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HALF THE OIL

Pathways to Reduce Petroleum Use on the West Coast

Prepared by

ICF INTERNATIONAL

Stakeholder Advisory Committee

ICF would like to thank the members of the Stakeholder Advisory Committee for providing insight and feedback throughout the research and production of this report. The members of the committee reviewed the report prior to completion but assume no responsibility or liability for the content, including any errors or omissions contained therein.

Don Anair
Research & Deputy Director, Clean Vehicle Program
Union of Concerned Scientists

Simon Mui Ph.D
Director, California Vehicles and Fuels
Natural Resources Defense Council

Chris Malins Ph.D.
Fuels Lead
The International Council on Clean Transportation

Laura Vimmerstedt
Senior Environmental Analyst
National Renewable Energy Laboratory

Christopher Hessler
Partner
AJW Inc.

Julie Witcover Ph.D.
Assistant Project Scientist
UC Davis Institute of Transportation Studies

Ryan McCarthy Ph.D.
Science & Technology Policy Advisor
California Air Resources Board

Colin Murphy Ph.D.
Climate Policy Advocate
NextGen Climate America

Steve Plotkin
Transportation Energy and Environmental Systems Analyst
Argonne National Laboratory

John Boesel
President & CEO
CALSTART

Marlyn Twitchell
Program Director, Sustainable Advanced Fuels
Climate Solutions

Cory-Ann Wind
Air Quality Planner
Oregon Department of Environmental Quality

Dan Bowermaster
Program Manager, Electric Transportation
Electric Power Research Institute

Jeffrey Greenblatt Ph.D.
Staff Scientist
Lawrence Berkeley National Laboratory

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List of Abbreviations and Acronyms

ADF	Alternative Diesel Fuel
ANL	Argonne National Laboratory
AVL	Automatic Vehicle Locator
BAU	Business-As-Usual
BEV	Battery Electric Vehicle
BOE	Board of Equalization
CAFE	Corporate Average Fuel Economy Standards
CalETC	California Electric Transportation Coalition
CARB	California Air Resources Board
CEQA	California Environmental Quality Act
CFP	Clean Fuels Program
CI	Carbon Intensity
CNG	Compressed Natural Gas
DEQ	Oregon Department of Environmental Quality
DGE	Diesel Gallon Equivalents
DOE	U.S. Department of Energy
EIA	Energy Information Administration
EIRs	Environmental Impact Reports
EISA	Energy Independence and Security Act
EPA	Environmental Protection Agency
EPAct	Energy Policy Act
EV	Electric Vehicle
eVMT	Electric Vehicle Miles Traveled
EVSE	Electric Vehicle Supply Equipment
FAA	Federal Aviation Administration
FAME	Fatty Acid Methyl Ester

FCV	Fuel Cell Vehicle
FFV	Flex Fuel Vehicle
FOKS	Fuel Oil and Kerosene Sales
GenSet	Generator Set
GGE	Gasoline Gallon Equivalents
GHG	Greenhouse Gas
GMA	Growth Management Act
GVWR	Gross Vehicle Weight Rating
HD	Heavy-duty
HEV	Hybrid Electric Vehicle
HHDV	Heavy heavy-duty vehicle
HVO	Hydrogenated Vegetable Oil
ICCT	International Council on Clean Transportation
ICE	Internal Combustion Engine
LCFS	Low Carbon Fuel Standard
LD	Light-duty
LDV	Light-duty Vehicle
LFG	Landfill Gas
LNG	Liquefied Natural Gas
MD	Medium-duty
MGY	million gallons per year
MHDV	Medium/Heavy-duty Vehicle
MPG	Miles per Gallon
MPO	Metropolitan Planning Organization
MY	Model Year
NAS	National Academy of Sciences
NHTSA	National Highway Traffic Safety Administration

OEM	Original Equipment Manufacturer
OFM	Washington Office of Financial Management
OGV	Ocean-going Vessel
PAYD	Pay as You Drive Insurance
PEV	Plug-in Electric Vehicle
PHEV	Plug-in Hybrid Electric Vehicle
RFG	Reformulated Gasoline
RFS2	Renewable Fuel Standard
RHNA	Regional Housing Needs Allocation
RNG	Renewable Natural Gas
RTP	Regional Transportation Plan
RVOs	Renewable Volume Obligations
SACOG	Sacramento Area Council of Governments
SANDAG	San Diego Association of Governments
SB 375	Senate Bill 375
SCAG	Southern California Association of Governments
SCS	Sustainable Communities Strategy
SOV	Single-Occupancy Vehicle
TDM	Transportation Demand Management
TEA	Transportation Electrification Assessment
TEU	Twenty-foot Equivalent Unit
TZEV	Transitional Zero Emission Vehicle
UCO	Used Cooking Oil
UCS	Union of Concerned Scientists
VMT	Vehicle Miles Traveled
WSDA	Washington State Department of Agriculture
ZEV	Zero Emission Vehicle

Executive Summary

Transportation in the Pacific Coast of the United States is overwhelmingly fueled by petroleum products, primarily gasoline and diesel. Burning petroleum emits pollutants which are harmful to human health and contribute to climate change; in some states, transportation accounts for as much as 40 percent of total greenhouse gas emissions. Reducing the consumption of petroleum has been widely accepted as a method to reduce these harmful impacts.

The Pacific Coast States—California, Oregon, and Washington—were projected to consume a combined 22 billion gasoline gallon equivalents of petroleum based fuels in the transportation sector in 2015. Policies and measures in place are forecasted to reduce this to about 18 billion gallons by 2030, with California achieving an estimated 24 percent reduction compared to 2015, and Oregon and Washington both achieving about an 8 percent reduction. In his 2015 inaugural address, California Governor Jerry Brown called for an ambitious target: Reduce petroleum consumption from 2015 levels by up to 50 percent by 2030. This attention to petroleum reduction has been added to the existing discussion of climate change mitigation and air quality improvement surrounding energy and environmental policies.

The purpose of this report is to evaluate the landscape of technological and policy options by which the Pacific Coast states could reduce petroleum consumption, and explore combinations of measures that could achieve a 50 percent petroleum reduction. This report does not make any policy recommendations or prescriptions; its purpose is to identify how the West Coast states could reduce their petroleum consumption, not whether or how they should do so.

ICF analyzed a combination of strategies that could be employed to achieve a 50 percent reduction in petroleum consumption in California, Oregon, and Washington by 2030 (i.e., Half the Oil, HtO). ICF considered strategies across three broad categories: (1) reducing vehicle travel by improving transportation options and land use planning, (2) improving vehicle efficiency, and (3) using more alternative fuels, including biofuels, electricity, and natural gas. These strategies were applied to on-road fuel consumption by light-, medium- and heavy-duty vehicles, as well as off-road fuel consumption in railroad, marine, and other applications (e.g., construction and mining equipment, cargo handling equipment, etc.). ICF's analysis made use of existing analyses of the petroleum reduction potential for each strategy, with the appropriate modifications for the states considered for this report. In other words, the strategies considered are not purely aspirational; they are grounded in existing technological assessments, incorporate supply constraints, and account for other factors that affect viability. All of these strategies are well described in existing research. The analysis has purposefully limited consideration of the economic (e.g., cost) and political barriers that must be overcome to achieve the HtO goal in order to maintain the descriptive, rather than prescriptive, focus of this work.

The analysis in this report demonstrates that there are various combinations of strategies that allow California, Oregon and Washington to reduce petroleum consumption by 50 percent by 2030. Given the number of policy and technology options available to achieve a 50 percent target, an explicit modeling of every conceivable permutation of policy combinations is impossible. To that end, we describe a HtO Pathway, drawing reductions from each of the three aforementioned categories, as well as three alternative cases, each of which focus on greater reductions in one of the three categories. The four cases are summarized in Table 1.

Table 1. Cases Considered in Half the Oil Analysis

Case	Assumptions
HtO Pathway	Distributes petroleum reductions across each category—transportation and land use planning, vehicle efficiency improvements, and alternative fuel deployment—as evenly as possible to achieve a 50 percent petroleum reduction while staying in the conservative or moderate range of possible reductions from a given strategy
In the following three cases, a limited subset of strategies was implemented in the analysis. All other aspects of the modeling were held constant at Business-As-Usual levels.	
High Efficiency/ High Electrification Case	Focuses on petroleum reduction via efficiency improvements and electrification in light- and heavy-duty vehicles
High Biofuels Case	Focuses on petroleum reduction via combination of increased biofuel blending and increased deployment of drop-in biofuels
Transportation and Land Use Planning Case	Reduces demand for driving by coupling incremental changes in smart mobility and land use planning with other local transportation policy measures

Figure 1 below presents the combined results of the HtO Pathways for the Pacific Coast States. Figure 2, Figure 3, and Figure 4 present the state-specific results for California, Oregon, and Washington, respectively. In each figure, the grey shaded area represents petroleum consumption in the on-road (light-, medium-, and heavy-duty vehicles) and off-road sectors. The green-, orange-, and yellow-shaded areas represent reductions that are achieved as a result of implementing strategies beyond existing policies that reduce miles traveled, vehicle efficiency improvements, and alternative fuel deployment, respectively. Finally, the blue shaded area represents the reductions achieved as a result of implementing existing policies compared to a so-called Do Nothing Scenario (in which there are no policies implemented that would reduce petroleum consumption, even those already adopted).

Figure 1. HtO Pathway in Pacific Coast States

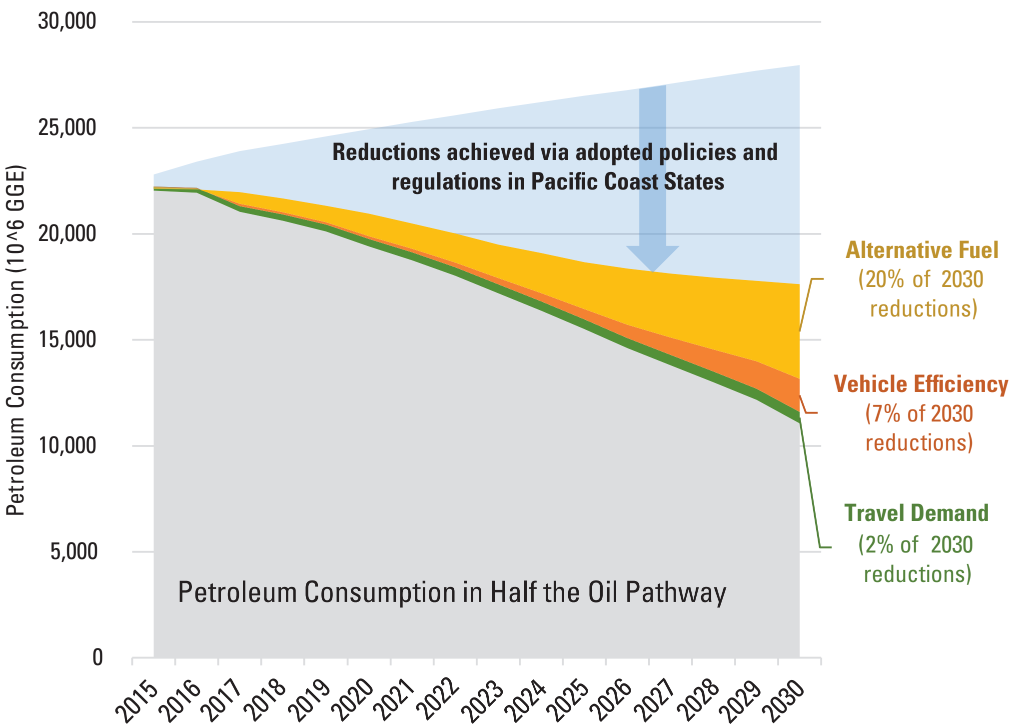


Figure 2. HtO Pathway in California

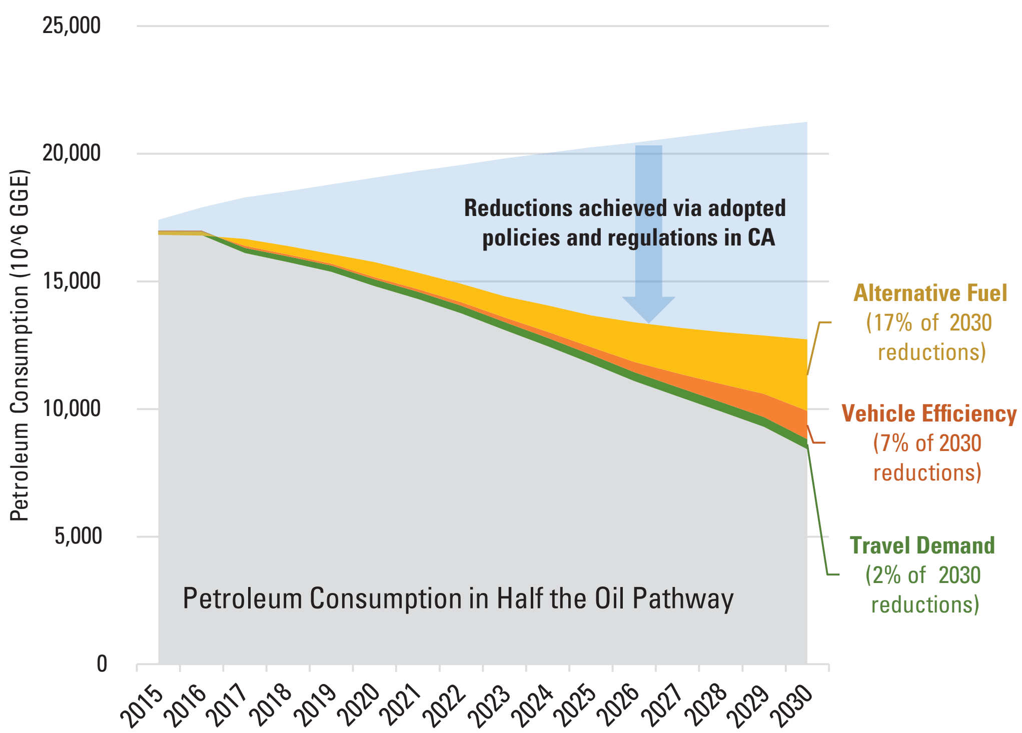


Figure 3. HtO Pathway in Oregon

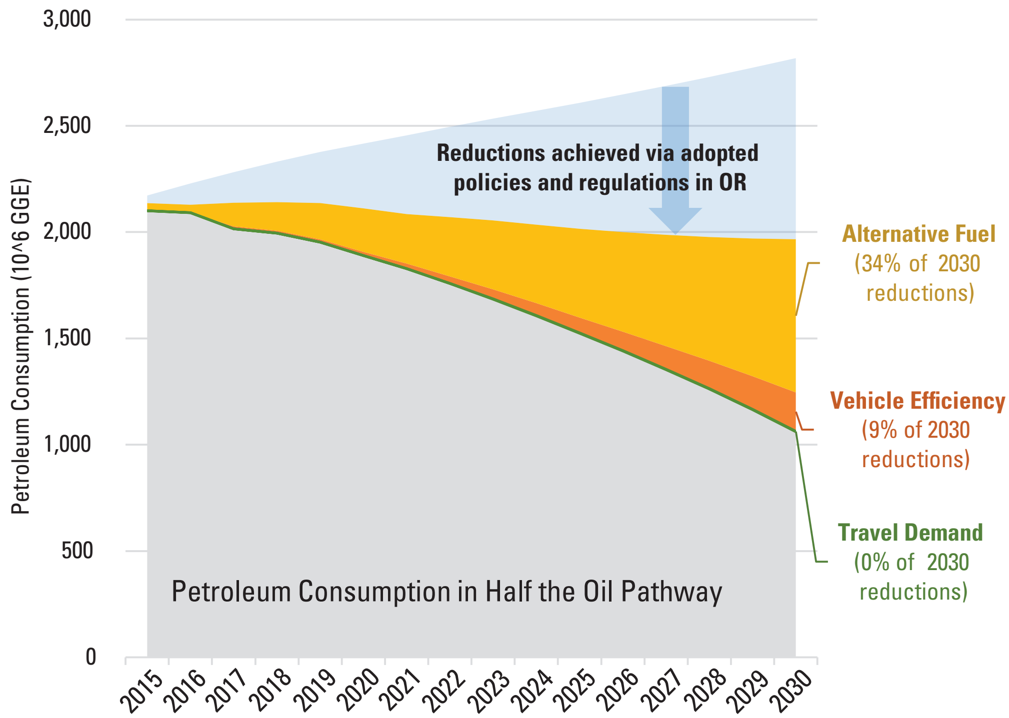
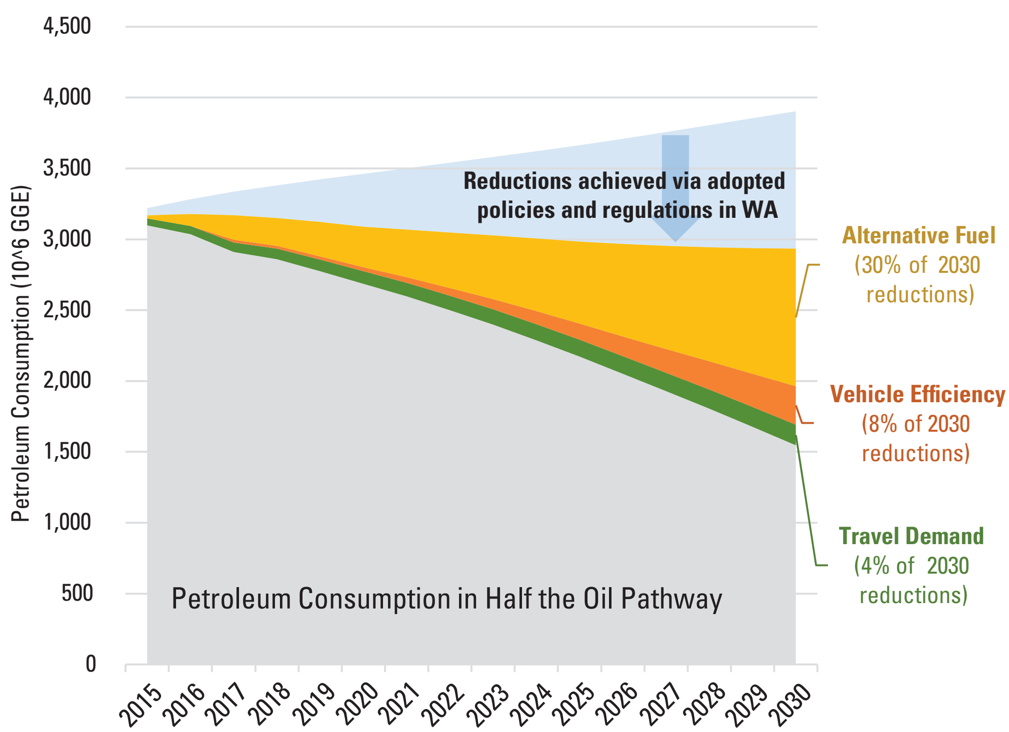


Figure 4. HtO Pathway in Washington



Key findings from the analysis are as follows:

- The full implementation of existing transportation policies (e.g., fuel economy and tailpipe greenhouse gas reduction standards) will yield petroleum reductions of 24 percent in California, and 8 percent in Oregon and Washington by 2030 compared to consumption levels in 2015. However, the majority of these policies have requirements that will plateau well before 2030, thereby providing opportunity for further petroleum reductions by 2030 by simply extending existing policies.
- Extending and, in some cases, accelerating strategies employed today offers a pathway to achieve the HtO target. Strategies like sustainable community planning, improved vehicle efficiency, and alternative fuel deployment (e.g., via low carbon fuel policies) minimize dependence on aggressive technological breakthroughs or drastic shifts in how people travel.
- The HtO Pathway also underscores that achieving the HtO target is more than simply "staying the course"; the pathway highlights the importance of implementing strategies as soon as possible to help achieve the 2030 target, thereby relieving pressure on technological advances or breakthroughs in one particular area or another. Furthermore, while the strategies in the HtO Pathway are similar to those in place today, they are not employed in all three states uniformly. For instance, Washington does not have an enforceable policy to promote alternative fuels such as a low carbon fuel standard or a zero emission vehicle program. As a result, it will be more challenging to achieve the HtO target in Washington than in states with such policies.
- The other cases in our analysis demonstrate that relying on a limited subset of strategies is unlikely to achieve a 50 percent petroleum reduction target. While the analysis was constrained based on existing research, these other cases push the upper bound of what may be achievable by 2030. In one regard, they illustrate that faster deployment of alternative fuels and electric vehicles, for example, can provide additional assurances that a HtO target can be achieved or exceeded; on the other hand, they can serve as a cautionary note of relying too heavily on a singular category of strategies given the higher uncertainty that these reductions would be achieved.
- Our analysis of California yields the following:
  - California has the top-level transportation policies in place to achieve significant petroleum reductions, including Sustainable Communities Strategies, light-duty tailpipe greenhouse gas standards, a Zero Emission Vehicle Program, and the Low Carbon Fuel Standard. However, achieving the HtO target will require deploying strategies that build upon and, in most cases, expand those policies.
  - The alternative cases in California, focusing on efficiency and electrification, biofuel deployment, and travel demand reductions individually yield petroleum reductions in the range of 31–45 percent compared to a 2015 baseline.
  - ICF reports a range of greenhouse gas emission reductions for each case based on life-cycle emission factors or carbon intensities for each transportation fuel (with considerations unique to California). For the HtO Pathway in California, we estimate a range of

37–43 percent reductions in carbon emissions from a 2015 baseline; and for the alternative cases (which do not achieve the 50 percent petroleum reduction target), we estimate reductions of 27–41 percent from a 2015 baseline.

- Our analysis of Oregon yields the following:
  - The HtO Pathway for Oregon relies on similar assumptions as those deployed in California, with a combination of strategies cutting across all three categories. Oregon has a similar policy baseline as California, in that it has transportation policies such as the Oregon Sustainable Transportation Initiative to reduce vehicle miles traveled, a Clean Fuels Program (similar to California's Low Carbon Fuel Standard), and having adopted the Zero Emission Vehicle program (developed by California). Similar to California, achieving the HtO target in Oregon will require deploying strategies that build upon and, in most cases, expand these policies. However, the timeline of Oregon's Clean Fuels Program is slightly delayed compared to California's Low Carbon Fuel Standard. Further, Oregon's business-as -usual projections indicate a higher rate of growth in diesel fuel consumption than California, for instance. Together, these issues reinforce our observation that imple-menting strategies as soon as possible will be necessary to help achieve the 50 percent petroleum reduction target by 2030.
  - The alternative cases in Oregon, focusing on efficiency and electrification, biofuel deployment, and travel demand reductions individually yield petroleum reductions in the range of 14–39 percent compared to a 2015 baseline.
  - We estimate greenhouse gas emission reductions of 31–39 percent for the HtO Pathway in Oregon from the 2015 baseline; whereas the alternative cases yield greenhouse gas emission reductions of 12–31 percent from the 2015 baseline.
- Our analysis of Washington yields the following:
  - Travel demand reductions, implementation of a Zero Emission Vehicle program, and alternative fuel deployment in line with a low carbon fuel standard program account for about 28–30 percent of petroleum reductions from the 2015 baseline in the HtO Pathway for Washington. Based on our analysis, there are still complementary policies and strategies that can be pursued; however, without these top-level policy mechanisms in place, the HtO target will be very difficult to reach. The HtO Pathway does demonstrate that Washington does not need to implement programs that are out of line with expectations in other states e.g., California and Oregon.
  - The alternative cases in Washington, focusing on efficiency and electrification, biofuel deployment, and travel demand reductions individually yield petroleum reductions in the range of 14–38 percent compared to a 2015 baseline.
  - We estimate greenhouse gas emission reductions of 42–45 percent for the HtO Pathway in Washington compared to a 2015 baseline; whereas the alternative cases yield greenhouse gas emission reductions of 17–36 percent compared to a 2015 baseline.
- As noted in the state-specific bullet points above, ICF calculated the greenhouse gas emission reductions for each state. ICF notes that the analysis focuses on petroleum reductions and was not explicitly designed to achieve a greenhouse gas emissions reduction target. ICF's analysis

suggests that the greenhouse gas impacts can vary by as much as 10 percent within each case analyzed, depending on factors such as the feedstocks used to produce liquid biofuels, the balance between fossil natural gas and renewable natural gas, and to what extent the power grid can be de-carbonized by 2030. This variation highlights the need for complementary policies that incentivize low carbon solutions in parallel with petroleum reductions.

1 Introduction

More than 95% of the energy consumed in the transportation sector for California, Oregon, and Washington comes from petroleum sources. Through a combination of regulations and policies at the state level—including Low Carbon Fuel Standards (LCFS), Zero Emission Vehicle (ZEV) Programs, Sustainable Community Strategies, Cap-and-Trade programs, and greenhouse gas (GHG) tailpipe standards[1]—California, Oregon, and Washington have or are strongly considering taking steps to reduce GHG emissions in the transportation sector. Although some of these will also affect petroleum consumption, they are not explicitly intended to displace petroleum. These are in addition to federal programs such as fuel economy standards and the Renewable Fuel Standard (RFS2).

Governor Brown's inaugural address in January 2015 called for a reduction of today's petroleum use in cars and trucks by up to 50%,[2] marking a significant shift in the conversation regarding energy consumption in the transportation sector.

The objective of this analysis is to characterize a sustainable transportation system that would achieve an ambitious target: 50% reduction in transportation petroleum consumption in the states of California, Oregon, and Washington by 2030. Further, this analysis seeks to outline the policy choices that can be employed to achieve that target. ICF's analysis was designed to achieve the following goals:

1. To inform key policy makers and stakeholders as California, Oregon, and Washington make policy decisions that will affect transportation over the next couple of decades.
2. To characterize the opportunities (via technology, investment, and policy instruments) available to achieve a 50% reduction in transportation sector petroleum consumption by 2030 in California, Oregon, and Washington.

The report is structured as follows:

- Section 2 provides an outline of our approach and methodology, with a brief description of data sources and the tools that ICF developed to conduct the analysis.

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1 States under Section 177 of Clean Air Act can adopt equivalent standards; and California has authority related to GHG standards, but not fuel economy regulations.

2 Edmund G. Brown Jr. Inaugural Address Remarks as Prepared January 5, 2015, available online at **http://gov.ca.gov/news.php?id=18828**.

- Sections 3–5 summarize the results of our analysis for California, Oregon, and Washington, respectively. Each section includes a review of the historical and forecasted petroleum baseline or business-as-usual scenario, a description of the regulatory/policy measures that have been implemented in each state, a presentation of the reduction cases analyzed, and a brief discussion of our key findings.
- The Appendix includes: a) additional information regarding petroleum reduction strategies considered and our approach to implementing these strategies, b) modeling assumptions and parameters, and c) emission factors used to estimate the lifecycle greenhouse gas emissions from our analysis.

2 Overview of Methodology

ICF's analysis of the HtO target was developed over the following phases; additional details on our analysis approach, data sources, and assumptions are included in the Appendix.

- In the first phase of the analysis, ICF developed a robust estimate of current and recent petroleum consumption in each state, focusing on the 2010–2015 period. ICF's analysis included on-road vehicles (light-, medium- and heavy-duty vehicles) and off-road modes (mobile equipment, railroad locomotives, and marine vessels).
- In the second phase of the analysis, ICF developed business-as-usual petroleum forecasts out to 2030. These forecasts were performed using existing work and assumptions developed by others regarding compliance with policies that will impact petroleum consumption moving forward. The California forecasts are based in large part on the EMissions FACtor (EMFAC) model developed and maintained by the California Air Resources Board. For the Oregon and Washington forecasts, ICF employed state-specific versions of the VISION model, which is developed and maintained by Argonne National Laboratory (ANL).
- In the third phase of the analysis, ICF introduced a mix of strategies that could be implemented to reduce petroleum consumption by 50% from 2015 levels by 2030.

ICF's analysis of the HtO target is based on a combination of strategies within the following three distinct categories:

- **Travel demand reductions.** ICF considered an array of strategies designed to reduce light-duty vehicle travel (measured using vehicle miles traveled or VMT), primarily by offering consumers alternatives and incentives to reduce dependence on single-occupancy vehicles (SOVs). These strategies combine the improved transportation choices for consumers (smart mobility) with improved land use planning, and local transportation policies.
- **Vehicle efficiency improvements.** ICF considered the potential to increase internal combustion engine vehicle efficiency for new and existing light-, medium-, and heavy-duty vehicles.
- **Alternative fuel deployment.** ICF considered the potential for the increased deployment of alternative fuels, including zero emission vehicles (electricity and hydrogen fuel cell vehicles), natural gas, and liquid biofuels.

ICF implemented these strategies in the order that they are presented above. Each strategy that was considered and implemented was based on ICF's review of relevant literature, and required some judgment by ICF as to how to implement the strategy. The Appendix provides explicit rationale for how findings from our literature review were incorporated or modified into this analysis.

For each state, ICF conducted two types of modeling:

- Firstly, we implemented a mix of petroleum reduction strategies across each category—travel demand reductions, vehicle efficiency improvements, and alternative fuel deployment—to achieve the HtO target. We refer to this as the HtO Pathway.
- Secondly, we implemented a set of aggressive strategies in each petroleum reduction category, and report the extent to which the strategies in an individual category can contribute towards the HtO target. We refer to these as cases. This analysis offers a comparative basis for the HtO Pathway.

3 California

3.1 Summary

Our results for California are presented via the modeling of a single pathway that achieves 50% petroleum reduction by 2030, and three alternative cases that illustrate strong and focused implementation of strategies within a specific category of reductions. In each case, the strategies are not intended to endorse or prescribe any policy; they are a quantitative exploration of how California might achieve a 50% petroleum reduction target. As noted previously, the order of operations in the modeling is consistent with the way that we have presented the strategies in the text. In other words, we first apply travel demand reduction strategies, then apply vehicle efficiency strategies, and finally alternative fuel deployment strategies. The order of operations in the modeling is simply a matter of choice; however, for comparative purposes it is critical that the order of operations be applied consistently across all cases and states. The table below summarizes the four cases considered. The work presented here does not comprehensively describe all combinations of policies which could achieve a 50% petroleum reduction by 2030; rather, the modeling results are intended to present an instructive approach to petroleum reduction.

Table 2. Overview of Cases Considered in HtO Analysis

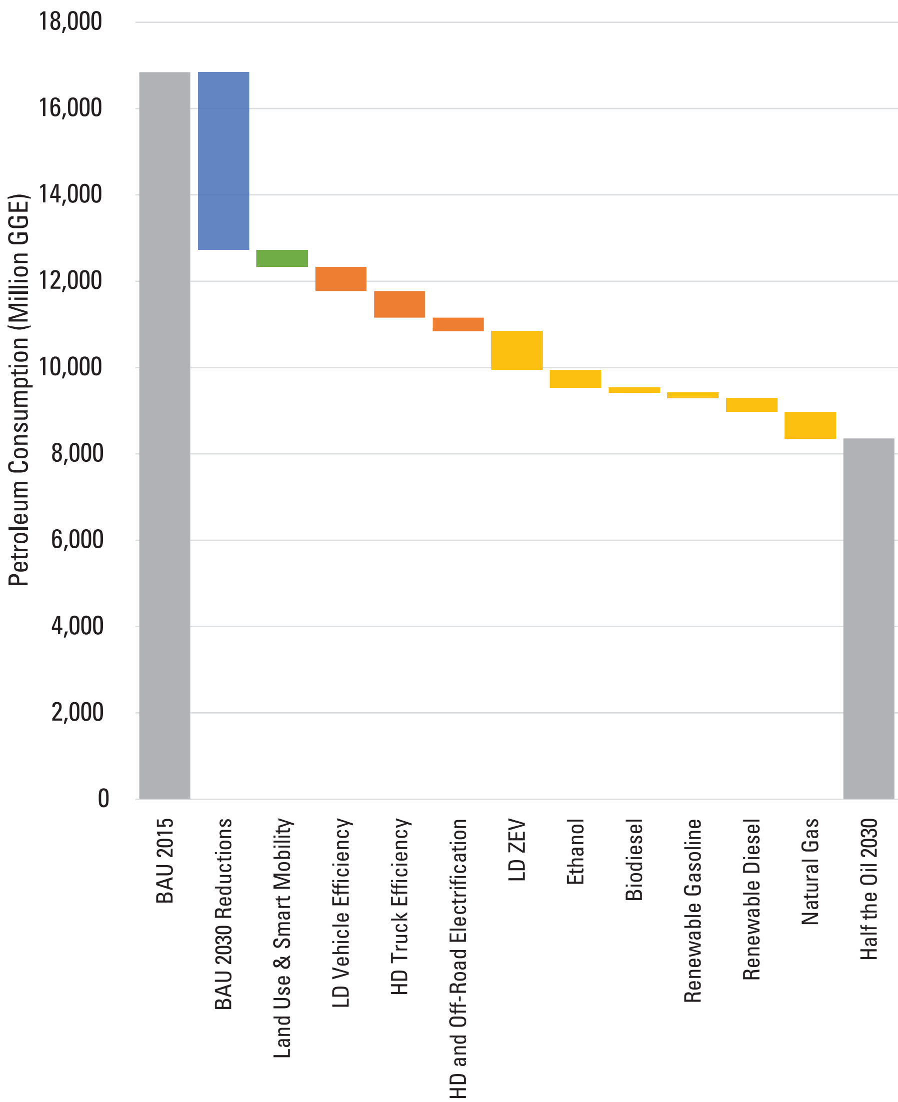
Case	Assumptions
HtO Pathway	Distributes petroleum reductions across each category—travel demand reductions, efficiency improvements, and alternative fuel deployment—as evenly as possible to achieve a 50% petroleum reduction while staying in the conservative or moderate range of possible reductions from a given strategy
In the following three cases, a limited subset of strategies was implemented in the analysis. All other aspects of the modeling were held constant at Business-As-Usual levels.	
High Efficiency/ High Electrification Case	Focuses on petroleum reduction via efficiency improvements and electrification in light- and heavy-duty vehicles
High Biofuels Case	Focuses on petroleum reduction via combination of increased biofuel blending and increased deployment of drop-in biofuels
Transportation and Land Use Planning Case	Reduces demand for driving by coupling incremental changes in smart mobility and land use planning with other local transportation policy measures

As noted previously, one of the main objectives of this analysis is to characterize the opportunities (via technology, investment, and policy instruments) available to achieve a 50% reduction in transportation sector petroleum consumption by 2030 in California, Oregon, and Washington.

This analysis has limited consideration of the economic (e.g., cost) and political barriers that must be overcome to achieve what we consider a challenging goal of 50% petroleum reduction in the next 15 years.

The figure below summarizes the results for California from the HtO Pathway modeled based on the petroleum reductions in various categories to achieve the HtO target. Note that in the figure below, and throughout the report, we report petroleum consumption in units of gasoline gallon equivalents (GGE).

Figure 5. Petroleum Reductions in California HtO Pathway



3.2 Petroleum Consumption in California, Business-As-Usual

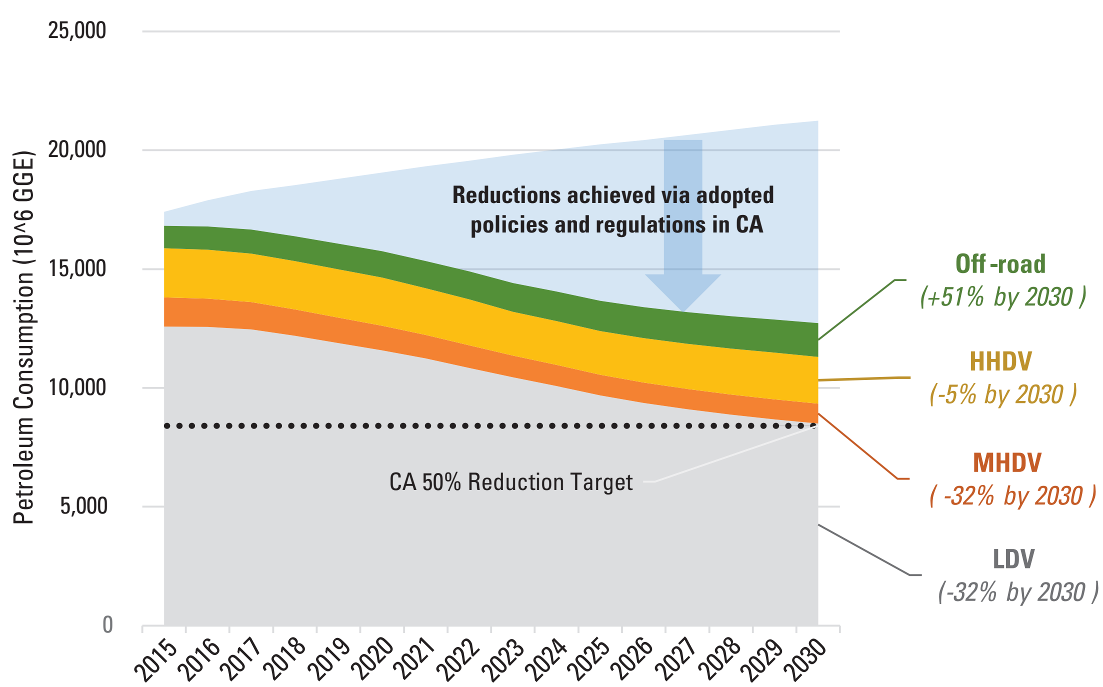
ICF developed a Business-As-Usual (BAU) Scenario projecting petroleum consumption in the transportation sector from 2015 to 2030 for California and included the following modes in our assessment:

- On-road
  - Light-duty vehicles (autos and light trucks)
  - Medium- and heavy-duty vehicles
- Off-road
  - Off-road mobile equipment used in construction, agriculture, mining, port cargo handling, etc.
  - Railroad locomotives, both freight and passenger
  - Marine vessels, including ships, commercial harbor craft (e.g., tugs, fishing boats), and recreational boats; for ships, fuel use was limited to that consumed at berth and in port/harbor areas

California consumed about 17.6 billion gasoline gallon equivalents (GGE) of petroleum in 2010 and will consume an estimated 16.8 billion GGE in 2015. ICF developed the BAU Scenario considering existing measures in California as well as an illustrative Do Nothing Scenario, in which there are no travel demand reductions, no improvements in fuel economy from Model Year (MY) 2015 for light- or heavy-duty vehicles, no increase in zero emission vehicle (ZEVs) sales, and no implementation of a low carbon fuel standard. The Appendix includes the data sources and tools that ICF employed to estimate baseline petroleum consumption for on-road and off-road applications.

As shown in the figure below, ICF's baseline forecasts estimates 12.7 billion GGE in 2030, a 24% reduction from 2015. This is equivalent to a 40% reduction in petroleum consumption from the Do Nothing Scenario for California, which would otherwise be 21.2 billion GGE in 2030.

Figure 6. Forecasted Petroleum Consumption in California (2015-2030; in units of GGE)



The table below includes a summary of the state-specific measures that were included in our analysis of the forecasted BAU scenario for petroleum consumption in California.

Table 3. Description of Measures Included in California's BAU Petroleum Consumption

Category	Measure/Regulation	Implementation in BAU Scenario
Travel Demand Reductions	Land Use Planning, VMT Reductions, and GHG Reductions	• Reductions corresponding to plans submitted in response to SB 375 • 5.4% VMT reduction, 2030[3]
Vehicle Efficiency	LD fuel economy standards/GHG tailpipe standards	• Fuel economy of about 30–45 mpg of new light-duty vehicles sold in 2025 and beyond • No assumed improvements post-2025
	MD/HD fuel economy standards	• Fuel economy of about 9 mpg for Class 3–6, 7 mpg for Class 7 and 8 vehicles • No assumed improvements post Phase 1 rulemaking
Alternative Fuels	Zero Emission Vehicle Program	• ZEVs account for 15.7% of new light-duty vehicles sales in 2025 and beyond • No assumed increases in ZEV sales post-2025
	Low Carbon Fuel Standard	• Used CARB's Illustrative Scenario[4]

The benefits associated with achieving the goals in each of the regulatory programs outlined in the table above are dependent on the corresponding view of compliance. For the most part, regulators have shifted towards market-based mechanisms rather than more traditional command-and-control type initiatives. As a result, there is no "standard" assumption regarding compliance. Making assumptions about compliance via scenarios is challenging, especially in fields like sustainable transportation, where changes in technology, culture and economies can reshape fundamental principles within relatively short timeframes. This makes quantifying the reductions from market-based mechanisms challenging, even more so when multiple market based mechanisms are considered. The following subsections describe the measures considered in California's BAU Scenario in more detail, summarize the compliance outlook assumed in our modeling, and identify the source of those assumptions.

Transportation and Land Use Planning Strategies

Sustainable Community Strategies via SB 375

California's Senate Bill 375 (2008) aims to reduce energy use and GHG emissions from the transportation sector by reducing the amount that Californians drive. The goal of SB 375 is to expand transportation choices that reduce the need to drive by focusing on new development in places where residents can travel by foot, bicycle, or transit. In all metropolitan areas with populations over 200,000, metropolitan planning organizations (MPOs) are responsible for preparing a regional transportation plan (RTP) describing how transportation revenues across the region will be spent over the next 25 years. SB 375 requires that MPOs include a sustainable communities strategy (SCS) that includes a regional land use plan and details how land use changes, in

[3] These VMT reductions are applied exclusively to urban VMT statewide. FHWA statistics from 2013 (the most recent year available) indicate that about 84% of VMT is urban in California. The statistics are available online at online at **https://www.fhwa.dot.gov/policyinformation/statistics/2013/vm2.cfm**).

[4] Staff Report: Initial Statement of Reasons (ISOR, Appendix B, Development of Illustrative Compliance Scenarios and Evaluation of Potential Compliance Curves, 2015. Available online at **http://www.arb.ca.gov/regact/2015/lcfs2015/lcfs15appb.pdf**.

combination with the transportation projects and policies in the RTP, will help the region meet GHG reduction targets set by the state. Prior to SB 375, there were no state-issued GHG reduction targets for RTPs, and the land use scenarios included in RTPs were more likely to be a compilation of local plans than a cohesive regional plan. However, local governments in California have exclusive authority over land use changes, and neither SB 375 nor any of the other travel demand measures described in this report does anything to change that. Instead, the bill aligns other planning process with the SCS and creates a set of incentives to help implement the strategy:

- SB 375 requires MPOs to spend the federal and state transportation funds that they allocate in a manner consistent with the SCS—so an MPO cannot increase the amount of growth in central neighborhoods that are well-served by transit in its SCS while spending its RTP funding on new highways that serve the suburbs.
- The bill amends the California Environmental Quality Act (CEQA) to limit the environmental review for some projects that conform to the SCS. CEQA review is the primary mechanism that opponents use to delay development projects, so this can be a powerful incentive if the SCS is clear about where growth will go and developers have confidence in CEQA streamlining.
- Finally, SB 375 aligns the Regional Housing Needs Allocation (RHNA) process with the SCS, and creates penalties for local governments that do not zone to meet their allocation. Local governments have a fiscal incentive not to plan for new housing, which generates fewer revenues and requires more services than commercial development, so these penalties are designed to ensure that the housing envisioned in the SCS is planned for and ultimately built.

ICF implemented the SB 375 reductions based on our analysis of plans submitted to and approved by CARB from the four major MPOs in California—including Sacramento Area Council of Governments (SACOG), the Bay Area's Metropolitan Transportation Commission (MTC), Southern California Association of Governments (SCAG), and San Diego Association of Governments (SANDAG).

Vehicle Efficiency Strategies

Tailpipe GHG Standards/Light-Duty Fuel Economy Standards

The most recent passenger vehicle standards, covering cars and light trucks, were promulgated by the National Highway Traffic Safety Administration (NHTSA) and the Environmental Protection Agency (EPA) in 2012 for model years 2017 and beyond. The standards are a combination of fuel economy standards (referred to as Corporate Average Fuel Economy standards or CAFE standards)[5] established by NHTSA and greenhouse gas emission standards from the EPA.[6] NHTSA and EPA projected that the fleet-wide on-road fuel economy of new passenger vehicles to be in the range of 40 miles per gallon (mpg) in 2025. California, under Clean Air Act authority, has also adopted light-duty greenhouse gas standards which are consistent with federal fuel economy and greenhouse gas standards.

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5 Under the authority of the Energy Policy and Conservation Act (EPCA) and amend by the Energy Independence and Security Act (EISA).

6 Under the authority of the Clean Air Act.

ICF notes that the NHTSA and EPA standards are introduced in two phases, with Phase One applied to model years 2017–2021 and Phase Two applied to model years 2022–2025. The agencies are scheduled to conduct a mid-term review and determine the appropriateness of the Phase Two standards by November 2017, and final decision made in April 2018.

The analysis presented here assumes that the passenger vehicle fuel economy and GHG standards are implemented in both phases as outlined in the 2012 ruling.

Medium- and Heavy-Duty Fuel Economy Standards

In August of 2011, NHTSA and EPA finalized new GHG and fuel economy standards for new medium- and heavy-duty vehicles. New heavy-duty big rig trucks must reduce fuel consumption by 20%, medium-duty trucks are required to reduce fuel consumption by 15% and vocational trucks (delivery, garbage, buses) must reduce consumption by 10% by 2018. California, under Clean Air Act authority has also adopted heavy-duty GHG standards which are consistent with federal fuel economy and GHG standards.

In June 2015, NHTSA and EPA proposed Phase 2, covering model years 2021 through 2027; however, we did not include these standards in the BAU Scenario as they are not yet final.

Alternative Fuel Strategies

California's Low Carbon Fuel Standard Program

California's LCFS is designed to be a flexible market-based mechanism to reduce GHG emissions of transportation fuels on a lifecycle basis, as measured by the carbon intensity (CI) of a fuel, which is reported in units of grams of carbon dioxide equivalents per megajoule of fuel (g/MJ). The program is implemented using a system of credits and deficits: transportation fuels that have a higher carbon intensity than the compliance schedule yield deficits, and fuels that have a lower carbon intensity generate credits. LCFS compliance can be achieved using an array of solutions. The most common pathways to date are described here:

- **Lower CI corn ethanol:** In most gasoline markets, ethanol is blended at 10% by volume with gasoline (as an oxygenator to produce reformulated gasoline). Corn ethanol producers can decrease their CI to differentiate themselves from their competitors. For instance, the "standard" gallon of corn ethanol prior to the introduction of the LCFS in California had a CI around 95 g/MJ; more than 30 ethanol production facilities have submitted 85 ethanol pathways with a low of 64 g/MJ.
- **Sugarcane ethanol:** Based on its carbon intensity, the availability of supply—as demonstrated by the 500 million gallons imported to the US as recently as 2012—and fuel pricing, sugarcane ethanol will definitely play an important role towards compliance as programs are currently structured. The potential for cross-compliance with the RFS2 at the federal level using Brazilian sugarcane ethanol also serves to increase the likelihood of Brazilian sugarcane ethanol playing a significant part of LCFS compliance in multiple markets.
- **Biodiesel:** Biodiesel is blended into conventional diesel at low levels (generally at 5–20%, B5–B20). Biodiesel blended up to 5% by volume can actually be labeled as diesel. To date, biodiesel blends have generated about 13% of LCFS credits in California.

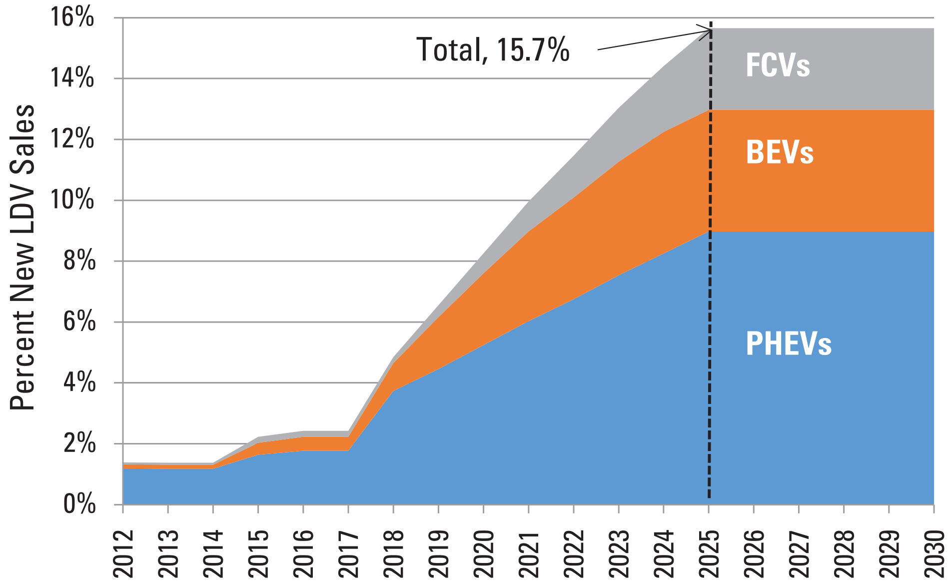
- **Renewable diesel:** Renewable diesel is a drop-in replacement and can be blended into the conventional diesel supply without limitations. The most active player in this market is Neste, who have a large production facility in Singapore that delivers low carbon fuel to the West Coast of the United States. They have delivered around 100–130 million gallons for each of the last two years and are expected to increase those volumes considerably in the near-term future.
- **Natural gas:** Natural gas is consumed as compressed (CNG) or liquefied (LNG) as a transportation fuel. It can be sourced from conventional/fossil sources or renewable resources like landfills, wastewater treatment plants, and dairy digesters.
- **Electricity used in plug-in electric vehicles** (both plug-in hybrids like the Chevrolet Volt and full battery electric vehicles like the Nissan LEAF or Tesla Model S) generate LCFS credits, primarily for utilities. These currently represent a small part of the market at about 2%; however, given other regulations (i.e., federal fuel economy/GHG standards and the ZEV program), these are poised to increase considerably moving forward.

Zero Emission Vehicle Program

CARB established the ZEV Program in 1990 to increase penetration rates of zero emission vehicles to reduce criteria pollutant emissions. The program today requires a certain percentage of light duty vehicles sold in California to be zero emission vehicles (ZEVs), which includes battery electric vehicles (BEVs), fuel cell vehicles (FCVs), and transitional zero emission vehicle (TZEVs) like plug-in hybrid electric vehicles (PHEVs). Because of the limited availability of true ZEVs until recently, manufacturers were allowed to comply with the regulations by selling larger numbers of very low emitting vehicles. In March 2008, CARB directed staff to strengthen the ZEV Program requirements for 2015 and beyond by focusing solely on electric and hydrogen vehicles. Proposed modifications to the ZEV Program were accepted as part of the Advanced Clean Cars Program, dramatically increasing the requirements for sales of ZEVs beginning in 2018. As a result of the program, over 1.4 million ZEVs and so-called transitional zero emission vehicles (TZEVs; which are effectively PHEVs) are expected to be produced cumulatively in California by 2025, with 500,000 of those vehicles being pure ZEVs (BEVs and FCVs).[7]

[7] Advanced Clean Cars Summary, CARB, Available online at **http://www.arb.ca.gov/msprog/clean_cars/acc%20summary-final.pdf**.

Figure 7. Percent New LDV Sales of ZEVs in CARB's Likely Compliance Scenario, 2012–2025



Nine additional states have adopted California's ZEV Program, including Oregon.[8] Further, in October 2013, Oregon was one of the seven states that joined California signing a Memorandum of Understanding on State Zero-Emission Vehicle Programs.[9]

ICF's analysis assumes that the ZEV Program is implemented according to CARB's likely compliance scenario; however, an alternative compliance scenario is conceivable whereby automobile original equipment manufacturers (OEMs) bank credits in the early years of the regulation to put downward pressure on their compliance burden in later years. This compliance scenario has the potential to reduce the number of ZEVs on the road in later years by 200,000–250,000 vehicles.

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8 The other so-called ZEV states include Connecticut, Maryland, Massachusetts, Maryland, New Jersey, New York, Rhode Island, and Vermont.

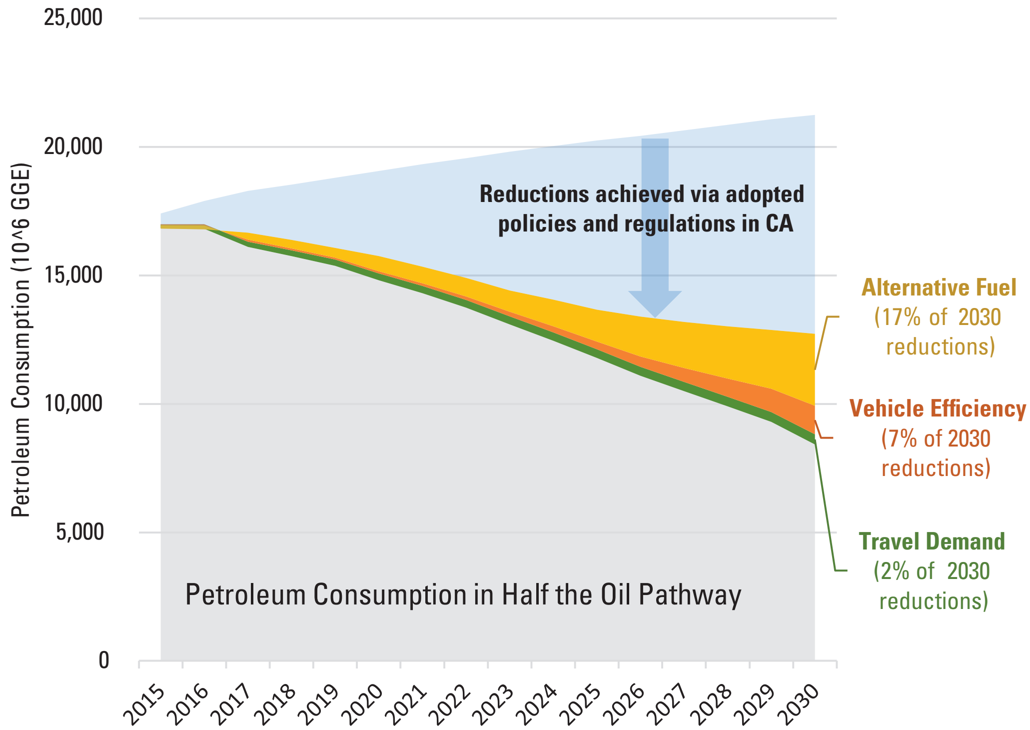
9 The MOU on State Zero-Emission Vehicle Programs is available online at **http://www.arb.ca.gov/newsrel/2013/8s_zev_mou.pdf**.

3.3 Petroleum Reductions in California

HtO Pathway in California

The graph below includes the HtO Pathway for California, compared to the BAU Scenario (a 24% reduction from 2015) and the Do Nothing Scenario.

Figure 8. HtO Pathway in California



The table on the following page summarizes the petroleum reduction strategies that were employed in the HtO Pathway for California, and includes a brief description of how they were implemented.

Table 4. Petroleum Reduction Strategies Implemented in the HtO Pathway, California

Category	Strategy	Description of Petroleum Reduction Strategy Implementation	Petroleum Reduction (MGGE)
Travel Demand Reductions	Smart Mobility and Land Use	• Implemented additional regional transportation planning measures, achieving a weighted average reduction of 8%[10]	395
Efficiency	LD efficiency	• Extended existing standards to MY2030 by a sales weighted average of 5% improvement in fuel economy per year • Final sales weighted on-road fuel economy average of ~48 mpg in 2030[11]	480
		• Included fuel efficient replacement tires for vehicles already in the fleet	80
	HD efficiency	• Implemented Phase 2 standards through 2024 using Alternative 4	470
		• Included platooning	15
		• Included hybrid tug boats and ferries	20
	Off-Road efficiency	• Included hybrid tug boats and ferries	20
Alternative Fuels	Zero Emission Vehicles/ Electrification	• Introduced higher ZEV populations starting in 2026 by enhancing existing sales targets, increase to 2.4% year over year increase, compared to baseline 1.5%/yr increase • Percent of new light duty vehicle sales as ZEVs in 2030: 27.9%	730
		• Increased baseline PHEV eVMT to a weighted utility factor of 70%	165
	HD and Off-Road Electrification	• Incorporated medium scenario from IEE for work trucks and delivery vans, equivalent to ~5% of total fleet market share in medium-duty vehicles by 2030 • Included electrified drayage trucks reaching 25% at major ports by 2030	315
	Liquid Biofuels	• Ethanol: Equivalent to 15% blended in gasoline (could also be a mix of E85 and other blend levels)	410
		• Biodiesel: 15% blended into diesel	120
		• Renewable gasoline: 375 million gallons by 2030	130
		• Renewable diesel: Implemented medium-high scenario from ICCT report; 870 million gallons by 2030	310
	Natural Gas	• Total consumption in 2030: 1 billion diesel gallon equivalents (dge) • Fossil gas: Implemented volumes similar to CEC's draft 2015 forecasts; revised downward slightly and subtracted RNG deployment for total of 550 million dge • RNG: Implemented values consistent with CARB's illustrative LCFS compliance scenario, with 450 million dge in 2030	620
		Total	4,370
		%Reduction from 2015	50%

10 Note that we report that SB 375 and additional regional transportation planning measures will achieve VMT reductions of 5.6% and 4.3%, respectively. These are applied exclusively to urban VMT, which comprises 84% of VMT in California (see online at https://www.fhwa.dot.gov/policyinformation/statistics/2013/vm2.cfm). Furthermore, VMT reductions are introduced sequentially rather than as a simple sum of VMT reductions, such that the entire number of VMT measures, characterized as n, will achieve an overall reduction of $VMT_{reduction}$=1-{(1-VMTi)x(1-VMTi+1) …x(1-VMTn)}.

11 This value is presented as the harmonic mean of on-road light-duty vehicle fuel economy.

California, Alternative Petroleum Reduction Cases

High Efficiency and High Electrification Case in California

The table below summarizes the petroleum reduction strategies that were employed in the High Efficiency/High Electrification Case for California, and includes a brief description of how they were implemented and the reductions achieved.

Table 5. Petroleum Reduction Strategies Implemented in High Efficiency/Electrification Case, California

Category	Strategy	Description of Petroleum Reduction Strategy Implementation	Petroleum Reduction (MGGE)
Efficiency	LD efficiency	• Extended existing standards to MY2030 by a sales weighted average of 7% improvement in fuel economy per year • Final sales weighted on-road fuel economy average of ~52 mpg in 2030[12]	650
		• Included fuel efficient replacement tires for vehicles already in the fleet	80
	HD efficiency	• Implemented Phase 2 standards through 2024 using Alternative 4	470
		• Introduced a 4% annual fuel reduction starting with MY2025	160
		• Included platooning	16
	Off-Road efficiency	• Included hybrid tug boats and ferries	20
Alternative Fuels	Zero Emission Vehicles/ Electrification	• Introduced higher ZEV populations starting in 2026 by enhancing existing sales targets, increase to 2.85% year over year increase, compared to baseline 1.5%/yr increase • Percent of new light duty vehicle sales as ZEVs in 2030: 36.4%	1,280
		• Increased PHEV eVMT to a weighted utility factor of 80%	400
	HD and Off-Road Electrification	• Incorporated high scenario from IEE for work trucks and delivery vans, equivalent to ~7% of total fleet market share in medium-duty vehicles by 2030 • Included electrified drayage trucks reaching 25% at major ports by 2030 • Included off-road electrification opportunities	490
		Total	3,566
		%Reduction from 2015	45%

High Biofuels Case in California

The table below summarizes the petroleum reduction strategies that were employed in the High Biofuels Case for California, and includes a brief description of how they were implemented.

[12] This value is presented as the harmonic mean of on-road light-duty vehicle fuel economy.

Table 6. Petroleum Reduction Strategies Implemented in High Biofuels Case, California

Category	Strategy	Description of Petroleum Reduction Strategy Implementation	Petroleum Reduction (MGGE)
Alternative Fuels	Liquid Biofuels	• Ethanol: Equivalent to 25% blended in gasoline (could also be a mix of E85 and other blend levels)	1,220
		• Biodiesel: 20% blended into diesel	285
		• Renewable gasoline: Implemented a modified version of ICCT's high scenario,[13] 500 million gallons by 2030	260
		• Renewable diesel: Implemented an average of CARB's illustrative compliance scenario and ICCT's high scenario, 1.2 billion gallons by 2030	1,110
		Total	2,875
		%Reduction from 2015	44%

Transportation and Land Use Planning Case in California

The table below summarizes the petroleum reduction strategies that were employed in the Transportation and Land Use Planning Case for California, and includes a brief description of how they were implemented and the reductions achieved.

Table 7. Petroleum Reduction Strategies Implemented in Transportation and Land Use Planning Case, California

Category	Strategy	Description of Petroleum Reduction Strategy Implementation	Petroleum Reduction (MGGE)
Travel Demand Reductions	Smart Mobility and Land Use	• Implemented smart mobility (TDM, transit and bicycle/pedestrian improvements, carsharing) and compact land use with VMT reductions of 5.2% and 4%, respectively • Implemented parking pricing, road pricing, and pay as you drive insurance at a combined VMT reduction of 12.5% • Weighted average VMT reduction of 20.4% in 2030[14]	1,460
		%Reduction from 2015	31%

[13] We assumed that a portion of the cellulosic feedstocks would be used to produce renewable gasoline instead of cellulosic ethanol in this scenario.

[14] Travel demand reductions are introduced sequentially rather than as a simple sum of travel demand reductions, such that the entire number of travel demand measures, characterized as n, will achieve an overall reduction of $VM_{Treduction}=1\text{-}\{(1\text{-}VMTi)x(1\text{-}VMTi+1)\ \ldots x(1\text{-}VMTn)\}$.

3.4 Discussion

Our analysis highlights the differences between a balanced approach to petroleum reduction and the upper limit of the petroleum reduction potential of separate categories. These results help illustrate the mix of strategies that could be deployed to achieve HtO targets in California. As noted previously, this analysis is intended to be descriptive rather than prescriptive; further, it is not intended to be a comprehensive review of every possible petroleum reduction strategy. Rather, through the HtO Pathway and alternative cases, it describes the potential reductions from combinations of policies which are well-characterized by current literature and whose effects can be estimated in the 2030 timeframe with reasonable accuracy.

The HtO Pathway highlights that by extending and, in some cases, accelerating strategies employed today offers a pathway to achieve the Half the Oil target. Moving forward with all three strategy areas—including sustainable community planning, improved vehicle efficiency, and alternative fuel deployment (e.g., via low carbon fuel policies)—minimizes dependence on aggressive technological breakthroughs or major shifts in how people travel.

The following aspects are critical components of meeting the reduction target in the HtO Pathway, accounting for nearly 80% of the additional reductions required to reach Half the Oil. These are existing strategies that are extended and/or enhanced beyond existing policy end dates:

- **Travel demand reductions.** The major MPOs in California have agreed to GHG targets through the development of their respective sustainability community strategies in compliance with SB 375, which are set to be implemented by 2035. In the HtO Pathway, California MPOs would need to enhance current measures to achieve about 8% VMT reductions compared to 4.7% expected from the existing plans.
- **Extend vehicle efficiency improvements.** Continuing vehicle efficiency improvements beyond existing policy sunsets are a primary pathway for additional petroleum reductions. ICF increased new light-duty vehicle fuel efficiency for 2026–2030 by levels consistent with MY2020–2025 rates of improvement. For heavy-duty vehicles, we advance the timing of the preferred alternative in the federal July 2015 Phase 2 proposal by several years to achieve greater petroleum reductions (consistent with Alternative 4). Our modeling assumes that the primary medium and heavy-duty vehicle types would have to see fuel consumption reduced by 15–30% in Phase 2 standards, instead of the proposed standards' 12–24% per-mile fuel consumption reductions across the major vehicle categories. This is achieved via the implementation of Alternative 4, which is phased in by 2024 (not 2027); and then increasing fuel reduction incrementally thereafter at a more modest rate of 2.5% per year (which would otherwise flatline for 2028–2030).
- **Extend ZEV sales.** ICF increased the sale of new ZEVs for model years 2026–2030 at a rate of 2.4% per year, compared to the 1.5% per year increase between 2020 and 2025 (based on CARB's likely compliance scenario of the existing ZEV program). This yields a share of 28% of new light-duty vehicle sales in 2030 compared to 15.7% in 2025.

- **Increased alternative fuel use.** We did not explicitly model a more stringent LCFS program; however, the alternative fuel volumes included in the HtO Pathway by 2030 were uniformly higher than those assumed in CARB's illustrative LCFS compliance scenario (which extends to 2025). To achieve alternative fuel volumes that exceed those included in CARB's illustrative LCFS compliance scenario for 2025, it is likely that either a) the LCFS program will need to go beyond its current 10% carbon intensity reduction requirement by 2020 or b) similar measure(s) that support the deployment of low carbon alternative fuels will need to be implemented between 2020 and 2030.

The HtO Pathway also underscores that achieving the Half the Oil target is more than simply "staying the course"; it highlights the value and importance of implementing strategies as soon as possible to help achieve the 2030 target, thereby relieving pressure on the need for more rapid reductions in one particular area or another. These include continued transformation in the transportation fuels market, including production and infrastructure, deployment of alternative fuel vehicles and advanced technologies in the truck and off-road markets. For example:

- Higher blends of ethanol and biodiesel are more constrained by fueling infrastructure than fuel supply; however, ICF notes that the blend levels used in our analysis can be supported through incremental improvements to fueling infrastructure. These improvements can be implemented over time to avoid disruptions to or further volatility in fuel markets. ICF also notes that the increased biodiesel blending will require reconsideration of the Alternative Diesel Fuel (ADF) Rulemaking (discussed in more detail in the Appendix), and that testing on new diesel engines continues to demonstrate that there are no adverse criteria pollutant impacts.
- The HtO Pathway includes the displacement of more than 2 billion gallons of petroleum through the introduction of drop-in biofuels and natural gas. The former will require technological advancements and expansion of existing production capacity, while the latter will require accelerated uptake of natural gas vehicles combined with expanded natural gas fueling infrastructure.
- The introduction of increased electric vehicle charging opportunities can provide significant benefits, but will likely require infrastructure investments to expand (e.g., via utilities and other stakeholders seeking to provide charging solutions) and/or continued technology improvement (e.g., larger and cheaper batteries).
- ICF also finds that ancillary strategies in both the on- and off-road sectors—ranging from the mundane (tire replacement) to the more innovative (e.g., truck platooning)—will help achieve the HtO target. These may have modest impacts individually; however, in aggregate these strategies can reduce petroleum consumption by more than 200 million gallons, equivalent to 5% of the reductions required for California to improve upon the BAU Scenario.[15]

Although the analysis focuses on the implementation and extension of existing strategies and policies, it is highly likely that complementary policies will be needed to achieve the HtO target. For instance, while higher light-duty fuel economy may be technologically achievable, implemented through a federal fuel economy standard or resulting from state greenhouse gas

[15] This is 5% of the reductions achieved beyond the BAU scenario, which represent 26% of total petroleum reductions. In other words, this represents 5%x26%=1.3% of overall petroleum reduction.

tailpipe standards, the actual benefits may differ significantly from forecasts due to changes in the vehicle sales mix (e.g., shifts in preference for light trucks versus passenger cars). State-level policies that provide incentives for more efficient vehicle, like feebates or scrappage programs, can help assure that the regulatory standards will achieve forecasted results in 2030.

In the absence of the HtO Pathway, the other alternative cases—High Electrification/High Efficiency, High Biofuels, and Transportation and Land Use Planning—demonstrate that achieving the HtO target, even when relying on innovation in particular areas, will be very challenging. For instance, the High Efficiency and Electrification Case relies more heavily on vehicle technology innovation (e.g., 60+ mpg vehicles and a more rapid expansion of the ZEV program), the High Biofuels Case relies on rapid increases in biofuel production (>2 billion gallons of drop-in liquid biofuels), and the Transportation and Land Use Planning Case relies on greater reductions in travel demand (a 3.5 fold increase in what is currently in SB 375 targets). These cases characterize broadly what is technically feasible based on existing research and push the upper limits of what may be achievable by 2030. We estimate petroleum reductions in the range of 31–45% for each of these, falling shy of the HtO target. Despite not being able to hit the target, these cases illustrate two sides of the debate: On the one hand, they illustrate that innovation can provide additional assurances that the HtO target can be achieved; on the other hand, they can serve as a cautionary note of relying too heavily on a singular category of strategies given the higher uncertainty that these reductions would be achieved.

4 Oregon

4.1 Summary

Our results for Oregon are presented via the modeling of a single pathway that achieves 50% petroleum reduction by 2030, and three alternative cases that illustrate strong and focused implementation of strategies within a specific category of reductions. These strategies are not intended to endorse or prescribe any policy; they are a quantitative exploration of how Oregon might achieve a 50% off petroleum target. As noted previously, the order of operations in the modeling is consistent with the way that we have presented the strategies in the text. In other words, we first apply travel demand reduction strategies, then apply vehicle efficiency strategies, and finally alternative fuel deployment strategies. The order of operations in the modeling is simply a matter of choice; however, for comparative purposes it is critical that the order of operations be applied consistently across all cases and states. The table below summarizes the four cases considered. These cases do not comprehensively describe all combinations of policies which could achieve a 50% petroleum reduction by 2030; rather, they are intended to describe several instructive approaches to petroleum reduction.

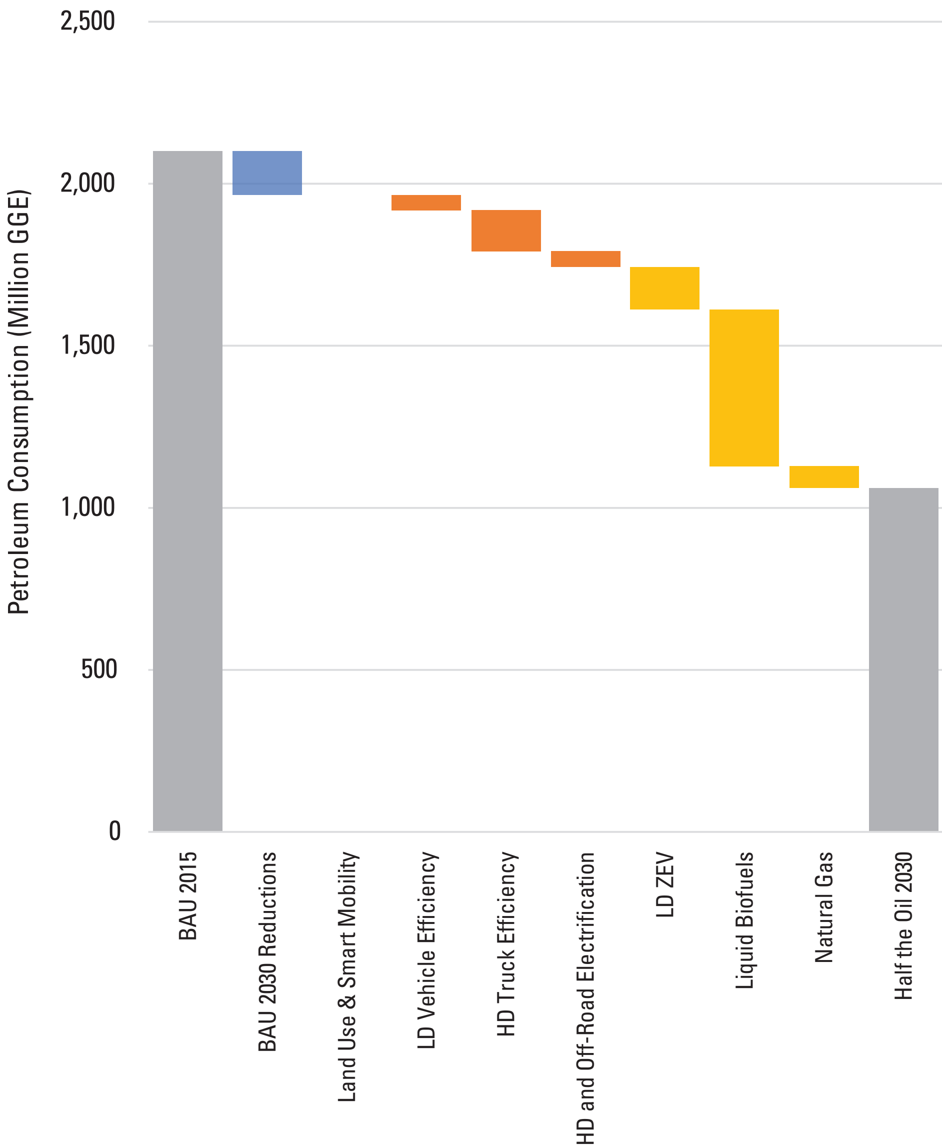
Table 8. Overview of Cases Considered in HtO Analysis

Case	Assumptions
HtO Pathway	Distributes petroleum reductions across each category—travel demand reductions, efficiency improvements, and alternative fuel deployment—as evenly as possible to achieve a 50% petroleum reduction while staying in the conservative or moderate range of possible reductions from a given strategy
In the following three cases, a limited subset of strategies was implemented in the analysis. All other aspects of the modeling were held constant at BAU levels.	
High Efficiency/ High Electrification Case	Focuses on petroleum reduction via efficiency improvements and electrification in light- and heavy-duty vehicles
High Biofuels Case	Focuses on petroleum reduction via combination of increased biofuel blending and increased deployment of drop-in biofuels
Transportation and Land Use Planning Case	Reduces demand for driving by coupling incremental changes in smart mobility and land use planning with other local transportation policy measures

As noted previously, one of the main objectives of this analysis is to characterize the opportunities (via technology, investment, and policy instruments) available to achieve a 50% reduction in transportation sector petroleum consumption by 2030 in California, Oregon, and Washington. This analysis has limited consideration of the economic (e.g., cost) and political barriers that must be overcome to achieve what we consider a challenging goal of 50% petroleum reduction in the next 15 years.

The figure below summarizes the results for Oregon from the HtO Pathway modeled based on the petroleum reductions in various categories to achieve the HtO target.

Figure 9. Petroleum Reductions in Oregon HtO Pathway



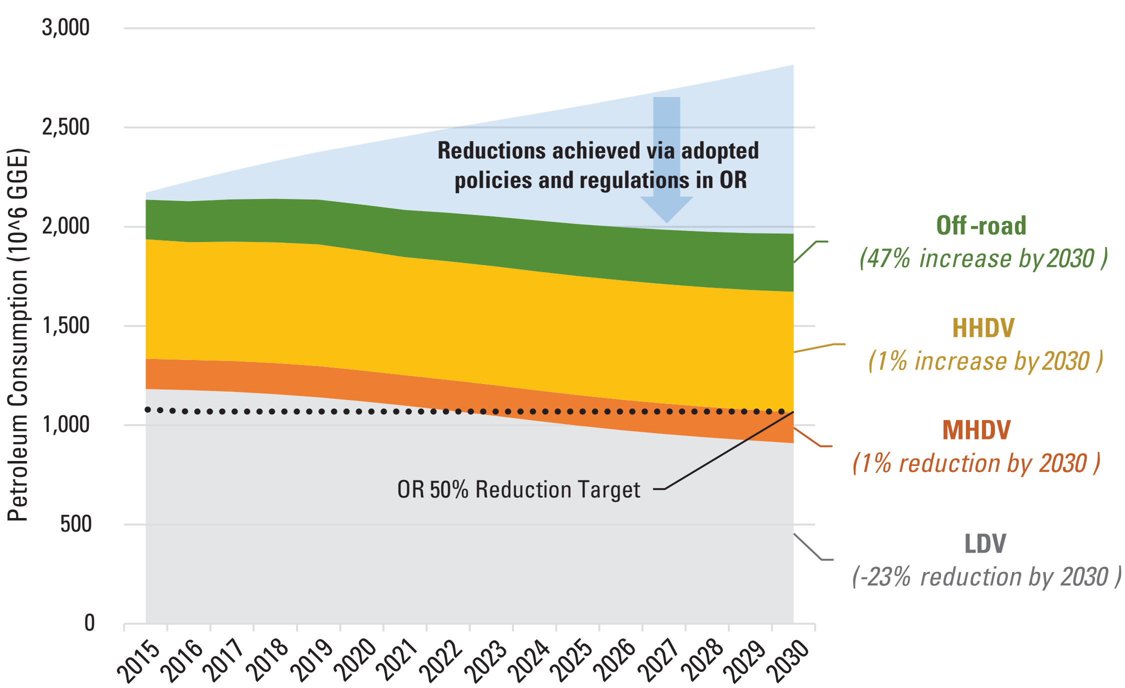
4.2 Petroleum Consumption in Oregon, Business-As-Usual

ICF developed a baseline projection for petroleum consumption in the transportation sector from 2010 to 2030 for Oregon and included the following modes in our assessment:

- On-road
  - Light-duty vehicles (autos and light trucks)
  - Medium- and heavy-duty vehicles
- Off-road
  - Off-road mobile equipment used in construction, agriculture, mining, port cargo handling, etc.
  - Railroad locomotives, both freight and passenger
  - Marine vessels, including ships, commercial harbor craft (e.g., tugs, fishing boats), and recreational boats; for ships, fuel use was limited to that consumed at berth and in port/harbor areas

Oregon consumed about 1.99 billion gasoline gallon equivalents (GGE) of petroleum in 2010 and will consume an estimated 2.14 billion GGE in 2015, as shown in the figure below. ICF's baseline forecasts estimates 1.97 billion GGE in 2030, an 8% reduction from 2015. Petroleum consumption in the Do Nothing Scenario for Oregon, in which there are no travel demand reductions, no improvements in fuel economy from Model Year (MY) 2015 for light- or heavy-duty vehicles, no increase in zero emission vehicle sales, and no implementation of a clean fuels program would be 2.8 billion GGE in 2030. The Appendix includes the data sources and tools that ICF employed to estimate baseline petroleum consumption for on-road and off-road applications.

Figure 10. Forecasted Petroleum Consumption in Oregon (2015–2030; in units of GGE)



The table below includes a summary of the state-specific measures that were included in our analysis of the forecasted BAU scenario for petroleum consumption in Oregon.

Table 9. Description of Measures Included in Oregon's BAU Petroleum Consumption

Category	Measure/Regulation	Implementation in BAU Scenario
Travel Demand Reductions	Land Use Planning, Transportation Policies, and GHG Reductions	• Reductions corresponding to Portland's plan • 5.8% VMT reduction, 2030[16]
Vehicle Efficiency	LD fuel economy standards/GHG tailpipe standards	• Fuel economy of about 30–45 mpg of new light-duty vehicles sold in 2025 and beyond • No assumed improvements post-2025
	MD/HD fuel economy standards	• Fuel economy of about 9 mpg for Class 3–6, 7 mpg for Class 7 and 8 vehicles • No assumed improvements post Phase 1 rulemaking
Alternative Fuels	Zero Emission Vehicle Program	• ZEVs account for 19% of new light-duty vehicles sales in 2025 and beyond • No assumed increases in ZEV sales post-2025
	Clean Fuels Program	• Used ICF's Compliance Scenario 2[17]

The benefits associated with achieving the goals in each of the regulatory programs outlined in the table above are dependent on the corresponding view of compliance. For the most part, regulators have shifted towards market-based mechanisms rather than more traditional command-and-control type initiatives. As a result, there is no "standard" assumption regarding compliance. Making assumptions about compliance via scenarios is challenging, especially in fields, like sustainable transportation, where changes in technology, culture and economies can reshape fundamental principles within relatively short timeframes. This makes quantifying the reductions from market-based mechanisms challenging, even more so when multiple market based mechanisms are considered. The following subsections describe the measures considered in Oregon's BAU Scenario in more detail, summarize the compliance outlook assumed in our modeling, and identify the source of those assumptions.

[16] These VMT reductions are applied exclusively to urban VMT statewide. FHWA statistics from 2013 (the most recent year available) indicate that about 56% of VMT is urban in Oregon. The statistics are available online at online at https://www.fhwa.dot.gov/policyinformation/statistics/2013/vm2.cfm).

[17] ICF International, CFP Analysis for Oregon DEQ, Task 3—Updated Compliance Scenarios, Final Report, August 2014. Note that we used the scenario labeled as S2-B5, indicating that biodiesel was blended with conventional diesel at 5%; an alternative scenario included only B2 i.e., biodiesel blended at 2%.

Transportation and Land Use Planning Strategies

Oregon Sustainable Transportation Initiative (OSTI)

The Oregon Sustainable Transportation Initiative was borne out of Oregon's HB 2001 (2009) and SB 2059 (2010); these regulations are similar to California's SB 735. Oregon's Land Conservation and Development Commission (LCDC) appointed the Target Rulemaking Advisory Committee (TRAC) in 2010 to develop targets and administrative rules. The Metropolitan Area Per Capita Reduction Targets by 2035 (over 2005 levels) are summarized below:

- Portland metropolitan area 20%
- Bend metropolitan planning area 18%
- Corvallis metropolitan planning area 21%
- Eugene-Springfield metropolitan planning area 20%
- Rogue Valley metropolitan planning area 19%
- Salem-Keizer metropolitan planning area 17%

The administrative rules only require the Portland metropolitan area to submit a scenario plan to reach targeted GHG per capita reductions.

ICF implemented the OSTI reductions based on the Portland plan to estimate planned VMT reductions from local transportation planning.

Vehicle Efficiency Strategies

Tailpipe GHG Standards/Light-Duty Fuel Economy Standards

The most recent passenger vehicle standards, covering cars and light trucks, were promulgated by NHTSA and EPA in 2012 for model years 2017 and beyond. The standards are a combination of fuel economy standards (referred to as Corporate Average Fuel Economy standards or CAFE standards)[18] established by NHTSA and greenhouse gas emission standards from the EPA.[19] NHTSA and EPA projected that the fleet-wide on-road fuel economy of new passenger vehicles to be in the range of 40 miles per gallon (mpg) in 2025. Oregon cannot adopt its own standards (per Section 177 of the Clean Air Act), however, it has adpted California's light-duty greenhouse gas standards.

ICF notes that the NHTSA and EPA standards are introduced in two phases, with Phase One applied to model years 2017–2021 and Phase Two applied to model years 2022–2025. The agencies are scheduled to conduct a mid-term review and determine the appropriateness of the Phase Two standards by November 2017, and final decision made in April 2018.

The analysis presented here assumes that the passenger vehicle fuel economy and GHG standards are implemented in both phases as outlined in the 2012 ruling.

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[18] Under the authority of the Energy Policy and Conservation Act (EPCA) and amend by the Energy Independence and Security Act (EISA).

[19] Under the authority of the Clean Air Act.

Medium- and Heavy-Duty Fuel Economy Standards

In August of 2011, NHTSA and EPA finalized new GHG and fuel economy standards for new medium and heavy duty vehicles. New heavy duty big rig trucks must reduce fuel consumption 20%, medium duty trucks are required to reduce fuel consumption by 15% and vocational trucks (delivery, garbage, buses) must reduce consumption 10% by 2018.

In June 2015, NHTSA and EPA proposed Phase 2, covering model years 2021 through 2027; however, we did not include these standards in the BAU Scenario as they are not yet final.

Alternative Fuel Strategies

Oregon's Clean Fuels Program

Oregon's Clean Fuels Program (CFP) is modeled after California's LCFS and is designed to be a flexible market-based mechanism to reduce GHG emissions of transportation fuels on a lifecycle basis. The program officially started on January 1, 2016. The program is implemented using a system of credits and deficits: transportation fuels that have a higher carbon intensity than the compliance schedule yield deficits, and fuels that have a lower carbon intensity generate credits. CFP compliance can be achieved using an array of solutions. Some of the possible pathways to achieve CFP compliance are described here:

- **Lower CI corn ethanol:** In most gasoline markets, ethanol is blended at 10% by volume with gasoline (as an oxygenator to produce reformulated gasoline). Corn ethanol producers can decrease their CI to differentiate themselves from their competitors.
- **Sugarcane ethanol:** Based on its carbon intensity, the availability of supply—as demonstrated by the 500 million gallons imported to the US as recently as 2012—and fuel pricing, sugarcane ethanol will definitely play an important role towards compliance as programs are currently structured. The potential for cross-compliance with the RFS2 at the federal level using Brazilian sugarcane ethanol also serves to increase the likelihood of Brazilian sugarcane ethanol playing a significant part of CFP compliance.
- **Biodiesel:** Biodiesel is blended into conventional diesel at low levels (generally at 5–20%, B5–B20). Biodiesel blended up to 5% by volume can actually be labeled as diesel.
- **Renewable diesel:** Renewable diesel is a drop-in replacement and can be blended into the conventional diesel supply without limitations. The most active player in this market is Neste, who have a large production facility in Singapore that delivers low carbon fuel to the West Coast of the United States.
- **Natural gas:** Natural gas is consumed as compressed (CNG) or liquefied (LNG) as a transportation fuel. It can be sourced from conventional/fossil sources or renewable resources like landfills, wastewater treatment plants, and dairy digesters.
- **Electricity used in plug-in electric vehicles** (both plug-in hybrids like the Chevrolet Volt and full battery electric vehicles like the Nissan LEAF or Tesla Model S) will generate CFP credits, primarily for utilities.

Zero Emission Vehicle Program

Oregon has adopted California's ZEV Program to increase penetration rates of zero emission vehicles to reduce criteria pollutant emissions. The program requires a certain percentage of light duty vehicles sold in Oregon to be ZEVs, which includes battery electric, fuel cell, and transitional zero emission vehicle (TZEVs) like plug-in hybrid electric vehicles. Because of the limited availability of true ZEVs until recently, manufacturers were allowed to comply with the regulations by selling larger numbers of very low emitting vehicles.

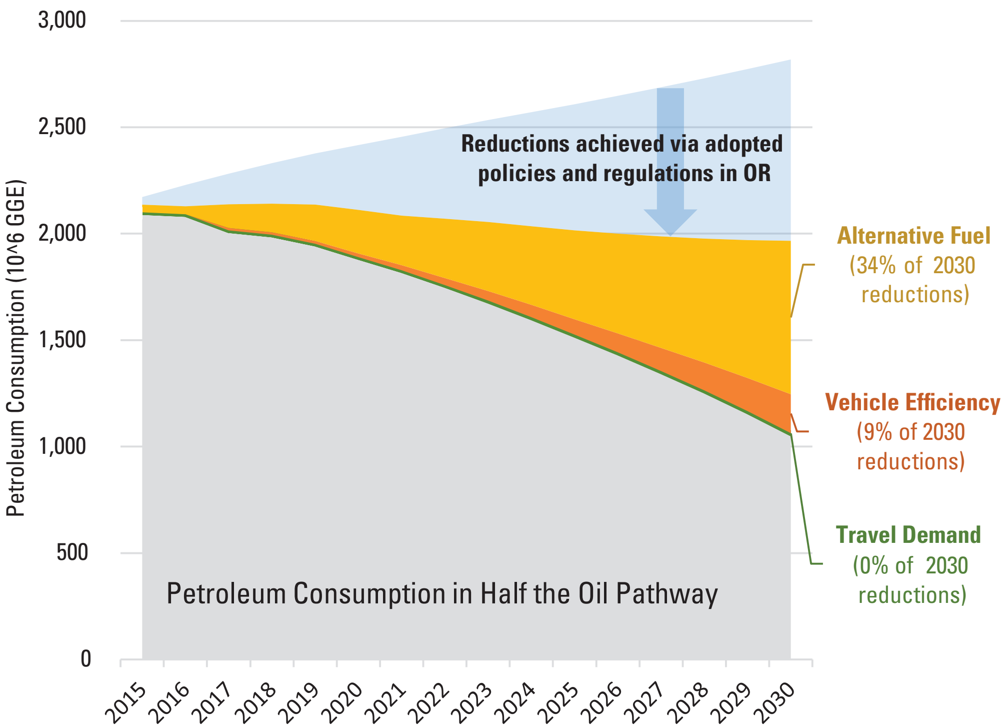
ICF's analysis assumes that the ZEV Program is implemented in Oregon, largely consistent with previous assumptions that were developed in the analysis of the Clean Fuels Program.[20] For years 2018–2025, we assumed that the ZEV program would be implemented similar to CARB's most likely compliance scenario with no fuel cell vehicles (FCVs). The resulting PEV market share is 5.1% in 2018 and increasing to 19% in 2025.

4.3 Petroleum Reduction in Oregon

HtO Pathway in Oregon

The graph below includes the HtO Pathway for Oregon, compared to the BAU Scenario (an 8% reduction from 2015) and the Do Nothing Scenario.

Figure 11. HtO Pathway in Oregon



[20] ICF International, Clean Fuels Program Analysis, Task 2—Updated Business As Usual Scenario, May 2014, Oregon DEQ. Available online at: http://www.oregon.gov/deq/RulesandRegulations/Documents/task2bau.pdf.

The table below summarizes the petroleum reduction strategies that were employed in the HtO Pathway for Oregon, and includes a brief description of how they were implemented.

Table 10. Petroleum Reduction Strategies Implemented in the HtO Pathway, Oregon

Category	Strategy	Description of Petroleum Reduction Strategy Implementation	Petroleum Reduction (MGGE)
Travel Demand Reductions	Smart Mobility and Land Use	• Implemented baseline regional transportation planning measures consistent with BAU; no additional reductions	—
Efficiency	LD efficiency	• Extended existing standards to MY2030 by a sales weighted average of 5% improvement in fuel economy per year • Final sales weighted on-road fuel economy average of ~48 mpg in 2030[21]	37
		• Included fuel efficient replacement tires for vehicles already in the fleet	8
	HD efficiency	• Implemented Phase 2 standards through 2024 using Alternative 4	96
		• Included platooning	26
		• Included hybrid tug boats and ferries	4
	Off-Road efficiency	• Included hybrid tug boats and ferries	9
Alternative Fuels	Zero Emission Vehicles/ Electrification	• Introduced higher ZEV populations starting in 2026 by extending existing sales targets, with a 1.7%/yr increase in new light-duty vehicle sales • Percent of new light duty vehicle sales as ZEVs in 2030: 29.2%	83
		• Increased baseline PHEV eVMT to a weighted utility factor of 75%	48
	HD and Off-Road Electrification	• Included electrified drayage trucks reaching 25% at major ports by 2030	39
	Liquid Biofuels	• Ethanol: Equivalent to 15% blended in gasoline (could also be a mix of E85 and other blend levels)	45
		• Biodiesel: 20% blended into diesel	45
		• Renewable gasoline: 26 million gallons by 2030	26
		• Renewable diesel: Implemented medium-high scenario from ICCT report; 370 million gallons by 2030report; 870 million gallons by 2030	370
	Natural Gas	• Total consumption in 2030: 70 million dge • Implemented volumes from ICF analysis of Clean Fuels Program for OR DEQ • RNG: Implemented ICCT's medium scenario, with 450 million dge in 2030	67
		Total	903
		%Reduction from 2015	50%

[21] This value is presented as the harmonic mean of on-road light-duty vehicle fuel economy.

Oregon, Alternative Petroleum Reduction Cases

High Efficiency and High Electrification Case in Oregon

The table below summarizes the petroleum reduction strategies that were employed in the High Efficiency/High Electrification Case for Oregon, and includes a brief description of how they were implemented.

Table 11. Petroleum Reduction Strategies Implemented in High Efficiency/Electrification Case, Oregon

<table>
<tr><th>Category</th><th>Strategy</th><th>Description of Petroleum Reduction Strategy Implementation</th><th>Petroleum Reduction (MGGE)</th></tr>
<tr><td rowspan="6">Efficiency</td><td rowspan="2">LD efficiency</td><td>• Extended existing standards to MY2030 by a sales weighted average of 7% improvement in fuel economy per year
• Final sales weighted on-road fuel economy average of ~50 mpg in 2030[22]</td><td>43</td></tr>
<tr><td>• Included fuel efficient replacement tires for vehicles already in the fleet</td><td>8</td></tr>
<tr><td rowspan="3">HD efficiency</td><td>• Implemented Phase 2 standards through 2024 using Alternative 4</td><td>96</td></tr>
<tr><td>• Introduced a 4% annual fuel reduction starting with MY2025</td><td>50</td></tr>
<tr><td>• Included platooning</td><td>4</td></tr>
<tr><td>Off-Road efficiency</td><td>• Included hybrid tug boats and ferries</td><td>10</td></tr>
<tr><td rowspan="3">Alternative Fuels</td><td rowspan="2">Zero Emission Vehicles/ Electrification</td><td>• Introduced higher ZEV populations starting in 2026 by enhancing existing sales targets, increase to 2.5% year over year increase, compared to baseline 1.9%/yr increase
• Percent of new light duty vehicle sales as ZEVs in 2030: 37%</td><td>110</td></tr>
<tr><td>• Increased PHEV eVMT to a weighted utility factor of 80%</td><td>60</td></tr>
<tr><td>HD and Off-Road Electrification</td><td>• Incorporated high scenario from IEE for work trucks and delivery vans, equivalent to ~7% of total fleet market share in medium-duty vehicles by 2030
• Included electrified drayage trucks reaching 25% at major ports by 2030
• Included off-road electrification opportunities</td><td>38</td></tr>
<tr><td colspan="3" align="right">Total</td><td>419</td></tr>
<tr><td colspan="3" align="right">%Reduction from 2015</td><td>27%</td></tr>
</table>

High Biofuels Case in Oregon

The table below summarizes the petroleum reduction strategies that were employed in the High Biofuels Case for Oregon, and includes a brief description of how they were implemented.

[22] This value is presented as the harmonic mean of on-road light-duty vehicle fuel economy.

Table 12. Petroleum Reduction Strategies Implemented in High Biofuels Case, Oregon

Category	Strategy	Description of Petroleum Reduction Strategy Implementation	Petroleum Reduction (MGGE)
Alternative Fuels	Liquid Biofuels	• Ethanol: Equivalent to 25% blended in gasoline (could also be a mix of E85 and other blend levels)	130
		• Biodiesel: 20% blended into diesel	40
		• Renewable gasoline: Implemented ICCT's high scenario, 25 million gallons by 2030	30
		• Renewable diesel: Implemented ICCT's high scenario, 370 million gallons by 2030	410
		Total	610
		%Reduction from 2015	39%

Transportation and Land Use Planning Case in Oregon

The table below summarizes the petroleum reduction strategies that were employed in the Transportation and Land Use Planning Case in Oregon, and includes a brief description of how they were implemented.

Table 13. Petroleum Reduction Strategies Implemented in the Transportation and Land Use Planning Case, Oregon

Category	Strategy	Description of Petroleum Reduction Strategy Implementation	Petroleum Reduction (MGGE)
Travel Demand Reductions	Smart Mobility and Land Use	• Implemented smart mobility (TDM, transit and bicycle/pedestrian improvements, carsharing) and compact land use with VMT reductions of 4% and 2%, respectively • Implemented parking pricing, road pricing, and pay as you drive insurance with a VMT reduction of 12% • Weighted average VMT reduction of 21.8% in 2030[23]	155
		%Reduction from 2015	41%

[23] Travel demand reductions are introduced sequentially rather than as a simple sum of travel demand reductions, such that the entire number of travel demand measures, characterized as n, will achieve an overall reduction of $VMT_{reduction}=1-\{(1-VMTi)x(1-VMTi+1) \ldots x(1-VMTn)\}$.

4.4 Discussion

Our analysis employed four cases modeled to illustrate the mix of strategies that could be deployed to achieve the HtO target in Oregon. As noted previously, this analysis is intended to be descriptive rather than prescriptive; further, it is not intended to be a comprehensive review of every possible petroleum reduction strategy. Rather, through the four cases outlined previously, it describes the potential reductions from combinations of policies which are well-characterized by current literature and whose effects can be estimated in the 2030 timeframe with reasonable accuracy.

The HtO Pathway highlights that by extending and, in some cases, accelerating strategies employed today offers a pathway to achieve the Half the Oil target. Moving forward with in all three strategy areas—including sustainable community planning, improved vehicle efficiency, and alternative fuel deployment (e.g., via low carbon fuel policies)—minimizes dependence on aggressive technological breakthroughs or major shifts in how people travel.

The following aspects are critical components of meeting the HtO target in the HtO Pathway, accounting for more than 60% of the additional reductions need to reach Half the Oil. These are existing strategies that are extended and/or enhanced beyond existing policy end dates:

- **Extend vehicle efficiency improvements.** Continuing vehicle efficiency improvements beyond existing policy sunsets are a primary pathway for additional petroleum reductions. ICF increased new light-duty vehicle fuel efficiency for 2026–2030 by levels consistent with MY2020–2025 rates of improvement. For heavy-duty vehicles, we advance the timing of the preferred alternative in the federal July 2015 Phase 2 proposal by several years to achieve greater petroleum reductions (consistent with Alternative 4). Our modeling assumes that the primary medium and heavy-duty vehicle types would have to see fuel consumption reduced by 15–30% in Phase 2 standards, instead of the proposed standards' 12–24% per-mile fuel consumption reductions across the major vehicle categories. This is achieved via the implementation of Alternative 4, which is phased in by 2024 (not 2027); and then increasing fuel reduction incrementally thereafter at a more modest rate of 2.5% per year (which would otherwise flat-line for 2028–2030).
- **Extend ZEV sales.** ICF increased the sale of new ZEVs for model years 2026–2030 at a rate of 2.5% per year, compared to the 1.9% per year increase between 2020 and 2025 (based on a version of CARB's likely compliance scenario of the existing ZEV program, modified based on Oregon's light-duty vehicle market). This yields a share of 29.2% of new light-duty vehicle sales in 2030 compared to 19% in 2025.
- **Increased alternative fuel use.** We did not explicitly model a more stringent CFP; however, the alternative fuel volumes included in the HtO Pathway by 2030 were uniformly higher than those assumed in any of the CFS scenarios developed by ICF for the Oregon DEQ. To achieve alternative fuel volumes that exceed those included in ICF's analysis for OR DEQ, it is likely that either a) the CFP will need to go beyond its current 10% carbon intensity reduction requirement by 2025 or b) similar measure(s) that support the deployment of low carbon alternative fuels will need to be implemented between 2020 and 2030.

The HtO Pathway also underscores that achieving the Half the Oil target is more than simply "staying the course"; it highlights the value and importance of implementing strategies as soon as possible to help achieve the 2030 target, thereby relieving pressure on the need for more rapid reductions in one particular area or another. These include continued transformation in the transportation fuels market, including production and infrastructure, deployment of alternative fuel vehicles and advanced technologies in the truck and off-road market. For example:

- Higher blends of ethanol and biodiesel are more constrained by fueling infrastructure than fuel supply; however, ICF notes that the blend levels used in our analysis can be supported through incremental improvements to fueling infrastructure. These improvements can be implemented over time to avoid disruptions to or further volatility in fuel markets.
- The HtO Pathway includes the displacement of about 500 million gallons of petroleum through the introduction of drop-in biofuels and natural gas. The former will require technological advancements and expansion of existing production capacity, while the latter will require accelerated uptake of natural gas vehicles combined with expanded natural gas fueling infrastructure.
- The introduction of increased electric vehicle charging opportunities can provide significant benefits, but will likely require infrastructure investments to expand (e.g., via utilities and other stakeholders seeking to provide charging solutions) and/or continued technology improvement (e.g., larger and cheaper batteries).
- ICF also finds that ancillary strategies in both the on- and off-road sectors—ranging from the mundane (tire replacement) to the more innovative (e.g., truck platooning)—will help achieve the HtO target. These may have modest impacts individually; however, in aggregate these strategies can reduce petroleum consumption by more than 20 million gallons, equivalent to 5% of the reductions required for Oregon to improve upon the BAU scenario.[24]

Although the analysis focuses on the implementation and extension of existing strategies and policies, it is highly likely that complementary policies will be needed to achieve the HtO target. For instance, while higher light-duty fuel economy may be technologically achievable, implemented through a federal fuel economy standard or resulting from state greenhouse gas tailpipe standards, the actual benefits may differ significantly from forecasts due to changes in the vehicle sales mix (e.g., shifts in preference for light trucks versus passenger cars). State-level policies that provide incentives for more efficient vehicle, like feebates or scrappage programs, can help assure that the regulatory standards will achieve forecasted results in 2030.

In the absence of the HtO Pathway, the other alternative cases—High Electrification/High Efficiency, High Biofuels, and Transportation and Land Use Planning—demonstrate that achieving the HtO target will rely more significantly on innovation in particular areas. For instance, the High Electrification/High Efficiency Case relies more heavily on vehicle technology innovation (e.g., 60+ mpg vehicles and a more rapid expansion of the ZEV program), the High Biofuels Case relies on rapid increases in biofuel production (>2 billion gallons of drop-in liquid biofuels), and the

[24] This is 2% of the reductions achieved beyond the scenario, which represent 42% of total petroleum reductions. In other words, this represents 2%x42%=0.8% of overall petroleum reduction.

Transportation and Land Use Planning Case relies on greater reductions in travel demand (a two-fold increase in what is currently in OSTI targets). These cases characterize broadly what is technically feasible based on existing research and push the upper limits of what may be achievable by 2030. We estimate petroleum reductions in the range of 14–39% for each of these, falling shy of the HtO target. Despite not being able to hit the target, these cases illustrate two sides of the debate: On the one hand, they illustrate that innovation can provide additional assurances that the HtO target can be achieved; on the other hand, they can serve as a cautionary note of relying too heavily on a singular category of strategies given the higher uncertainty that these reductions would be achieved.

5 Washington

5.1 Summary

Our results for Washington are presented via the modeling of a single pathway that achieves 50% petroleum reduction by 2030, and three alternatives that illustrate strong and focused implementation of strategies within a specific category of reductions. These strategies are not intended to endorse or prescribe any policy; they are a quantitative exploration of how Washington might achieve a 50% petroleum reduction target. As noted previously, the order of operations in the modeling is consistent with the way that we have presented the strategies in the text. In other words, we first apply travel demand reduction strategies, then apply vehicle efficiency strategies, and finally alternative fuel deployment strategies. The order of operations in the modeling is simply a matter of choice; however, for comparative purposes it is critical that the order of operations be applied consistently across all cases and states. The table below summarizes the four cases considered. These cases do not comprehensively describe all combinations of policies which could achieve a 50% petroleum reduction by 2030; rather, they are intended to describe several instructive approaches to petroleum reduction.

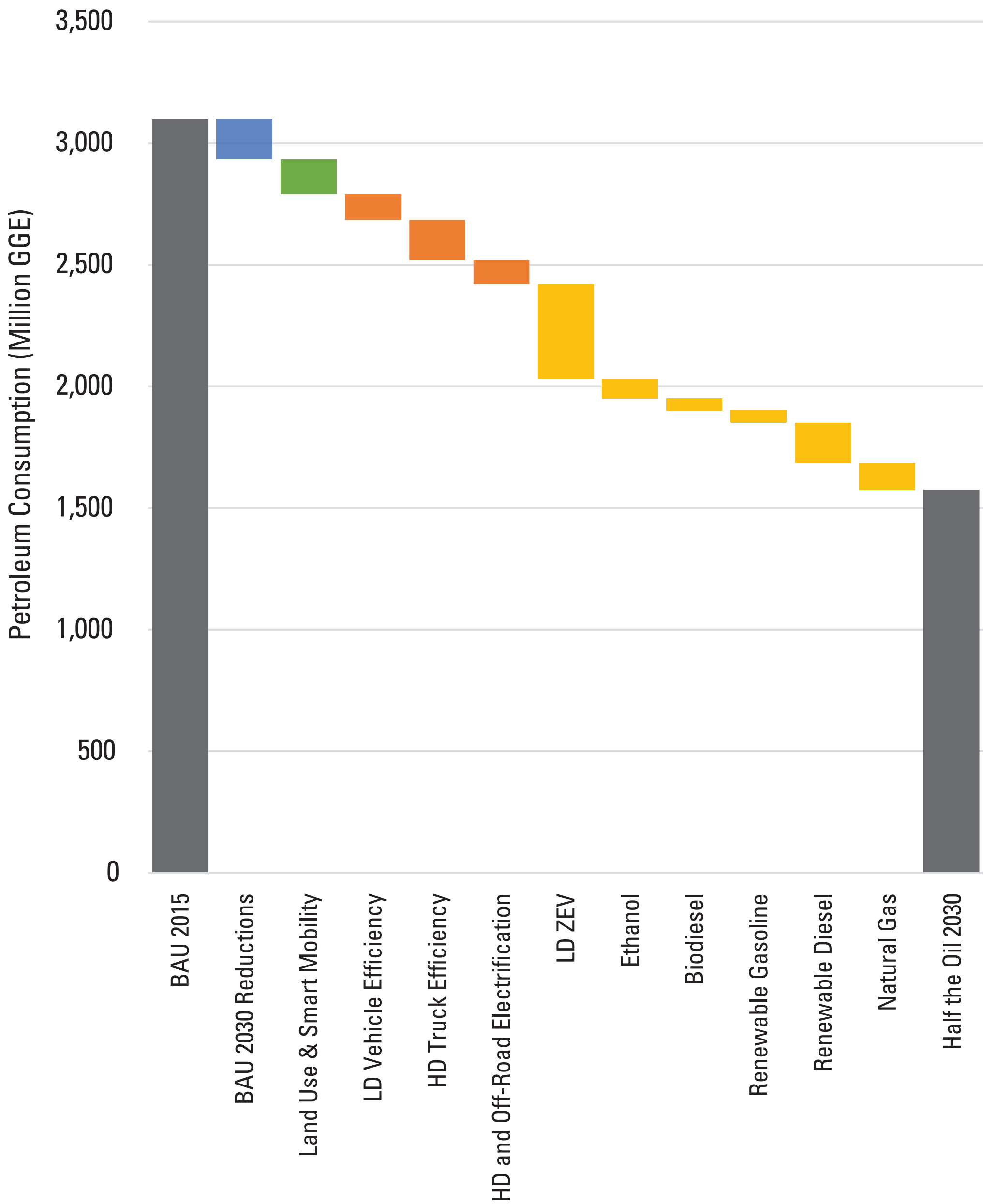
Table 14. Overview of Cases Considered in HtO Analysis

Case	Assumptions
HtO Pathway	Distributes petroleum reductions across each category—travel demand, efficiency improvements, and alternative fuel deployment—as evenly as possible to achieve a 50% petroleum reduction while staying in the conservative or moderate range of possible reductions from a given strategy
In the following three cases, a limited subset of strategies was implemented in the analysis. All other aspects of the modeling were held constant at BAU levels.	
High Efficiency/ High Electrification Case	Focuses on petroleum reduction via efficiency improvements and electrification in light- and heavy-duty vehicles
High Biofuels Case	Focuses on petroleum reduction via combination of increased biofuel blending and increased deployment of drop-in biofuels
Transportation and Land Use Planning Case	Reduces demand for driving by coupling incremental changes in smart mobility and land use planning with other local transportation policy measures

As noted previously, one of the main objectives of this analysis is to characterize the opportunities (via technology, investment, and policy instruments) available to achieve a 50% reduction in transportation sector petroleum consumption by 2030 in California, Oregon, and Washington. This analysis has limited consideration of the economic (e.g., cost) and political barriers that must be overcome to achieve what we consider a challenging goal of 50% petroleum reduction in the next 15 years.

The figure below summarizes the results for Washington from the HtO Pathway modeled based on the petroleum reductions in various categories to achieve the HtO target.

Figure 12. Petroleum Reductions in Washington HtO Pathway



5.2 Petroleum Consumption in Washington, Business-As-Usual

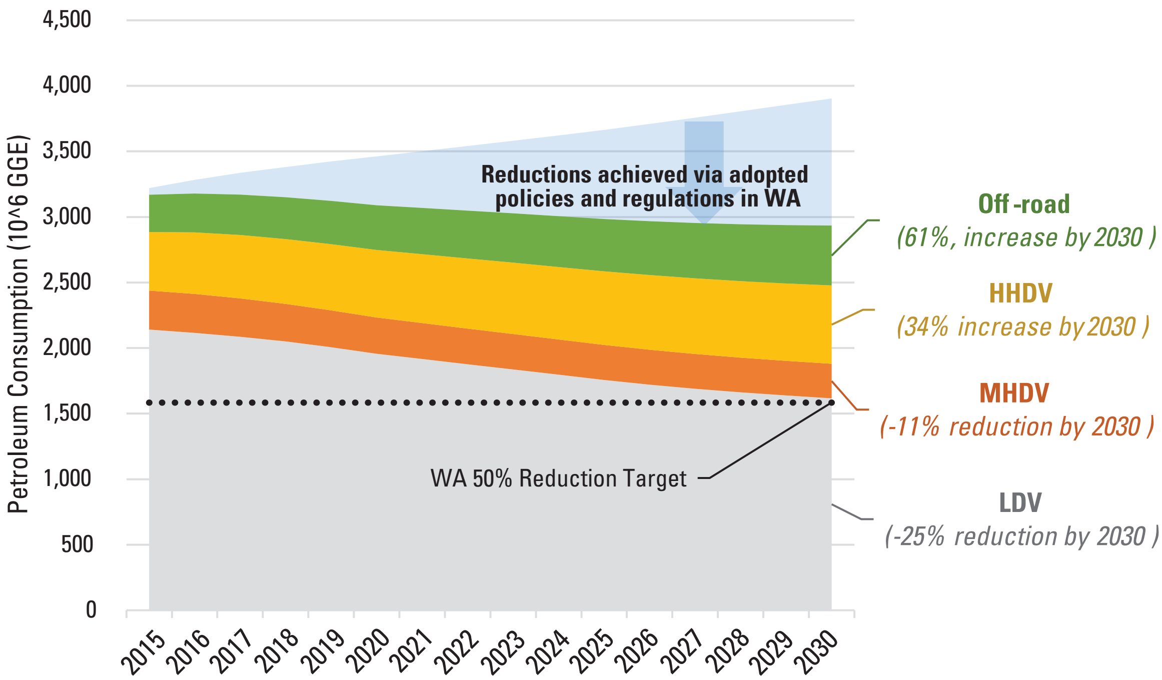
ICF developed a baseline projection for petroleum consumption in the transportation sector from 2010 to 2030 for Washington and included the following modes in our assessment:

- On-road
  - Light-duty vehicles (autos and light trucks)
  - Medium- and heavy-duty vehicles
- Off-road
  - Off-road mobile equipment used in construction, agriculture, mining, port cargo handling, etc.
  - Railroad locomotives, both freight and passenger
  - Marine vessels, including ships, commercial harbor craft (e.g., tugs, fishing boats), and recreational boats; for ships, fuel use was limited to that consumed at berth and in port/harbor areas

Washington consumed about 3.4 billion GGE of petroleum in 2010 and will consume an estimated 3.2 billion GGE in 2015, as shown in the figure below. ICF's baseline forecasts estimates 2.9 billion GGE in 2030, a 7.5% reduction from 2015. ICF developed a BAU Scenario considering existing measures in Washington as well as an illustrative Do Nothing Scenario, in which there are no travel demand reductions, no improvements in fuel economy from Model Year (MY) 2015 for light- or heavy-duty vehicles, and no increase in zero emission vehicle sales. The Appendix includes the data sources and tools that ICF employed to estimate baseline petroleum consumption for on-road and off-road applications.

As shown in the figure below, ICF's baseline forecasts estimates 2.9 billion GGE in 2030, a 7.5% reduction from 2015. This is equivalent to a 25% reduction in petroleum consumption from the Do Nothing Scenario for Washington, which would otherwise be 3.9 billion GGE in 2030.

Figure 13. Forecasted Petroleum Consumption in Washington (2015–2030; in units of GGE)



The table below includes a summary of the state-specific measures that were included in our analysis of the forecasted BAU scenario for petroleum consumption in Washington.

Table 15. Description of Measures Included in Washington's BAU Petroleum Consumption

Category	Measure/ Regulation	Implementation in BAU Scenario
Vehicle Efficiency	LD fuel economy standards/ GHG tailpipe standards	• Fuel economy of about 30–45 mpg of new light-duty vehicles sold in 2025 and beyond • No assumed improvements post-2025
	MD/HD fuel economy standards	• Fuel economy of about 9 mpg for Class 3–6, 7 mpg for Class 7 and 8 vehicles • No assumed improvements post Phase 1 rulemaking

The benefits associated with achieving the goals in each of the regulatory programs outlined in the table above are dependent on the corresponding view of compliance. For the most part, regulators have shifted towards market-based mechanisms rather than more traditional command-and-control type initiatives. As a result, there is no "standard" assumption regarding compliance. Making assumptions about compliance via scenarios is challenging, especially in fields, like sustainable transportation, where changes in technology, culture and economies can reshape fundamental principles within relatively short timeframes. This makes quantifying the reductions from market-based mechanisms challenging, even more so when multiple market based mechanisms are considered. The following subsections describe the measures considered in Washington's BAU Scenario in more detail, summarize the compliance outlook assumed in our modeling, and identify the source of those assumptions.

Transportation and Land Use Planning Strategies

ICF finds that while there are certainly measures in place for Washington that will likely reduce VMT, and petroleum consumption in the light-duty vehicle sector through providing alternatives to car travel, there is a dearth of information regarding what the programs may look like and how they will impact VMT. As a result, we have not modeled any VMT reductions in Washington.[25]

Vehicle Efficiency Strategies

Tailpipe GHG Standards/Light-Duty Fuel Economy Standards

The most recent passenger vehicle standards, covering cars and light trucks, were promulgated by NHTSA and EPA in 2012 for model years 2017 and beyond. The standards are a combination of fuel economy standards (referred to as Corporate Average Fuel Economy standards or CAFE standards)[26] established by NHTSA and greenhouse gas emission standards from the EPA.[27] NHTSA and EPA projected that the fleet-wide on-road fuel economy of new passenger vehicles to be in the range of 40 miles per gallon (mpg) in 2025. Washington cannot adopt its own standards (per Section 177 of the Clean Air Act), however, it has adopted California's light-duty greenhouse gas standards.

ICF notes that the NHTSA and EPA standards are introduced in two phases, with Phase One applied to model years 2017–2021 and Phase Two applied to model years 2022–2025. The agencies are scheduled to conduct a mid-term review and determine the appropriateness of the Phase Two standards by November 2017, and final decision made in April 2018.

The analysis presented here assumes that the passenger vehicle fuel economy and GHG standards are implemented in both phases as outlined in the 2012 ruling.

Medium- and Heavy-Duty Fuel Economy Standards

In August of 2011, NHTSA and EPA finalized new GHG and fuel economy standards for new medium- and heavy-duty vehicles. New heavy-duty big rig trucks must reduce fuel consumption by 20%, medium-duty trucks are required to reduce fuel consumption by 15% and vocational trucks (delivery, garbage, buses) must reduce fuel consumption by 10% by 2018.

In June 2015, NHTSA and EPA proposed Phase 2, covering model years 2021 through 2027; however, we did not include these standards in the BAU Scenario as they are not yet final.

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[25] Note that the absence of VMT reductions appears to be consistent with OFM's analysis of the potential Clean Fuels Standard, conducted by Life Cycle Associates and Jack Faucett Associates.

[26] Under the authority of the Energy Policy and Conservation Act (EPCA) and amend by the Energy Independence and Security Act (EISA).

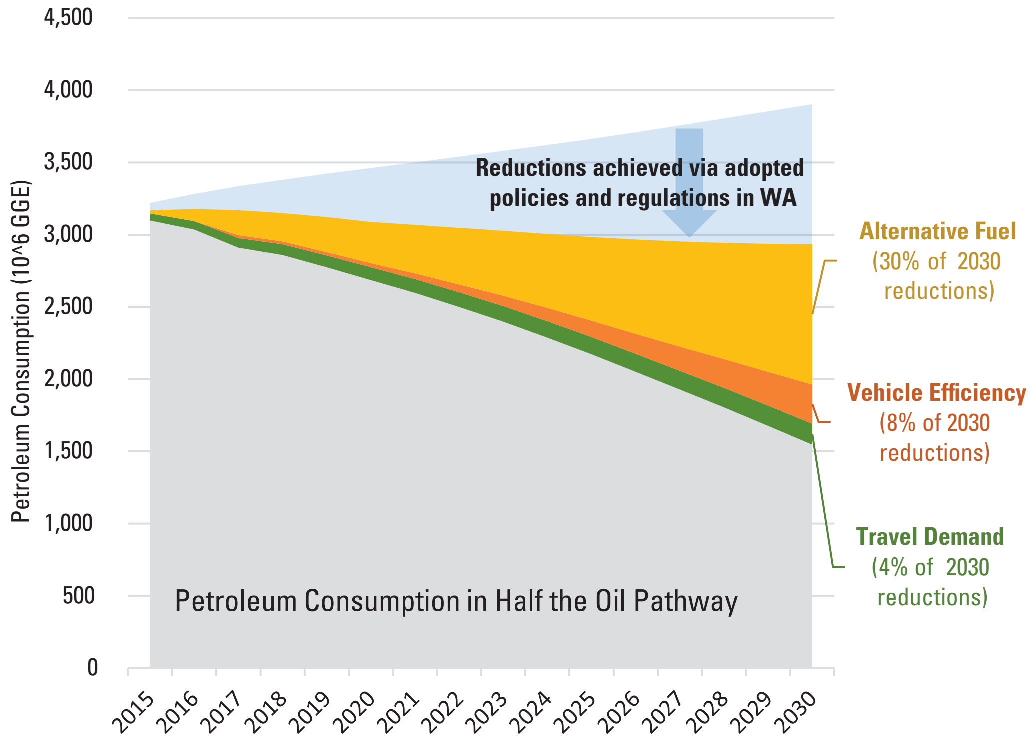
[27] Under the authority of the Clean Air Act.

5.3 Petroleum Reductions in Washington

HtO Pathway in Washington

The graph below includes the HtO Pathway for Washington, compared to the BAU Scenario (a 7.5% reduction from 2015) and the Do Nothing Scenario.

Figure 14. HtO Pathway in Washington



The table below summarizes the petroleum reduction strategies that were employed in the HtO Pathway for Washington, and includes a brief description of how they were implemented.

Table 16. Petroleum Reduction Strategies Implemented in the HtO Pathway, Washington

Category	Strategy	Description of Petroleum Reduction Strategy Implementation	Petroleum Reduction (MGGE)
Travel Demand Reductions	Smart Mobility and Land Use	• Implemented regional transportation planning measures, achieving a weighted average VMT reduction of 9%[28]	145
Efficiency	LD efficiency	• Extended existing standards to MY2030 by a sales weighted average of 5% improvement in fuel economy per year • Final sales weighted on-road fuel economy average of ~48 mpg in 2030[29]	90
		• Included fuel efficient replacement tires for vehicles already in the fleet	14
	HD efficiency	• Implemented Phase 2 standards through 2024 using Alternative 4	108
		• Introduced a 2.5% annual fuel reduction starting with MY2025	26
		• Included platooning	3
	Off-Road efficiency	• Included hybrid tug boats and ferries	29
Alternative Fuels	Zero Emission Vehicles/ Electrification	• Assumed introduction of ZEV Program in Washington • Introduced higher ZEV populations starting in 2026 by extending program with a 1.8%/yr increase • Percent of new light duty vehicle sales as ZEVs in 2030: 26.4%	387
		• Introduced PHEV eVMT at a weighted utility factor of 40%	2
	HD and Off-Road Electrification	• Included electrified drayage trucks reaching 25% at major ports by 2030	100
	Liquid Biofuels	• Ethanol: Equivalent to 15% blended in gasoline (could also be a mix of E85 and other blend levels)	80
		• Biodiesel: 15% blended into diesel	50
		• Renewable gasoline: 50 million gallons by 2030	50
		• Renewable diesel: Implemented average of medium and medium-high scenarios from ICCT report; 165 million gallons by 2030	165
	Natural Gas	• Total consumption in 2030: 110 million dge • Fossil gas: Implemented volumes at 4 times the level from Washington's CFS analysis, Scenario D • RNG: Implemented values consistent with ICCT report, 51 million dge	110
		Total	1.390
		%Reduction from 2015	50%

[28] VMT reductions are introduced sequentially rather than as a simple sum of VMT reductions, such that the entire number of VMT measures, characterized as n, will achieve an overall reduction of $VMT_{reduction}$=1-{(1-VMTi)x(1-VMTi+1) …x(1-VMTn)}.

[29] This value is presented as the harmonic mean of on-road light-duty vehicle fuel economy.

Washington, Alternative Petroleum Reduction Cases

High Efficiency and High Electrification Case in Washington

The table below summarizes the petroleum reduction strategies that were employed in the High Efficiency/High Electrification Case for Washington, and includes a brief description of how they were implemented.

Table 17. Petroleum Reduction Strategies Implemented in the High Efficiency/ Electrification Case, Washington

Category	Strategy	Description of Petroleum Reduction Strategy Implementation	Petroleum Reduction (MGGE)
Efficiency	LD efficiency	• Extended existing standards to MY2030 by a sales weighted average of 7% improvement in fuel economy per year • Final sales weighted on-road fuel economy average of ~56 mpg in 2030[30]	185
		• Included fuel efficient replacement tires for vehicles already in the fleet	15
	HD efficiency	• Implemented Phase 2 standards through 2024 using Alternative 4	110
		• Introduced a 4% annual fuel reduction starting with MY2025	70
		• Included platooning	3
	Off-Road efficiency	• Included hybrid tug boats and ferries	30
Alternative Fuels	Zero Emission Vehicles/ Electrification	• Assumed introduction of ZEV Program in Washington • Introduced higher ZEV populations starting in 2026 by enhancing existing sales targets, increase to 1.7% year over year increase, compared to baseline 0.7%/yr increase • Percent of new light duty vehicle sales as ZEVs in 2030: 28.1%	365
		• Increased PHEV eVMT to a weighted utility factor of 80%	70
	HD and Off-Road Electrification	• Incorporated high scenario from IEE for work trucks and delivery vans, equivalent to ~7% of total fleet market share in medium-duty vehicles by 2030 • Included electrified drayage trucks reaching 25% at major ports by 2030 • Included off-road electrification opportunities	100
		Total	950
		%Reduction from 2015	38%

High Biofuels Case in Washington

The table below summarizes the petroleum reduction strategies that were employed in the High Biofuels Case for Washington, and includes a brief description of how they were implemented.

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[30] This value is presented as the harmonic mean of on-road light-duty vehicle fuel economy.

Table 18. Petroleum Reduction Strategies Implemented in the High Biofuels Case, Washington

Category	Strategy	Description of Petroleum Reduction Strategy Implementation	Petroleum Reduction (MGGE)
Alternative Fuels	Liquid Biofuels	• Ethanol: Equivalent to 25% blended in gasoline (could also be a mix of E85 and other blend levels)	235
		• Biodiesel: 20% blended into diesel	175
		• Renewable gasoline: Implemented ICCT's high scenario, 50 million gallons by 2030	50
		• Renewable diesel: Implemented an average of medium-high and high scenarios from ICCT report; 285 million gallons by 2030	330
	Natural Gas	• Total consumption in 2030: 60 million dge • RNG: Implemented values consistent with high scenario from ICCT report, 60 million dge in 2030	70
		Total	860
		%Reduction from 2015	35%

Transportation and Land Use Planning Case in Washington

The table below summarizes the petroleum reduction strategies that were employed in the Transportation and Land Use Planning Case for Washington, and includes a brief description of how they were implemented.

Table 19. Petroleum Reduction Strategies Implemented in the Transportation and Land Use Planning Case, Washington

Category	Strategy	Description of Petroleum Reduction Strategy Implementation	Petroleum Reduction (MGGE)
Travel Demand Reductions	Smart Mobility and Land Use	• Implemented smart mobility (TDM, transit and bicycle/pedestrian improvements, carsharing) and compact land use with VMT reductions of 5.2% and 4%, respectively • Implemented parking pricing, road pricing, and pay as you drive insurance at a combined VMT reduction of 12% • Weighted average VMT reduction of 19.5% in 2030[31]	315
		%Reduction from 2015	14%

[31] VMT reductions are introduced sequentially rather than as a simple sum of VMT reductions, such that the entire number of VMT measures, characterized as n, will achieve an overall reduction of $VMT_{reduction}=1-\{(1-VMTi)x(1-VMTi+1) \ldots x(1-VMTn)\}$.

5.4 Discussion

Our analysis employed four cases modeled to illustrate the mix of strategies that could be deployed to achieve HtO targets in Washington. As noted previously, this analysis is intended to be descriptive rather than prescriptive; further, it is not intended to be a comprehensive review of every possible petroleum reduction strategy. Rather, through the four cases outlined previously, it describes the potential reductions from combinations of policies which are well-characterized by current literature and whose effects can be estimated in the 2030 timeframe with reasonable accuracy.

Achieving HtO targets in Washington will require significant changes in policies and the introduction of several policy mechanisms. For instance:

- **Travel demand reductions.** Washington does have laws that link land use planning to GHG or VMT reductions, but these laws are focused on local planning, not regional planning as in California and Oregon. Further, they do not have as strong of links to the transportation planning and funding process. On the land use planning side, Washington has far more robust and sustainable land use planning than most states—better than California, but not as good as Oregon—via its Growth Management Act (GMA), and SB 6580 enacted GHG targets via the GMA. So while Washington does link GHG emissions to land use planning, the GMA focuses on local governments, not regional governments. Based on ICF's review, the follow-up on the climate-related portions of the legislation has not been as robust as in California or Oregon, and we found very few specific actions focused on local incentives and penalties for localities that do or do not meet targets coming out of the state. Without some enforcement mechanism or improved link between planning and GHG or VMT reductions, it is highly unlikely that Washington will achieve an HtO target.
- **Alternative fuel deployment, zero emission vehicles.** In each of the four cases, ICF assumed the introduction of a ZEV Program; Washington has not adopted CARB's ZEV Program to date. This yields significant petroleum savings for Washington, accounting for nearly 30% of reductions in 2030.
- **Alternative fuel deployment, alternative fuels including liquid and gaseous fuels and electricity.** Washington does not have a low carbon fuel standard program akin to California's LCFS or Oregon's CFP. Washington does have a renewable fuel standard (via ESSB 6508), that went into effect in 2008. However, the bill was silent on the appropriate enforcement mechanism and there is wide recognition that the mandate is unenforceable.[32] In order to achieve the deployment of alternative fuels in any one of the cases considered, it is likely that some sort of program, whether it be a blending requirement or more flexible program like a low carbon fuel standard, will have to be implemented and enforced.

These three elements—travel demand reductions, a ZEV program, and alternative fuel deployment—account for about 65–70% of petroleum reductions in the HtO Pathway. Based on our analysis, there are still complementary policies and strategies that can be pursued; however,

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32 And for this reason was not included in the BAU Scenario, for instance.

without these top-level policy mechanisms in place, the HtO targets are near-impossible to reach. The HtO Pathway does demonstrate that Washington does not need to implement programs that are out of line with expectations in other states e.g., California and Oregon.

In the absence of the HtO Pathway, the other cases—High Electrification/High Efficiency , High Biofuels, and Transportation and Land Use Planning—demonstrate that achieving the HtO target will rely more significantly on innovation in particular areas. In the case of Washington, there is a cautionary note in these cases: that without a more diversified approach, there is the risk of relying too heavily on a singular category of strategies given the higher uncertainty that these reductions would be achieved.

Appendix

Petroleum Reduction Strategies

ICF's analysis of the HtO target is based on the combination of strategies within three distinct categories:

- **Travel demand reductions.** ICF considered an array of strategies designed to reduce light-duty vehicle travel, primarily by offering consumers alternatives and incentives to reduce dependence on single-occupancy vehicles. These strategies combine the improved transportation choices for consumers (smart mobility) with improved land use planning, and pricing measures.
- **Vehicle efficiency improvements.** ICF considered the potential to increase internal combustion engine vehicle efficiency for new and existing light-, medium-, and heavy-duty vehicles.
- **Alternative fuel deployment.** ICF considered the potential for the increased deployment of alternative fuels, including zero emission vehicles (electricity and hydrogen fuel cell vehicles), natural gas, and liquid biofuels.

ICF implemented these strategies in the order that they are presented above.

The subsections below outline the specific strategies considered, the rationale for including them, the extent to which they were implemented, and where appropriate, a description of how the strategy was implemented in ICF's modeling. Generally, the text in the following subsections characterizes a range of petroleum reduction potential for each strategy based on ICF's review of relevant literature, with a description of how the literature was incorporated or modified into this analysis.

The discussion in this section is limited exclusively to the petroleum reduction potential of individual strategies; the sections above in the body of the report (Sections 3–5) outline which of these strategies were bundled and how they were implemented to reach the HtO target in California, Oregon, and Washington, respectively. ICF notes that the strategies are included and varied within the constraints and bounds specified in the subsections below, or excluded entirely from the analysis. Furthermore, we note that the list of strategies considered is not exhaustive, but is intended to capture the most significant measures available to reduce petroleum consumption, and those most supported in the literature.

Existing Measures in All Business As Usual Scenarios

ICF developed a Business As Usual (BAU) Scenarios for each state to demonstrate what the estimated petroleum reductions in 2030 would be based on the measures in place today. The following vehicle efficiency measures were implemented across all three states (California, Oregon, and Washington). The state-specific measures are discussed in Sections 3-5 in the body of the report.

Tailpipe GHG Standards/Light-Duty Fuel Economy Standards

The most recent passenger vehicle standards, covering cars and light trucks, were promulgated by NHTSA and EPA in 2012 for model years 2017 and beyond. The standards are a combination of fuel economy standards (referred to as Corporate Average Fuel Economy standards or CAFE standards)[33] established by NHTSA and greenhouse gas emission standards from the EPA.[34] NHTSA and EPA projected that the fleet-wide on-road fuel economy of new passenger vehicles to be in the range of 40 miles per gallon (mpg) in 2025. California, under Clean Air Act authority, has also adopted light-duty greenhouse gas standards which are consistent with federal fuel economy and greenhouse gas standards.

ICF notes that the NHTSA and EPA standards are introduced in two phases, with Phase One applied to model years 2017–2021 and Phase Two applied to model years 2022–2025. The agencies are scheduled to conduct a mid-term review and determine the appropriateness of the Phase Two standards by November 2017, and final decision made in April 2018.

The analysis presented here assumes that the passenger vehicle fuel economy and GHG standards are implemented in both phases as outlined in the 2012 ruling.

Medium- and Heavy-Duty Fuel Economy Standards

In August of 2011, NHTSA and EPA finalized new GHG and fuel economy standards for new medium- and heavy-duty vehicles. New heavy-duty big rig trucks must reduce fuel consumption by 20%, medium-duty trucks are required to reduce fuel consumption by 15% and vocational trucks (delivery, garbage, buses) must reduce fuel consumption by 10% by 2018. California, under Clean Air Act authority has also adopted heavy-duty greenhouse gas standards which are consistent with federal fuel economy and greenhouse gas standards.

In June 2015, NHTSA and EPA proposed Phase 2, covering model years 2021 through 2027; however, we did not include these standards in the BAU Scenario as they are not yet final.

Transportation and Land Use Planning

Petroleum consumption can be cut by reducing the demand for transportation. Urban areas can accomplish this through land-use planning, such as locating services near residential areas, and offering or incentivizing alternatives to cars, such as mass-transit or non-motorized options. This has the effect of reducing total VMT, which leads to less petroleum consumption.

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33 Under the authority of the Energy Policy and Conservation Act (EPCA) and amend by the Energy Independence and Security Act (EISA).

34 Under the authority of the Clean Air Act.

The strategies in this subsection are limited to those that reduce the demand for travel in light-duty vehicles, which is reflected in the model through reduced VMT in the light-duty sector. ICF implemented VMT reductions in the modeling in two broad ways:

- We coupled additional travel demand reductions with those already outlined in existing regional and state plans.
- We introduced additional travel demand reductions characterized as regional transportation planning measures.

State-level VMT is distinguished further by urban and rural VMT; some strategies apply to both urban and rural VMT, while others apply only to urban VMT.

ICF notes that there are VMT reduction opportunities in the medium- and heavy-duty sectors (e.g., freight). For instance, mode switching from trucks to rail is often identified as a strategy to reduce truck travel. Given the state- and regional-level scope of our analysis, however, these types of reductions were excluded because they are more applicable on a national-level scale.[35]

Light-Duty (and Some Medium-Duty) Vehicles

Regional Transportation Planning Measures (California Only)

The four California MPOs examined alternative scenarios in the Environmental Impact Reports (EIRs) for their RTPs.[36,37,38,39] All EIRs include a No Project scenario that examines business-as-usual development without the plan, and MPOs may also assess alternatives that focus on specific transportation modes (e.g., alternatives that only include road projects or transit projects) or make different land use assumptions (e.g., that regions will continue to experience conventional suburban development rather than the more compact development pattern typically called for in a sustainable community strategy). Alternatives that represent more sustainable land use scenarios (e.g., increased transit-oriented development), transportation scenarios (e.g., additional transit, bicycle, and pedestrian funding, potentially coupled with reduced funding for highway projects), and/or additional feasible pricing scenarios based on existing local regulatory

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[35] For instance, the consideration of mode shift between truck and rail is generally not considered feasible at distances less than 500 miles.

[36] Southern California Association of Governments, 2012–2035 Regional Transportation Plan/Sustainable Communities Strategy Draft Program Environmental Impact Report, Chapter 4, Alternatives, December 2011, Available online at **http://rtpscs.scag.ca.gov/Documents/peir/2012/draft/2012dPEIR_4_0_Alternatives.pdf**.

[37] San Diego Association of Governments, 2050 Regional Transportation Plan/Sustainable Communities Strategy Final Environmental Impact Report, Chapter 6.0, Alternatives Analysis, October 2011, Available online at **http://www.sandag.org/uploads/2050RTP/F2050RTPEIR6.pdf**.

[38] Metropolitan Transportation Commission, Plan Bay Area, Final Environmental Impact Report, Chapter 3.1, Alternatives to the Proposed Plan, April 2013, **http://planbayarea.org/pdf/Draft_EIR_Chapters/3.1_Alternatives.pdf**.

[39] Sacramento Area Council of Governments, Final Environmental Impact Report, Chapter 18, Alternatives, February 2012, **http://www.sacog.org/mtpscs/files/Draft-eir/18-Alternatives.pdf**.

authority.[40] ICF compared GHG reductions in the lowest-GHG scenario to the GHG reductions from the plan and treated GHG reductions as proportional to VMT reductions. Different MPOs' alternatives include different strategies; we did not account for this variation.

ICF notes that there is no standardized approach to analyzing alternatives in the EIRs submitted by MPOs, nor is there a requirement that MPOs present alternatives in the EIR that go above-and-beyond the GHG reductions they achieve in the plan. The extent to which the alternatives are ambitious with regard to reductions depends upon political considerations; we treat the more ambitious alternatives identified by MPOs as typical of the amount of VMT reductions urban areas could achieve through stronger commitment to sustainable transportation.

Based on our review of EIR documentation, two of the MPOs analyzed an alternative with lower GHG emissions: SCAG (2% reductions beyond those already accounted for in their proposed plan) and MTC (3.6% reductions beyond those already accounted for in their proposed plan). Based on these results, we estimate that enhancements to regional transportation plans, such as increased funding or environmental incentives for high-growth areas designated in SB 375, could produce additional VMT reductions of up to 3%. We adjusted downward slightly to account for the use of 2030 as a horizon year instead of 2035.

Note that the reductions are reported as a percent difference in VMT per capita. After adjusting for forecasted population growth in California, we find an additional 4.3% VMT reduction (beyond the SB 375 VMT reductions included in the BAU scenario) via the implementation of additional regional transportation planning measures. ICF notes that this strategy is exclusively considered in our analysis of options in California.

Broader VMT Reductions

ICF also investigated broader VMT reduction measures. ICF notes that the following VMT reduction strategies were not coupled with VMT reduction measures included in the baseline or additional regional transportation planning measures because of the potential overlap in strategies. ICF found it impractical to unbundle the elements of the local and regional transportation planning measures and the VMT reduction measures included in the table below, categorized as smart mobility, land use, and pricing.

[40] The differences between these alternatives and the RTPs are small because MPOs' alternatives largely work within the constraints of regional planning—deferring local control over land use, not re-programming transportation funding already allocated to projects, working within the constraints of federal funding sources available to MPOs, and considering only politically feasible pricing measures (e.g., existing tolling).

ICF's analysis of broader VMT reductions is based on a literature review that focused primarily on the following studies, which are highlighted for being geographically appropriate, and providing a suitable level of analytical detail:

- Moving Cooler—a national level study (2009)[41]
- Portland Metro's Climate Smart Strategy (2014)
- Oregon Statewide Transportation Strategy (2012)

Of these, we relied most significantly on Moving Cooler for our analytical assumptions because it provides the most significant level of analytical detail and is also the most broadly applicable to the three states that are included in the analysis. Moving Cooler remains the most comprehensive national study of VMT reduction strategies published in the U.S. At the time of publication, Moving Cooler drew on the most current research available in the field for each type of GHG reduction strategy. ICF's research as part of this project indicates that the sources and assumptions used in the Moving Cooler study remain valid.

It is important to note that at present, the measures discussed in this section would likely be implemented through local and regional action. California, Oregon and Washington have regulatory authority to set targets and create incentives, but not to impose these measures at the state level (with the exception of a pilot program for Pay-As-You-Drive insurance in Oregon). The analysis presented in this section evaluates the potential VMT reductions of implementing these policies, not the mechanism by which they would be implemented.

41 Cambridge Systematics, Inc. Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions. Washington, D.C.: Urban Land Institute, 2009.

Table 20. VMT Reduction Strategies Considered in ICF Transportation and Land Use Planning Cases

VMT Reduction Strategy	Elements of strategy	%VMT Reduction	Sources employed in Moving Cooler
Smart Mobility	Transportation demand management (TDM)	2%	• EPA's COMMUTER model
	Transit	1–2%	• "Transportation Elasticities: How Prices and Other Factors Affect Travel Behavior," 26 July 2008, Victoria Transport Policy Institute. • National Transit Database
	Bicycle and pedestrian improvements	1%	• Ewing, R. and R. Cervero (2001) Travel and the Built Environment. Transportation Research Record 1780, 87–114. Available at http://mrc.cap.utah.edu/wp-content/uploads/sites/8/2015/04/fulltext.pdf • 1,000 Friends of Oregon. Making the Land Use Transportation Air Quality Connection: Volume 4A, The Pedestrian Environment. Portland, OR, 1993. Available at http://ntl.bts.gov/DOCS/tped.html • Bicycle Commuting and Facilities in Major U.S. Cities: If You Build Them, Commuters Will Use Them—Another Look. Dill, J., and T. Carr (2003). Transportation Research Record No. 1828, National Academy of Sciences, Washington, D.C.
	Carsharing	0.3%	• Assumptions unique to Moving Cooler, but remain valid based on ICF's research.
Land Use	Compact land use	2–4%	• The Center for Urban Transportation Research (CUTR)'s VMT Forecasting Model (2007) • Ewing et al, Growing Cooler (2007)
Pricing	Parking pricing	1–2%	• The Dynamics of On-Street Parking in Large Central Cities Available at, http://wagner.nyu.edu//transportation/files/street.pdf • Commuting in America III: The Third National Report on Commuting Patterns and Trends. Transportation Research Board, 2006. Executive summary at: http://onlinepubs.trb.org/onlinepubs/nchrp/CIAIII.pdf • Transportation Elasticities: How Prices and Other Factors Affect Travel Behavior. Victoria Transport Policy Institute, July 2008.
	Road pricing—congestion pricing and VMT fee	6–9%	• FHWA's 2006 Conditions and Performance Report • Effect of Gasoline Prices on Driving Behavior and Vehicle Markets. U.S. Congressional Budget Office, 2008. http://www.cbo.gov/ftpdocs/88xx/doc8893/01-14-GasolinePrices.pdf
	VMT-based insurance	2–5%	• Pay-As-You-Drive Auto Insurance: A Simple Way to Reduce Driving-Related Harms and Increase Equity. Bordoff and Noel, The Brookings Institution. July 2008. http://www.brookings.edu/papers/2008/07_payd_bordoff-noel.aspx

Smart Mobility

TRANSPORTATION DEMAND MANAGEMENT

Transportation Demand Management (TDM) consists of programs that provide encouragement, information, and incentives for people to travel by carpool, transit, walking and biking, or to work by telecommuting. Many existing programs are focused on work travel and delivered through employers to employees. Some states and regions (Washington State and the San Francisco Bay Area) already have legislation in place requiring employers above a certain size threshold to provide TDM programs.

Drawing on the Moving Cooler analysis, we assume that 100% of employers in urban areas with 50 or more employers will offer aggressive subsidies (approximately $2 per day) for use of non-auto modes. Moving Cooler estimated that this strategy would reduce VMT by 3%. Given that the Seattle, Portland, and San Francisco regions already have aggressive TDM programs in place, we pro-rate this reduction to 2% for this analysis.

TRANSIT EXPANSION AND IMPROVEMENT

Providing more bus and train lines, and more frequent service, draws more people to ride transit. This strategy requires a substantial amount of both capital and operating funding to provide new service. Improvements to existing service include signal prioritization, signal synchronization, automatic vehicle locator (AVL) systems, and upgrade to full-scale Bus Rapid Transit.

The Moving Cooler study estimates that transit ridership could grow by up to 5% a year due to a combined package of transit expansion and improvement, particularly including improvements to travel times and reliability. Based on Moving Cooler's assumptions, these investments will reduce VMT by 2%.

BICYCLE/PEDESTRIAN IMPROVEMENTS

Bicycle and pedestrian improvements—such as providing sidewalks on all streets, and expanding dedicated bicycling facilities—encourage people to make more short trips by walking and biking. In addition to providing facilities, local governments need to make travel by bike and foot both safe and convenient.

With the proper bicycle and pedestrian environments, more people will be willing to make trips of 1 mile or less by foot and of 3 miles or less by bike. We estimate that aggressive expansion and improvement of bicycle and pedestrian facilities[42] will shift 20% of trips less than 3 miles that are currently made by SOVs to walking and biking. Based on data drawn from the San Francisco Bay Area on the typical lengths of SOV trips, this would reduce VMT by 1%.

CARSHARING

Carsharing programs allow members to use cars that are parked in their neighborhoods and pay by the hour, day, or mile. People who join carsharing programs tend to drive less than they did before. Expansion of car-sharing programs, which now include peer-to-peer and one-way carsharing, can thereby reduce VMT. At least one MPO—the Metropolitan Transportation Commission—is actively involved in expanding car-sharing programs.

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[42] For instance, the Great Streets Initiative in Los Angeles, http://www.lamayor.org/greatstreets.

Drawing on the Moving Cooler study, we assume that car-sharing in urban areas will provide 1 car per 500 inhabitants. The resulting VMT reduction is estimated at 0.3%.

Land Use Measures—Smart Growth

Smart growth land use patterns, characterized by compact, mixed-use developments, generate less vehicle travel than conventional sprawling development patterns. People living and working in smart growth developments often walk and bike more for short trips and take transit more frequently. When driving is necessary, trips are often shorter. Increasing the share of development that is smart growth requires local governments (who typically have authority over land use) to cooperate with regional and state governments in land use planning.

Moving Cooler assumed that 90% of new metropolitan development would occur in compact, walkable (smart growth) neighborhoods. These assumptions lead to smart growth development of up to 4%.

On-Demand Carsharing

There are also opportunities for on-demand carsharing systems to reduce VMT by matching riders into multi-passenger trips (e.g. Uber Pool, Lyft Line). Due to a lack of available research quantifying these potential benefits, however, this was not included as a reduction measure in this study.

Pricing

Pricing attempts to use market forces to incentivize transit, carpooling or non-motorized modes of urban transport. ICF notes that the pricing analysis from which we draw upon is more ambitious than other VMT reduction strategies, in part because of the relatively limited operational experience with vehicle pricing policies. Considering that transportation investments and land use planning are part of ground-up process with a lot of inertia behind them at the local and regional levels, any analysis that considers additional VMT reductions from these strategies tend to be conservative and make incremental changes to the existing constraints (e.g., amount of funding available for transit or the rate at which land use change occurs). Pricing, on the other hand is a relatively new approach, and the measures outlined below have not gone through as many public processes, and as a result analyses tend to not be as constrained.

Parking Pricing

Raising the price of parking in urban activity centers can incentivize shifts to carpooling, transit or non-motorized transport. Parking pricing can be implemented through a combination of raising rates on street parking and publicly owned garages and incentivizing owners of large private parking facilities to charge for parking. Typically parking pricing is only feasible in dense activity centers.

Our parking pricing option models a scenario in which 90% of parking in activity centers, excluding disabled parking, loading zones and other special parking designations, will be priced at an average cost of $3 per trip. We assume that up to 25% of urban VMT is associated with trips to activity centers.[43] Assuming that VMT is split evenly between urban and rural areas, we

[43] This assumption is adapted from Moving Cooler, which estimates that 15% of all VMT is accounted for in trips to activity centers.

then estimate that 5% of rural VMT is accounted for in trips to activity centers and that 25% of urban VMT is accounted for in trips to activity centers. Further assuming that the average cost per round trip (fuel, maintenance and tires) is $5, that 50% of parking in activity centers is already priced, and a price elasticity of 0.3, this policy will reduce urban VMT by up to 2%.

VMT AND CONGESTION PRICING

The concept of a per mile driving charge to replace the gas tax is being piloted in Oregon and debated at the local, state, and national levels. State or federal action is required to authorize VMT fees. Congestion pricing is a separate but related measure that is intended to reduce congestion by assessing charges during peak periods. London, Singapore, Stockholm, and Milan have reduced congestion in city centers through pricing, while many areas including Orange County and San Diego have used dynamic tolls, a limited form of congestion pricing, on some highways.

We adapted Moving Cooler's findings on pricing to the states in this report and find potential VMT reductions of up to 9%, though only the VMT-focused cases account for more than 1% of reductions above BAU from pricing policies and the HtO Pathway does not use this measure at all.

PAY AS YOU DRIVE INSURANCE

Unlike traditional insurance, Pay as You Drive (PAYD) Insurance charges a per mile fee, so that people who drive less have the potential to save money on insurance. PAYD is already available in California, Oregon, and Washington—made possible by state legislation in all three states. Additional state legislation could require insurance companies to convert all polices to a PAYD basis.

Drawing on the Moving Cooler analysis, we assume that in cases which use the PAYD option, all households will use PAYD, and that insurance policies are structured so that at least 75% of premiums are paid on a per mile basis. The resulting VMT reduction, extrapolated from Moving Cooler, is up to 3%; only the Transportation and Land Use Planning Cases actually account for reductions through this measure.

Autonomous Vehicles

Autonomous, or self-driving, vehicles have the potential to change the landscape of transportation over the coming decades. Some analysts anticipate fully autonomous cars widely deployed on the road by 2040. In fact, technological elements that will be part of a self-driving vehicle are already employed in many newer vehicles; for example, some cars can self-park, automatically brake in emergencies, and adjust to stay in a lane.

The impacts of autonomous vehicles arise from how they will affect congestion, fuel economy, vehicle ownership patterns, and travel patterns.

- According to one study, vehicles controlled by sensors and computers and communicating with each other will increase congested traffic speeds by 8-13% and improve fuel efficiency by 23-39% (*Eno Center for Transportation, 2013*).
- Some analysts expect to see reduced vehicle ownership and more models of shared vehicles that can pick up passengers, nearly equivalent to an automated taxi system. This may reduce environmental impacts related to vehicle manufacturing; however, according to one model, travel distances may increase as shared vehicles travel empty to pick up a new passenger (*Fagnant and Kockelman, 2014*).
- Others have pointed out that some populations restricted from operating vehicles (e.g., those without a driver's license, elderly, disabled, inebriated, etc.) may travel more, while others may travel more due to the increased convenience (*Washington Post, March 2013*).
- Other possible impacts on travel patterns (some of which are contradictory) discussed in the literature include: reduced VMT searching for parking (by one estimate, 40% of total gasoline use in congested urban areas (*W Mitchell, Personal Mobility, MIT*)); increased bicyclists and pedestrians because of reduced safety concerns (*Mother Jones, March 2012*); decreased transit use because of increased car convenience; and increased transit use because self-driving cars can fulfill "last mile" trips.
- Autonomous vehicles may also affect land use patterns. A number of analysts expect space and infrastructure devoted to parking will be reduced, partly because of reduced vehicle ownership and partly because these vehicles can park in tighter spaces and will need only 75% of the current space allotted to parking, opening up 5.7 billion square meters of space (*Wired, March 2015*). Other observers suggest that the convenience of self-driving cars may reduce the discouragement of being in a car for long periods of time, which could result in increased sprawl (*RAND, 2014*).

Overall, because this is an emerging technology, there has been limited quantification of expected impacts (especially as it relates to the petroleum reduction potential), and those that do exist are extremely speculative this early on in the development of the technology. Autonomous vehicles will most likely have broad and complex effects on travel behaviors and land use patterns; however, given the uncertainty surrounding the corresponding petroleum reduction potential, we did not consider these in our analysis.

Vehicle Efficiency

Vehicle efficiency measures are characterized as those that improve the efficiency of traditional internal combustion engine vehicles. These include a mix of regulations or standards, policies, and operational improvements that improve the fuel economy of new vehicles as well as vehicles already deployed. Although electric vehicles improve vehicle efficiency via advanced powertrains, these vehicles are considered an alternative fuel strategy.

Light-Duty Vehicles

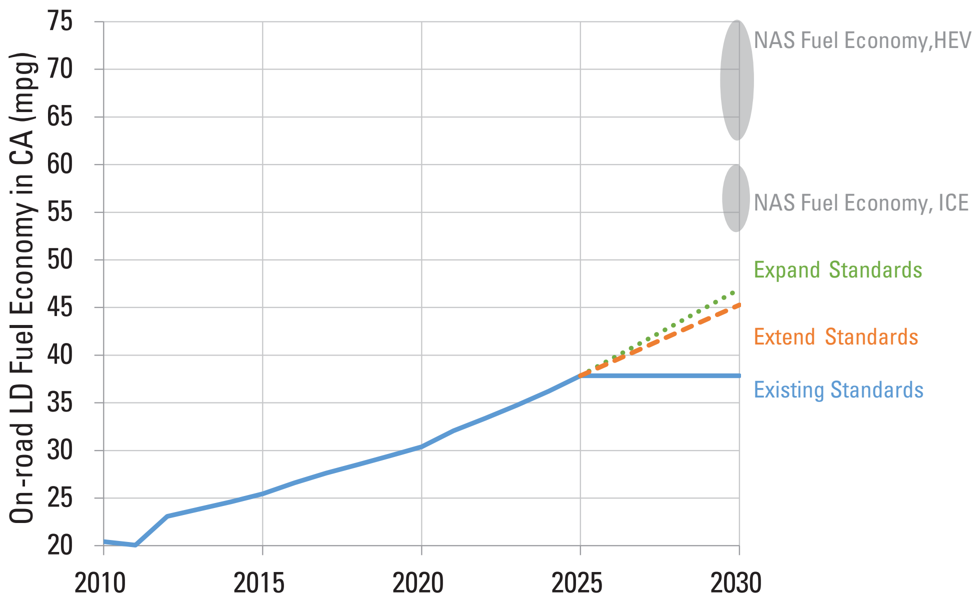
Extend and Expand Tailpipe GHG Standards/Light-Duty Fuel Economy Regulations

The on-road fuel economy of new light-duty vehicles is projected to be between 26–42 mpg (depending on size and body type) by 2025 in California and 32–43 mpg in Oregon and Washington due to the combination of the federal light duty fuel economy standards and GHG tailpipe standards. ICF considered two types of changes to tailpipe GHG standards/fuel economy standards for light-duty vehicles:

- **Extend** the federal program[44] to MY2026-MY2030 at levels consistent with the average annual percent increase in fuel economy between MY2020-MY2025, equivalent to a 5% annual increase.
- **Expand** the federal program, whereby the regulations are extended to MY2026–MY2030 vehicles, and the percent increase in fuel economy improvement is higher than the average annual percent increase of pre-2025 improvements.

The figure below highlights the extension and expansion options using California's on-road light-duty fuel economy for illustrative purposes; the graph also includes the range of on-road fuel economy that can be achieved (discussed in more detail below).

Figure 15. Illustrative Graph of Light-Duty Fuel Economy Modifications Considered in Analysis



[44] California, under Clean Air Act authority, can also adopt more stringent light-duty greenhouse gas standards.

A recent report from the National Academy of Sciences (NAS) found that large increases in light-duty vehicle fuel economy are possible with incremental improvements to technology that is currently known for both load reduction and drivetrain improvements. Using computer simulations to establish conventional powertrain improvements, NAS estimated that the new-vehicle fleet average fuel economy based on EPA test cycles could reach efficiencies of 65–74 mpg by 2030 for internal combustion engines (ICE) and 78–92 mpg for hybrid electric vehicles (HEVs).[45] This translates to on-road efficiencies of 52–59 mpg for ICEs and 62–74 mpg for HEVs.[46] The NAS projections are based on both existing cutting-edge technologies and analyses of technologies at advanced stages of development.

Scrappage Programs

Scrappage programs promote the retirement of older, less efficient vehicles through monetary incentives. In California, CARB provides $1,000 per vehicle and $1,500 for low-income consumers for unwanted vehicles that have failed their last Smog Check Test. By accelerating vehicle turnover, these programs reduce emission from the existing fleet to help meet health-based ambient air quality standards. Depending on the fuel economy threshold set by the program, the combination vehicle buyback and incentive program is intended to induce demand in middle and lower income brackets that might otherwise delay car purchasing, purchase a new conventional vehicle, or purchase a used vehicle.[47]

The largest scrappage program was the Car Allowance Rebate System (also known as "Cash for Clunkers"), a $3 billion U.S. federal program that spurred the retirement of 677,000 vehicles (and near equal new-car sales) during the 2009 recession. NHTSA estimates the average traded vehicle got 15.8 mpg. Prompted by voucher

The Rebound Effect

The *rebound effect* is based on the idea that the demand for driving is a function of vehicle operating costs. In other words, when operating costs change, such as when fuel prices increase, then driving becomes more expensive and people drive less. Conversely, if fuel prices decrease, then people may drive more. The potential magnitude of the rebound effect is the subject of extensive academic research (and is summarized nicely in Appendix S of CARB's LEV 3 ISOR).

EMFAC2014 does include a rebound effect and is described in considerable detail in the Technical Documentation.

The VISION model, on which the BAU Scenarios for Oregon and Washington are based, does not include the rebound effect.

The model that was used for this analysis, although based on EMFAC2014 and the VISION models, does not explicitly include the rebound effect. However, it does implicitly account for the rebound effect for modeling in California given that the HtO scenario modeling is linked to EMFAC2014 results.

45 National Research Council. 2013. Transitions to Alternative Vehicles and Fuels. Washington, DC: The National Academies Press. Available online at **http://www.nap.edu/catalog/18264/transitions-to-alternative-vehicles-and-fuels**.

46 According to the EPA, Label MPG values are, on average, 20–25% lower than CAFE MPG values. Available online at **http://www.epa.gov/fueleconomy/documents/420b14015.pdf**.

47 California also has a low income program to incentivize the purchase of a more recent used car and higher incentives for replacement with a hybrid or electric vehicle, referred to as Enhanced Fleet Modernization Program (EFMP) and Plus-Up Pilot Project, respectively. More information is available online at **http://www.arb.ca.gov/newsrel/efmp_plus_up.pdf**.

requirements, its replacement averaged 24.9 mpg, a 58% improvement. However, the new vehicle purchases under this program accounted for less than one percent of the total on-road vehicle fleet in the United States. An analysis conducted by Li, Linn, and Spiller (2012) found that the Cash for Clunkers program resulted in a petroleum reduction of 884 to 2,916 million gallons.[48]

ICF considered scrappage programs as a viable measure, however, they ultimately were not employed in our analysis because extending and expanding federal fuel economy standards and more aggressive ZEV requirements reduce the petroleum consumption from the average vehicle fleet significantly and reduce the marginal benefit of scrapping less-efficient vehicles in the later years of this analysis. As a result, the benefits of a scrappage program are not strongly noticed in the 2030 timeframe, though they can have near term benefits and can be employed as a complementary measure (as discussed in more detail in Sections 3–5 in the body of the report).

Feebate Programs

Originally coined in the 1990s, feebate programs have typically been used to shift buying habits in the transportation and energy sectors. Feebate programs are designed to incentivize consumers to prefer more efficient vehicles when making purchase decisions. A feebate program uses a combination of fees and rebates to change consumer behavior. Consumers purchasing a vehicle that emit more CO_2 on a gram per mile basis than a defined standard are assessed a fee at the point of purchase. These fees are used to provide rebates to consumers that purchase vehicles that emit less CO_2 on a gram per mile basis than the defined standard.

Feebates have been used with some success in other countries, including Denmark, France, the Netherlands, and Norway. The structure of a feebate program for California was studied in considerable detail for the CARB.[49] In fact, California has come close to implementing a statewide feebate program on multiple occasions through legislative efforts—the first time in the early 1990s and more recently in 2008.

Feebates were ultimately not employed in our analysis because we effectively considered them as a complementary policy that enabled other strategies, namely an increase in more fuel efficient vehicles.

Fuel Efficient Tires

Low rolling resistance tires improve fuel economy by reducing the energy lost to friction. While most new passenger cars and light trucks have fuel efficient tires, about 80% of light duty vehicles are equipped with replacement tires, which generally are not as fuel efficient.[50] Research by the California Energy Commission indicates that for every 10% change in rolling resistance, fuel efficiency improves by up to 2% and that overall, low rolling resistance tires can improve the fuel economy of a passenger vehicle by approximately 3%. In theory, this means that if a campaign or

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[48] Brookings Institute. 2013. Cash for Clunkers: An Evaluation of the Car Allowance Rebate System. http://www.brookings.edu/~/media/research/files/papers/2013/10/cash-for-clunkers-evaluation-gayer/cash_for_clunkers_evaluation_paper_gayer.pdf.

[49] Greene, David L. and Bunch, David S., "Potential design, implementation, and benefits of a feebate program for new passenger vehicles in California", Prepared for the California Air Resources Board, Contract UCD 08-312, February 2011.

[50] Transportation Research Board, Tires and Passenger Vehicle Fuel Economy, Special Report 286, 206. Available online at: http://www.energy.ca.gov/2006publications/TRB-1000-2006-001/TRB-1000-2006-001.PDF.

incentive program could result in a 25 to 35% penetration at the state-wide level, then gasoline consumption in California could decrease by 77 to 107 million gallons annually.[51] The upper end of this range represents 1.0% of current LDV gasoline consumption in California.

Low rolling resistance tires can also improve the fuel economy of light trucks in the medium-duty (6,000 to 8,500 lbs GVWR) category. There has been less research on the extent of new OEM versus replacement tires in this segment of the vehicle population. However, the tire manufacturers are similar to those for the light-duty fleet, and the efficiency improvements of fuel efficient tires should be similar.

This strategy assumes similar improvement in fuel efficiency as we estimated for light-duty vehicles. Based on a campaign that begins in 2020, we estimate a 1% reduction in fuel use by 2030 among medium-duty vehicles in the 6,000 to 8,500 lbs GVWR range.

For light-duty vehicles, this strategy includes an incentive program or educational campaign to promote fuel efficient tires, similar to that envisioned by the California Energy Commission. We model a campaign that begins in 2020, and by 2030 achieves a 1% reduction in light-duty vehicle fuel use.

Medium- and Heavy-Duty Vehicles

Implementation of Phase 2 Standards and Expanded Regulations

The EPA proposed Phase 2 regulations[52] for medium- and heavy-duty vehicles in June 2015 that include performance standards designed to promote a diverse range of technologies that will reduce fuel consumption and decrease CO_2 emissions. The EPA's Preferred Alternative (also known as Alternative 3) will deliver fuel reductions ranging from 13–24% in combination tractors by model year 2027, reduce fuel consumption from trailers by 4–8%, and reduce fuel consumption from vocational vehicles (in Classes 2b-8) by 7–16%.

Although the proposed standards focus nearly exclusively on the Preferred Alternative, the EPA also assessed and is taking comments on Alternative 4, which would achieve the same level of performance in vehicles in the latter years of the Preferred Alternative (e.g., 2027–2029), however, it would achieve these benefits three years earlier (by MY2024 instead of MY2027).

ICF's modeling included fuel economy improvements for a Phase 2 regulation that are consistent with Alternative 4. Furthermore, we included options to increase fuel economy of medium- and heavy-duty vehicles beyond the end date of proposed Phase 2 standards. We considered upper limits for various vehicle classes based on analysis presented by the Union of Concerned Scientists (UCS),[53] International Council on Clean Transportation (ICCT),[54] the National Research

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51 California State Fuel-Efficient Tire Report: Volume 1. California Energy Commission. 2003. Available online at **http://www.energy.ca.gov/reports/2003-01-31_600-03-001F-VOL1.PDF**.

52 Greenhouse Gas Emissions and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles—Phase 2, Federal Register, Vol. 80, No. 133, July 13, 2015. Available online at **http://www.gpo.gov/fdsys/pkg/FR-2015-07-13/pdf/2015-15500.pdf**.

53 Union of Concerned Scientists, Big Fuel Savings in Available in New Trucks, May 2014. **http://www.nrdc.org/transportation/files/fuel-savings-in-trucks-FS.pdf**.

54 Delgado, O. and Lutsey, N. Advanced Tractor-Trailer Efficiency Technology Potential in the 2020–2030 Timeframe, April 20145. Available online at **http://www.theicct.org/sites/default/files/publications/ICCT_ATTEST_20150420.pdf**.

Council,[55] and TIAX LLC.[56] By and large, these analyses find that the technologies required to achieve fuel consumption reductions in the medium- and heavy-duty vehicle sectors can be adopted cost-effectively with payback periods ranging from 1–5 years.

The following is a summary of the maximum achievable improvements and corresponding fuel economies for relevant medium- and heavy-duty vehicles considered in our analysis.

- Heavy-duty pick-ups and vans: The upper limit for the improvement in heavy-duty pick-ups and vans is 10–15% with a fuel economy upwards of 15–16 mpg.
- Vocational vehicles: The upper limit for the improvement of vocational vehicles is around 75%, depending on vehicle type, with fuel economies in the range of 11.7–15.5 mpg.
- Tractor-trailers: Tractor-trailers can improve fuel economy by 45–56% with a fuel economy range of 9.6–11.4 mpg.

ICF considered two types of changes to the federal medium- and heavy-duty vehicle standards:

- **Implementation of the Phase 2 standards with Alternative 4.** ICF implemented the federal program at levels consistent with the average percent reduction in fuel consumption attributable to Alternative 4, with the reductions occurring by MY2024.
- **Expansion of the federal program.** ICF implemented further fuel reductions out to 2030, and the percent reduction in fuel consumption is accelerated or increased as early as MY2024 by varying amounts, with a maximum annual increase of 4%.

Freight Efficiency Opportunities

There are many freight efficiency measures and technologies that could impact truck fuel use, such as route optimization, strategies to reduce empty loads, mode-shifting, information technology to better coordinate and plan freight movements, and others. These measures were outside of the scope of this analysis. Further examination of these types of technologies and strategies is currently being undertaken by CARB to inform the development of the sustainable freight strategy in California.

Truck Platooning

Several research teams have demonstrated the operation of Class 8 line-haul trucks using semi-automated platooning. Using vehicle-to-vehicle communication, radar, and active braking, two or more trucks can operate at high speeds in close proximity, which reduces aerodynamic drag. Recent tests by the National Renewable Energy Laboratory (NREL) using two trucks in platoon showed fuel savings of up to 5.3% for the lead truck, up to 9.7% for the trailing truck, and a net savings of up to 6.4% for the platooned pair.[57] This strategy assumes that platooning can be adopted by Class 8 tractor-trailer trucks outside of metropolitan areas, during extended periods of

55 National Research Council (NRC). 2010. Technologies and approaches to reducing the fuel consumption of medium- and heavy-duty vehicles. Washington, DC. Online at http://www.nap.edu/catalog.php?record_id=12845.

56 Kromer, M.A., Bockholt, W.W., and Jackson, M.D. Assessment of fuel economy technologies for medium- and heavy-duty vehicles. TIAX, LLC Report. Cupertino, CA. July 2009.

57 See http://www.nrel.gov/transportation/fleettest_platooning.html.

cruising operation on major interstate highways. We assume 50% of Class 8 tractor-trailer trucks on these highway segments employ this strategy by 2030.[58] Using Caltrans truck count data, we estimate there is approximately 7 million daily VMT by 5-axle trucks in California in inter-city operation. This VMT accounts for about 20% of all Class 8 tractor-trailer truck VMT in California. Based on the NREL work, platooned trucks are modeled as reducing fuel consumption by 6.4%.

Off-Road

GenSet Switcher Locomotives

Generator Set ("GenSet") switcher locomotives are typically powered by a bank of three non-road engines, each approximately 750 horsepower, rather than a single locomotive engine of 2,000 to 3,000 horsepower. The GenSet locomotive can shut down one or two engines during periods of low power demand, saving fuel and reducing emissions. GenSet locomotives use approximately 25% less fuel than conventional switcher locomotives. They are currently operated by BNSF and Union Pacific in select California locations, as well as several other states.

The duty cycle of switcher locomotives does not vary significantly with geography or cargo type, so Genset switchers would be viable replacements for conventional technology in virtually all circumstances. As result, this strategy is implemented by replacing all switcher locomotives with GenSet units by 2030. We estimate that petroleum reduction from the strategy would be minimal before 2021 and increase linearly thereafter to 2030. The resulting petroleum reductions in 2030 would be 5 million gallons in California, 1.9 million gallons in Oregon, and 1.6 million gallons in Washington.

Hybrid Tugs and Ferries

Hybrid-electric technology can be applied to tugboats and ferries to reduce fuel use and emissions. The nation's first hybrid tugboat began operation at the ports of Los Angeles and Long Beach in 2009; a second, more advanced hybrid tug entered service there in 2012. Hybrid-electric tugs reduce diesel consumption by approximately 30%, based on EPA-verified retrofit technology estimates.[59] Hybrid ferries are also an emerging technology, with several in service or on order in the U.S. and Europe. Fuel savings from hybrid ferries is uncertain; we estimate 30% savings, similar to tugs.

This strategy assumes that all tugboat and ferry powertrains are replaced, or retrofitted, with hybrid electric technology by 2030. We assume that petroleum reduction from the strategy would begin in 2021 and increase linearly to 2030. The resulting petroleum reductions in 2030 would be 12 million gallons in California, 6 million gallons in Oregon, and 24 million gallons in Washington.

Alternative Fuels

Alternative transportation fuels are non-petroleum based fuels that are used in transportation applications, such as ethanol, biodiesel, drop-in biofuels (e.g., renewable gasoline or diesel), electricity, hydrogen, or natural gas. These fuels have varying levels of deployment today in

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[58] This strategy was not employed in all cases.

[59] Based on EPA-verified Foss Maritime/AKA XeroPoint Hybrid Tugboat Retrofit System. Available online at **http://www.epa.gov/cleandiesel/verification/techlist-foss.htm**.

California, Oregon, and Washington. Their reduction potential depends on fuel availability, fueling infrastructure availability, and in some cases, vehicle technologies. The following subsections briefly outline how alternative fuel measures were introduced into the analysis.

Light-Duty Vehicles

Transition to Higher Blends of Ethanol

There is an active discussion in the fueling industry and automotive industry today regarding the potential to transition to higher blends of ethanol. The federal Renewable Fuel Standard has introduced a substantial amount of ethanol into the U.S. fuel mix. Most of this ethanol has been introduced as E10, a 10% ethanol blend. Higher-ethanol blends are currently limited by technical and warranty concerns. Displacing additional petroleum through substitution with ethanol will necessitate exceeding this "blend wall." There are several options to allow ethanol in excess of 10% of the gasoline supply into the market including, but not limited to:

- **Transition to E15:** Today, reformulated gasoline (RFG) contains 10% ethanol by volume—and RFG makes up more than 95% of the gasoline fuel market in the United States. This is largely driven by the RFS2, which is a supply-side driver for ethanol production. The EPA approved waivers for the sale of E15 in vehicle model years 2001 (MY2001) and newer. However, there are still a significant number of pre-MY2001 vehicles on the road. Moreover, the automotive industry contends that even for some post MY2001 vehicles the use of E15 has the potential to accelerate wear and tear and ultimately lead to vehicle failure. There are also significant concerns about consumer education and outreach regarding the appropriate use of E15.
- **Increased E85 consumption:** Flex fuel vehicles (FFVs) can use higher blends of ethanol, up to 85% by volume ethanol and 15% by volume gasoline. ICF estimates that there are about 1 million FFVs in California,[60] about 160,000 FFVs in Oregon,[61] and 260,000 FFVs in Washington.[62] Despite the prevalence of these vehicles, however, FFVs have consumed little E85—in other words, they typically are fueled using gasoline. Propel's recent white paper, however, indicates that E85 sales are increasing in California, with a seven-fold increase between 2009 and 2014 (from 1.6 million gallons to 11.1 million gallons).

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60 Propel, E85: A California Success Story, White Paper, June 2015. Available online at http://propelfuels.com/images/uploads/media_kit/CA_E85_Propel_White_Paper_6.1.15.pdf.

61 Based on ICF's work for the Oregon DEQ regarding a Clean Fuels Standard Program.

62 Based on information included in the file provided by Life Cycle Associates, used in their analysis of a Clean Fuels Program in Washington for the Washington Department of Ecology.

- **Mid-level blends of ethanol:** Higher levels of ethanol can be used to increase the octane rating of the gasoline pool (e.g., via E20 or E30) and enable higher engine efficiency by reducing engine knock constraints, thereby enabling the design of engines with higher compression ratios and boost levels.[63,64,65,66] These mid-level blends would require a transition to blender pumps, which provide the consumer with the flexibility to fuel vehicles at various blend levels.

Given the range of options in the ethanol blend market, ICF has purposely avoided picking any one of these options (or others not listed). Rather, we introduced higher levels of ethanol into the model as a percent of the gasoline pool, ranging from E10 in the BAU scenarios up to a maximum of E25 by 2030. Because gasoline consumption is projected to drop significantly in our cases, higher blends of ethanol are required to maintain the same volume of ethanol currently used as well as to facilitate increased use of ethanol for additional gasoline reductions. The higher volumes of ethanol as a percent blend with gasoline are simply a proxy for the combination of strategies—such as low carbon fuel standards, biofuel blending mandates, and financial incentives that will likely be pursued between now and 2030 by the automotive and transportation fuel industries.

Ethanol can be produced from a variety of feedstocks, including corn, sugarcane, sorghum, wheat, molasses, agricultural residues (e.g., corn stover), and lignocellulosic biomass. For the purposes of this report, as outlined in the text box on the

Biofuel Feedstocks

With an emphasis on petroleum reductions, our analysis does not explicitly consider feedstocks for liquid biofuels (i.e., ethanol, renewable gasoline, biodiesel, and renewable diesel). We present the range of GHG emissions of each scenario to illustrate one of the impacts of using different feedstocks for alternatives like liquid biofuels. It is also important to note that there are other sustainability considerations, for example, pressure on land use, water consumption, and competition with food and feed markets. Our analysis is explicitly constrained by the following analyses, which have considered feedstock constraints, GHG emissions, indirect land use change, and sustainability more broadly:

- CARB's Analysis of the LCFS Program (via the Illustrative Compliance Scenario)
- ICF's analysis of a Clean Fuel Standard in Oregon (for OR DEQ)
- Life Cycle Associate's analysis of a Clean Fuel Standard Program in Washington (for WA OFM)
- ICCT's Potential Low-Carbon Fuel Supply to the Pacific Coast Region of North America

63 Chow, E., Heywood, J., and Speth, R. (2014) "Benefits of a Higher Octane Standard Gasoline for the US Light-Duty Vehicle Fleet," SAE Technical Paper 2014-01-1961 doi: 10.4271/2014-01-1961.

64 Derek A. Splitter and James P. Szybist (2014a) "Experimental Investigation of Spark-Ignited Combustion with High-Octane Biofuels and EGR. 1. Engine Load Range and Downsize Downspeed Opportunity" Energy & Fuels doi: 10.1021/ef401574p.

65 Derek A. Splitter and James P. Szybist (2014b) "Experimental Investigation of Spark-Ignited Combustion with High-Octane Biofuels and EGR. 2. Fuel and EGR Effects on Knock-Limited Load and Speed" Energy & Fuels doi: 10.1021/ef401575e.

66 Stein, R., Anderson, J., and Wallington, T., "An Overview of the Effects of Ethanol-Gasoline Blends on SI Engine Performance, Fuel Efficiency, and Emissions," SAE Int. J. Engines 6(1): 2013, doi: 10.4271/2013-01-1635.

previous page, we did not explicitly consider individual feedstocks for ethanol. Rather, we relied on the constraints imposed in reference material to ensure that reasonable supply and sustainability constraints were considered.[67]

Renewable Gasoline Blending

ICF considered the deployment of drop-in biofuels as gasoline substitutes, referred to in the analysis as renewable gasoline. Renewable gasoline is similar to conventional gasoline, however, it is produced from biomass feedstocks, such as perennial grasses or woody biomass through a variety of biological and chemical processes. Renewable gasoline is considered a "drop-in" fuel because it will not require significant modifications to existing fuel distribution infrastructure or vehicle engine modifications (for gasoline or diesel powered vehicles), unlike ethanol as it is used today.

CARB's illustrative compliance scenario for the LCFS includes 250 million gallons of renewable gasoline by 2025. By comparison, ICCT's recent report regarding the potential supply of low carbon fuels to the Pacific Coast Region included a range of 10–230 million gallons of renewable gasoline by 2030. ICF used an upper limit of 900 million gallons for renewable gasoline across all three states, most notably in the High Biofuels Case, with the assumption that there will be a transition from cellulosic ethanol production to renewable gasoline production.[68]

ZEV Program Enhancements

CARB's likely compliance scenario, which is used by CARB staff in the development of the EMFAC2014 model, assumes that ZEVs comprise 15.7% of new light-duty vehicle sales by 2025. ICF included a similar program in Oregon in the BAU Scenario and introduced the ZEV Program in Washington as a strategy. We also considered several enhancements to the ZEV Programs. The first two focus on extending and enhancing the program, while the third relies on an increase in the all-electric miles traveled by PHEVs.

CARB introduces ZEVs in the EMFAC2014 model exclusively in passenger vehicles and excludes their penetration from the light-duty truck sector. ICF modified this assumption slightly and introduces ZEVs into passenger vehicles and light-duty trucks at 80% and 20%, respectively.[69] The total number of ZEVs is unchanged in our modeling; this modification was simply treated a shift in the light-duty vehicle population.

ZEV Extension

The ZEV extension is akin to the extension of the federal fuel economy and tailpipe GHG regulations: Rather than having the ZEV requirements plateau at 15.7% of new vehicle sales in 2025, we model a linear increase in compliance required, increasing the number of new ZEVs sold by 1.5% annually (as shown in the figure below).

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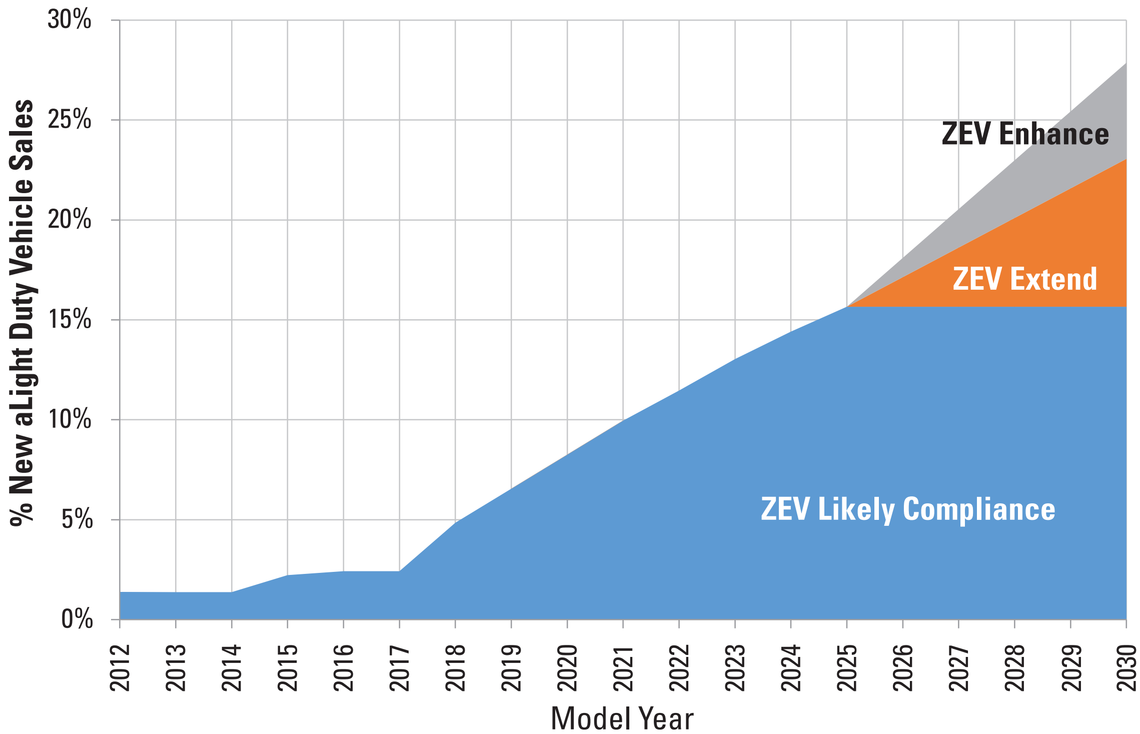
[67] For example via ICCT, Potential low carbon fuel supply to the Pacific Coast region of North America, January 2015. Available online at http://www.theicct.org/sites/default/files/publications/PacificCoastRegionLCF_Jan2015.pdf and references therein.

[68] Note that the ICCT report on potential low-carbon fuel supply to the Pacific Coast region includes a range of 20–950 million gallons of cellulosic ethanol by 2030.

[69] The Toyota RAV4 EV and the Tesla Model X are examples of plug-in light trucks available or soon to be available in California.

Figure 16. Illustrative Graph of ZEV Program Modifications Considered in Analysis



ZEV Enhancement

As shown in the figure above, the ZEV Program is enhanced by incorporating the impacts of an intervention or technology improvement—such as increased financial incentives, new regulations, or improvements in battery range with reductions in battery costs—that leads to an enhanced version of the existing program, thereby leading to greater deployment of ZEVs pre- and post-2025.

In their optimistic scenario for technology projections, NAS assumes that the new vehicle sales in 2030 will be comprised of about 40% PEVs (of which the majority are BEVs).[70] The NAS report is a national-level assessment; therefore ICF believes it is reasonable to assume a higher percentage of PEV sales in 2030 under more aggressive policy assumptions (e.g., extending and enhancing ZEV program requirements) and more engaged markets, such as those in California, Oregon and Washington.[71] In fact, a recent report[72] by the ICCT agrees with this assumption, concluding that manufacturers are targeting markets with more aggressive ZEV policies and these markets account for a disproportionate fraction of national ZEV sales, to date. For the purposes of this analysis, we model an upper limit of 45% of new light-duty vehicle sales as ZEVs by 2030.

70 National Research Council. 2013. Transitions to Alternative Vehicles and Fuels. Washington, DC: The National Academies Press. Page 374. http://www.nap.edu/catalog/18264/transitions-to-alternative-vehicles-and-fuels.

71 As of the end of 2014, six of the top seven cities with the highest electric vehicle share—San Francisco, Los Angeles, San Diego, Seattle, Portland, and Riverside—were in the study region.

72 ICCT, Assessment of leading electric vehicle promotion activities in United States cities, July 2015. Available online at http://www.theicct.org/sites/default/files/publications/ICCT_EV-promotion-US-cities_20150729.pdf.

Increase Electric VMT for PHEVs

PHEVs have what is referred to as an all-electric range (when in charge depleting mode) of about 10-40 miles. For instance, the Toyota Prius Plug-in has an all-electric range of 11 miles;[73] the Ford C-MAX Energi has an all-electric range of 21 miles; and the Chevrolet Volt has an all-electric range of 38 miles.[74] It is generally assumed that most PEV owners will charge their vehicles at home. Although at-home charging provides the most convenient form of charging, by providing PEV drivers access to charging infrastructure at workplaces, commuter hubs, and other destinations, the all-electric range of their vehicles can be extended. Miles traveled using electricity yield both a larger petroleum reduction and GHG benefit.

The baseline information from EMFAC2014 indicates that CARB staff modeled PHEVs as having a 25-mile all-electric range, which equates to a utility factor of 0.40. For the average commute, this would mean that 40% of the VMT could be from all-electric, and 60% would be from gasoline operations.[75]

In some cases, ICF left the 40% utility factor unchanged. To increase the utility factor, ICF considered a variety of alternatives. For instance, data from The EV Project[76] (as shown in the table below) and a recent paper from GM engineers[77] indicate that Volt drivers are able to drive about 74% of their total miles in EV-mode without support from the internal combustion engine.

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73 ICF notes that the Toyota Prius Plug-in does not operate in pure charge depleting mode under normal conditions; we have included it here to illustrate existing vehicles available to consumers with ranges comparable to a PHEV10, PHEV20, and PHEV40.

74 Chevrolet recently reported that the second-generation Voltec PHEV delivers 53 miles of all-electric range, based on EPA testing. More information available online at **http://media.gm.com/media/us/en/gm/news.detail.html/content/Pages/news/us/en/2015/aug/0804-volt-range.html**.

75 California Air Resources Board, EMFAC2014 Volume III—Technical Documentation v1.0.7, May 2015. Available online at **http://www.arb.ca.gov/msei/downloads/emfac2014/emfac2014-vol3-technical-documentation-052015.pdf**.

76 The EV Project, Q2 2013 Quarterly Report, available online at **http://avt.inel.gov/pdf/EVProj/EVProjectInfrastructureQ22013.pdf**.

77 Duhon, A., Sevel, K., Tarnowsky, S., and Savagian, P., "Chevrolet Volt Electric Utilization," SAE Int. J. Alt. Power. 4(2):269-276, 2015, doi:10.4271/2015-01-1164.

Table 21. Vehicle Miles Traveled by Region in The EV Project for Chevrolet Volts

Region	Chevrolet Volt		
	VMT	%eVMT	Total Vehicles
Overall	41.0	74.6%	1,895
Phoenix	39.6	76.7%	129
Tucson	n/a	n/a	<10
Los Angeles	39.0	75.8%	320
San Diego	40.2	71.9%	256
San Francisco	n/a	n/a	<10
Washington DC	42.5	75.9%	266
Oregon	39.3	77.6%	130
Chattanooga	52.5	60.3%	13
Knoxville	43.4	72.5%	31
Memphis	39.5	72.8%	31
Nashville	43.4	73.3%	50
Dallas/Ft Worth	42.3	73.3%	177
Houston	42.7	71.5%	73
Washington State	38.0	77.7%	160
Chicago	43.6	76.6%	128
Atlanta	44.6	70.4%	72
Philadelphia	44.0	68.0%	51

In a project with the California Electric Transportation Coalition (CalETC),[78] ICF worked with California utility stakeholders to develop a PEV forecast whereby the PHEV population was characterized as 50% PHEV40, 25% PHEV20, and 25% PHEV10. Data from the Clean Vehicle Rebate Project indicate that the current split of rebates issued for PHEV40/PHEV20/PHEV10 is 45%/22%/33% while national sales indicate a split of 49%/26%/25%.[79] If we assume that the

[78] California Transportation Electrification Assessment, prepared for the California Electric Transportation Coalition, September 2014. Available online at http://www.caletc.com/wp-content/uploads/2014/09/CalETC_TEA_Phase_1-FINAL_Updated_092014.pdf.

[79] Based on ICF analysis of sales data reported by InsideEVs (www.insideevs.com).

PHEV20 and PHEV10 will complete 50% and 25% of their all-electric miles (scaled based on the performance of the Volt), then the average weighted all-electric VMT (eVMT) is 56.3% for the hypothetical 50%/25%/25% PHEV fleet.

As the electric range of PHEVs increases, the fraction of miles driven on electricity will increase. As noted previously, the 2016 Chevrolet Volt will have an estimated electric range of 53 miles and therefore 71% of miles on average on electricity.[80]

ICF used a range of 60–80% for the utility factor in PHEVs.

- In the lower limit case, we started with ICF assumptions from the California Transportation Electrification Assessment, which assume about a 56% utility factor.
- In the upper limit case, we assume that the average PHEV sold in 2030 will achieve 50 miles electric range with a utility factor of about 70%.
- In both cases, we assume the additional margin of all-electric miles traveled would be achieved through a variety of mechanisms, including expanded charging infrastructure (e.g., at workplaces and in public),[81] incentives provided by utilities (e.g., use of LCFS credits), a shift in the market for PHEVs (e.g., towards the PHEV40) or technological improvements in batteries (thereby increasing the all-electric range of vehicles).

It is conceivable that the increased availability of charging infrastructure could increase the sales of BEVs or PHEVs. However, ICF did not assume that the increased availability of charging infrastructure would increase the sale of PEVs beyond what is already assumed under the ZEV program enhancements, in large part because the magnitude of the increase in vehicles sales with expanded charging infrastructure availability is difficult to quantify with current data.

Medium- and Heavy-Duty Vehicles

Biodiesel Blending

Biodiesel is a fatty acid methyl ester (FAME) that can be synthesized from vegetable oils, waste oils, fats, and grease. Biodiesel is generally used in low-level blends: biodiesel blended in at 5% by volume is considered the same as diesel and biodiesel blended at 20% by volume is the upper limit of blending for the majority of transportation applications due to vehicle warranty. Common biodiesel feedstocks include virgin oils (e.g., from soybeans or canola), corn oil (most often as a byproduct of corn ethanol production, used cooking oil (UCO), and animal fats. For the purposes of this report, as discussed previously, we did not explicitly consider biodiesel feedstocks. Rather, we relied on the constraints imposed in reference material to ensure that reasonable supply and sustainability constraints were considered.

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[80] SAE J2841, Utility Factor Definitions for Plug-In Hybrid Electric Vehicles Using 2001 U.S. DOT National Household Travel Survey Data, 2010. Available online at **http://standards.sae.org/j2841_200903/**.

[81] Zoepf, S. et al., Charging Choices and Fuel Displacement in a Large-Scale Demonstration of Plug-In Hybrid Electric Vehicles, available online at **http://web.mit.edu/sloan-auto-lab/research/beforeh2/files/Zoepf%20et%20al%20TRR%202385.pdf**

There are several significant developments that have and will continue to support increased biodiesel consumption in California, Oregon, and Washington. Most notably, the low carbon fuel standards in California and Oregon; whereas Oregon and Washington both have renewable fuel standards which require a certain percentage of liquid biofuels to be blended with petroleum-based fuels.

On the other hand, the Alternative Diesel Fuel (ADF) Rulemaking will limit the potential for biodiesel blending in the near-term future. There are air quality concerns regarding the use of higher blends of biodiesel with conventional diesel, especially as it relates to NOx emissions.[82] The ADF rulemaking[83] is highlighted by a) the characterization of a three-stage process for ADFs to be introduced and tested in California motor vehicles, at various blends and b) in-use requirements for ADF blends. With regard to the latter, CARB staff's statistical analysis demonstrated that for certain vehicles operating on biodiesel blends, there are potential adverse impacts on NOx. As a result, CARB proposed a control level for biodiesel at various saturation levels (which corresponds to the feedstock and fuel production processes). For low saturation biodiesel blends, the control level is 5% (B5) for April 1 to October 31 and 10% (B10) for November 1 to March 31; high saturation biodiesel blends are limited to B10 all year.

For California's BAU Scenario, ICF considered a limitation on the amount of biodiesel than can be blended into conventional diesel, with a seasonally adjusted limit of 7% (B7). However, in order to achieve the HtO petroleum reduction goals, higher blends (e.g., B15–B20) were required across all cases. ICF's inherent assumption is that the ADF Rulemaking will be phased out post-2023 because fleet turnover will yield newer diesel engines, thereby eliminating or drastically lowering the potential for higher NOx emissions.

The volumes of biodiesel blended into each category were constrained based on the volumes included in the ICCT study regarding the supply of low carbon fuels to the Pacific Region. In most cases, however, the volumes were relatively low because diesel consumption was reduced (via fuel economy improvements) or outright displaced (by renewable diesel blending or natural gas consumption).

Renewable Diesel Blending

Renewable diesel is similar to renewable gasoline in that it is produced via biomass-to-liquid processing. Renewable diesel, however, is currently being produced, primarily via hydrogenation of bio-oils, in commercial quantities and being consumed in California. In terms of chemical and physical properties, renewable diesel meets all the requirements of ASTM D975; for instance, Neste's NExBTL product meets the fuel quality specifications of CARB diesel, meaning no modifications are needed to existing storage and transport infrastructure.

Neste has been the most aggressive producer shipping renewable diesel to California. In 2010, Neste invested billions of dollars to build renewable diesel production plants in Singapore and Rotterdam (the Netherlands), in addition to facilities in Finland. All four of these facilities are

82 NOx is a precursor to photochemical ozone a.k.a. smog and is a criteria pollutant.

83 More information available online at http://www.arb.ca.gov/regact/2015/adf2015/adf2015.htm.

operational; the Singapore plant is well situated to deliver renewable diesel fuel to California. Furthermore, the renewable diesel industry has expanded significantly with the completion of Diamond Green's production facility in Norco, Louisiana. Diamond Green—a joint venture between Valero and Darling International Inc.—has a reported production capacity of 137 million gallons per year. Diamond Green indicated to CARB that it plans to use four feedstocks for renewable diesel production at its facility: soy oil, corn oil, used cooking oil, and animal fat.[84]

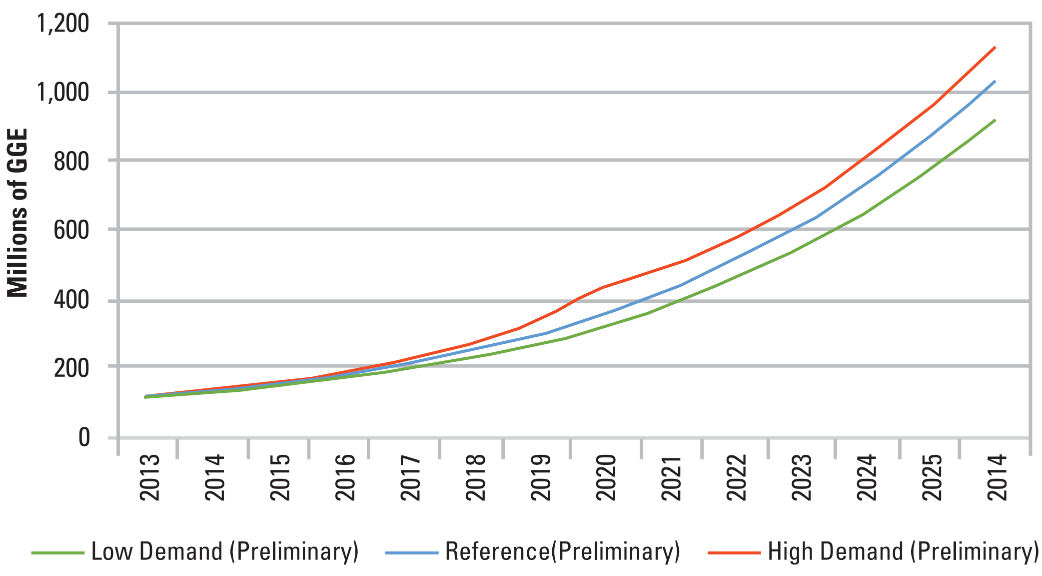
The volumes of renewable diesel deployed was constrained based on the volumes included in the ICCT study regarding the supply of low carbon fuels to the Pacific Region—with drop in renewable diesel ranging from 40–690 million gallons and hydrogenated vegetable oils (HVO) ranging from 120–970 million gallons.

Natural Gas

ICF considered the potential for natural gas—compressed (CNG), liquefied (LNG), and renewable natural gas (RNG)—in heavy-duty applications such as short-, medium-, and long-haul trucks, and refuse haulers. Natural gas was considered in trucks in the medium-duty and heavy-duty market segments. Although some industry stakeholders have indicated that CNG has potential in the light-duty vehicle market, we did not include this in our analysis.

ICF considered an upper limit on natural gas based on preliminary results presented by the California Energy Commission as part of the 2015 Integrated Energy Policy Report (IEPR), which shows about 900–1,100 million GGE by 2026.

Figure 17. Preliminary Forecasted Natural Gas Transportation Energy Consumption in California[85]



Source: California Energy Commission

[84] More information is available online at: **http://www.arb.ca.gov/fuels/lcfs/2a2b/apps/dgd-sum-120112.pdf**.

[85] California Energy Commission, Overview of Preliminary Transportation Energy Demand Forecast, June 2015. Available online at **http://www.energy.ca.gov/2015_energypolicy/documents/#06242015**.

CARB's illustrative compliance scenario assumes 485 million dge of natural gas consumption by 2025, with 450 million dge from RNG. ICCT reports a range of 100–1,700 million dge of RNG to the Pacific Coast Region by 2030.

Renewable Natural Gas

Renewable natural gas (RNG) is produced over a series of steps—namely collection of a feedstock, delivery to a processing facility for biomass-to-gas conversion, gas conditioning, compression, and injection into the pipeline or direct dispensing into a vehicle. RNG can be produced from a variety of feedstocks including agricultural residue, animal manure, energy crops, forestry and forest product residue, landfill gas (LFG), municipal solid waste, and wastewater treatment gas. It is generally produced via either anaerobic digestion or thermal gasification:

RNG is a "drop-in" replacement for natural gas used in electricity production, heating and cooling, commercial and industrial applications, and when used in transportation applications. To date, RNG has made a significant contribution towards meeting California's LCFS targets, representing about 20–40% of natural gas used as a transportation fuel in California.[86] ICF's analysis of various studies[87,88,89] indicates that the national-level potential ranging from 7.5 billion diesel gallon equivalents to 75 billion dge (although these volumes are highly unlikely by 2030). For the sake of comparison, CARB's illustrative compliance scenario assumes 485 million dge of natural gas consumption by 2025, with 450 million dge (i.e., >90%) from RNG. ICCT reports a supply in the range of 100–1,700 million dge of RNG to the Pacific Coast Region by 2030.

Medium- and Heavy-Duty Electrification

ICF considered limited electrification opportunities for medium- and heavy-duty vehicles. ICF recognizes that there are likely opportunities beyond those listed here, such as electric buses; however, we sought to rely on existing analyses and forecasts where possible, thereby limiting our consideration.

Medium-Duty E-Trucks

Medium-duty vehicles, including delivery vans and work trucks are considered a key opportunity for electrification.[90] CARB has targeted delivery vans and small trucks for zero emission applications as part of its Sustainable Freight Strategy, with potential incentive support in the 2017–2020 timeframe.[91] CARB focuses on the opportunity to electrify the last mile of delivery for freight,

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[86] Based on ICF analysis and confirmed by outreach to CARB for data from the LCFS Reporting Tool.

[87] National Petroleum Council (NPC), An Overview of the Feedstock Capacity, Economics, and GHG Emission Reduction Benefits of RNG as a Low-Carbon Fuel, March 2012

[88] American Gas Foundation (AGF), The Potential for Renewable Natural Gas: Biogas Derived from Biomass Feedstocks and Upgraded to Pipeline Quality, September 2011.

[89] U.S. Department of Energy (DOE), Billion Ton Update: Biomass Supply for a Bioenergy and Bioproducts Industry, August 2011.

[90] CALSTART, CalHEAT Research and Market Transformation Roadmap for Medium- and Heavy-Duty Trucks for CEC/PIER Program, February 2013. Available online at **http://www.calstart.org/Libraries/CalHEAT_2013_Documents_Presentations/CalHEAT_Roadmap_Final_Draft_Rev_7.sflb.ashx**

[91] CARB, Sustainable Freight: Pathways to Zero and Near-Zero Emissions, Discussion Document, April 2015. Available online at **http://www.arb.ca.gov/gmp/sfti/sustainable-freight-pathways-to-zero-and-near-zero-emissions-discussion-document.pdf**

highlighting the operation of these vehicles in urban applications. The first stage of e-trucks have been deployed in California, with many models available via the Hybrid Truck and Bus Voucher Incentive Program (HVIP), as shown in the table below.

Table 22. Sample List of E-Truck Manufacturers and Vehicles

Manufacturer	Electric Truck/Vehicle Type
AMP Electric Vehicles	• E-100 Workhorse Zero-Emissions Walk-In Van
EVI	• EVI WI (Walk In)129
Smith Electric Vehiclesn/a	• Box Truck • Step Van
Zenith Motors	• Electric Cargo Van • Shuttle Van

ICF considered forecasts for commercial light trucks included in an IEE White Paper entitled Forecast of On-Road Electric Transportation in the U.S. (2010–2035).[92]

Table 23. IEE's Forecasted Energy Consumption by Commercial Light Trucks to 2030

Scenario	Energy Consumption by Commercial Light Trucks (TWh)			
	2015	2020	2025	2030
Low	0	1	1	2
Medium	1	3	7	12
High	1	4	9	16

Source: IEE Forecast of On-Road Electric Transportation in the U.S. (2010–2035)

When this strategy was employed, ICF assumed that about 25% of the vehicles deployed would be in California.[93] ICF used test data reported by NREL regarding the efficiency of corresponding vehicles in our modeling.[94] NREL reports an efficiency of 1.265 kWh/mi; we used this value for Class 3 trucks and revised this downwards 10% for Class 2b trucks and used a value of 0.5 kWh/mi for Class 2a vehicles based on ICF's analysis of differences in fuel economy of internal combustion engine vehicles between these classes (Class 3, Class 2b, and Class 2a).

92 IEE and EnerNOC Utility Solutions Consulting, Forecast of On-Road Electric Transportation in the U.S. (2010–2035), White Paper, April 2013. Available online at http://www.edisonfoundation.net/iei/Documents/IEE_OnRoadElectricTransportation-Forecast_0413_FINAL.pdf.

93 The white paper assumes trucks with GVWR range 8,500–10,000 lbs. For the purposes of this analysis, ICF included vehicles in the GVWR range of 8,500–14,000 lbs.

94 NREL, Smith Newton Vehicle Performance Evaluation Gen 2 – Cumulative, January 2013 through September 2014. Available online at http://www.nrel.gov/docs/fy15osti/64238.pdf.

Electrified Drayage Trucks

Drayage trucks are likely to present an initial opportunity for electrification of the heavy-duty truck fleet due to the limited truck range and potential for a centralized charging infrastructure. While Class 8 PHEV and BEV trucks are still in demonstration and R&D phases, advances in battery technology are likely to enable all-electric port drayage trucks by 2030. Currently a southern California regional zero emission trucks working group is investing in testing of new technologies, such as the SR-103 Overhead Catenary Demonstration by Volvo/Siemens. And the Ports of Los Angeles and Long Beach continue to fund zero emission truck demonstrations to advance the technology, such as electric and hydrogen powered trucks.[95]

When this strategy was employed,[96] we assumed that 25% of drayage trucks at major seaports would be electrified by 2030 and that these vehicles would be introduced by 2025. To calculate the strategy impacts in California, we applied at 25% reduction in fuel use to port trucks; to calculate the strategy impacts in Oregon and Washington, we calculated the drayage truck VMT as a percent of total Class 8 truck VMT, and assumed this fraction applies to Oregon and Washington.

Off-Road

Off-Road Equipment Electrification

Estimates for off-road electrification and corresponding petroleum consumption reduction were estimated for California, Oregon, and Washington for the following technologies and market segments: forklifts, truck stop electrification, transport refrigeration units, port cargo handling equipment, and airport cargo handling equipment.

The California displacement volumes were taken directly from the California Transportation Electrification Assessment (TEA), prepared by ICF for CalETC.[97] Detailed information is available in Appendix A of the referenced study.

ICF developed a similar methodology for Oregon and Washington to estimate petroleum displacement potential in those states, as shown in the table below.

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95 Port of Los Angeles, Zero Emission White Paper (Draft), July 2015. Available online at http://www.portoflosangeles.org/pdf/Zero_Emmissions_White_Paper_DRAFT.pdf.

96 ICF notes that this strategy is either included or excluded from the cases analyzed; it is not varied.

97 California Transportation Electrification Assessment, ICF International and E3 for CalETC, 2014. Available online at: http://www.caletc.com/wp-content/uploads/2014/09/CalETC_TEA_Phase_1-FINAL_Updated_092014.pdf

Table 24. Data Sources Used in Off-Road Market Segments to Estimate Petroleum Reduction

Market Segment	Description of Data Sources
Fork lifts	• US Census Bureau for the population estimates[98] • ITA Market Intelligence report[99] for annual forklift sales
Truck Stop Electrification	• DOE Alternative Fuels Database[100] for current electrified truck stop spaces • Allstays[101] for current total truck spaces in Washington and Oregon
Transport Refrigeration Units	• US Census Bureau for the population estimates[102] to scale the TEA to Washington and Oregon
Port Cargo Handling Equipment	• Port of Seattle twenty-foot equivalent units (TEUs)[103] to scale the TEA to Washington estimates • Port of Portland twenty-foot equivalent units (TEUs)[104] to scale the TEA to Oregon estimates
Airport Cargo Handling Equipment	• Federal Aviation Administration (FAA) enplanements for Oregon and Washington airports[105]

Shore Power for Ocean-Going Vessels

Ocean-going vessels (OGVs) can virtually eliminate petroleum use from their auxiliary engines while at berth by using shore power. Use of shore power requires installation of both shore-side electrical infrastructure and modifications to the ship's electrical system. California regulations will require shore power from most cruise ships, container ships, and refrigerated-cargo ships. The regulation applies to cargo ship fleets that have 25 or more annual visits to a port; or cruise ship fleets with 5 or more annual visits. For fleets that meet this definition, the regulation requires that 80% of a fleet's vessel calls use shore power by 2020. In California, there is potential for additional petroleum reduction by requiring shore power for (1) the remaining cruise, container, and refrigerated-cargo ships, and (2) other ship types not affected by the regulation, such as tankers and bulk cargo ships. In Washington and Oregon, there is little current use of shore power and no regulations requiring it.

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98 State Population Estimates, United States Census Bureau, Available online at: http://www.census.gov/popest/data/historical/2010s/vintage_2011/state.html.

99 US Factory Shipments Through 2012, Industrial Truck Association, 2012. Available online at http://www.indtrk.org/wp-content/uploads/2013/04/US-Factory-Shipments-Through-2012.pdf.

100 Truck Stop Electrification Locator, NREL, Alternative Fuels Data Center, Available online at: http://www.afdc.energy.gov/tse_locator/.

101 Allstays Truck Stop Locator, Available online at http://www.allstays.com/c/truck-stops-washington.htm and http://www.allstays.com/c/truck-stops-oregon.htm.

102 State Population Estimates, United States Census Bureau, Available online at: http://www.census.gov/popest/data/historical/2010s/vintage_2011/state.html.

103 The Northwest Sea Alliance TEUs, Port of Seattle and Port of Tacoma, Available, 2015, online at: https://www.portseattle.org/About/Publications/Statistics/Seaport/Documents/mcps.pdf.

104 PortDispatch, Freight Transportation News, Port of Portland, 2014. Available online at https://www.portofportland.com/publications/PortDispatch/post/2013exportsanddevelopment.aspx.

105 Passenger Boarding (Enplanement) and All-Cargo Data for U.S. Airports, Federal Aviation Administration, 2011. Available online at: http://www.faa.gov/airports/planning_capacity/passenger_allcargo_stats/passenger/?year=2011.

This strategy would require shore power for all ocean-going vessels in California, Oregon, and Washington by 2030. We assume that petroleum reduction from the strategy would begin in 2021 and increase linearly to 2030. The resulting petroleum reductions in 2030 would be 25 million gallons in California, 4 million gallons in Oregon, and 50 million gallons in Washington.

Data Sources and Tools

On-Road Petroleum Consumption

California

ICF used 34 vehicles categories from EMFAC2014 to group fuel consumption intro three broad categories for consideration: light-, medium-, and heavy-duty vehicles. The table below shows how we mapped EMFAC2014 vehicle categories to light-,medium-, and heavy-duty vehicles.

Table 25. Vehicle Categories in EMFAC2014

ICF Category	EMFAC2014 Vehicle Category	Description
Light-Duty Vehicles	LDA	Passenger Cars
	LDT1	Light-Duty Trucks (0–3750 lbs)
	LDT2	Light-Duty Trucks (3751–5750 lbs)
	MDV	Medium-Duty Trucks (5751–8500 lbs)
Medium Heavy Duty Vehicles	LHD1	Light-Heavy-Duty Trucks (8501–10000 lbs)
	LHD2	Light-Heavy-Duty Trucks (10001–14000 lbs)
	T6 Ag	Medium-Heavy Duty Diesel Agriculture Truck
	T6 CAIRP heavy	Medium-Heavy Duty Diesel CA International Registration Plan Truck (GVWR>26000 lbs)
	T6 CAIRP small	Medium-Heavy Duty Diesel CA International Registration Plan Truck (GVWR<26000 lbs)
	T6 instate construction heavy	Medium-Heavy Duty Diesel instate construction Truck (GVWR>26000 lbs)
	T6 instate construction small	Medium-Heavy Duty Diesel instate construction Truck (GVWR<26000 lbs)
	T6 instate heavy	Medium-Heavy Duty Diesel instate Truck (GVWR>26000 lbs)
	T6 instate small	Medium-Heavy Duty Diesel instate Truck (GVWR<26000 lbs)
	T6 OOS heavy	Medium-Heavy Duty Diesel Out-of-state Truck (GVWR>26000 lbs)
	T6 OOS small	Medium-Heavy Duty Diesel Out-of-state Truck (GVWR<26000 lbs)
	T6 Public	Medium-Heavy Duty Diesel Public Fleet Truck
	T6 utility	Medium-Heavy Duty Diesel Utility Fleet Truck
	T6TS	Medium-Heavy Duty Gasoline Truck

ICF Category	EMFAC2014 Vehicle Category	Description
Heavy Heavy-Duty Vehicles	T7 Ag	Heavy-Heavy Duty Diesel Agriculture Truck
	T7 CAIRP	Heavy-Heavy Duty Diesel CA International Registration Plan Truck
	T7 CAIRP construction	Heavy-Heavy Duty Diesel CA International Registration Plan Construction Truck
	T7 NNOOS	Heavy-Heavy Duty Diesel Non-Neighboring Out-of-state Truck
	T7 NOOS	Heavy-Heavy Duty Diesel Neighboring Out-of-state Truck
	T7 other port	Heavy-Heavy Duty Diesel Drayage Truck at Other Facilities
	T7 POAK	Heavy-Heavy Duty Diesel Drayage Truck in Bay Area
	T7 POLA	Heavy-Heavy Duty Diesel Drayage Truck near South Coast
	T7 Public	Heavy-Heavy Duty Diesel Public Fleet Truck
	T7 Single	Heavy-Heavy Duty Diesel Single Unit Truck
	T7 single construction	Heavy-Heavy Duty Diesel Single Unit Construction Truck
	T7 SWCV	Heavy-Heavy Duty Diesel Solid Waste Collection Truck
	T7 tractor	Heavy-Heavy Duty Diesel Tractor Truck
	T7 tractor construction	Heavy-Heavy Duty Diesel Tractor Construction Truck
	T7 utility	Heavy-Heavy Duty Diesel Utility Fleet Truck
	T7IS	Heavy-Heavy Duty Gasoline Truck

ICF checked the EMFAC2014 fuel consumption (gasoline and diesel) for historical years (pre-2015) against several sources, including the data reported by CARB for the LCFS Reporting Tool,[106] taxable sales from the Board of Equalization (BOE),[107] historical sales of distillate fuel oil reported

[106] CARB 2015 Proposed LCFS Regulation Order, April 3rd 2015 Public Workshop Meeting Document -"Illustrative Scenario .xlsx" (updated to *Appendix B: Development of Illustrative Compliance Scenarios and Evaluation of Potential Compliance Curves*).

[107] Information available online from the California Board of Equalization at http://www.boe.ca.gov/sptaxprog/spftrpts.htm

by the Energy Information Administration (EIA), [108] and cases from the 2013 IEPR developed by the California Energy Commission.[109] There is good agreement between the fuel consumption estimates in EMFAC2014 compared to data reported by BOE via taxable sales (on-road only).

Gasoline fuel consumption forecasts differ across three sources considered: 1) EMFAC2014, 2) data included in CARB's LCFS rulemaking/re-adoption process (CARB, LCFS 2015), and 3) data from the most recently available IEPR forecasts from the CEC (CEC 2013 IEPR). ICF opted to use on-road gasoline forecasts from EMFAC2014 based on our review of the available supporting documentation from these various sources and consideration of transparency. CARB staff have recently updated EMFAC2014 to account for a variety of improvements, ranging from changes in counts of VMT, an improved understanding of vehicle ownership, regional-level vehicle ownership and fuel consumption data, and other measures. EMFAC2014 is available publicly, and the supporting data (e.g., vehicle populations, fuel consumption, fuel economy data, etc.) are mostly available via the online web-based tool.

The diesel fuel consumption forecasts are more difficult to compare because of the significant volume of fuel that is consumed in off-road applications. For instance, diesel consumption from EMFAC2014 is consistently 5–20% lower than the data reported in CARB's LCFS rulemaking process and the 2013 IEPR cases. Both the CARB LCFS data and the IEPR cases, however, include diesel consumption from more than on-road diesel. ICF could not disaggregate these data sources into on-road and off-road diesel consumption; as a result, we were unable to compare meaningfully across these sources. The growth rate of diesel fuel consumption from EMFAC2014 is within 2–6% of the growth rate of diesel fuel consumption included in the Pacific region of the Annual Energy Outlook 2015. As noted previously, the transparency and public availability of EMFAC2014 lends significant credence to our decision to rely on the model for on-road diesel consumption.

Adjusting VMT

EMFAC2014 does not account for SCSs adopted by MPOs in response to SB 375. Between 2010 and 2030, ICF estimates that efforts to coordinate regional land use and transportation planning toward reducing VMT and GHG emissions via California's SB 375, will reduce per capita VMT by 5.6%. We reviewed VMT forecasts for the four largest MPOs that are currently working to meet GHG reduction targets through their regional plans. Since improvements in vehicle technology also work to reduce GHG emissions and are accounted for in MPO GHG reduction forecasts, VMT reductions are lower than GHG reduction targets by anywhere from 20–66%. We assumed that regional plans reduce VMT in a linear fashion, and adjusted reductions to account for the difference in MPOs' baselines and target years (typically 2005–2035) and the baseline and target year in our analysis (2010–2030). We then took a population-weighted average of VMT reductions from EIR documentation submitted by four MPOs to estimate the average per capita VMT reduction.

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[108] Data are collected via Form EIA-821, "Annual Fuel and Kerosene Report". Data are available online at **http://www.eia.gov/dnav/pet/pet_cons_821dst_dcu_nus_a.htm**

[109] CEC, Integrated Energy Policy Report 2013. Available online at **http://www.energy.ca.gov/2013_energypolicy/**. ICF received some information directly from CEC staff.

Table 26. Adjusted VMT Reductions for BAU Scenario in California

State	MPO	Baseline year	Target year	% VMT reduction	Adjusted 2010–2030 % VMT reduction	Current population (from RTPs)	Population-weighted % VMT reductions
California	SCAG	2005	2035	5.5%	3.7%	18,000,000	2.2%
	MTC	2005	2035	9.0%	6.0%	7,000,000	1.4%
	SANDAG	2005	2035	6.7%	4.5%	3,000,000	0.5%
	SACOG	2008	2035	10.0%	7.4%	2,200,000	0.5%
	California Population-Adjusted Travel Demand Reduction in 2030						4.6%

To determine the absolute VMT reductions (as opposed to a per capita basis), we get an estimated VMT reduction of 5.4% for California by 2030 and 10.5% for Oregon.

Oregon and Washington

ICF utilized a modified version of the VISION2014 model. VISION is a fleet sales and turnover model developed by ANL that can be used to quantify future energy consumption and GHG emissions based on overall fleet characteristics and composition. The VISION2014 model does not have the same level of granularity regarding vehicle classes, as illustrated in the table below.

Table 27. Vehicle Categories in the VISION Model

ICF Category	VISION2014 Vehicle Classes	Description
Light-duty vehicles	LDA	Passenger Cars
	LDT	Light Trucks (up to 8500 lbs)
Medium-duty and Heavy-duty vehicles	Class 3–6	Medium duty vehicles using both gasoline and diesel
	Class 7 and 8	Heavy-duty vehicles using diesel; including single unit and combination unit trucks

For both Oregon and Washington, the VISION2014 baseline cases of the model that were modified explicitly for work performed for the Oregon Department of Environmental Quality (DEQ) and the Washington Office of Financial Management (OFM) regarding their respective low carbon fuel standard programs.[110] This helps maintain consistency with existing work—and in both cases, the VISION2014 model has been updated to reflect vehicle populations, vehicle miles traveled, and fuel consumption for Oregon and Washington respectively. As noted previously, the VISION model does not have as much granularity regarding vehicle types as EMFAC2014. Although this

[110] Note that the former work was performed by ICF International (under contract with OR DEQ) and the latter was performed by Life Cycle Associates (under contract with WA OFM).

limits our ability to apply targeted strategies in subsequent stages of the project modeling, this is a minor issue compared to the benefit of maintaining consistency with other work that has been performed in this space.

Off-Road Petroleum Consumption

Baseline projections of petroleum consumption for off-road sources were developed using a combination of data from the U.S. Department of Energy (DOE), state agencies, and port emission inventories. For the purposes of developing the baseline, off-road transportation was grouped into three categories: railroads, marine vessels, and other off-road.

Railroads

Railroad fuel consumption projections were developed for three types of locomotives: freight line-haul, freight switcher, and passenger.

- For California, a baseline forecast of freight line-haul fuel use to 2030 was obtained from CARB. This forecast reflects a recent update to CARB's line-haul locomotive emission inventory. Using data from CARB's 2012 emission inventory, we estimated that line-haul locomotives account for 88% of total locomotive fuel use in the state, while switchers and passenger locomotives account for 5% and 7% of total locomotive fuel use, respectively. The resulting total locomotive fuel use (253 million gallons) is close to the railroad fuel sales reported in the EIA's Fuel Oil and Kerosene Sales (FOKS) report (258 million gallons) for that year.[111] We assumed the distribution by locomotive type remains constant through 2030.
- For Oregon, we obtained 2010–2013 statewide railroad fuel sales from the FOKS report. The process for projecting total fuel use and estimating a distribution by locomotive type is identical to that described for Washington.
- For Washington, we obtained 2010–2013 statewide railroad fuel sales from the FOKS report. To project to 2030, we applied the growth rate of California line-haul locomotive fuel use, since most locomotive activity in both states is driven by Asian waterborne imports. To split total railroad fuel use by locomotive type, we applied the California distribution of 88% line-haul, 5% switcher, and 7% passenger.

Marine Vessels

Marine vessel fuel consumption projections were developed for three types of vessels: OGVs, commercial harbor craft (e.g., tugs, ferries, etc.), and recreational boats.

- For California, current (2012) and projected (2020 and 2030) OGV and harbor craft fuel use was derived from the CO_2 emission inventory presented in ARB's draft Sustainable Freight plan.[112] To estimate the OGV emissions associated with at-berth operation (i.e., hoteling), we summed hoteling CO_2 emissions reported in the 2012 and 2013 emission inventories for the Port of Los Angeles, Port of Long Beach, and Port of Oakland, and estimated fuel use based on the CO_2

[111] U.S. Department of Energy, Energy Information Administration, *Fuel Oil and Kerosene Sales 2013*. January 30, 2015.

[112] California Air Resources Board, *Sustainable Freight: Pathways to Zero and Near-Zero Emissions, Discussion Draft*, April 2015.

emissions. To estimate 2011 California recreational boat fuel use, we applied the ratio of recreational boat fuel use to population derived from the State of Washington. Recreational boat fuel use was projected to grow with population, consistent with CARB assumptions.[113]

- For Oregon, we used 2010–2013 marine vessel sales from the EIA's FOKS report to reflect the total of OGVs and harbor craft. This total was split between OGVs and harbor craft using the ratio from California. Growth of OGV and harbor craft fuel use was assumed to be consistent with growth rates developed by CARB for the draft Sustainable Freight plan. To estimate 2011 Oregon recreational boat fuel use, we applied the ratio of recreational boat fuel use to population derived from the State of Washington. Recreational boat fuel use was projected to grow with population.
- For Washington, we obtained 2011 OGV, harbor craft, and recreational boat CO_2 emissions from the Puget Sound emission inventory, and estimated fuel use based on the CO_2 emissions. OGV hoteling fuel use was also estimated by this method. Projections for OGV and harbor craft fuel use were based on the growth rates developed by CARB for the draft Sustainable Freight plan, which reflect forecast trade volumes between U.S. West Coast and Asian ports. Recreational boat fuel use was projected to grow with population.

Other Off-Road Equipment

This category includes construction equipment, mobile agriculture and mining equipment, cargo handling equipment at ports and railyards, airport ground support equipment, and other equipment types not captured in the on-road vehicle, railroad, or marine vessel categories. Fuel consumption projections for this category were not split into more specific equipment types.

- For California, we obtained 2010–2013 fuel use from the EIA's FOKS report (No. 2 Diesel Sales/Deliveries to Off-Highway Consumers). Our projections rely on the growth rates in CARB's projected emission inventory for off-road equipment.[114]
- For Oregon and Washington, we obtained 2010–2013 fuel use from the EIA's FOKS report (No. 2 Diesel Sales/Deliveries to Off-Highway Consumers). Our projections use the same growth rate as that used for California.

Greenhouse Gas Emissions

GHG Emissions Factors

ICF used the carbon intensity emission factors (reported in grams of carbon dioxide equivalents per unit energy of fuel, gCO_2e/MJ) shown in the table below to estimate the GHG emissions estimates shown Sections 3-5. The values are sourced from the following documentation:

- **California:** The CI values are taken from CARB's documentation included in the various 15-day packages as part of the LCFS Program re-adoption in 2015 and the fuel pathways that have been submitted to date.

[113] California Air Resources Board, *Spark-Ignition Marine Watercraft Regulation Update*, June 4, 2014.

[114] California Air Resources Board, Staff Report: Initial Statement of Reasons for Proposed Rulemaking, Proposed Amendments to the Regulation for In-Use Off-Road Diesel-Fueled Fleets and the Off-Road Large Spark-Ignition Fleet Requirements, Appendix D: OSM and Summary of Off-Road Emissions Inventory Update. October 2010.

- **Oregon:** The CI values are largely in line with those in California (based on discussions with OR DEQ staff), with the exception of gasoline and diesel, which are taken from a recent analysis by OR DEQ.[115] Other values are updated based on previous analyses performed for OR DEQ.[116]
- **Washington:** The CI values are taken directly from the report published by Washington OFM in December 2014.[117]

Table 28. Carbon Intensity Values Used in GHG Emissions Estimates (reported in gCO_2e/MJ)

Fuel	Feedstock	California	Oregon	Washington
CARBOB		99.78	100.77	100.70
Diesel		102.01	101.65	101.70

		low	high	low	high	low	high
Ethanol		20.00	72.04	20.00	72.04	37.20	48.07
	corn	63.90	75.97				85.60
	sorghum	63.90	83.49				
	sugarcane	35.50	56.66			37.20	43.60
	corn stover	41.05	41.05				
	cellulosic	20.00	35.00				15.00
Renewable Gasoline		15.00	35.00	15.00	35.00	7.29	17.00
Biodiesel		10.00	39.32	10.00	39.32	16.76	33.52
	soybean oil	42.03	51.85				59.60
	corn oil	5.00	10.00				14.00
	canola oil	40.19	57.87				46.00
	animal fats	15.00	37.54				29.70
	cooking oil						18.30

[115] Agenda Item D—Applying OPGEE to Oregon's Petroleum Fuels, Oregon Clean Fuels Program Updates Rulemaking Advisory Committee, available online at http://www.oregon.gov/deq/RulesandRegulations/Documents/072715CleanFuelsAgendaD.pdf.

[116] ICF International for OR DEQ, Task 3—Updated Compliance Scenarios, August 2014, available online at http://www.deq.state.or.us/aq/cleanFuel/docs/ComplianceScenarios_ICF.pdf.

[117] Life Cycle Associates, A Clean Fuel Standard in Washington State, December 2014, available online at http://ofm.wa.gov/initiatives/cleanfuelstandards/Documents/Carbon_Fuel_Standard_evaluation_2014_final.pdf.

Fuel	Feedstock	California		Oregon		Washington	
Renewable Diesel		20.00	40.00	20.00	40.00	20.00	40.00
Natural Gas		77.76	86.40	77.76	86.40	76.99	85.55
	CNG	70.53	78.37			69.84	77.60
	LNG	84.98	94.42			84.14	93.49
Renewable Natural Gas		7.85	55.53	7.85	55.53	7.85	55.53
	LFG, CNG	15.00	46.42				7.70
	LFG, LNG	20.00	64.63				
	HSAD		-22.93				
	WWTP		19.34				9.60
Electricity		68.29	105.16	125.38	154.97	44.00	49.40

GHG Emission Reductions

The analysis focuses on petroleum reductions and was not explicitly designed to achieve a greenhouse gas emissions reduction target. However, we calculated a range of greenhouse gas emissions for each of the four cases based on lifecycle emission factors or carbon intensities for each transportation fuel (with considerations unique to each state). The analysis suggests that the greenhouse gas impacts can vary by as much as 10% depending on factors such as the feedstocks used to produce liquid biofuels, the balance between fossil natural gas and renewable natural gas, and to what extent the power grid can be de-carbonized by 2030. This variation highlights the need for complementary policies that incentivize low carbon solutions in parallel with petroleum reductions.

California

The table below highlights our GHG emission calculations for California and the corresponding range of percent reductions in 2030 from 2015.

Table 29. Summary of GHG Emissions for Various Cases, California

Case		GHG Emissions (MMT CO_2e)				% Reduction (2015–2030)
		2015	2020	2025	2030	
California Baseline	Low	199	187	164	154	21–23%
	High	206	195	173	163	
HtO Pathway	Low	200	178	149	114	38–43%
	High	210	190	163	130	
High Efficiency/High Electricity Case	Low	199	185	152	118	36–41%
	High	208	196	166	133	
High Biofuels Case	Low	204	172	143	127	32–38%
	High	221	191	166	149	
Transportation & Land Use Planning Case	Low	194	177	150	136	27–30%
	High	204	188	163	148	

Oregon

The table below highlights our GHG emission calculations for Oregon and the corresponding range of percent reductions in 2030 from 2015.

Table 30. Summary of GHG Emissions for Various Cases, Oregon

Case		GHG Emissions (MMT CO_2e)				% Reduction (2015–2030)
		2015	2020	2025	2030	
OR Baseline	Low	25	25	24	24	4–5%
	High	26	26	25	25	
HtO Pathway	Low	25	23	21	15	31–39%
	High	26	25	23	18	
High Efficiency/High Electricity Case	Low	25	25	23	20	20–22%
	High	26	26	24	21	
High Biofuels Case	Low	25	22	20	17	22–31%
	High	26	24	22	20	
Transportation & Land Use Planning Case	Low	25	24	23	22	12%
	High	25	25	23	22	

Washington

The table below highlights our GHG emission calculations for Washington and the corresponding range of percent reductions in 2030 from 2015.

Table 31. Summary of GHG Emissions for Various Cases, Washington

Case		GHG Emissions (MMT CO_2e)				% Reduction (2015–2030)
		2015	2020	2025	2030	
WA Baseline	Low	38	37	36	35	7%
	High	38	37	36	35	
HtO Pathway	Low	37	33	28	21	42–45%
	High	37	34	29	22	
High Efficiency/High Electricity Case	Low	38	36	31	24	35–36%
	High	38	36	31	24	
High Biofuels Case	Low	38	33	30	27	25–29%
	High	38	34	31	29	
Transportation & Land Use Planning Case	Low	37	35	32	30	17%
	High	37	35	32	31	

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