: A roadmap toward 1.5 million zero-emission vehicles on California roadways by 2025." http://opr.ca.gov/docs/Governor's_Office_ZEV_Action_Plan_(02-13).pdf . February 2013.
	Olson, T. "New Motor Vehicle Board 9th Industry Roundtable." http://www.slideserve.com/sharona/new-motor-vehicle-board-9th-industry-roundtable-sacramento-california . March 21, 2012.
	Pike Research. "Electric Vehicle Geographic Forecasts." http://www.pikeresearch.com/research/electric-vehicle-geographic-forecasts . Accessed July 29, 2013.
Biodiesel (HDV)	Shackelford, J, A. Chase, M. McGaraghan, S. Tartaglia. "Reducing Barriers to Electric Vehicle Adoption through Building Codes." http://www.aceee.org/files/proceedings/2012/data/papers/0193-000012.pdf . 2012.
	California Energy Commission. "Transportation Energy Forecasts and Analyses for the 2011 Integrated Energy Policy Report." CEC-600-2011-007-SD. August 2011.
Ethanol	California Energy Commission, "2013 Integrated Energy Policy Report." CEC-100-2013-001-CMF. http://energy.ca.gov/2013publications/CEC-100-2013-001/CEC-100-2013-001-CME.pdf . 2013.
	California Air Resources Board. "Proposed Regulation to Implement the Low Carbon Fuel Standard, Volume I, Staff Report: Initial Statement of Reasons." March 5, 2009.
	California Energy Commission. "Transportation Energy Forecasts and Analyses for the 2011 Integrated Energy Policy Report." CEC-600-2011-007-SD. August 2011.
Ethanol	Jackson, M. "AB 1007 Workshop: Ethanol Implementation Scenarios." http://www.energy.ca.gov/ab1007/documents/2007-05-31_joint_workshop/2007-05-31_ETHANOL_IMPLEMENTATION_SCENARIO.PDF . May 31, 2007.
	Lin, C.-Y. C., W. Zhang, O. Rouhani, L. Prince. "The Implications of an E10 Ethanol-Blend Policy for California." <i>Agricultural and Resource Economics Update</i> 13(2). November/December 2009.
	Olson, T. "New Motor Vehicle Board 9th Industry Roundtable." http://www.slideserve.com/sharona/new-motor-vehicle-board-9th-industry-roundtable-sacramento-california . March 21, 2012.

Hydrogen (LDV)	<p>California Air Resources Board. "Advanced Clean Cars Summary." http://www.arb.ca.gov/msprog/clean_cars/acc%20summary-final.pdf. Accessed July 29, 2013.</p> <p>California Energy Commission. "2011-12 Investment Plan for the Alternative and Renewable Fuel and Vehicle Technology Program." CEC-600-2011-006-SD. February 2011.</p> <p>Hooks, M., M. Jackson. "AB 1007 Scenarios: Hydrogen Fuel Cell Vehicles." http://www.energy.ca.gov/ab1007/documents/2007-05-31_joint_workshop/2007-05-31_HYDROGEN_FUEL_CELL_SCENARIO.PDF. May 24, 2007.</p>
NGV (HDV)	<p>Law, K., M. Chan. "South Coast Air Basin Natural Gas Vehicle Roadmap." Prepared by Tetra Tech for Southern California Gas Company. July 2013.</p> <p>National Petroleum Council. "Advancing Technology for America's Transportation Future: Heavy-Duty Vehicles." http://www.npc.org/FTF-80112.html. August 1, 2012.</p> <p>Olson, T. "New Motor Vehicle Board 9th Industry Roundtable." http://www.slideserve.com/sharona/new-motor-vehicle-board-9th-industry-roundtable-sacramento-california. March 21, 2012.</p>
NGV (LDV)	<p>California Energy Commission. "California Energy Demand 2012-2022 Final Forecast, Volume 1: Statewide Electricity Demand and Methods, End-User Natural Gas Demand, and Energy Efficiency." CEC-200-2012-001. June 2012</p> <p>Green Car Congress. "Navigant Forecasts Global Natural Gas Fleet of 34.9M by 2020." http://www.greencarcongress.com/2013/06/navigant-forecasts-global-natural-gas-fleet-of-349m-by-2020.html. Accessed July 29, 2013.</p> <p>California Energy Commission. "Transportation Energy Forecasts and Analyses for the 2011 Integrated Energy Policy Report." CEC-600-2011-007-SD. August 2011.</p>
PHEV (HDV)	<p>California Energy Commission. "Option 2K: Heavy Duty Hybrid Electric Vehicles." CEC-600-2005-024-AD-2K. 2005.</p>
PHEV (LDV)	<p>California Energy Commission. "California Energy Demand 2012-2022 Final Forecast, Volume 1: Statewide Electricity Demand and Methods, End-User Natural Gas Demand, and Energy Efficiency." CEC-200-2012-001. June 2012.</p> <p>McCarthy, R., C. Yang. "Description of Alternative Fuel Penetration Scenarios (Draft)." Institute of Transportation Studies, UC Davis. Accessed July 29, 2013.</p>
PHEV (LDV and HDV)	<p>California Air Resources Board. "Advanced Clean Cars Summary." http://www.arb.ca.gov/msprog/clean_cars/acc%20summary-final.pdf. Accessed July 29, 2013.</p> <p>TIAX LLC. "California Low Carbon Fuel Standard (LCFS) Electric Pathway—On-Road and Off-Road." Presentation to California Electric Transportation Coalition. http://www.caletc.com/wp-content/uploads/2012/12/TIAX_CalETC_LCFS_Electricity_Potential_FINAL.pdf. November 14, 2012.</p>

APPENDIX D

Model results: range of economic benefits (\$ billions)

Model results	2010–2020			2010–2025		
	No-regulation scenario cost	Deployment scenario cost (with LCFS and C&T compliance)	Total societal economic benefit	No-regulation scenario cost	Deployment scenario cost (with LCFS and C&T compliance)	Total societal economic benefit
Overall societal economic impact	\$274.2	\$263.8	\$10.4	\$386.8	\$363.7	\$23.1
Health impact (PM _{2.5} , NO _x , SO _x)	\$140.0	\$135.6	\$4.32	\$188.2	\$179.9	\$8.28
Climate change impact (CO ₂)	\$93.2	\$90.1	\$3.11	\$139.5	\$131.6	\$7.90
Energy security impact (petroleum dependence)	\$41.1	\$38.1	\$3.01	\$59.1	\$52.1	\$6.95

APPENDIX E

Model results: range of health benefits (number of cases)

Model results	Description of health impact	2010-2020			2010-2025		
		No-regulation scenario cases (thousands)	Cases with LCFS and C&T compliance (thousands)	Total health benefit (avoided cases)	No-regulation scenario cases (thousands)	Cases with LCFS and C&T compliance (thousands)	Total health benefit (avoided cases)
Mortality	Premature death	15.4	14.9	470	20.4	19.6	882
Acute respiratory symptoms	Respiratory irritation (including lungs, nose, and throat) that is isolated and responds to treatment	7,854.1	7,615.4	238,675	10,318.6	9,878.9	439,629
Upper and lower respiratory symptoms	Chronic respiratory irritation, demanding a long-term and systematic approach to treatment	476.2	461.9	14,415	627.8	601.1	26,759
Acute bronchitis	Tubes carrying air to the lungs are inflamed and irritated; effects are usually relatively short-term and treatable	15.3	14.9	464	20.2	19.3	861
Asthma exacerbation	Worsening of asthma, a chronic illness that inflames and narrows the airways, making breathing difficult	666.4	645.8	20,645	878.4	840.1	38,321
Hospitalizations (cardiac and respiratory)	Admission to a healthcare facility for treatment of severe symptoms	11.0	10.7	340	14.7	14.1	643
Heart attack	A blockage of the artery that restricts blood flow and causes permanent damage to the heart muscle	10.0	9.7	311	13.5	12.9	597
Work loss days	Inability to work due to severity of the above illnesses	1,327.4	1,287.2	40,316	1,744.7	1,670.4	74,339

Notes

- ¹ California Air Resources Board, *Estimate of Premature Deaths Associated with Fine Particle Pollution (PM_{2.5}) in California Using a U.S. Environmental Protection Agency Methodology* (Aug. 31, 2010), http://www.arb.ca.gov/research/health/pm-mort/pm-report_2010.pdf.
- ² F. Caiazzo, et al., *Air Pollution and Early Deaths in the United States, Part 1: Quantifying the impact of major sectors in 2005* (2013), 79 *Atmospheric Environment* 198, <http://lae.mit.edu/wordpress2/wp-content/uploads/2013/08/US-air-pollution-paper.pdf>.
- ³ American Lung Association in California, *The Road to Clean Air: Public Health and Global Warming Benefits of Advanced Clean Car Standards* (2011), <http://www.lung.org/associations/states/california/assets/pdfs/advocacy/clean-cars-campaign/the-road-to-clean-air.pdf>.
- ⁴ American Lung Association, *A Penny for Prevention: The Case for Cleaner Gasoline and Vehicles* (2013), <http://www.lung.org/healthy-air/outdoor/defending-the-clean-air-act/interactive-presentations/cleaner-gasoline-and-vehicles-report-2013.pdf>.
- ⁵ California Energy Commission, *2010–2011 Investment Plan for the Alternative and Renewable Fuel and Vehicle Technology Program* (Jul. 2010), CEC-600-2010-001-CTD, <http://www.energy.ca.gov/2010publications/CEC-600-2010-001/CEC-600-2010-001-CTD.PDF>.
- ⁶ D. Greene, *Low Carbon Transportation: A Crucial Link to Economic and Energy Security* (Sep. 2012), <http://www.arb.ca.gov/research/lectures/speakers/greene/greene.pdf>.
- ⁷ See note 3
- ⁸ See note 3
- ⁹ California Department of Motor Vehicles, *Employee and Office Statistics* (2011), <http://dmv.ca.gov/about/profile/official.pdf>; see also U.S. Energy Information Agency, *Transportation Sector Energy Consumption Estimates* (2011), http://www.eia.gov/state/seds/sep_sum/html/pdf/sum_btu_tra.pdf.
- ¹⁰ American Lung Association, *State of the Air 2014: Statewide Summary* (2014), http://www.lung.org/associations/states/california/assets/pdfs/sota-2014/sota-2014_statewide-fact.pdf, see also California Air Resources Board, *California Air Resources Approves Advanced Clean Car Rules* (Jan. 2012), <http://www.arb.ca.gov/newsrel/newsrelease.php?id=282>.
- ¹¹ See note 9, also see California Air Resources Board, *Facts About California Clean Vehicle Incentives* (Feb. 2012), http://www.arb.ca.gov/msprog/zevprog/factsheets/clean_vehicle_incentives.pdf.
- ¹² U.S. Environmental Protection Agency, *California 8-hour Ozone Nonattainment Areas (2008 Standard)* (Dec. 2013), http://www.epa.gov/airquality/greenbook/map/ca8_2008.pdf.
- ¹³ California Office of Environmental and Health Hazard Assessment, *Indicators Of Climate Change In California: Environmental Justice Impacts* (Dec. 2010), <http://oehha.ca.gov/multimedia/epic/pdf/ClimateChangeEJ123110.pdf>.
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- ³⁵ It is impossible to predict the future with perfect accuracy. This analysis does not claim to do that. Instead, this report offers projected values for fleet deployment based on a careful assessment of long-term state goals and vehicle deployment patterns drawn from the literature. The results capture the clear trend toward increased diversification of the vehicle fleet in California driven by the innovative policies the state has in place.
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- ⁴¹ See Appendix E for full table of health scenario outcomes and total benefits.
- ⁴² The starting point for the scenarios is different than the diesel consumption in the no-regulation scenario because the vehicle population and fuel consumption numbers are based upon only the EMFAC model results, which only models gasoline and diesel fuel consumption. In contrast, our scenarios assumed diesel displacement from alternative fuels such as natural gas and biodiesel in 2010, which were subtracted out of diesel levels in the no-regulation scenario. To have the same starting point, the analysis would either have to assume that there were no alternative fuel vehicles in 2010 or modify the EMFAC results to take alternative vehicles into account—resulting in circular logic.
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