STATE ALTERNATIVE FUELS PLAN

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ABSTRACT

As required by Assembly Bill 1007, the State Alternative Fuels Plan (Plan) presents strategies and actions California must take to increase the use of alternative non-petroleum fuels in a manner that minimizes costs to California and maximizes the economic benefits of in-state production. The Plan assessed various alternative fuels and developed fuel portfolios to meet California's goals to reduce petroleum consumption, increase alternative fuels use, reduce greenhouse gas emissions, and increase in-state production of biofuels without causing a significant degradation of public health and environmental quality.

Plan examples and assumptions are discussed with an emphasis on outcomes for milestone years 2012, 2017, and 2022. Results are presented for integrated examples that satisfy the petroleum reduction goals, greenhouse gas emissions outcomes, and possible Low-Carbon Fuels Standards impact. Cost and macro-economic impacts are characterized; in-state biofuels production potential is presented, and the possible trade policy implications of the Plan are discussed.

The key circumstances and conditions necessary to achieve the Plan outcomes are presented for each fuel based on Plan assumptions and analysis. The Plan presents findings and recommendations to increase the use of alternative fuels in California with an emphasis on near-term to mid-term actions. The Plan describes a 2050 Vision that extends the Plan outcomes beyond the milestone years of 2012, 2017, and 2022 and lays a foundation for building a multi-fuel transportation energy future for California by 2050.

KEYWORDS

State Alternative Fuels Plan, 2050 Vision, Low-Carbon Fuels Standard

EXECUTIVE SUMMARY

The emergence of global climate change as a global imperative has attracted public attention to state and national level actions to reduce greenhouse gas (GHG) emissions. In California, the transportation sector is responsible for approximately 40 percent of statewide GHG emissions, over half of statewide criteria air pollution, and significant degradation of public health and environmental quality. A reasoned and well-planned transition to a diversified alternative transportation future can be a critical step toward achieving California's goals of improved air quality, reduced petroleum dependence and improved energy security, reduced GHG emissions, in-state biofuel production and use, and improved air quality.

California's transportation sector is more than 95 percent dependent on a single fuel source, petroleum, and over 60 percent of the nation's petroleum consumption comes from foreign sources. In 2006, Californians consumed an estimated 20 billion gallons of gas and diesel fuel on the state's roadways. The state and the nation are extremely vulnerable to petroleum price and supply disruptions at a time when crude oil prices exceed $90 per barrel.

While the United States consumes nearly 25 percent of the world's petroleum, as a country it maintains only 2 percent of the world's petroleum reserves. The Organization of Petroleum Exporting Countries continues to control over 65 percent of the world's oil supplies, and instability in the Middle East continues to threaten oil supplies. Diversifying the state's and the nation's fuels supplies through the introduction of alternative and renewable fuels will help to ease price volatility and improve fuel supply security. However, it is imperative that these goals are pursued while maintaining or improving air quality and public health impacts.

In January 2007, the Governor issued Executive Order S-01-07, establishing a goal to reduce carbon intensity of transportation fuels sold in California by 10 percent by 2020. The California Air Resources Board plans to develop a Low-Carbon Fuel Standard and will adopt the standard in late 2008. The "full fuel cycle" analysis conducted as part of this plan provides an analytical foundation and establishes a common technical basis for this standard, which the California Air Resources Board adopted as a "discrete early action measure" under Assembly Bill 32 (Núñez /Pavley, Chapter 488, Statutes of 2006).

The Plan presented in this report meets the requirements of Assembly Bill 1007 (Pavley, Chapter 371, Statutes of 2005) to develop and adopt a plan to increase the use of alternative fuels without adversely affecting air quality or water quality, or causing negative health effects. The Plan is presented as an alternative fuels goal coupled with a series of implementing requirements. These implementing requirements include such provisions as the Low-Carbon Fuel Standard, financial incentives authorized by the recent signing of Assembly Bill 118 (Núñez, Chapter 750, Statutes of 2007), policy recommendations for the affected state agencies, and a summary of actions that can be taken by the industry itself to innovate and promote alternative fuel use and production.

While this Plan focuses on transportation fuels and alternative fuels in particular, as required by AB 1007, other components of the transportation system, including advanced vehicle technology and efficiency improvements in conventional vehicles, are key elements needed to achieve the state's petroleum reduction, air quality, and climate change goals. In addition, significant efforts are needed to reduce vehicle miles traveled by all Californians through more effective land use and transportation planning and greater mass movement of people and goods.

Multiple State Policies

Governor Schwarzenegger, in his response to the California Energy Commission's (Energy Commission) *2003 Integrated Energy Policy Report*, called for a workable long-term plan to increase the use of alternative fuels. Subsequent legislation, Assembly Bill 1007 (Pavley, Chapter 371, Statutes of 2005), signed into law by the Governor, further directed the Energy Commission, in partnership with the California Air Resources Board, to develop a State Alternative Fuels Plan to increase the use of alternative fuels without adversely affecting air quality, water quality, or causing negative health effects.

The State Alternative Fuels Plan presents clear strategies and steps California must take to increase the use of alternative fuels. The Plan identifies actions that California must take to keep alternative fuels as a significant option to meet the state's transportation energy needs in an environmentally sound and sustainable manner. Sustainability requires the state to meet its future transportation energy needs with viable supply of alternative fuels. Sustainability also requires the state to insure that in accessing biofuels, food access and energy crops needs are balanced, biodiversity is protected, and water demands and use of agricultural chemicals do not harm the environment.

The State Alternative Fuels Plan recommends a combination of regulations, incentives, and market investments to achieve increased penetration of alternative and non-petroleum fuels. In addition, to accomplish a longer-term vision for 2050, vehicle efficiency improvements and significant reductions in vehicle miles traveled are needed. This Plan describes strategies, highlights actions, and recommends mechanisms to concurrently address multiple state policies in an integrated fashion: petroleum reduction, GHG reduction, and in-state biofuels production and use goals. Each of these policies sets specific targets.

Petroleum Reduction: In response to Assembly Bill 2076 (Pavley, Chapter 936, Statutes of 2000), the Energy Commission and the California Air Resources Board prepared and adopted a joint agency report, *Reducing California's Petroleum Dependence*. Included in this report are recommendations to increase the use of alternative fuels to 20 percent of on-road transportation fuel use by 2020 and 30 percent by 2030[1], significantly increase the efficiency

[1] *Reducing California's Petroleum Dependence*, California Energy Commission and Air Resources Board, joint agency report, August 2003, publication #P600-03-005.

of motor vehicles, and reduce per capita vehicles miles traveled. Further, in response to the Energy Commission's 2003 and 2005 *Integrated Energy Policy Reports*, the Governor directed the Energy Commission to take the lead in developing a long-term plan to increase alternative fuel use.[2]

GHG Reduction: The state's GHG emission reduction goals are to reduce GHG emissions to the level emitted in 2000 by 2010, to the level emitted in 1990 by 2020, and to 80 percent below the level emitted in 1990 by 2050.[3] Assembly Bill 32 sets forth requirements for the California Air Resources Board on achieving 1990 GHG emission levels by 2020.[4] In addition, the Low-Carbon Fuels Standard requires fuel suppliers and distributors to reduce the carbon intensity of their fuels by 10 percent by 2020.[5]

In-State Biofuels Production and Use Goals: Contained in the *Bioenergy Action Plan for California*, approved and publicly released by the Governor in July 2006, are specific biofuels use targets in California of 0.93 million gasoline gallon equivalents in 2010, 1.6 billion in 2020, and 2 billion in 2050.[6] In addition, the Governor emphasized the need for California to produce these biofuels within the state, establishing goals of a minimum of 20 percent of biofuels production within California by 2010, 40 percent by 2020, and 75 percent by 2050.[7]

California has large, untapped biomass resources that can be used as a source to produce energy in the form of electricity, biomethane (natural gas), and biofuels. The gross potential of these resources approaches 80 million dry tons of biomass from the state's farms, dairies, forests, and landfills. Using California's waste stream as a source of transportation fuel provides multiple public benefits, contributing to the state's petroleum reduction, waste reduction, and climate change goals. Using waste materials from the state's agricultural, forestry, and urban waste streams to produce energy may improve forest and animal health, reduces the risk of catastrophic wildfires, and reduces the volumes of landfill wastes. Biomass-based fuels should be pursued as one of the state's top priorities for achieving the Low-Carbon Fuels Standard, while ensuring that they do not degrade ecosystems.

Advanced biofuels can be produced from indigenous wastes and purpose-grown energy crops, with a lower carbon footprint than conventional gasoline and diesel fuels. Biofuels

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[2] Letter from Governor Arnold Schwarzenegger to the Legislature, attachment: Review of Major Integrated Energy Policy Report Recommendations, August 23, 2005.

[3] Governor's Executive Order S-3-05 on Climate Change (2005).

[4] Assembly Bill 32 (Núñez/Pavley, Chapter 488, Statutes of 2006): the California Global Warming Solutions Act of 2006.

[5] Governor's Executive Order S-1-07 on the Low-Carbon Fuels Standard (2007).

[6] *Bioenergy Action Plan for California*, California Energy Commission, June 2007, publication CEC-600-2006-010.

[7] Governor's Executive Order S-06-06, April 25, 2006.

can provide large GHG emission reductions (up to 75 percent compared to gasoline) because carbon dioxide emissions are recycled through plant photosynthesis. Changes in agricultural land can have a dominant impact on biofuel pathways using purpose-grown crops, and the potential land conversion effects need to be better quantified.

Air Quality Goals: Over 90 percent of Californians breathe unhealthy air at times. Both the United States Environmental Protection Agency and the California Air Resources Board have established ambient air quality standards for regional ozone and particulate matter. The air quality goal is to achieve these standards.

Air quality modeling indicates that significant reductions in key pollutants are needed to achieve the ozone and $PM_{2.5}$ standards. To achieve these federal standards, both the San Joaquin Valley Unified Air Pollution Control District and the South Coast Air Quality Management District must develop state implementation plans. The ozone State Implemenation Plans will be submitted to the U.S. Environmental Protection Agency in the fall of 2007, followed by submittal of the particulate matter State Implementation Plans in the spring of 2008.

Legislative Requirements

Assembly Bill 1007 directs the Energy Commission, in partnership with the California Air Resourses Board, to develop and adopt the State Alternative Fuels Plan to:

- Recommend policies, such as standards, financial incentives, research and development programs, to stimulate the development of alternative fuel supply, new vehicles and technologies, and fueling stations.
- Evaluate alternative fuels using a full fuel cycle analysis of emissions of criteria air pollutants, air toxics, greenhouse gases, water pollutants, and other substances that are known to damage human health.
- Set goals to increase alternative fuels in 2012, 2017, and 2022 that there is no net material increase in air pollution, water pollution, or any other substances that are known to damage human health.

The State Alternative Fuels Plan was prepared through an open and public process, involving one-on-one meetings with key stakeholders and four public workshops conducted over the past year.

Plan Conclusions

This Plan concludes that existing regulations and programs alone cannot achieve any of the state's multiple policy goals; the state needs a portfolio of alternative, low-carbon fuels to meet the state's multiple goals of petroleum reduction, GHG emissions reductions, and biofuels production and use. The Plan also concludes that meeting the state's long-term goal

of reducing GHG emissions to 80 percent below the 1990 level will require a multi-faceted approach, including increased use of alternative fuels, significant improvements in the energy efficiency of the vehicle fleet, and reducing trips and vehicle miles traveled through changes in travel habits and land management policies. The State Alternative Fuels Plan recommends a strategy that combines private capital investment, financial incentives, and technology advancement approaches.

Achieving the state's petroleum reduction, climate change, and biofuels goals will require substantial investment in fueling infrastructure, production facilities, vehicle components, and commercial development of "second generation" alternative fuels and advanced technology vehicles. The Plan depends on private capital investment, financial incentives, and technology advancement and innovation. The Plan identifies the potential for steady and substantial growth in the use of many alternative fuels, the mix of which will change and evolve over the near term (2007-2015), mid term (2016-2030), and long term (2031-2050).

Sustained and properly targeted federal incentives, augmented by state incentives, will be needed to complement policy mechanisms, mandates, standards, and regulations. All of these mechanisms should be maintained consistently over an extended period. More importantly, substantial capital investment by the private sector must be directed toward advanced technology and infrastructure.

Results of the State Alternative Fuels Plan's full fuel cycle (*Wells-to-Wheels*) analysis further demonstrate that alternative fuels can provide substantial GHG emission reduction benefits when used in mid-size passenger cars and urban buses.[8] Depending on the fuel pathway chosen, fuels such as ethanol, natural gas, liquefied petroleum gas, electricity, and hydrogen have decided advantages over conventionally produced gasoline and diesel fuels in that regard. In addition, the use of blends, such as renewable diesel, biomass-to-liquids, and gas-to-liquid, can have significant short-term advantages. However, the full fuel cycle analysis will need to be refined and updated to address sustainability issues and land use conversion impacts of biofuels.

Biofuels are a good option in the short term because they are available now and have petroleum reduction, waste reduction, and climate change benefits. The state should encourage and support the in-state production of these fuels from the state's agricultural, forestry, and urban waste residues. Over the longer term, advanced biofuels, hydrogen, and plug-in hybrid electric vehicles are expected to play growing roles as there is a continuing need for even greater reductions.

Lastly, the Plan concludes that a five-part strategy is needed: (1) promote alternative fuel blends with gasoline and diesel in the near and mid term and stimulate innovation through the development of a low-carbon fuels standard; (2) maximize alternative fuels in early adopter market niches, such as heavy-duty vehicles, fleets, off-road vehicles, and ports in

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[8] *Full Fuel Cycle Assessment: Well-to-Wheels Energy Inputs, Emissions, and Water Impacts*, California Energy Commission, August 2007, CEC-600-2007-004-Rev.

the near and mid term; (3) maximize use of alternative fuels in internal combustion engines and develop new transportation technologies, such as electric drive and hydrogen fuel cells, in the mid-to-long term; (4) maximize the use of mass transit, encourage smart growth and land use planning to help reduce vehicle miles traveled and vehicle hours traveled, and encourage improvements in vehicle efficiency to improve fuel economy; and (5) most important for the mid-to-long term, achieve the maximum feasible improvements in vehicle efficiency to reduce the total energy needed to power transportation in California.

It is not possible to accurately predict the fuel mixes and proportionate market share each alternative fuel will eventually realize. All of the alternative fuels evaluated during the development of this Plan have the potential for expanded use and are included in the projection on how California can shift to a sustainable mix of future transportation fuels. The State Alternative Fuels Plan presents three illustrative examples of fuel combinations, which include a mix of fuel options to demonstrate that the ambitious alternative fuel use goals are achievable. To fulfill California's petroleum reduction goals, a mixture of alternative fuel strategies will be needed.

Goals and Outcomes

The Plan was developed with the objective of achieving the following goals and outcomes.

1. Define the actions needed to diversify the state's transportation fuel supply while concurrently reducing the total amount of energy needed to power the transportation sector.
2. Set alternative transportation fuel use goals, designed to ensure that there are further reductions in air pollution, water pollution, or any other substances that are known to damage human health.
3. Surpass California's existing 2020 and 2030 goals to increase the use of alternative transportation fuels under all three moderate case portfolio mixes.
4. Achieve maximum feasible emission reductions, relative to baseline, in criteria, and toxic air pollutants under the Plan.
5. Ensure that implementation of the State Alternative Fuels Plan will support the state's commitments, under the State Implementation Plan, to improve air quality and achieve ambient air quality standards.
6. Increase the use of renewable and sustainable alternative fuels, on a full fuel cycle basis, compared to petroleum fuels, to achieve the potential to lower the overall carbon intensity of California's transportation fuel pool through the implementation of the state's Low Carbon Fuel Standard.
7. Adopt and implement the Low-Carbon Fuel Standard to help achieve the transportation sector's proportional share of the GHG reductions and to provide a durable framework for the use of low-carbon alternative fuels and stimulate technology innovation.

8. Ensure that vehicles operating on alternative fuels comply with motor vehicle emission standards.

Specific Findings

The following sections outline the key findings that underlie the State Alternative Fuels Plan and the recommendations for its implementation.

Fuels

1. A number of different analyses were done that looked at the penetration of various alternative fuels into the transportation fuel sector. These analyses were done using the best available full fuel cycle analysis method. Analysis of a moderate growth case shows that plausible goals, on a gasoline gallon equivalent basis, for the use of alternative fuels in the on-road and off-road sectors (excluding air, rail, and marine), including, but not limited to, electricity, natural gas, propane, hydrogen, ethanol, renewable diesel, and biodiesel are:
    - 9 percent by 2012
    - 11 percent by 2017
    - 26 percent by 2022
2. With these goals, the Plan accelerates the growth of alternative fuels, displacing more than 4 billion gasoline gallon equivalents (20 percent) in 2020. This could grow to at least 30 percent by 2030. By 2050, alternative fuels could provide more than half the energy needed to power California's transportation system.
3. Primary biofuels include ethanol, biodiesel, renewable diesel, and biomethane produced from agricultural, forestry, and urban wastes, and other renewable feedstocks.
4. Biodiesel and renewable diesel, natural gas, propane, and electric drive technologies are primary options to displace diesel fuel in markets such as transit buses, school buses, delivery vans, truck refrigeration units, and port vehicles.
5. Natural gas use in heavy-duty vehicles alone could represent about 36 percent of the freight and off-road vehicle fuel use by 2050.

Vehicles

1. Flexible fuel, plug-in hybrid electric, battery electric, and fuel cell vehicles will lead a wave of new automobiles into California's market.
2. Advanced biofuels could be used in conventional vehicles; and flexible fuel, plug-in hybrid electric, and fuel cell vehicles could increase to 5 million vehicles in 2020 and

to more than 35 million in 2050 (over 75 percent of all vehicles operating in California).

3. Light-duty diesel vehicles will enable the use of renewable diesel and biodiesel in the light-duty vehicle fleet.
4. Automakers are beginning to introduce light-duty diesel vehicles in California to comply with California air quality standards. This will offer potential to increase biodiesel and renewable diesel fuel use.

Infrastructure

1. Ethanol (E-10), biodiesel (B20), and renewable diesel fuel blends can use existing fueling infrastructure.
2. Alternative fuel stations that require new fuel pumps (E-85, propane, natural gas, hydrogen) will need to operate commercially with 20 percent market share before costs approach parity with gasoline and diesel pump costs.
3. Home refueling appliances for natural gas and hydrogen vehicles and home electric recharging of plug-in electric hybrids present consumer options for refueling/recharging.

Market Niches

1. Biodiesel and renewable diesel, natural gas (including from biomethane), propane, and electric drive technologies are primary options to displace diesel fuel in market niches, such as transit buses, school buses, delivery vans, truck refrigeration units, and port vehicles.
2. Natural gas use in heavy-duty vehicles alone could represent about 36 percent of the freight and off-road vehicle fuel use by 2050.

Government Actions

1. Mandates alone will not achieve the single policy goals outlined or multiple goals as a group. While the Low-Carbon Fuel Standard can achieve a substantial percentage of the greenhouse gas reduction needed from the transportation sector, it is clear that complementary government actions are needed to fully achieve the state's 2020 and longer-term reduction goals.
2. Sustained or increased federal incentives, augmented by state incentives, will be needed to complement policy mechanisms, regulations, such as fuel specifications, and vehicle tailpipe standards. Continual private sector and state and federal government research and development are essential to stimulate alternative fuel commercialization.

3. Clear market signals are necessary. Adoption of the Low-Carbon Fuel Standard will certainly provide one clear market signal. In addition, it is essential to sustain consistent and transparent government mandates and incentives over a 20-to 30-year timeframe.
4. To stimulate a moderate growth rate of alternative fuels, it is estimated that $2 billion in government incentives invested between 2008 and 2022 will stimulate more than $40 billion in private investment leading to a mature market rollout of alternative fuel options in 2050. Between 2008 and 2050 about $100 billion in total market (public and private) investment will be required. These estimates are based on capital cost assumptions, technology research and development needs, infrastructure requirements, manufacturing investments and consumer education program cost estimates.
5. Private sector investment, including investor-owned and municipal utilities, should be encouraged to become major new investors in the development and commercialization of electric drive and natural gas vehicles.
6. Corporate Average Fuel Economy standards and credits must improve.

Costs

1. Most alternative fuels are less costly today than gasoline and diesel on a fuel use, cents-per-mile basis. However, alternative fuels options are not currently competitive with gasoline or diesel because alternative fuel vehicles and fueling infrastructure are more expensive (market entry costs, not fuel) than those using gasoline and diesel, but alternative fuels begin to reach overall price parity, including infrastructure, when petroleum fuels reach the $3.50 - $5.00 per gallon range. Government financial and regulatory incentives may be needed to offset the market entry cost differential for alternative fuels.
2. Each of the three illustrative examples under the moderate growth case shows that all of the alternative fuel mix options are cost-effective to achieve petroleum reduction and GHG emission reduction goals by 2050 or earlier. The three examples discuss the dominance of biofuels (Example 3), hydrogen fuel cells (Example 2), and plug-in hybrid electric vehicles (Example 1) to show that it's possible to achieve the earliest petroleum reduction cost effectiveness in 2017, and these examples appear to offer GHG emission cost effectiveness in all years.
3. Nearly all of the alternative fuels evaluated for this Plan achieve growth in the moderate market penetration case. Together, they exceed the petroleum reduction goals to increase alternative fuel use and provide substantial progress to fulfill GHG emission goals.
4. Proposed policies will divert purchases from traditional petroleum fuels, resulting in projected avoided petroleum purchases of up to $19 billion in 2022 and $42 billion in 2050. Consumer and government spending will shift from the petroleum sector to

other sectors of the economy, including agriculture ($9 billion to $12 billion), the natural gas/propane industry ($8 billion), and chemical industries ($6 billion to $15 billion) in 2050.

5. The increase in alternative fuel use will result in small costs or net benefits to the overall economy through 2017, followed by increased government expenditures to support alternative vehicles and infrastructure in later years. Due to government incentives and avoided petroleum purchases, the private sector is projected to save money in all years, to a maximum of $4 billion in 2050.
6. The proposed incentives and regulatory actions provide a small but positive impact on the California economy (real productivity, personal income, and employment).
7. While state funding is an essential part of the overall plan, substantial private sector investment is needed to achieve the objectives of the Plan. Public investments will be a catalyst for significant private investment.
8. Biofuels from California's waste streams would be even more cost-effective, if the waste treatment costs were considered in the analysis, and savings from avoiding these costs would improve the economics of these fuels.
9. All of the alternative fuel mixes shown in the illustrative case examples in Chapter 5, are cost-effective in achieving petroleum reduction and GHG reduction goals by 2050, or even earlier.

Plan Scope

As required by Assembly Bill 1007, this Plan presents strategies and actions California must take to increase the use of alternative and non-petroleum fuels in a manner that minimizes costs to California and maximizes the economic benefits of in-state production. The State Alternative Fuels Plan assessed various alternative fuels and developed fuel portfolios to meet California's goals to reduce petroleum consumption, increase alternative fuels use, reduce GHG emissions, and increase in-state production of biofuels without causing a material increase in emissions.

The key circumstances and conditions necessary to achieve the Plan outcomes are presented for each of the following transportation fuels, which fall within the scope of this Plan:

- Biodiesel
- Electricity
- Ethanol (in the form of E-10 and E-85)
- Hydrogen
- Natural Gas (methane in the form of compressed and liquefied natural gas)
- Propane
- Renewable Diesel (includes Biomass-to-Liquid)
- Synthetic Fuels (Dimethyl Ether and Methanol)

- Gas-to-Liquid (GTL) and Coal-to-Liquid (CTL) Fuels
- Conventional Gasoline and Diesel (the baseline against which the alternative fuels are compared)

The Plan recommends alternative fuel targets of 9 percent in 2012, 11 percent in 2017, and 26 percent in 2022. The Plan also presents a "2050 Vision" that extends the Plan outcomes beyond the milestone years 2012, 2017, and 2022, and lays a plausible foundation for building a potential multi-fuel transportation energy future scenario for California by 2050. The 2050 Vision anticipates improvements in vehicle efficiency, reductions in energy demand due to improved travel habits, and the widespread use of low GHG-emitting fuels. As a result of these strategies, the 2050 Vision presents a transportation future that greatly reduces the energy needed for transportation, provides that energy through a diverse set of transportation fuels, eliminates overdependency on oil, and achieves an 80 percent reduction in GHG emissions.

Key Circumstances, Conditions, and Barriers

Increasing alternative fuel use to achieve petroleum reduction goals and to reduce GHG emissions will require development of new and emerging fuels, vehicle and fuel production technology advances, and manufacturing cost reductions of vehicles, engines, and component parts. Private and public investment will be needed to develop alternative fuel supply infrastructure and fueling stations. Consumer education about each alternative fuel as it becomes widely available will also be necessary to maximize the use of non-petroleum fuels.

This Plan discusses the market barriers impeding progress and the circumstances, conditions, and actions needed to address the barriers. The market investment, government co-funding, and other incentives needed are associated with the circumstances, conditions, and actions for each alternative fuel option. Additional investment and, in some instances, continual government incentives will be required for these fuels to experience market maturity.

Recommended Actions

The Committee recommends that the Energy Commission adopt the Alternative Fuels Plan presented in this report. The Committee also recommends that the Energy Commission work in partnership with the California Air Resources Board and other appropriate agencies to implement the Alternative Fuels Plan. Specific additional actions are recommended as listed below.

California should support a Clean Alternative and Renewable Fuel, Vehicle and Advanced Technology Initiative, which advances the state's leadership on clean transportation

technology. Ongoing funding in the range of $100 million to $200 million per year should be directed at the transportation sector to advance innovative and pioneering technologies.

The Alternative Fuels and Vehicle Technologies Funding Program legislation (AB 118, Núñez, Statutes of 2007) proactively acts on this recommendation. The Energy Commission and the California Air Resources Board must act to leverage the more than $100 million annually provided under AB 118 to achieve the Plan goals.

Use of California's urban, agricultural, and forestry wastes to produce energy and fuels should be aggressively pursued.

A combination of regulations or standards, financial incentives, and other policy mechanisms is needed to achieve the state's multiple policy goals. The Low-Carbon Fuel Standard will be critical to establishing the framework for the use of alternative fuels. Incentives will be needed to stimulate expanded production of alternative fuels in California, offset the cost difference between gasoline or diesel and alternative fuel vehicles, and share the cost of installing fueling stations, to the extent market competition and market mechanisms do not fulfill this need.

While state funding is an essential part of the overall Plan, substantial private sector investment is needed to achieve the objectives of the Plan. Public investments will serve as a catalyst for significant private investment. The Plan's goals will not be achieved without a strong private sector role. In the early years investors will look for signals that the regulatory and policy support will continue to exist before private capital flows in. This model is similar to successful strategies the state has employed in both renewable electricity development and energy efficiency improvement.

In implementing the State Alternative Fuels Plan, the focus on achieving all of the goals should be considered. This includes reducing the dependency on petroleum, reducing greenhouse gases, encouraging in-state biofuels production and use, and meeting ambient air quality standards.

CHAPTER 1: Introduction

Roughly half of the energy Californians consume is for transportation. To meet that demand, the state relies almost exclusively on petroleum. This singular dependence on petroleum has set the stage for the short-term price volatility and long-term sustained increases in retail gasoline and diesel fuel prices experienced by Californians during the last decade. It also has created the single largest source of greenhouse gas (GHG) and criteria air pollutant emissions in California.

Petroleum Dependence – California's transportation sector is more than 95 percent dependent on petroleum. More than 60 percent of this nation's petroleum consumption relies on foreign sources. The state and the nation remain extremely vulnerable to petroleum price and supply disruptions.

While the United States consumes nearly 25 percent of the world's petroleum, it maintains only 2 percent of the world's petroleum reserves. The Organization of Petroleum Exporting Countries (OPEC) continues to control more than 65 percent of the world's oil supplies, and instability in the Middle East and elsewhere in the world continues to threaten oil supplies.

Since crude oil is a global commodity, the world market dictates its price. Skyrocketing demand in China and other developing countries, coupled with political and social upheaval in key oil supply nations, is further taxing the international supply/demand equation, further degrading the nation's energy security and driving up prices at the pump.

Transportation Growth – Compounding the tightening demand for petroleum worldwide is the demand for gasoline and diesel fuel here at home. California is the second largest consumers of gasoline and diesel fuels in the world, surpassed only by the United States. as a whole. In 2006, Californians consumed an estimated 20 billion gallons of gasoline and diesel fuel on the state's roadways, an increase of nearly 50 percent over the last 20 years. This demand continues, even in the face of record petroleum prices, for several reasons:

- Population growth and more on-road vehicles.
- Low per-mile cost of gasoline use during the past two decades.
- Lack of alternatives to conventional gasoline and diesel fuels.
- Consumer preference for larger, less fuel-efficient vehicles.
- Lack of mass transit.
- Lack of effective Corporate Average Fuel Economy (CAFÉ) standards.
- Land use planning that places jobs and housing farther apart without transportation integration.

In Governor Schwarzenegger's May 13, 2005, letter, the Governor urged Congress to establish CAFÉ standards that double the fuel efficiency of new cars, light trucks, and sport utility vehicles. CAFÉ standards have been largely unchanged since 1985.[9]

Petroleum Supply and Price Volatility – Over the past decade, short-term volatility and long-term increases have become the hallmarks of retail pricing for gasoline and diesel fuel nationwide. Short-term volatility is the outgrowth of an overstressed petroleum refining and delivery system. The state's petroleum refineries are the centerpiece of a regional gasoline and diesel supply network that includes California, Nevada, Arizona, Washington, and Oregon. These facilities, however, are no longer able to meet current and future petroleum demand in California and the region and must increasingly rely on imports of refined products. Since California's petroleum infrastructure operates at near capacity to meet its increasing fuel supply demand, breakdowns and outages at in-state refineries and pipeline facilities quickly tighten gasoline and diesel fuel supplies and create price spikes. Since California is not directly connected by pipeline to other domestic refining centers, in-state refiners cannot readily procure gasoline, diesel, and other blending components when outages do occur. This contributes to higher and more prolonged price spikes.

Long-term sustained increases in the retail price of gasoline and diesel fuel are largely the result of world oil prices, which have nearly tripled in the last three years. Crude oil is the single largest cost component in the production of transportation fuels, accounting for between 42 and 56 percent of the price of regular gasoline in the last year. In early May 2007, the average retail price for regular grade gasoline reached $3.46 per gallon, a record high, while diesel fuel reached $3.10 per gallon.

The combined effects of incident-caused volatility and sustained price increases are clearly seen in Figure 1 as the retail price of gasoline in California has more than tripled over the last decade. There is no clear sign that this supply and price volatility will abate. The 2007 prices, adjusted for inflation, have begun to equal oil prices of the 1970s stimulated by oil embargoes. And, recently, the price of oil hit an all-time record of $98 per barrel.

California's high gasoline and diesel fuel prices have created a significant consumer impact as California consumers are spending more of their household income on transportation fuels than ever before. High fuel prices also reduce profit margins for the manufacturing and industrial sectors, which pass the higher cost of their goods and services to consumers. Californians are therefore not only paying higher prices for the gasoline they need, they are using the rest of their disposable incomes to pay higher prices for other products. Since September 2004, the monthly average price of gasoline has increased by more than $1.35 per gallon, costing consumers an additional $25 billion for gasoline, a staggering blow for both consumers and California's rebounding economy.

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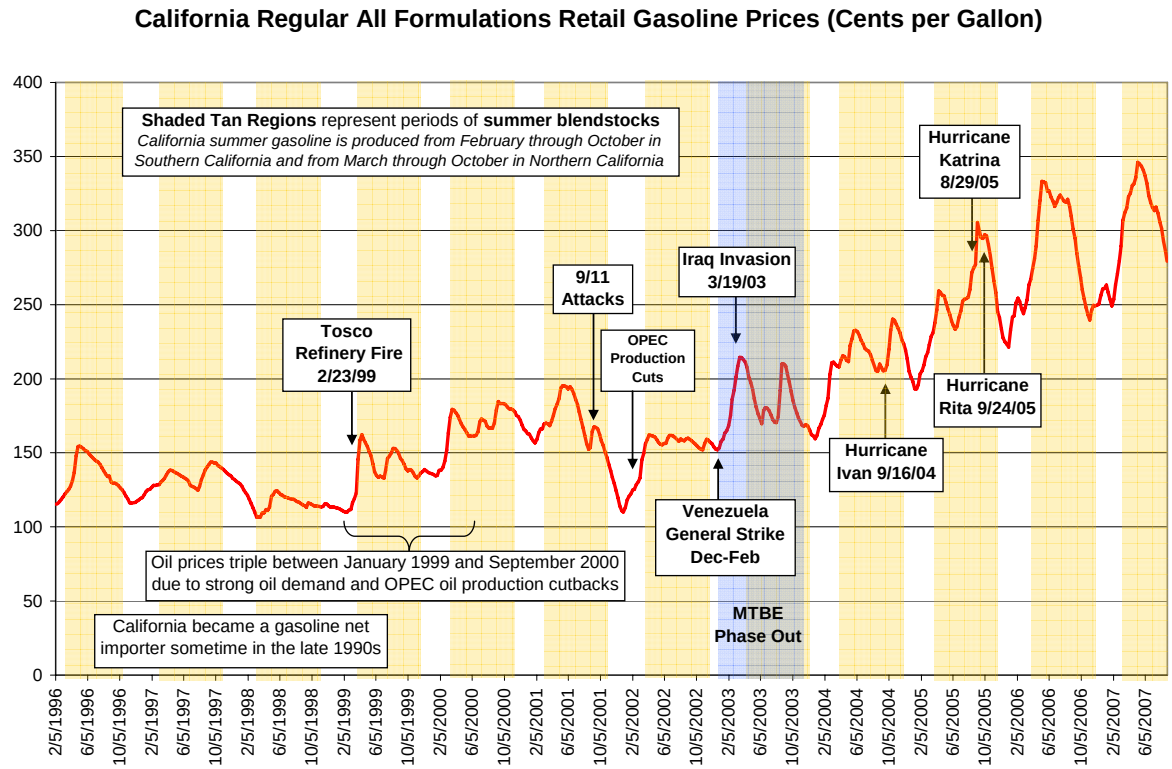
[9] May 13, 2005, letter from Governor Arnold Schwarzenegger to Pete Dimenici and Jeff Bignaman, Members U.S. House of Representatives.

Figure 1: California Retail Gasoline Prices



Source: California Energy Commission

Transportation Environmental Impacts – Through regulations, the California Air Resources Board (ARB) has effectively pushed the state-of-the-art in clean fuel and vehicle technology and the understanding of the public health effects of mobile source emissions. Gasoline and diesel fuels sold in California today are the cleanest burning in the world**.** The emergence of climate change, however, as a global imperative has attracted public attention to the need for state and national level actions to reduce GHG emissions as well.

No matter how clean gasoline and diesel fuels are with respect to criteria air pollutants, their production, transport, and use result in significant carbon dioxide (CO_2) emissions, the primary GHG. In California, for example, the transportation sector is responsible for approximately 40 percent of statewide GHG emissions and significantly contributes to degradation of public health and environmental quality.

The Way Forward

In recent years, California has called for aggressive steps to reduce the economic, energy security, and environmental impacts of its dependence on petroleum. With Assembly Bill (AB) 1007 (Pavley, Chapter 371, Statutes of 2005) the Legislature directed the California Energy Commission (Energy Commission), in partnership with the ARB, to develop and

adopt a State Alternative Fuels Plan (Plan) to increase the use of alternative fuels without adversely affecting air quality and water quality or causing negative health effects.

The transportation fuel market is enormously complex. Policy makers and elected officials need to guide the creation of new transportation fuel and vehicle markets in California to begin transitioning the eighth largest economy in the world from a petroleum-based economy to a multi-fuel economy. To understand the magnitude of this undertaking, increasing the use of non-petroleum fuels to 20 percent of on-road fuel demand by 2020 is equivalent to 4.8 billion gallons of non-petroleum fuels. Achieving this goal will require the introduction and use of an additional 370 million gallons of new non-petroleum fuel supplies into the California transportation market each year, or about 1 million gallons of new supply each day for the next 12 years.

By enacting AB 1007, the Governor and Legislature have established that it is now the clear and unambiguous policy of the State of California to move decisively away from petroleum fuels. The state needs a flexible overarching strategy that simultaneously reduces petroleum fuel use, increases fuel diversity, supply, and security, and reduces emissions of air pollution and GHG. The Plan must establish, maintain, and balance the synergy between energy and environmental objectives. The Plan also must recognize that setting goals or establishing mandates alone will not achieve the state's multiple energy and environmental goals. A broad collaborative framework is needed to effectively and rapidly introduce more non-petroleum fuel and vehicle options into the market while balancing environmental requirements.

The Plan must provide consumer choice. Presently, consumers in California have little or no discretion in the fuels they use in their vehicles. In many respects, the expanded use of non-petroleum fuels in the near term will be invisible to most consumers as it will likely be limited largely to those non-petroleum fuels that can be produced, distributed, and dispensed through the existing infrastructure. A major objective in the Plan is to ultimately provide vehicle technologies that will allow consumers to choose between fuel types and how, when, and where they fuel their vehicles. Such market diversity and choice could have a moderating effect on fuel prices while maximizing the potential air quality and climate change benefits at the same time.

The Plan must be flexible. It has been developed using a number of empirical and analytical tools and with extensive input from stakeholders through workshops and work group forums. Although this Plan involved extensive information gathering and analysis, this should not impart a false sense of precision due to the uncertainty of the numerous future markets and market players involved. The Plan should be viewed as a roadmap. Establishing new transportation fuel markets will need support and encouragement beyond what might be calculated as providing economic parity with conventional gasoline and diesel fuels to foster increasing long-term private investment.

The Plan must be responsive to all fuel and vehicle options. Given the enormity of the task of transitioning away from gasoline and diesel fuels, the state cannot afford to pick

"winners." All reasonable non-petroleum fuel and vehicle options must be provided the opportunity to compete in the evolving transportation fuels market. Singular alternative fuels options have not and cannot meet the multiple goals outlined.

The Plan has to be dynamic. It has been prepared based on the best information available today. There will be however, better information in the future. Therefore, the Energy Commission and ARB will update the Plan every two years, reflecting market, technology, and environmental conditions, to ensure that the goals established in this Plan are achieved.

Finally, the Plan must complement the state's efforts to develop the Low-Carbon Fuel Standard (LCFS). This standard developed by ARB in close coordination with the Energy Commission provides a durable framework for the transition to alternative fuels.

Report Structure

As directed by AB 1007, this Plan presents strategies and actions California must take to increase the use of alternative non-petroleum fuels, in a manner that minimizes costs to California and maximizes the economic benefits of in-state production. The Plan is structured as follows.

Chapter 1 provides a description of the challenges California is facing and the reasons why California is looking at ways to increase alternative fuels.

Chapter 2 presents findings and recommendations to increase the use of alternative fuels in California with an emphasis on near-term to mid-term actions.

Chapter 3 discusses the results from a full fuel-cycle analysis, adopted by the Energy Commission in June 2007 and submitted to the ARB for its use in establishing the LCFS.

Chapter 4 describes specific goals for increased alternative fuel use for 2012, 2017, and 2022.

Chapter 5 discusses the underlying assumptions for three integrated moderate case example scenarios that satisfy the petroleum reduction goals, GHG emissions outcomes, and meet the LCFS goal.

Chapter 6 presents a "2050 Vision," which extends the Plan outcomes beyond the three milestone years 2012, 2017, and 2022, and lays the foundation for building a multi-fuel transportation energy future for California by 2050.

Chapter 7 presents cost and macro-economic impacts and discusses in-state biofuels production potential.

Chapter 8 discusses possible trade barriers and the policy implications of these barriers.

CHAPTER 2: State Alternative Fuels Plan

AB 1007 recognizes the important relationships between transportation fuel use, air quality, and climate change, and this is reflected in the Plan. This Plan provides a comprehensive framework to examine broad transportation fuel issues to effectively integrate transportation energy, air quality, and climate change policies.

AB 1007 specifically identified ethanol, biodiesel, hydrogen, methanol, natural gas, and electricity as alternative fuels and technologies that should be subject to evaluation. The Energy Commission and ARB refined this list to add propane and other fuels to the scope of this evaluation.

For each transportation fuel and technology, AB 1007 required comparative evaluations of full fuel cycle impacts, including criteria air pollutants, GHG, toxics, and water pollutants. The statute also requires the Plan to ensure no net material increase in air, water, and toxic pollution occurs. To complete this analysis, both agencies used a publicly available fuel cycle model, the GHG Emissions, Criteria Air Emissions, and Energy Efficiency in Transportation (GREET) model, which has been modified to reflect California conditions. The Energy Commission adopted the full fuel cycle report comparing transportation fuels and technologies on June 27, 2007.

The Energy Commission and ARB evaluated many different scenarios in the process. Both agencies developed practical growth examples in conjunction with several stakeholder groups to characterize the circumstances, conditions, timing, and costs to increase the use of alternative fuels in California's transportation market. Stakeholders included international oil companies, automakers, alternative fuel producers, fleet managers, fueling station developers and operators, environmental organizations, consumers, and a multitude of federal, state, and local government agencies. The Plan identifies example alternative fuel mixes, which will change and evolve over the near term (2007 – 2015), mid term (2016 – 2030) and long term (2031 – 2050). These examples are not predictions or policy preferences for any fuel or technology and are not intended to represent the full scope of possible examples, nor do they necessarily reflect the important role that alternative fuel may play in niche markets. The examples show that the Plan's alternative fuel use goals of 9 percent in 2012, 11 percent in 2017, and 26 percent in 2022 are achievable.

Other key components of the Plan include assessing the economics of producing alternative fuels within California, optimizing the environmental and health benefits of alternative fuels in a cost-effective manner, and estimating the Plan's economic impacts on the state's economy.

Elements of the State Alternative Fuels Plan

AB 1007 specifically requires that the Plan recommend policies to ensure that alternative fuels goals are attained, including, but not limited to:

- Standards on transportation fuels and vehicles.
- Requirements, financial incentives, and other policy mechanisms to ensure that vehicles capable of operating on alternative fuels use those fuels as much as possible.
- Requirements, financial incentives, and other policy mechanisms to ensure that alternative fueling stations are available to drivers of alternative fuel vehicles.
- Incentives, requirements, programs, or other mechanisms to encourage the research, development, demonstration, commercialization, manufacturing, or production of vehicles that use alternative fuels

The nexus of policy, financial incentives, and requirements is the key to whether this state can and will achieve its stated alternative fuels use goals, and is, therefore, highlighted in this Plan. In addition, harmonizing and aligning these three elements allow for the most rapid and efficient achievement of the Alternative Fuels Use goals and are by far the most cost-effective manner for the state to pursue its goals. Without this harmonization, the incentives provided will be more costly, and the time required will be much longer than is expected or necessary.

Requirements

Requirements involve government or industry standards imposed on fuels and vehicles as a condition of their sale or operation. Such requirements can be defined as those institutional needs that surround the development of the alternative fuels market that, in this case, are critical to be addressed to foster and enable fulfillment of an important societal policy. Some examples of these are the motor vehicle emissions standards, fuels specifications, and exhaust standards for engines and fueling stations that ensure that environmental degradation does not occur.

The Plan seeks ways to remove impediments to progress without lessening the standards that have been established to protect public health and the environment.

Examples of ways to aid alternative fuels market development include reducing the costs of vehicle certification, offering experimental permitting of engines and vehicles, allowing low-volume stations to self-certify over time, the purchase of offset emission credits or bonds for same (to ensure eventual compliance), or other suggestions from stakeholders that can be assured to overcome an impediment while not causing environmental degradation. If the policy of the state is to encourage alternative fuels use, the state should explore ways to facilitate market entry without violating environmental standards.

The Governor's Executive Order S-01-07, establishing the LCFS,[10] directs the Energy Commission to incorporate a draft compliance schedule, where appropriate, into the Plan required by AB 1007. Clearly, there are many options for complying with the proposed LCFS, which the ARB will consider in establishing its regulations. These fuel options are a function of conversion pathway, technology, feedstock choice, timing, cost, and other factors.

The Low-Carbon Policy Analysis, completed by the University of California (UC) in August 2007,[11] considered four pathways for a compliance schedule to achieve the 10 percent reduction by 2020 goal. The four illustrative compliance schedule options were called the Linear, the Rationalized, the Technology Forcing, and the Accelerating compliance pathways. The study's authors recommend that the ARB choose either the Technology Forcing or the Accelerating option. The Energy Commission and ARB will work together over the next year to develop a schedule for complying with the regulations to implement the LCFS and consider the recommended compliance schedule options in the UC study. The Plan incorporates, by this reference, consideration of those draft compliance schedules but also notes that the LCFS alone will not sufficient to meet the state's GHG goals.

Financial Incentives

Financial incentives will be a key factor for the transition from petroleum-based fuels to the non-petroleum alternatives, and nascent or non-existing alternative fuels markets must be supported and fostered to maturity. Most alternative fuels have not achieved a commercial, mature market status due to higher market entry costs in developing vehicle technology, fuels and fuel distribution systems that are comparative to their conventional fuels counterparts in convenience, reliability, and costs. Not all alternative fuels require incentives in all these areas, and so the evaluation of these incentive needs becomes critical.

Over many years, several alternative fuels and vehicle technologies have been developed and demonstrated but have lacked the consistent support and strong market signals to sustain them in the market. Today's petroleum fuels, vehicle technologies, and fuel infrastructure have benefited from being the only fuels in the marketplace, have long-ago achieved a mature market, and have been able to improve their products and delivery all with ongoing and consistent financial incentives. Annual U.S. federal tax breaks and other direct subsidies for oil are estimated to be from $65 billion to $113 billion.[12] Clearly, alternatives can benefit from a similar level of support.

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[10] Governor's Executive Order S-1-07, signed January 18, 2007.

[11] *A Low Carbon Fuel Standard for California Part II: Policy Analysis*, University of California, August 2007. UC 1000-2007-002-PT2.

[12] *Lives Per Gallon: The True Cost of Our Oil Addiction*, Terry Tamminen, page 60.

Financial incentives must be calculated in accordance with existing federal incentives and at a level that is sufficient to achieve the size and the pace of market development to meet stated utilization goals. Often the two main questions posed regarding incentives are: Are the incentives necessary? Are the incentives levels sufficient to meet stated goals in a market developing to maturity?

Another important aspect of financial incentives is administrative flexibility; that is, can these financial incentives be evaluated and provided in a manner that can allow for course correction and modification to meet rapidly changing needs and circumstances over time and still be seen as a consistent, steady market signal? Assessing the alternative fuels market is a critical factor for the evaluation of financial incentives and should be performed periodically to best assure that incentives are adequate, that they are being adequately subscribed, and are achieving the intended goals for alternative fuel use.

Many different types of financial incentive mechanisms are being considered, depending on the costs of market entry for vehicle development, production, purchase and fuel production, distribution, and use. Specific incentive mechanisms include, but are not limited to:

- Cost-shared establishment of alternative or renewable transportation fuels production.
- Cost-shared funding for project feasibility studies.
- Cost-shared funding for the establishment of alternative storage, dispensing, or charging systems.
- Cost-shared funding for upgrades and improvements to the existing alternative fuel infrastructure.
- Cost-shared funding for the differential costs of alternative fuel vehicle purchases.
- Funding of fuel and vehicle technology demonstration programs.

Policy Mechanisms

Policy mechanisms can be quite useful to indicate the need for and direction of a given policy and can add particular emphasis for governments to achieve stated goals. Examples of useful and successful policy declarations include:

- Legislation signed into law
- Policy recommendations, approved and adopted by the Executive branch
- Executive Orders, signed by the Governor or the President

Three recent examples of such policy mechanisms related to alternative fuels are the Executive Order(s) on Climate Change (S-3-05), on Bio-Energy (S-06-60), and the LCFS (S-01-07), and all have considerable influence on the Plan and its success. Legislation affecting alternative fuels development includes AB 2076, AB 32, AB 1007, and AB 118.

An Alternative Fuels Use Strategy

To meet the various policy goals associated with alternative fuels in California, the state will need to use a four-part strategy:

1. Promote alternative fuel blends with gasoline and diesel in the near and mid term and stimulate innovation through the development of an LCFS.
2. Maximize alternative fuels in early adopter market niches, such as heavy-duty, fleets, off-road, and ports in the near and mid term.
3. Maximize use of alternative fuels in internal combustion engines and develop new transportation technologies, such as electric drive and hydrogen fuel cells, in the mid-to-long term.
4. Maximize the use of mass transit and encourage smart growth and land use planning to help reduce vehicle miles traveled (VMT) and vehicle hours traveled. Maximize the use of alternative fuels in mass transit, encourage smart growth and land use planning to help reduce VMT and vehicle hours traveled (VHT), and encourage improvements in vehicle efficiency to improve fuel economy.

Key Conclusions of the Plan

1. Mandates or policy mechanisms alone will not achieve the state's multiple goals. While LCFS is expected to achieve a 30 percent reduction in GHG emissions and substantial reduction in petroleum use by 2020, provide substantial reductions in petroleum use by 2020, and provide a durable framework for the production and use of alternative fuels, additional actions are necessary to achieve the stated goals.
2. California can achieve petroleum reduction and in-state bioenergy production goals based on a moderate growth of alternative fuels in 2012, 2017, 2022, 2030, and on to 2050. This moderate growth of alternative fuels could also achieve the LCFS goal in 2020, but alternative fuels alone cannot achieve California's ultimate GHG emission reduction goals.
3. Federal incentives, augmented by state incentives, must be sustained or increased to complement mandates.
4. Government, utility, and private industry research and development (R&D) investment are also needed.
5. Clear, long-term market signals must be given to existing and new fuel suppliers and vehicle manufacturers and will need to be sustained, consistent, and transparent over a 20- to 30-year timeframe.
6. An estimated market investment of $100 billion from public and private sources is needed to achieve 2030 and 2050 (long-term) petroleum and GHG reduction goals.

7. Biofuels from biomass and purpose-grown energy crops should be pursued because of their relative lower carbon footprint. However, sustainability issues, such as land use conversion and water consumption, still need to be addressed.
8. Most alternative fuels are less costly today than gasoline and diesel on a fuel-use, cents-per-mile basis. Alternative fuel vehicles and fueling stations are still higher priced than gasoline and will need incentives to offset differential costs.
9. Alternative fuel stations will need to operate commercially with a 20 percent market penetration (2,000 stations primarily in urban areas) before costs approach parity with gasoline and diesel station pump costs.
10. Alternative fuel vehicles will need to reach price parity with gasoline or diesel passenger cars. Incentives will be needed to enable consumer selection of alternative fuels and vehicles.
11. New industry participants will diversify the transportation fuels and technology sector and help accelerate achieving the state's multiple policy goals.
12. The private sector, including electric and natural gas utilities, must become major new investors in electric drive and natural gas vehicle technologies.
13. Meeting the state's long-term goal of reducing GHG emissions to 80 percent below the 1990 level will require a multi-faceted approach, including increased use of alternative fuels, significant improvements in the energy efficiency of the vehicle fleet, and reducing trips and VMT through changes in travel habits and land management.
14. The alternative transportation fuel use goals are designed to ensure that there are further reductions in air pollution, water pollution, or any other substances that are known to damage human health and ensure that no net material increase occurs under the Plan.
15. Implementation of the Plan will support the state's commitments, under the State Implementation Plan (SIP), to improve air quality and achieve ambient air quality standards.
16. Light-duty diesel vehicles will enable the use of renewable diesel and biodiesel in the light-duty vehicle fleet.

Recommended Government Actions

While this Plan focuses primarily on state government, actions by federal, regional, and local agencies are needed to identify and seek to resolve market barriers impeding the market introduction and commercial maturity of emerging and alternative transportation fuels. The actions listed below are not fuel-specific, but rather they are intended to address some of the key circumstances preventing the orderly transition of alternatives to conventional gasoline and diesel fuels. Recommended actions that address the unique characteristics and market status of the individual fuels are listed in the next section of this chapter.

The Energy Commission should work with ARB and other appropriate agencies to implement the Alternative Fuels Plan. Specific additional actions are recommended as listed below.

California State Government

Energy Commission

1. Establish and administer government incentive programs (such as AB 118) to provide varying types and levels of incentives for all alternative fuels to address multiple policy goals.
2. Establish programs to link research, development, and demonstration to commercialization and deployment activities to accelerate commercial availability of alternative transportation fuels and technologies.
3. Conduct joint education and technical assistance programs to support the early adoption of alternative fuels, troubleshoot problems, provide educational training, and conduct other consumer education and information outreach programs.
4. Refine and update the full fuel cycle analysis to address sustainability issues and land use conversion impacts with ARB.
5. Take a major role in maximizing smart growth and land use planning approaches.
6. Update and add additional detail to the State Alternative Fuels Plan every two years to ensure that the goals established in this Plan are achieved.

California Air Resources Board

1. Establish regulations for a LCFS to meet or exceed the Governor's carbon intensity goal for transportation fuels with consideration for California's petroleum reduction goals and in-state Bioenergy Action Plan goals, sustainability of alternative fuels, and further reduction of criteria and toxic air pollutants. The LCFS will establish a durable framework for the production and use of alternative fuels.
2. Evaluate the feasibility of mandating alternative fuel vehicle purchases as a GHG emission reduction strategy in partnership with the Energy Commission.
3. Explore the feasibility of allowing utilities to receive carbon credits for investments in electric, natural gas, and hydrogen fuel cell transportation vehicles and infrastructure equivalent to the social benefit value.
4. Examine the feasibility of giving GHG emission credits under AB 32 to projects that received state government incentives. Consider allowing carbon credits for non-mandated, surplus, and early emission reduction measures.

California Public Utilities Commission (CPUC)

1. Encourage/allow preferential or special (for example, off-peak) rates for electricity and natural gas transportation fuels and as feedstock fuel for producing hydrogen.

2. Allow ratebase recovery of investments for home natural gas and hydrogen vehicle refueling equipment and home electric vehicle charging equipment and meter installations.
3. Explore the feasibility of allowing utilities to receive carbon credits for investments in electric and natural gas transportation vehicles and infrastrucuture equivalent to their social benefit value.

Other State Agencies

The Department of General Services and California Department of Transportation should require state government fleets to purchase alternative fuel vehicles phased in by 2012 and to use alternative fuels in state vehicles based on full fuel cycle costs criteria.

Governor and Legislature

Modify existing tax structures and funding programs to establish multiple sources of revenue to increase state funding of alternative fuel incentives and programs. Measures should include:

1. Increase funding for alternative fuels programs intended to reduce petroleum dependence and curb GHG emissions.
2. Evaluate existing tax structures to remove disincentives and reflect the relative public benefits of alternative fuels compared to gasoline and diesel.

California Regional Planning Agencies and Local Government

1. Assist local and regional government fleets to purchase alternative fuel vehicles and use alternative fuels in a phased in policy by 2012.
2. Establish quantifiable goals to reduce petroleum dependence and curb GHG emissions and establish metrics to measure progress toward meeting these goals. Initiate specific ordinances, zoning requirements, and planning regulations to enforce these reductions.

United States Federal Government

1. Extend and/or increase existing federal tax credits and financial incentives and fuel subsidies for all alternative fuels for a period of 20 years or until a substantial alternative fuel market penetration occurs consistent with assured compliance of California's petroleum reduction and GHG emission goals.
2. Increase the federal CAFÉ standards for new vehicles and modify CAFÉ credits for automobiles to ensure that alternative fuels are used for those vehicles receiving credits.
3. Re-evaluate the federal Energy Policy Act (EPAct) fleet regulations and add measures to ensure that alternative fuels are used.

4. Modify the Renewable Fuels Standard to include an expanded group of alternative fuels under a new Alternative Fuels Standard and increase the goal from 7.5 billion to over 35 billion gallons of gasoline equivalent (GGE). Legislation on this issue is pending before Congress.
5. Expand federal funding of alternative fuels R&D and demonstration to support ethanol from cellulose, hydrogen fuel cells, and other low-carbon fuels and advanced alternative fuel vehicle technologies.

Actions Needed by Fuel Type

While all alternative fuels could benefit from general state support such as fleet and market niche support, favorable state tax treatment, and business attraction and retention initiatives, the following actions reflect a broad range of viewpoints from alternative fuel industry representatives, environmental organizations, and other participants. These commenters believe these actions are needed for each fuel to achieve its moderate growth potential.

Biofuel Actions

Biofuels are a type of transportation fuels derived from biological materials, as opposed to fossil fuel feedstock. Several types of biofuels are being produced from a wide range of biomass materials and through a variety of conversion processes of pathways. The primary biofuels that are commercially produced today are ethanol, made from sugars and starches, and biodiesel produced from animal fats or vegetable oils.[13]

Corn ethanol is widely used in California in today's 5.7 percent blended gasoline. In June 2007, ARB revised its reformulated gasoline regulations. The amended regulations make it more feasible and likely that up to 10 percent ethanol can be blended with gasoline. If all gasoline were to be blended with 10 percent ethanol (E-10), California will see an increased use of ethanol from 900 million gallons today to approximately 1.5 billion gallons by 2012.

Increasing California ethanol/biofuels use beyond that will require widespread use of flexible fuel vehicles (FFVs) running on 85 percent ethanol blended gasoline (E-85) along with the necessary E-85 distribution infrastructure (stations). Further, the development of advanced gasoline biofuels blending components could allow systemwide blends beyond 10 percent.

Virtually all of the ethanol currently used in California is imported from out of state. Near-term ethanol supplies will continue to be produced from imported Midwest corn, while

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[13] UC, *A Low Carbon Fuel Standard; Part 1: Technical Analysis*, prepared by Alexander Farrell and Daniel Sperling, August 2007.

in-state production will feature both waste stream sources and purpose-grown energy crops, such as switchgrasses and sugar cane in the Imperial Valley. Relying on biomass residues from agricultural, forestry, and urban sources should be optimized, given the large volume of California's untapped biomass resources.

Renewable diesel and biodiesel fuels can be produced from a broad range of feedstock options, including animal waste, soy beans, vegetable oils, wood wastes, animal fats, and protein. Renewable diesel and biodiesel contain no petroleum but can be blended with diesel fuel. Renewable diesel can be used in diesel engines with no major modifications. The U.S. Navy and Marine Corps use B20 in their non-tactical diesel vehicles and account for approximately one-third to one-half of all biodiesel purchases in California.

Biomethane is being produced from animal manure at dairies in California's Central Valley as a methane fuel (natural gas) for electricity generation. Capturing methane from dairy farms is an important GHG reduction strategy, especially since methane has 23 times more global warming potential than CO_2. Biomethane can also be used as a feedstock for ethanol and hydrogen production.

General Biofuels – Immediate and Mid-Term Actions

1. Address regulatory uncertainty in the permitting of new biofuels production facilities. Ensure that projects meet California Environmental Quality Act (CEQA) requirements, including a multimedia evaluation of the effects on air quality, water quality, and waste disposal requirements. In some cases, legislative clarification is needed to define the parameters and limits of state authority versus local permitting authority. In other cases, statutory modifications are needed to define "waste transformation."
2. Encourage California businesses to develop fuel production technologies and produce low-carbon biofuels from in-state feedstocks.
3. Verify the performance and environmental attributes of advanced gasoline biofuel blending components for compliance with the LCFS by 2020.
4. Improve and expand terminal storage of fuel and transport logistics in California to account for increased transportation fuel demand and biofuels production.
5. Monitor the progress by fuel producers to blend up to E-10 with gasoline to comply with ARB predictive model specifications by 2012.

Ethanol – Immediate Actions

1. Develop 30-60 ethanol production plants in California using imported corn feedstocks initially, but transitioning to production from agricultural, forestry, and urban wastes; producing biomethane and biogas; using purpose-grown crops such as sugar cane.
2. Complete a cellulosic ethanol proof-of-concept production plant.
3. Facilitate/resolve automaker certification of FFVs to meet California air emission standards.

4. Facilitate automaker commitments to produce FFVs as a portion of all alternative fuel vehicles sold in California each year. This would be a sizeable portion of a total of 750,000 alternative fuel vehicles added per year over five years.
5. Expand installation of higher blends of ethanol (E-85) pumps in 2,000 stations over the next 10 years based on geographic distribution of FFVs within the state.
6. Conduct consumer education and outreach programs to highlight FFV and biofuel attributes and identify locations for alternative fueling stations.

Ethanol – Mid-Term Actions

1. Ease transition of ethanol production facilities in California from imported corn feedstocks to low-carbon California biomass feedstocks.
2. Monitor potential modifications to California ethanol production plants and refinery upgrades to produce advanced biofuels.

Renewable Diesel and Biodiesel Immediate Actions

1. Develop renewable diesel and biodiesel production plants in California to displace 1 billion gallons of diesel over 10 years.
2. Establish a California fuel producer's tax credit or subsidy to complement the existing federal fuel producers' credit.
3. Continue and expand ongoing R&D to optimize favorable fuel characteristics, performance, fuel quality, and environmental impacts, such as nitrogen oxide emissions of higher blend renewable/biodiesel in ratios between 5 to 20 percent.
4. Facilitate development of "sustainability standards" for renewable diesel and biodiesel feedstock sources (canola oil, palm oil, soy oil, waste grease, and other sources).
5. Research and develop ways to resolve cold weather performance for higher level renewable/biodiesel blends in engines.
6. Encourage in-state production of renewable diesel and biodiesel supplies that are currently being imported into California.
7. Conduct consumer and market niche education and outreach programs to highlight renewable/biodiesel attributes and identify fueling station locations.

Propane Immediate Actions

In the early 1980s, propane was the leading alternative fuel in California with more than 200,000 propane vehicles operating in the state. Despite the advantages offered by propane, such as its availability and less costly infrastructure, the fuel saw a decline in its use and an attrition of the market to negligible levels in 2007 as vehicle availability declined.

Nevertheless, propane continues to be an attractive motor fuel for medium-duty vehicle fleets in California.

1. Facilitate improvement in propane fuel quality characteristics for California use.
2. Facilitate/resolve volatile organic compound emissions (leaks) from refueling systems in 700-900 existing propane refueling stations.
3. Develop heavy-duty engine/fuel system technologies for use in California by fleet operators.
4. Introduce off-road propane technology in California markets.
5. Expedite/resolve certification of propane vehicles and engines in California.
6. Expedite/resolve permitting of propane fueling station construction, improve storage systems, and expand the number of fueling stations.
7. Encourage fleet and market niche purchases of propane vehicles.
8. Encourage investments in vehicle and refueling technology through business attraction and retention actions.
9. Conduct outreach, training, and demonstration programs for users and fleet operators.

Electric Transportation Technology Actions

Electricity is used in various segments that are collectively called "electric drive applications." These include battery electric vehicles (that is, on-road and off-road vehicles, such as electric forklifts and airport ground support equipment), plug-in hybrid electric vehicles (PHEV), electric truck refrigeration units, truck stop electrification, and ship cold ironing. The latter two applications refer to the use of electricity from the grid to eliminate truck idling at truck stops and ships in port using their main or auxiliary internal combustion diesel engines.

Although most of the on-road electric drive technologies require high capital cost investments in the near-term (through 2012), anticipated technology improvements, scale economies, and state incentives will reduce the associated incremental costs and improve the economic performance of these vehicles. Light-duty PHEVs are anticipated to achieve attractive economic performance earlier than pure battery electric vehicles (EVs) and heavy-duty PHEVs. Moreover, the success of other alternative fuels could be enhanced by integration with PHEV technology. A number of off-road electrification applications are already cost-competitive.

Electric Transportation Technologies – Immediate Actions

1. Continue support for the Energy Commission's Plug-In Hybrid Center at UC Davis.
2. Develop battery manufacturing production plants to support manufacturing of 100,000 new PHEV and battery EVs sold in California each year.

3. Modify utility tariff structure to support off-peak rates for PHEVs and hydrogen generation for fuel cell vehicles (FCVs.)
4. Manage EV charging to maximize off-peak power use and support development for up to 290,000 PHEV and battery EVs in 2012, 1 million in 2017, and 2 million in 2022.
5. Integrate utility "Renewables Portfolio Standard for California" (RPS) compliance and clean power initiatives with electric drive technologies to reduce GHG emissions.
6. Provide low carbon generation sources through utilities to address electric transportation demand.
7. Encourage evaluation of tire performance in PHEVs to address increased vehicle weight from batteries.
8. Research and develop advanced battery models to improve performance, reduce weight, lower costs, and demonstrate safety for light-duty and heavy-duty vehicles.
9. Research and develop ways to integrate new battery charging and recharging profiles into drive cycles for electric drive vehicle models.
10. Install up to 2 million PHEV recharging systems over 15 years.
11. Install up to 3,500 recharging stations in off-road and other electric drive market niche applications, such as ship cold ironing, truck refrigeration units, truck stop electrification, warehousing (forklifts), and other applications.
12. Speed up automaker production lines of PHEVs and battery EVs.
13. Develop battery electric and PHEV manufacturing plants in California.
14. Support utility investment in infrastructure, technology, and vehicles.
15. Expand automaker product lines and introduce innovative pricing strategies.
16. Encourage expansion of intermediary businesses to facilitate investment in market niches.
17. Research and develop projects to integrate PHEV architecture with fuel cell systems.
18. Conduct consumer and market niche education and outreach programs to highlight electric and hydrogen FCV technology attributes, costs, and performance.
19. Research and develop projects to integrate passenger PHEV's and heavy-duty vehicles with other alternative fuels.
20. Promote the installation of 7,000 electric transportation market niche projects.
21. Examine additional electric niche markets in future reports, including light rail, high-speed rail, small non-road EVs (such as burden and personnel carriers) and electric handheld and push equipment such as electric lawnmowers and other lawn and garden equipment.

Natural Gas Fuel and Technology Immediate Actions

Natural gas (methane) has been used as motor fuel in California for more than 20 years. Its use has experienced expansion in the transit sector, some package and beverage delivery applications as well as limited trash truck and port applications. The natural gas supply and fuel infrastructure is gradually expanding as a result of fleet rules in several California air basins, market-leader fleets, and the persistence of infrastructure developers. However, as opportunities expand to increase motor fuel natural gas use, vehicle availability is declining because fewer manufacturers are producing natural gas vehicles.

1. Stimulate the development of biomethane/biogas production for use as a transportation fuel and as a renewable feedstock for hydrogen.
2. Develop low-pressure, low-cost, on-board storage technology to improve range and reduce operating costs.
3. Develop three low-pressure, low-cost tank designs for fueling station storage and deploy the new tanks at up to 100 fueling stations.
4. Integrate new engines/vehicles advances into market niche applications (for example, short-haul trucks and delivery vehicles).
5. Research and develop ways to integrate homogeneous charge compression ignition (HCCI) engine technology advancements into natural gas vehicle systems.
6. Research and develop natural gas hybrid electric technology for medium- and heavy-duty vehicles and PHEV for light-duty vehicles.
7. Research/evaluate the extraction of associated natural gas from depleted/associated petroleum fields in California for use as transportation fuel.
8. Install up to 120 new liquefied natural gas (LNG) and 540 new compressed natural gas (CNG) stations for fleet and public access customers over 10 years and ensure they are designed to accommodate future hydrogen fueling.
9. Develop new utility rate structures to encourage installation of natural gas home refueling appliances in a significant market level over 10 years.
10. Develop natural gas vehicle manufacturing plants in California.
11. Integrate low-pressure (500 pounds per square inch [psi]), flat panel, natural gas tanks into light-duty vehicle platforms.
12. Support natural gas vehicles through business attraction and retention.
13. Promote expansion of anchor fleet infrastructure model.
14. Encourage fleet and market niche purchases.
15. Capture GHG emission credits in investment and business operation plans.
16. Encourage volume production by automakers beyond the threshold business case of 3,000 units/year.

17. Conduct consumer and market niche education and outreach programs to highlight vehicle availability, performance, station locations, and natural gas vehicle attributes.
18. Promote automaker production of dedicated passenger natural gas vehicles.
19. Develop in-state LNG cryogenic processing/production plants in California.
20. Develop new engines/fuel system technologies for medium-duty and heavy-duty vehicle platforms for California applications.

Hydrogen Immediate Actions

Although significant progress is being made in developing vehicles that use hydrogen and overcoming key technical barriers such as on-board storage and cost, deep challenges remain. To resolve these deep challenges, automobile manufacturers, energy suppliers, and government agencies are investing substantial resources to harness the potential benefits of hydrogen as a transportation fuel.

1. Support implementation of high-volume, retail-oriented hydrogen fuel stations strategically located to serve early market vehicles.
2. Conduct proof-of-concept R&D to determine feasibility and support demonstration of low-cost production of hydrogen from biomass and solid waste stream feedstock.
3. Vehicle manufacturers should develop proof-of-concept fuel cell plug-in hybrid drive train systems for California applications.
4. Support development of reduced-pressure, low-cost tank designs for fueling station storage and deploy these storage systems at up to 100 fueling stations. Support development of up to 2,500 hydrogen plants producing at least 360,000 kilograms each per year in California.
5. Support demonstrations of proof of concept to evaluate use of fuel cells in transportation market niche applications (that is, truck stop electrification systems).
6. Vehicle manufacturers should integrate new fuel cell plug-in hybrid drive train systems into vehicle applications (passenger light-duty vehicles, airport shuttles, transit buses, and short haul delivery vehicles).
7. Develop FCV production plants in California and promote the development of supply chain industries that can build from the state's expertise in electronics and other high-tech components.
8. Facilitate mixed use hydrogen fuel infrastructure to support both transit buses and other applications (such as forklifts), as well as light-duty vehicle fleets.
9. Ensure the credit of GHG emission reductions in business operation plans.
10. Facilitate automaker vehicle volume purchases beyond the threshold business case of at least 3,000 units/year (for example, through government lease or purchase of hydrogen fueled vehicles).

11. Conduct consumer and market niche education and outreach programs to highlight vehicle availability, performance, station locations, and fuel cell vehicle attributes.
12. Install up to 170,000 hydrogen home refueling appliances over 10 years and integrate production from rooftop solar photovoltaic systems through utility programs and rate structure.
13. Support research for reduced-pressure (such as 1,000 psi), low-cost, on-board storage technology for vehicle models.

Gas-to-Liquid (GTL) and Coal-to-Liquid (CTL) Fuels Immediate Actions

GTL and CTL fuels are produced using a broad range of technologies. GTL fuel is commercially available today; CTL fuels will need further development to overcome environmental issues associated with their production and use. To play a major role in meeting Plan goals, however, innovation to reduce their impacts and costs will be required before these are widely used in California.

1. GTL being produced from flared natural gas offers positive benefits on a global basis, but transport to California increases costs and GHG and other emissions. Innovations to reduce costs and environmental impacts should be pursued.
2. CTL provides significant petroleum reduction benefits but has high GHG emission impacts. Widespread use will require proven carbon capture and sequestration, improved environmental performance, and cost reduction for use as a California alternative fuel.

Estimated Investments Needed

Table 1 lists estimates of the market investment, government cofunding, and other government incentives associated with the circumstances, conditions, and actions and emphasized in the 2008-2022 timeframe. From 2022-2050, each alternative fuel option experiences market maturity and requires additional investment and, in some instances, continual government incentives. The market investment estimates are based on capital cost assumptions, technology R&D needs, infrastructure requirements, manufacturing investments, and consumer education program cost estimates.

Table 1: Total Estimated Investments Needed 2008 to 2022 (Million $)

Alternative Fuel	Market Investment	State Government Incentives and Co-funding	Federal Government Incentives and Co-funding
Ethanol	$9,000	$370	$1,800
Renewable/Biodiesel	$3,400	$284	$1,150
Propane	$276	$10	$8
Natural Gas	$3,600	$59	$48
Electric Drive Technologies	$10,700	$255	$200
Hydrogen	$17,200	$514	$500
TOTAL	**$44,176**	**$1,492**	**$3,706**
Annual Average (15 years)	**$3,000 / year**	**$100 / year**	**$250 / year**

Source: California Energy Commission

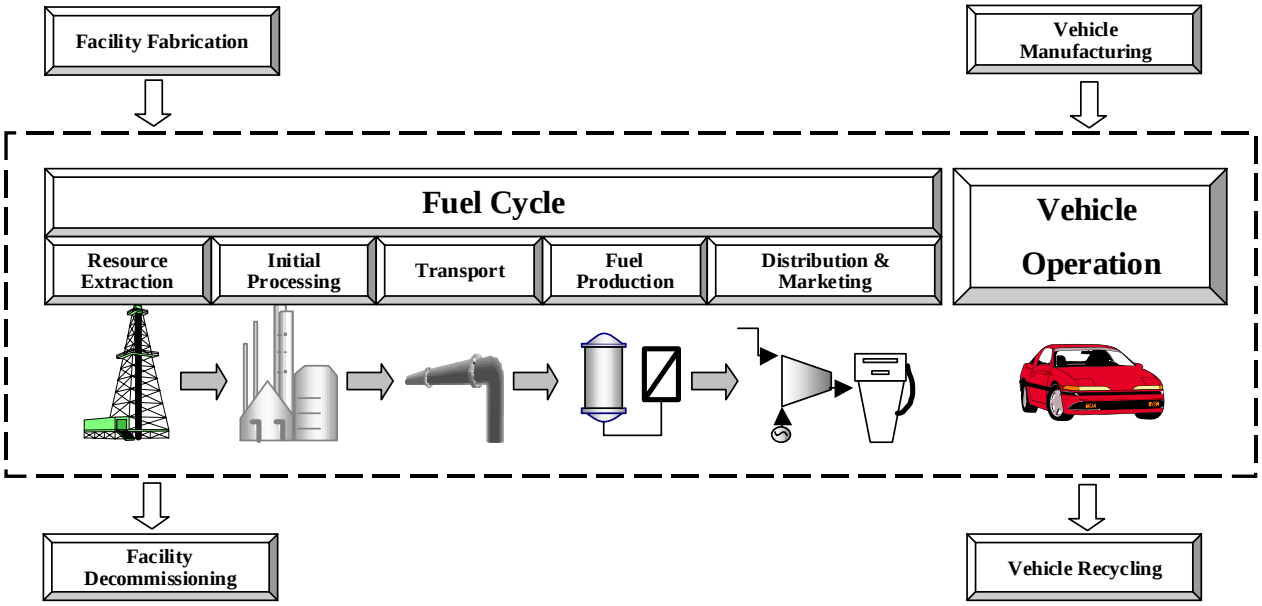
CHAPTER 3: Full Fuel Cycle Assessment

To assess the real impact of an alternative fuel, the Energy Commission and ARB quantified the environmental and health impacts of each step in the life cycle of that fuel. As required by AB 1007, the two agencies prepared a full fuel cycle assessment, also known as a "well-to-wheels" (WTW) analysis.[14] This analytical work provided the foundation for developing this Plan and was submitted to the ARB for its use in establishing the LCFS.

For each of more than 50 fuel and vehicle combinations, this analysis examined effects from feedstock extraction, transportation, and storage; fuel processing, transport, delivery, and storage; and vehicle operation, including refueling and evaporation. The study developed a thorough picture for each fuel of emissions of criteria air pollutants, air toxics, GHG, water pollutants, other substances known to damage human health, as well as the impacts each alternative fuel would have on petroleum consumption.

Figure 2 below presents a graphical representation of each step in the life cycle of a fuel. Figure 3 presents a graphical representation of the quantified emissions at each step of the fuel cycle analysis.

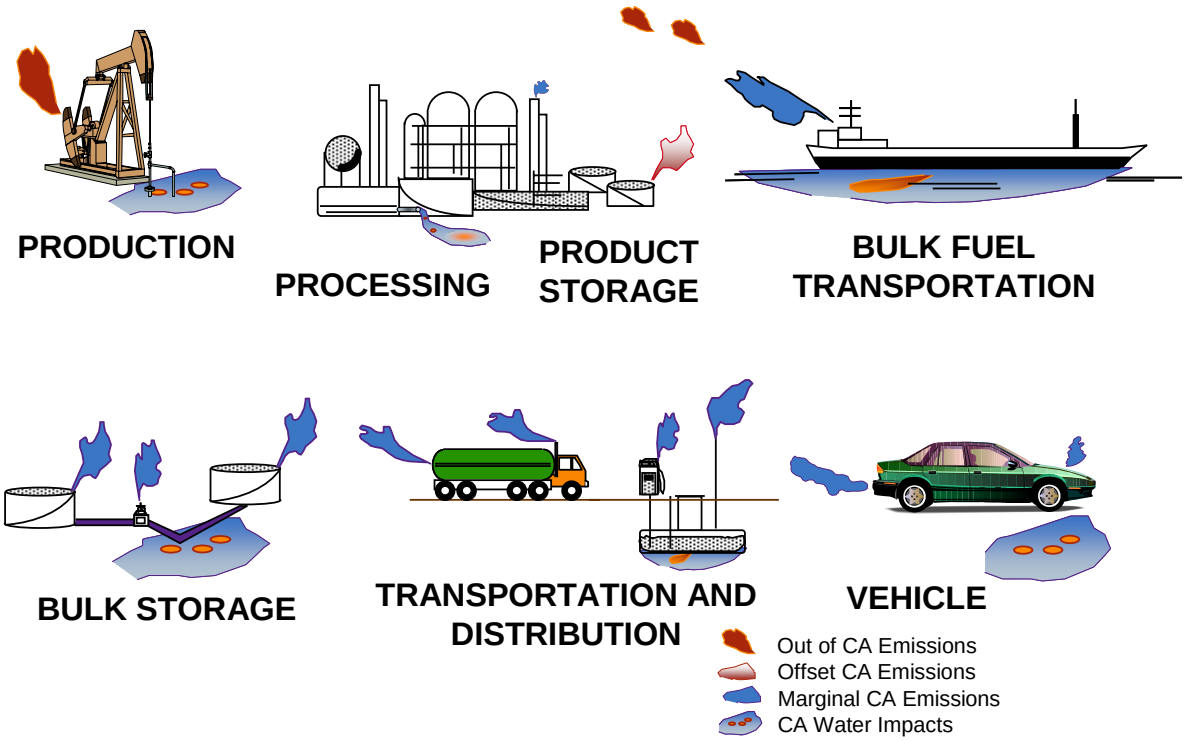
Figure 2: The Full Fuel Cycle Analysis



Source: TIAX, LLC

[14] *Full Fuel Cycle Assessment: Well-to-Wheels Energy Inputs, Emissions, and Water Impacts*, California Energy Commission, August 2007, CEC-600-2007-004-Rev.

Figure 3: Full Fuel Cycle Emissions



Source: TIAX, LLC

Results of the Full Fuel Cycle Analysis

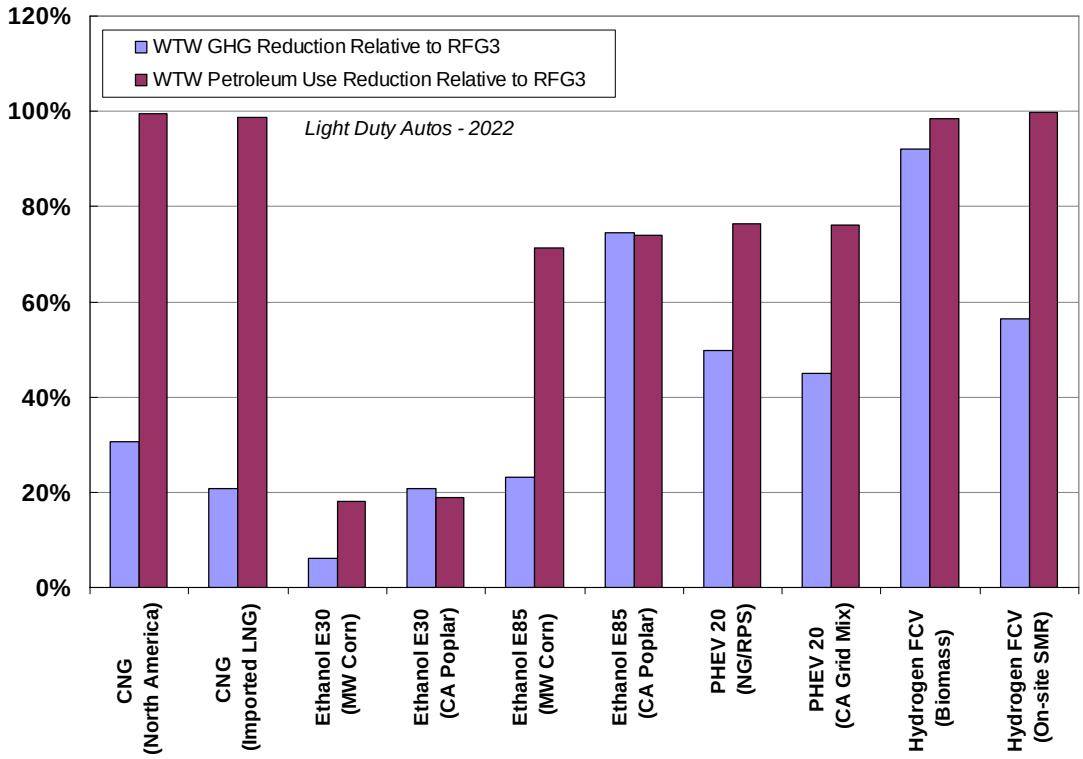
The full fuel cycle assessment demonstrated that alternative fuels can provide substantial GHG and petroleum reductions while meeting California's stringent environmental criteria requirements. Further, nearly all of the alternative fuels evaluated have a relative carbon intensity that is at least 10 percent less than gasoline, as shown in Figure 4. Each fuel may be viewed as an early action toward achievement of the LCFS goal for 2020. The analysis also showed that the effects of many fuels are heavily dependent on production and distribution pathways.

Biofuels in particular can provide large GHG reductions (up to 75 percent compared to gasoline) because CO_2 emissions are recycled back into fuel through photosynthesis. Changes in agricultural land can have a dominant effect on biofuels impacts, however, and the potential land conversion effects need to be carefully considered. Biofuels produced from the state's agricultural, forestry, and urban waste residues should be preferred in the short term because of their petroleum reduction, waste reduction, and climate change benefits.

Over the long term, staff expects advanced biofuels, hydrogen, pure EVs, and PHEVs to provide significant benefits. Depending on the pathway chosen, fuels such as natural gas, liquefied propane gas (LPG), electricity, and hydrogen can also have decided advantages over conventional gasoline and diesel fuels.

Figure 4 shows the GHG and petroleum reduction performance of new light-duty vehicles on a WTW basis for selected alternative non-petroleum fuels as a function of feedstock, compared to Phase 3 Reformulated Gasoline (RFG3). For this analysis, the two *Ethanol E-30* entries in Figure 4 are surrogates for a range of advanced biofuel blends. The figure clearly shows the GHG emissions are dependent on feedstock origins and production pathways.

Figure 4: Vehicle GHG and Petroleum Reduction Performance of Alternative Fuels for Light-Duty Vehicles as a Function of Feedstock



Source: TIAX LLC – Full Fuel Cycle Analysis

The Full Fuel Cycle Assessment

The assessment considered all parts of the fuel cycle, including energy, GHG, criteria pollutant, air toxics, and multimedia impacts. The assumptions used in the assessment are clearly identified, and they can be easily modified in the future as conditions evolve. These assumptions include quantities of fuels used, as well as the production of new fuel conversion facilities in California subject to prevailing emission constraints. Energy inputs and emissions correspond to vehicle technologies and fuel production assumptions in the 2012 through 2030 timeframe.

The assessment evaluated WTW emissions in the context of marginal emissions associated with marginal petroleum demand. A moderate use of alternative fuels would displace finished petroleum fuels imported to California. Increments of alternative fuel use would

displace emissions from transporting fuels, fueling vehicles, and the use of marine vessels to import refinery blending components into the state. Many alternative fuels are produced outside California, so the marginal treatment of fuel production is consistent with that applied to finished petroleum fuels.

Marginal emissions result largely from the transportation and distribution impacts associated with marine vessel activity, rail transport, fuel trucking, or distribution and local vehicle fueling. New fuel production facilities and power plant emissions that are attributable to incremental fuel production and use also contribute to the impacts.

Vehicle emissions depend on vehicle energy consumption combined with the carbon intensity of the fuel and vehicle emission factors. The emission estimates are consistent with ARB projection for the existing vehicle stock for blend fuel strategies through 2010 and for new vehicle technologies beyond 2010.

Energy Input, GHG Emissions, and Sustainability

The energy inputs and GHG emissions for alternative fuels depend on the conversion efficiency and carbon intensity of the fuels used. Vehicle efficiency and fuel production process energy input assumptions dominate the conclusions. The key conclusions regarding GHG emissions are:

1. GHG emissions from fossil fuels depend on both the carbon content of the fuel and fuel processing energy inputs.
2. Off-road internal combustion engine equipment that is powered by and uses alternative fuels will have similar GHG emissions reductions to on road vehicles.
3. A wide range of GHG emission factors are achievable for various hydrogen and electric generation pathways. The significant GHG emission reductions noted are due to the higher vehicle efficiency for electric drive technologies.
4. An electric generation mix based on natural gas combined cycle power combined with California's RPS policy is a valid mix for electric transportation and the electricity inputs for fuel production. The use of renewable power allows for the reduction of GHG emissions from other processes, which is an option for all fuel providers.
5. The analysis shows a 50 percent or greater GHG emissions reduction for pure electric, PHEV, hydrogen FCVs, and electric forklift applications. This is due to the naturally high efficiency of electric drive technologies converting electric energy into locomotion.
6. The GHG emissions from biofuel production vary greatly depending on the agricultural inputs to the feedstock and the level and carbon intensity of process energy inputs.

As increased opportunities develop for biofuels and other fuels considered under the Plan, the state and its private sector partners must be sensitive to overarching sustainability concerns related to each fuel. Changes in land use due to biofuel feedstock farming can have a substantial GHG impact but are not included in a full fuel cycle assessment because they are variable and not fully quantified, one-time changes. The analysis provided only the vehicle tailpipe emissions and process energy and feedstock inputs employed. Impacts associated with changes in land use need to be carefully considered as well and added to these values. Additional land use issues associated with a modest growth in United States-based energy crops are likely to be somewhat insignificant because energy crops are likely to replace other crops rather than expand the use of additional land for agriculture. These economic impacts are consistent with producing an additional 5 billion gallons of ethanol per year in the United States beyond present production. To the extent that this assumption holds true, however, the impact of differing agricultural land uses represents a minor addition to the overall impact. Land use impacts associated with biofuel feedstock sources produced outside the United States require further study.

Deforestation is an unfortunate potential impact of several biofuel options. California should insure that feedstock for biofuels used to meet California's alternative fuels requirements do not harm biodiversity or lead to soil erosion or other unintended harmful environmental or human impacts. California should insure that palm oil feedstocks for California biodiesel production come from plantations whose creation does not disrupt the habitat of rare species. Agricultural displacement effects must be avoided to realize the full GHG benefit of some biofuels.

Criteria Pollutant and Air Toxics Emissions

The assessment assumes vehicle and fuel production emissions comply with current California criteria pollutant and air toxics emissions standards. Vehicle emissions were based on ARB's emissions factors (EMFAC) model for existing and new vehicle stocks. The key conclusions regarding criteria pollutant and air toxics emissions are:

1. California maintains stringent requirements on vehicle emissions and fuels properties. ARB requires that all future changes in fuel blends result in no increase in emissions. Therefore, any successful alternative fuel will result in no significant criteria pollutant or air toxics increase from either the vehicles or retail-fueling infrastructure.
2. Some fuel blends, such as biodiesel and renewable diesel, may result in decreased criteria pollutant emissions if used in today's vehicles. ARB and vehicle manufacturers will examine the effect of alternate fuels on future vehicles before those vehicles become widely available in the California market. Final benefits will depend on sometimes competing optimization between reduced emissions and fuel economy.

3. Assumptions regarding the marginal source of gasoline result in the attribution of emissions to refineries and fuel production facilities outside California. New fuel production facilities in California would be subject to stringent emission constraints. In general, criteria pollutant emissions are lower for fuels produced in state. Conversely, emissions are generally higher for imported fuels due to less stringent emissions requirements at the site of production.
4. New fuel production facilities in California would likely be required to offset emissions of nitrogen oxides, precursor organic compounds, and, in some cases, particulate matter. Necessary permits, offsets, and emission control equipment will play an important role in both the speed with which these new fuels become available and the resultant emissions attributed to those fuels.
5. Emissions from marine vessel and rail transport are the dominant source of fuel/feedstock delivery emissions in California. For the assumed transportation distances to and within California, delivery emissions from fuels transported by rail are comparable to those imported by tanker ship on a WTW basis.
6. Agricultural equipment emissions associated with feedstock farming is a significant source of emissions for biofuels.
7. Diesel particulate is the major contributor to weighted toxics emissions in California for the marginal fuel production analyses. Therefore, fuels delivered by ship or rail have the highest weighted toxics impact. This point is clearly demonstrated in the difference between LPG from in-state wells compared to LPG produced from imported LNG in the future.
8. Criteria pollutant emissions for electric transportation are comparable to, or lower than, those from conventional fuels. The lower emission levels result from efficient new power plants that are required to offset criteria pollutant emissions, combined with efficient vehicles. Emissions associated with the average statewide generation mix are higher than the marginal mix but are still below the baseline gasoline vehicle.
9. Emissions from hydrogen reforming and gasification production facilities are inherently low because the waste gas burned to generate process heat consists primarily of carbon monoxide and hydrogen. However, very little source test data is available for hydrogen reformer criteria pollutant emission levels.
10. Evaporation and fuel spills of gasoline and diesel are a significant source of air toxic emissions. The use of most alternative fuels largely eliminates these toxic emissions.

Multimedia Impacts

Fuel production and vehicle operations can result in significant impacts on water, soil, and air. These significant sources of pollution, known as "multimedia impacts," include:

- Engine oil leaks and illegal discharges

- Tanker ship spills
- Fuel spills from delivery trucks and vehicle fueling
- Underground storage tank leaks
- Agricultural runoff
- Oil and gas production emissions

The assessment yielded the following multimedia impact conclusions:

1. Oil and gas production results in significant potential multimedia impacts. These impacts are subject to stringent regulation in the United States.
2. The use of nonpetroleum alternative fuels significantly reduces or eliminates the potential for hydrocarbon releases.
3. Pure electric drive systems can reduce or eliminate engine oil losses, which are a significant source of potential multimedia impacts.
4. While agricultural activities are subject to oversight from environmental agencies, the impacts are difficult to quantify in an integrated manner and not yet quantified for biofuels crops for energy.
5. While multimedia impacts are difficult to compare in a unified manner because of the wide range of release scenarios and impacted environments, their quantification is possible through additional analysis.

The Future Value of the Full Fuel Cycle Assessment

The tools and methods developed in the full fuel cycle assessment are an important part of both this alternative fuel Plan and future development of the state's LCFS. It is important for policy makers to have the tools to compare competing fuel resources and even competing production pathways for a single fuel. This method provides a flexible basis for future comparisons of not only the fuels analyzed here, but also fuels and fuel production pathways that are not yet fully developed or known.

The potential land use impacts of biofuels production will need better quantification and improved full fuel cycle methods. The full fuel cycle analysis will need to be refined and updated to address sustainability issues of current and future production of biofuels.

CHAPTER 4: Alternative Fuel Use Goals

In AB 1007, the Governor and the Legislature directed the Energy Commission, along with ARB, to develop a state plan to increase the use of alternative fuels and reduce emissions of GHG without adversely affecting air quality, water quality, or otherwise causing negative health effects.

The two agencies developed the Plan that concludes that regulations alone cannot achieve the state's multiple policy goals; the state needs a portfolio of alternative, low-carbon fuels, incentives and market investments, vehicle efficiency improvements, and reductions in vehicle miles traveled.

Multiple State Policies

In developing the new goals and plan required by AB 1007, the agencies recognized that there were already established state policy goals (see Table 2)that also must be met. The Plan describes strategies, highlights actions, and recommends mechanisms to concurrently address several state policies in an integrated fashion:

Petroleum reduction: Joint recommendations by the Energy Commission and ARB in response to AB 2076 (Chapter 936, Statutes of 2000).

In-state biofuels production and use: California Bioenergy Action Plan and the Governor's Executive Order S-06-06 on Biomass.

GHG reduction: Governor's Executive Order S-3-05 on Climate Change (2005), AB 32, Global Warming Act (2006), and Governor's Executive Order S-1-07 on LCFS.

Air Quality Goals: To attain the state and federal ambient air quality standards consistent with the State Implementation Plan.

Petroleum Reduction

In 2003, the Energy Commission and the ARB jointly adopted a strategy to reduce California's dependence on petroleum.[15] The two agencies demonstrated that it is feasible to reduce the on-road use of gasoline and diesel fuel to 15 percent below 2003 levels by 2020 based on technology and fuel options that are achievable and cost-beneficial. The two agencies recommended that the state pursue the strategy by establishing a goal to increase the use of non-petroleum fuels to 20 percent of on-road fuel demand by 2020 and 30 percent in 2030.

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[15] *Reducing California's Petroleum Dependence*, an Energy Commission and ARB, joint agency report, August 2003, publication #P600-03-005.

Table 2: Policy Goals Related to the State Alternative Fuels Plan

	1990	2000	2003	2007	2010	2020	2030	2050
Petroleum Reduction Goals (Billion GGE)								
Transportation Demand - Diesel and Gasoline			18	19	19.8	19.8	21.2	24
Reduce Demand by 15 percent Below 2003 Level by 2020						15.3 (-2.7)		
Increase Alternative Fuels to 20 percent of On-road Transportation Fuel Consumption by 2020						3.9		
Increase Alternative Fuels to 30 percent of On-road Transportation Fuel Consumption by 2030							6.4	
Bioenergy Action Plan Goals (Billion GGE)								
Total California Biofuel Consumption				0.9	0.93	1.6		2
In-State Production of Biofuels				0.0045	0.186	0.64		1.5
GHG Reduction Targets * (Million Metric Tons (MMT) of CO_2 Equivalent)								
Transportation Emissions - Inventory and Tellus Institute Forecast	149	163			195	217		283
Reduce GHG Emissions to 2000 Levels in 2010					163 (-32)			
Reduce GHG Emissions to 1990 Levels in 2020						149 (-68)		
Reduce GHG Emissions 80 Percent Below 1990 Levels in 2050								30 (-253)
	1990	**2000**	**2003**	**2007**	**2010**	**2020**	**2030**	**2050**

Numbers in parentheses are reduction amounts, all other numbers are target amounts.
***** The GHG Reduction Targets here are estimates; actual targets are dependant on the ARB AB 32 proceedings and an updated 1990 GHG emissions inventory.

Source: California Energy Commission

The Energy Commission incorporated the findings of the joint report into the 2003 and 2005 *Integrated Energy Policy Reports (IEPR)*[16] and recommended that the Governor and Legislature adopt the goals and strategy as state policy. In response to these recommendations, the Governor directed the Energy Commission to take the lead in developing a long-term plan to increase alternative fuel use.[17]

In-State Biofuels Production and Use

In 2006, the *California Bioenergy Action Plan* (Bioenergy Plan)was prepared and submitted to the Governor by the Interagency Bioenergy Working Group.[18] The membership of this committee includes the Energy Commission, ARB, CPUC, Department of Food and Agriculture, and the Department of Forestry. The Bioenergy Plan proposed targets for biofuel use in California of nearly 1 billion GGE in 2010, 1.6 billion in 2020 and 2 billion in 2050. The Bioenergy Plan also called for the state to produce a minimum of 20 percent of its biofuels within California by 2010, 40 percent of 2020, and 75 percent by 2050. The Governor's Executive Order S-06-06 formalized these biofuel production targets.

Greenhouse Gas Reduction

In 2002, California enacted AB 1493 (Pavley, Chapter 200, Statutes of 2002) directing the ARB to establish regulations reducing GHG emissions from passenger cars and light trucks by 18 percent in 2020 and 27 percent by 2030. These regulations take effect with the 2009 model year and will save many MMTs of GHG emissions.

The Governor's Executive Order S-3-05, signed in 2005, established goals to reduce statewide GHG emissions to the level emitted in 2000 by 2010, to the level emitted in 1990 by 2020, and to 80 percent below the 1990 level by 2050. AB 32, among other things, codified the 2020 goal and directed ARB to make recommendations to the Governor and Legislature on how to continue reductions of GHG emissions beyond 2020.[19]

Executive Order S-01-07, signed in 2007, established the LCFS in California, the world's first global warming standard for transportation fuels. The LCFS will require fuel providers (including producers, importers, refiners, and blenders) to ensure that the mix of fuels they sell in California meets, on average, a declining standard for GHG emissions that result

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[16] *2005 IEPR*, Publication #CEC-100-2005-007CMF. *2003 IEPR*, publication #CEC-100-03-019F.

[17] Letter from Governor Arnold Schwarzenegger to the Legislature, attachment: Review of Major IEPR Recommendations, August 23, 2006.

[18] *Bioenergy Action Plan for California*, Energy Commission, June 2007, publication #CEC-600-2006-010.

[19] AB 32 (Núñez Pavley, Chapter 488, Statutes of 2006), the California Global Warming Act of 2006.

from the use of transportation fuel. The goal of the initial standard is to reduce the "carbon intensity" of California's transportation fuels, on a life-cycle basis, by at least 10 percent by 2020.

Air Quality Goals

Over 90 percent of Californians breathe unhealthy air at times. Both the U.S. Environmental Protection Agency (U.S. EPA) and the ARB have established ambient air quality standards for regional ozone and particulate matter. The air quality goal is to achieve these standards.

Air quality modeling indicates that significant reductions in key pollutants are needed to achieve the ozone and 2.5 micron particulate matter ($PM_{2.5}$) standards. To achieve these federal standards, both the San Joaquin Valley Unified Air Pollution Control District and the South Coast Air Quality Management District must develop SIPs. The ozone SIPs will be submitted to the U.S. EPA in the fall of 2007, followed by submittal of the $PM_{2.5}$ SIPs in the spring of 2008.

Alternative Fuel Use Goals

AB 1007 goals for each fuel were developed using a scenario approach. Each scenario has a business-as-usual, moderate, and aggressive case. The cases differ by the assumptions made about technology maturity, vehicle and infrastructure availability, fuel supply and fuel type. Alternative fuel and vehicle goals were not simply based on desired reductions in petroleum use and emissions, but were derived from assessments about the potential market expansion of each alternative fuel, informed by substantial research and discussions with the alternative fuel industries and other stakeholders. Fuel use goals were determined by several approaches appropriate to the data available for the AB 1007 candidate fuel or an appropriate analog for the fuel and vehicle technology combination.

Broadly, the conservative or business-as-usual case assumes market conditions under which there is limited breakthrough on innovation and the adoption of innovation, limited product availability, cost constraints, and slow infrastructure expansion, leading to modest market growth. In other words, the alternatives are barely competitive with the conventional fuels and require substantial support to achieve market success.

The moderate case assumes market conditions under which moderate progress is made on technology innovation to remove barriers unique to the vehicle and fuel combination, and there is expanded product availability and significant reduction in vehicle and infrastructure costs, leading to anticipated market growth. For example, in the case of motor fuel natural gas and biodiesel, the five-year historical growth rates in fuel demand are exceeded.

The aggressive case assumes market conditions under which technology innovation targets are met to remove all barriers to technology competitiveness and use; substantial cost

reductions occur so that the alternatives are fully competitive with, or in some cases enjoy price advantages compared to the conventional fuels; a full range of vehicle product offerings are widely available; and infrastructure expansion keeps pace with the growing alternative fuel vehicle population, leading to better than anticipated market growth. For example, in the case of ethanol, cellulosic ethanol production technology is fully matured and production costs are competitive with the conventional fuels. For battery EVs, PHEVs, and hydrogen FCVs, performance, range, durability, reliability, and competitive cost targets are met. In the case of motor fuel natural gas and biodiesel, the five-year historical growth rates in fuel demand are exceeded substantially.

The results from these examples are summarized in Table 3.

Table 3: Maximum Feasible Alternative Fuel Use Results (Billions GGE)

Alternative Fuels Case	Milestone Year		
	2012	2017	2022
Business as Usual	1.4	1.7	2.1
AB 1007 Results (Moderate Case)	2.4	3.7	5.3
Aggressive Case	2.9	6.8	11.3

Source: California Energy Commission

The moderate growth case represents a plausible depiction of the market circumstances, technology advances, investment requirements, and government incentives needed for alternative fuels to fulfill the petroleum reduction and proportionate GHG emission reduction goals. Table 4 presents the maximum feasible alternative fuel use results for each fuel in the moderate case.

Table 4: Maximum Feasible Alternative Fuel Use Results by Fuel

Mile Stone Year	2012		2017		2022	
	Fuel Use	GHG	Fuel Use	GHG	Fuel Use	GHG
Propane	48	<0.1	173	0.1	282	0.2
Natural Gas	306	1.5	518	2.5	885	4.4
E10 (MW Corn)	1,394	3.8	1,354	3.8	1,327	3.6
E-85 (CA Poplar)	83	0.7	434	3.9	738	6.6
Hydrogen	40	0.3	80	0.6	440	4.4
Electricity	86	2.1	187	5.1	376	6.7
GTL, CTL, & PTL[20]	320	0	530	0	630	0
Renewable Diesel	130	1	310	2.4	530	4.2
Dimethyl Ether	13	0	62	0	101	0
Total	**2,420**	**10**	**3,648**	**18**	**5,309**	**30**

Fuel use measured in million GGE. For hydrogen and electricity, the petroleum displacement is greater than the fuel used due to the vehicle efficiency. GHG measured in MMT per year.

Source: California Energy Commission

The GTL and CTL cover a broad range of fuel production technologies. Use of CTL is highly dependent on carbon capture and sequestration. The cost of delivery and full fuel cycle environmental impacts pose barriers for GTL use in California.

Using this moderate case, example scenarios were developed to address instances when uncertain options cannot sustain growth. These examples are described in more detail in Chapter 5. The examples show that the Plan's alternative fuel use goals are achievable. The Plan's targets on a GGE basis for the use of alternative fuels in the on-road and off-road sectors (excluding air, rail and marine), including but not limited to, electricity, natural gas, propane, hydrogen, ethanol, renewable diesel, and biodiesel, are to increase alternative fuels use by 9 percent by 2012, 11 percent by 2017, and 26 percent by 2022.

[20] PTL stands for "petroleum coke-to-liquid fuel."

CHAPTER 5: Moderate Case Examples

For several alternative fuel options (natural gas, propane, electric drive, and renewable diesel), the moderate growth case provides greater predictability to achieve individual goals up to 2020 than some other options (biofuel source and makeup and hydrogen vehicle and infrastructure costs). Three examples have been developed under the moderate case to address instances when uncertain options cannot sustain growth. The examples are not intended to represent the full scope of possibilities or predict future amounts of fuel use. Further, these examples do not reflect a policy preference for any fuel or technology. The examples were developed to address:

- What happens if advanced biofuels cannot achieve a moderate level (30 percent) blending with gasoline? If this does not materialize, greater reliance on other options such as high-blend ethanol (E-85) and FFV would be needed.
- What happens if biofuels do achieve a moderate level of blending with gasoline? The need for other options would diminish.
- What happens if hydrogen fuel cells cannot meet vehicle and infrastructure cost reduction targets? A greater number of other options (such as PHEVs) would be needed.

Alternative Fuel Moderate Case Examples

Throughout the course of developing this Plan, the agencies met with interested stakeholders to determine the possible role of various alternative fuels in achieving petroleum and GHG emission reductions. The stakeholders included petroleum suppliers as well as proponents of alternative fuels including natural gas, propane, electric, hydrogen, and biofuels such as ethanol, biodiesel, and renewable diesel. From this, possible business cases, called "storylines," were developed for each of the fuels.

These storylines analyzed vehicle penetrations, petroleum reduction, emission impacts, and cost. They also provided a status of the technology and the developments and investments required to put the technology into the market. Markets included on-road passenger cars and light-duty trucks as well as on-road medium-duty and heavy-duty applications. Off-road markets using diesel fuel were also included in the storyline assessments.

Alternative fuel scenarios were developed from the individual alternative fuel storylines. Four major technology groupings were used in developing scenarios: fuel efficiency, biofuels, electric drive, and gaseous fuels.

Fuel efficiency was not included at the same level of detail as the alternative fuel options but is included as part of the "2050 Vision" described in Chapter 6. The moderate case examples reflect doubling of fuel efficiency inherent in electric and hydrogen FCVs. The growth rates of alternative fuels in the examples assume an increase in the fuel efficiency of all conventional, gasoline-electric hybrid, flexible fuel, and alternative fuel vehicles to achieve

an overall average of 66 miles per gallon in 2050. The Plan also assumes that efficiency improvement stimulated by land use planning, greater use of mass transit, and other means of moving people and goods will reduce per capita VMT by 5 percent in 2050 compared to 2007. Although the number of vehicles increases as the population increases, the total per capita VMT and total fuel use declines.

Biofuels are presently playing a significant role in California as nearly 1 billion gallons of ethanol are currently blended into gasoline (at 5.7 percent volume). Ethanol is used to meet the ARB requirements for Phase 3 California gasoline (CA RFG3). Biofuels can also be used directly in engines or vehicles designed for their use.

Electric drive technologies include battery EVs, hybrid EVs, PHEVs, and FCVs. FCVs use hydrogen, which can be produced from a variety of feedstocks such as natural gas, electricity, or renewable resources.

Gaseous fuel technologies include natural gas, biomethane, propane, and hydrogen used in internal combustion engines (ICEs).

Figure 5 shows alternative fuel (and advanced conventional technology) scenarios. The figure includes key elements of efficiency, biofuels, electric drive, and gaseous fuels. The market is segmented between light- and heavy-duty applications. No distinction is made between heavy-duty on- and off-road applications, but both are important. This figure illustrates the timing of possible technology developments and how these developments may affect the market.

From the technology road map illustrated in Figure 5, three alternative fuel moderate case examples were developed:

- Example 1: Ethanol and Hydrogen FCVs
- Example 2: Biofuels and PHEVs
- Example 3: Biofuels and Hydrogen FCVs

The examples described in this chapter illustrate common events and a roadmap up to 2022, then diverge in that year to reflect three different long-term pathways. The examples reflect a moderate growth trend for each fuel, but more achieved under aggressive growth trends. The outcome of each pathway beyond 2022 depends on the success of key alternative fuel options.

In each of these examples, estimates were made as to major technology innovations that will allow alternative technologies to compete in the transportation marketplace. For example, PHEVs require a cost-effective battery to be developed if they are to compete with advanced gasoline or diesel vehicles. If this advancement does not occur, then other technologies are possible.

The same goes for biofuels or hydrogen. In the case of biofuels, the LCFS will encourage innovation resulting in processes that convert biomass to gasoline like components (alkynes or other components). The LCFS is a performance standard that also allows for the use of

lower-intensity carbon fuels including electricity, natural gas, propane, and hydrogen.[21] Major technology milestones are identified on Figure 5.

Light-Duty Vehicle Market

Figure 5 also illustrates possible transitions that may occur when advanced technologies enter the marketplace. It is assumed, for example, that low-level ethanol blends will be used in both existing (legacy fleet) and new vehicles as the blend percentage changes from 5.7 percent to 10 percent. Higher-level blends of ethanol may also evolve as indicated by the dashed line in Figure 5.

Approximately 260,000 FFVs operate in California, primarily on gasoline, but efforts are underway to expand the E-85 infrastructure. Staff anticipates that FFVs and the E-85 infrastructure will continue to expand. The evolution of biofuels may result in the phase-out of E-85 and FFVs (discussed further in the biofuel examples).

The major developments needed to facilitate electric drive technologies are the development of robust, cost-effective lithium ion batteries and the development of cost competitive fuel cell powertrains. Stakeholders have projected that lithium ion battery technology will enter the marketplace around 2012 as shown in Figure 5. Stakeholders have projected that the fuel cell technology is will enter the marketplace in the 2011 to 2017 timeframe.

The roadmap shown in Figure 5 assumes that if lithium ion batteries enter the marketplace and PHEVs are a market success, then there will be a natural progression of PHEV technology to FCVs (plug-in hydrogen FCV). The transition to hydrogen will require close integration of vehicle sales growth and fueling infrastructure development.

Natural gas and propane are currently used in light-duty vehicles in California. However, their use is limited by vehicle and fueling infrastructure availability. Only one original equipment manufacturer (OEM)—Honda—is producing a natural gas vehicle (NGV) and in only one model, the NGV Honda Civic. Others are retrofitting NGV and propane vehicles. It is possible that this market, which primarily serves high fuel-use fleets, will give way to advanced technologies like PHEVs or hydrogen fuel cells.

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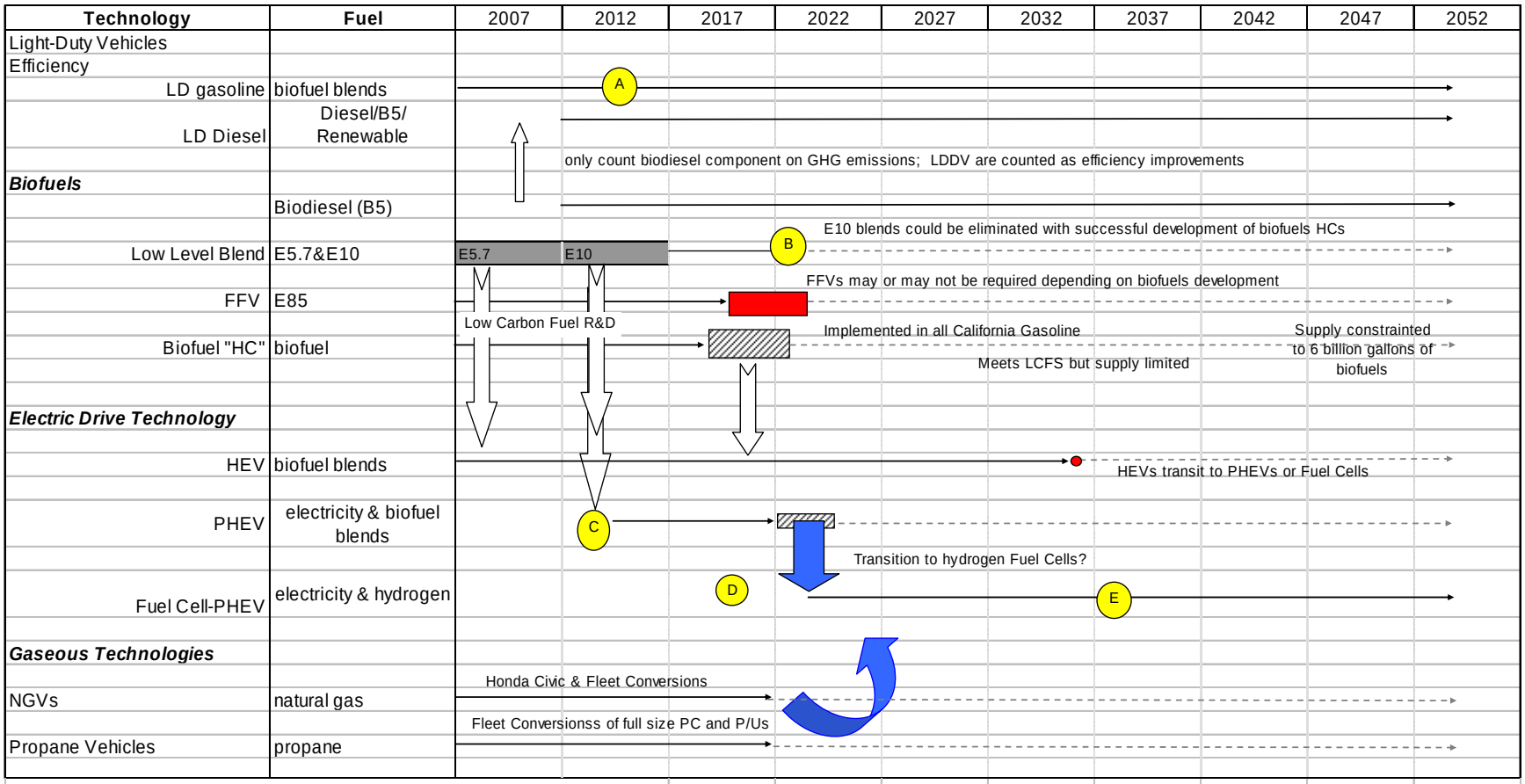
[21] Diesel is also a possible low carbon fuel due to higher engine efficiency compared to today's gasoline ICEs. In this assessment diesel technology is considered an efficiency option and may be one of the technologies that compete to achieve California's GHG emission standards.

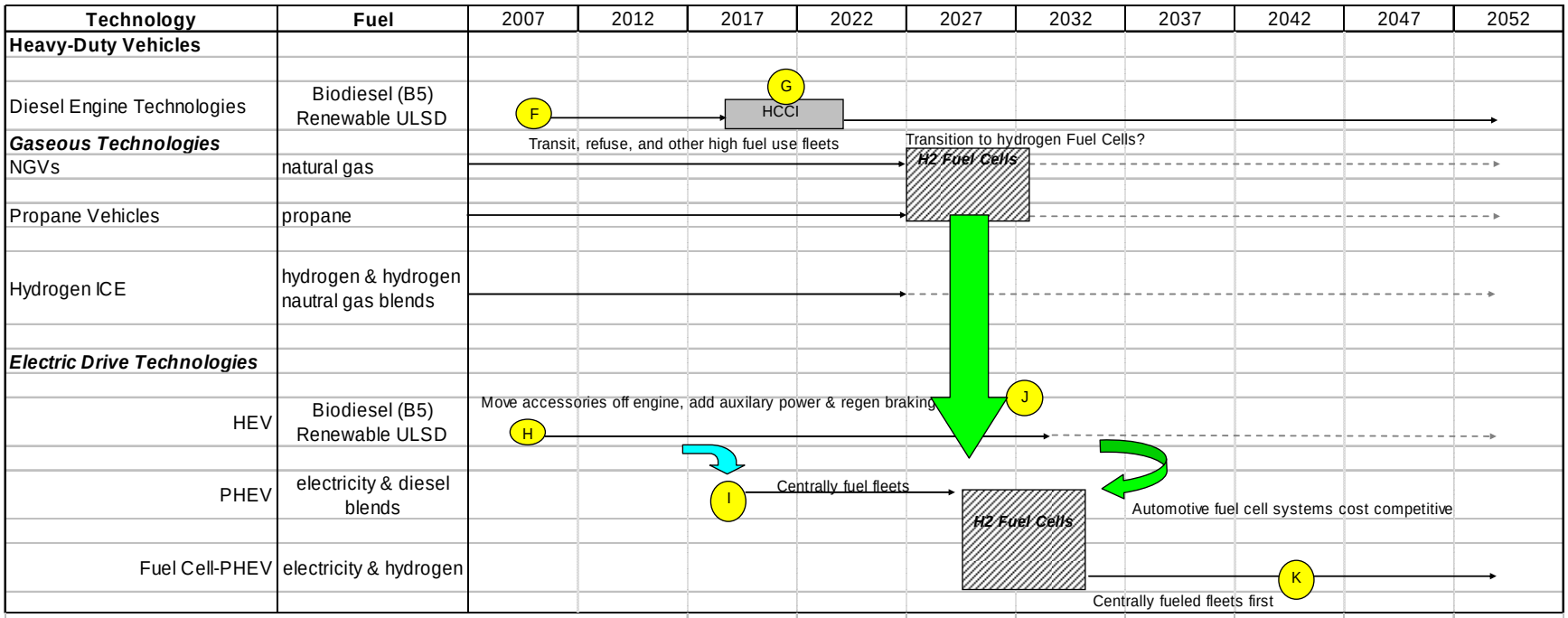
Figure 5: Alternative Fuel Technology Road Map, 2007 through 2050.



Major Technical Milestones for Light-Duty Vehicles

A	Gasoline approaches diesel efficiencies with HCCI type technologies 2012-2017
B	Biofuel "HC" standardized by oil companies to meet LCFS in 2020
C	Lithium Ion battery developed for IHEV applications and ICE PHEVs available in 2012
D	Hydrogen FC technologies achieve "cost" targets for mass production; local gaseous hydrogen production using steam reformed natural gas 2020-2035
E	Centralized hydrogen production and distribution 2035-2040

Figure 5 Continued: Alternative Fuel Technology Road Map, 2007 through 2050.



Major Technical Milestones for Heavy-Duty Vehicles

F	Biodiesel/renewable diesel added to California ULSD spec 2012
G	Diesel technology starts transition to HCCI 2017
H	Hybrid technology starts to be incorporated in vehicle platforms
I	Lithium Ion battery technology advances PHEV technology to vehicle platforms
J	Fuel cell costs competitive with diesel ICEs, fuel cell technology moves to heavy duty niche markets
K	Centralized hydrogen production broadens infrastructure and vehicle applications

Source: TIAX, LLC

Heavy-Duty Vehicle Market

In the heavy-duty market, similar technology transitions will occur. Diesel engine technologies will continue to improve in both efficiency and control of exhaust emissions. Advanced technologies like HCCI or other similar concepts may possibly enter the market place in 2018. Engines using HCCI will have improved fuel economy. In addition, heavy-duty truck OEMs will be introducing vehicle technologies such as improved aerodynamics and lower rolling resistance tires to improve fuel economy.

NGVs are currently used as transit buses, school buses, and refuse haulers as well as in short-haul trucking applications. CNG is generally used in the transit bus, school bus, and refuse hauler markets. LNG is used in the return to base, short-haul market segments that require improved range. Propane is used primarily in medium-duty applications. Currently engines are retrofitted for these propane applications. Vehicle manufacturers are also exploring the use of hydrogen in ICEs.

In the case of natural gas (methane) and propane, it is anticipated that there will continue to be a market for these technologies since the overall life cycle costs of these technologies are projected to be cheaper than advanced diesel options.[22] These technologies could move to hydrogen fuel cells when fuel cells have been successfully implemented in the light-duty vehicle sector and then subsequently in the heavy-duty vehicle segment. Because heavy-duty vehicles tend to have longer lifetimes and turnover rates than passenger vehicles, fuel cells used in these applications will need to demonstrate longevity, too.

Electric drive technologies, including fuel cell transit buses, are beginning to play a larger role in heavy-duty vehicles. Transit buses are now available with hybrid drive systems, and truck OEMs are beginning to look to hybrid systems to move accessories like pumps (water, fuel, and oil) and air conditioning off the engine to improve overall efficiency. Auxiliary power is another heavy-duty demand that can be met by alternative fuels.

The opportunities considered in this analysis include truck stop electrification, truck refrigeration units, and auxiliary marine power. As light-duty technology evolves and moves into the marketplace, costs will decrease, and the technology will move toward the heavy-duty trucking market. This could result in PHEV technology being used in return-to-base, centrally fueled fleets, and, ultimately, to hydrogen fuel cells.

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[22] This assumes that CNG, LNG, and propane will continue to have a price advantage large enough to offset the higher incremental engine and vehicle costs on a life cycle basis and that the payback period is acceptable.

Example 1: Ethanol and Hydrogen Fuel Cell Vehicles

This example assumes that technology evolution in the development and implementation of biofuels does not occur. Instead, ethanol continues to be a primary alternative fuel, used as both a low-level gasoline blend (less than 10 percent by volume) and a denatured, neat fuel (E-85). In this example, all or some portion of the new vehicle fleet would be FFVs that are capable of using gasoline (with low levels of ethanol) and E-85 or any other ethanol/gasoline blend.

Fuel providers would invest in an E-85 fueling infrastructure to comply with the LCFS. This would introduce yet another fuel into the transportation marketplace that would have to compete with gasoline. In this example, the fuels for the light-duty vehicle market would be gasoline, E-85, natural gas, electricity (for PHEVs) and hydrogen for FCVs. As they are single-fuel vehicles, natural gas and hydrogen vehicles will not compete for fuel with gasoline vehicles after purchase.

The biofuels pathway is the only change in this example compared to the "advanced biofuels and hydrogen fuel cell example." Natural gas vehicles play a minor role in the light-duty sector but a major role in the heavy-duty sector. There is a natural progression of electric drive technology moving from hybrid drive to plug-in hybrid drive to fuel cell electric drive vehicles. A similar progression occurs in the heavy-duty sector albeit later and only in limited vehicle applications and for niche applications such as transit buses. Figure 6 shows the selected results for Example 1 (the E-85 and hydrogen fuel cell example). The top of the figure shows light-duty vehicle population. In this example, FFVs are capturing a substantial share of the new car market and at 2050 populate about 45 percent of the total light duty vehicle fleet with gasoline and diesel being about 25 percent and PHEVs and FCVs making up the remaining 30 percent. In 2050, most new cars are either FFVs or FCVs.

The fuel consumption for Example 1 is shown in Figure 7. In 2050, a little more than 45 percent of fuel consumption is gasoline and diesel with the remaining being ethanol, hydrogen, electricity, and some natural gas and biodiesel. The heavy-duty sector consumes natural gas, diesel, biodiesel, hydrogen, electricity, and propane. Natural gas and diesel dominate in 2050. Total petroleum displaced in this example is 13.6 billion gallons in 2050. Light-duty contributes 8.8 billion gallons and heavy-duty 4.5 billion gallons.

Figure 8 shows the GHG emission reductions. As shown, the maximum potential GHG reductions are estimated at 111 MMT of CO_2 equivalent. The minimum GHG reduction estimate is 56 MMT. As with the previous examples, the majority of the estimated GHG reductions come from the light-duty sector: 87 MMT for the estimated maximum and 39 MMT for the estimated minimum. The maximum and minimum GHG emission reductions for the heavy-duty sector are 21 MMT and 14 MMT. Approximately three MMT of GHG emission reductions from off-road applications are not shown in Figure 8.

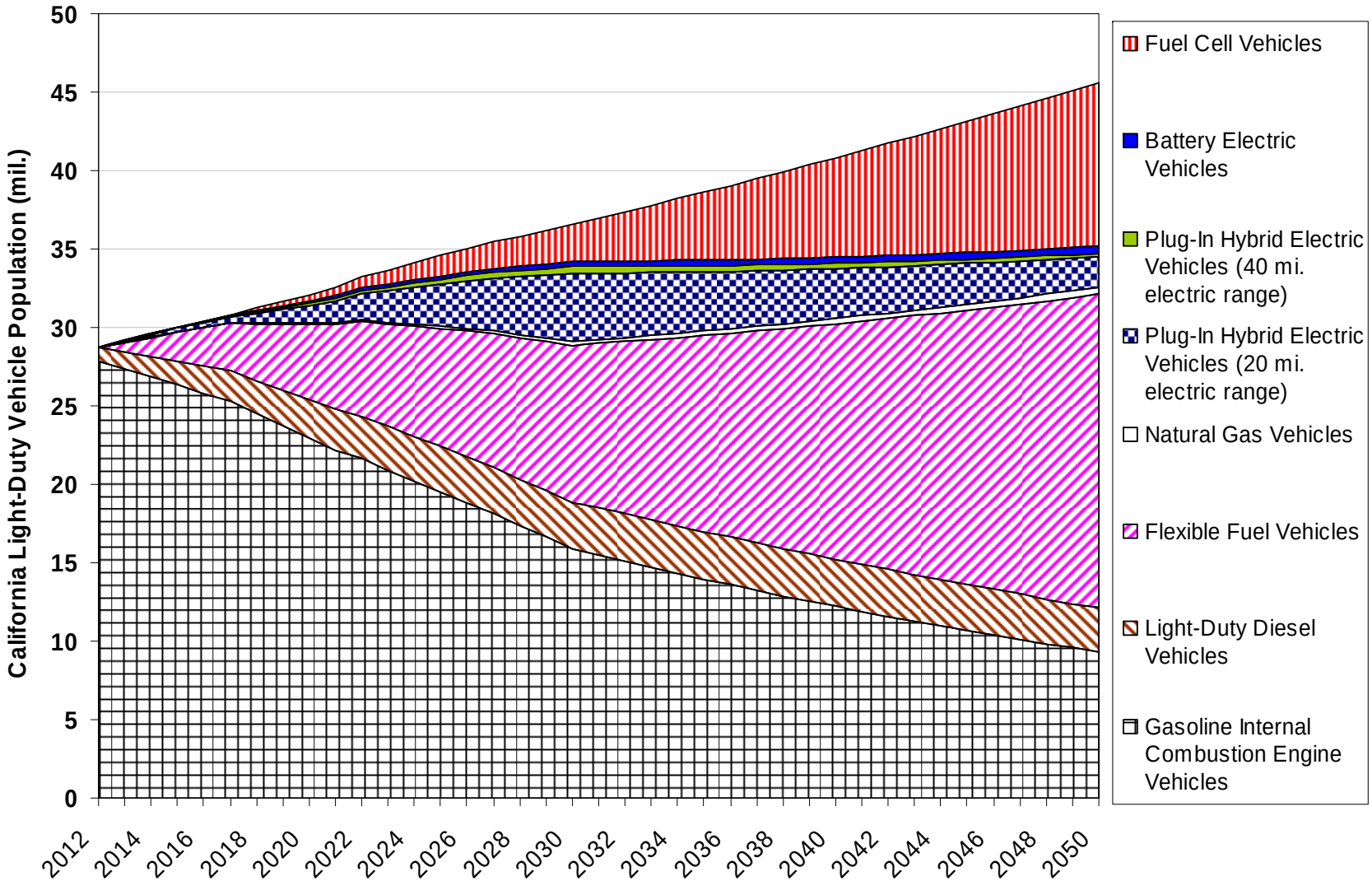
As before, the heavy-duty sector contributes less to GHG emission reductions (in proportion to energy used) because more displacement comes from natural gas, which has limited GHG benefits (about 20 percent lower carbon intensity and no efficiency benefits compared

to diesel). Nevertheless, this example provides the highest potential reduction in GHG emissions of the three examples modeled. This is a result of FFVs—which are commercially available today—entering the fleet much earlier than either PHEVs or FCVs.

Table 5 shows how this example compares to the goals of petroleum displacement, GHG emission reduction, and LCFS. Again, as with the previous examples, this example — using E-85 and FFVs instead of biofuels — achieves the petroleum displacement or alternative fuels usage goals but falls short of the GHG reduction goals and meeting the LCFS. It is possible to meet the LCFS and 2020 GHG goal with an increased use of ethanol derived from sources such as biomass, sugar cane, or cellulosic material (provided land conversion does not cancel out the benefits of these feedstocks).

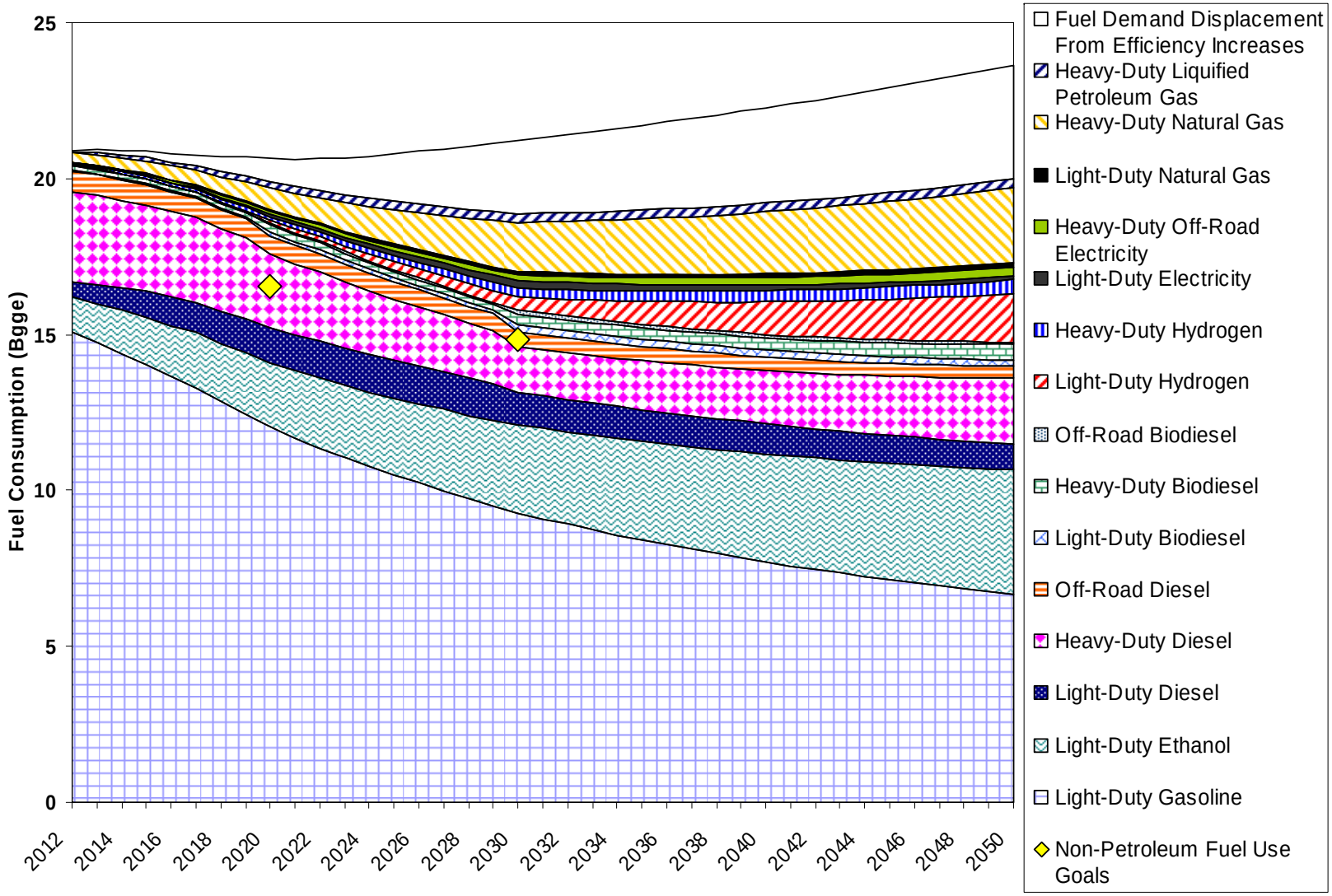
The long-range GHG reduction goals are not achievable without further efficiency improvements in the light- and heavy-duty fleet, use of the lowest GHG feedstocks, and very aggressive penetration of these technologies into the marketplace. In addition, reducing VMT through more efficient land use planning and implementation will be necessary.

Figure 6: Vehicle Population Results for Example 1



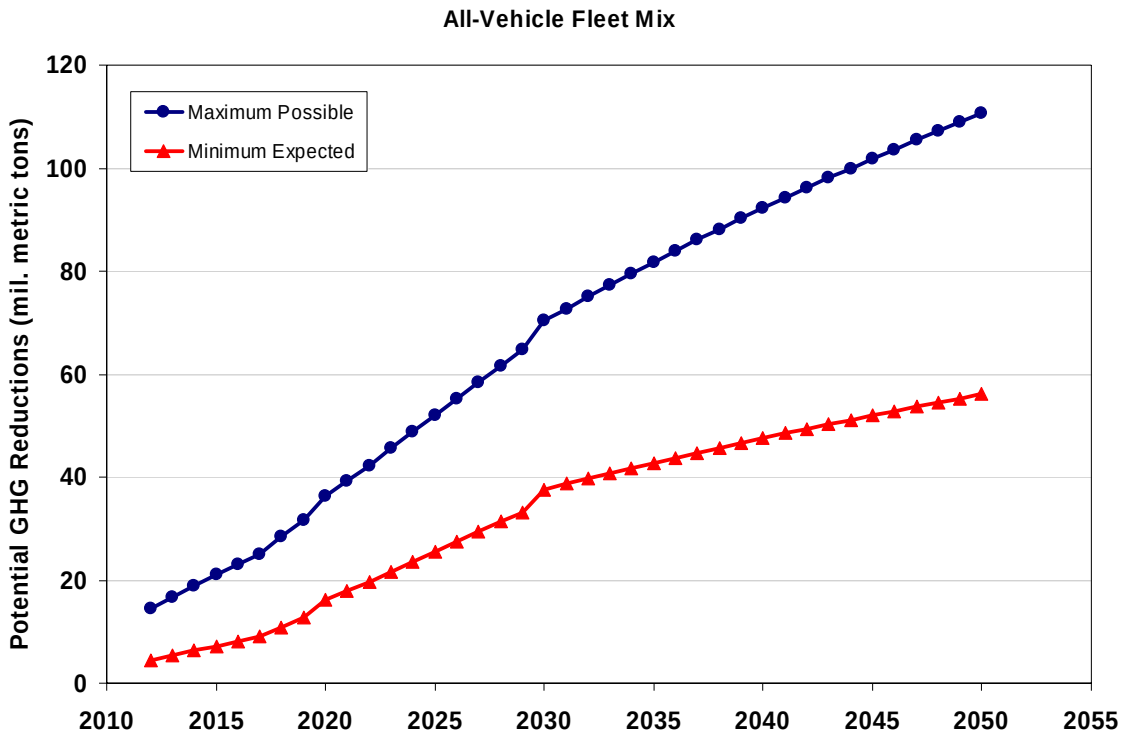
Source: TIAX, LLC

Figure 7: All Vehicles Mix - Fuel Consumption for Example 1



Source: TIAX, LLC

Figure 8: GHG Results for Example 1



Source: TIAX, LLC

Table 5: Results for Example 1

Year	Petroleum Displacement (billions GGE)		GHG Reduction (MMT) *		LCFS (Percent Carbon Intensity)	
	Goal	Example 1 Result	Target	Example 1 Result	Goal	Example 1 Result
2012	---	1.8	---	4 – 14	---	1.1 – 5.3
2020	4	4.6	39	16 – 36	10	4.7 – 13.0
2030	6	9.0	---	38 – 70	---	10.4 – 23.4
2050	---	13.6	202	56 – 111	---	15.8 – 34.9

* GHG Reduction Targets are initial AB 32 and Governor's Executive Order targets, less Pavley GHG reduction estimates.

Source: TIAX, LLC

Example 2: Advanced Biofuels and PHEVs

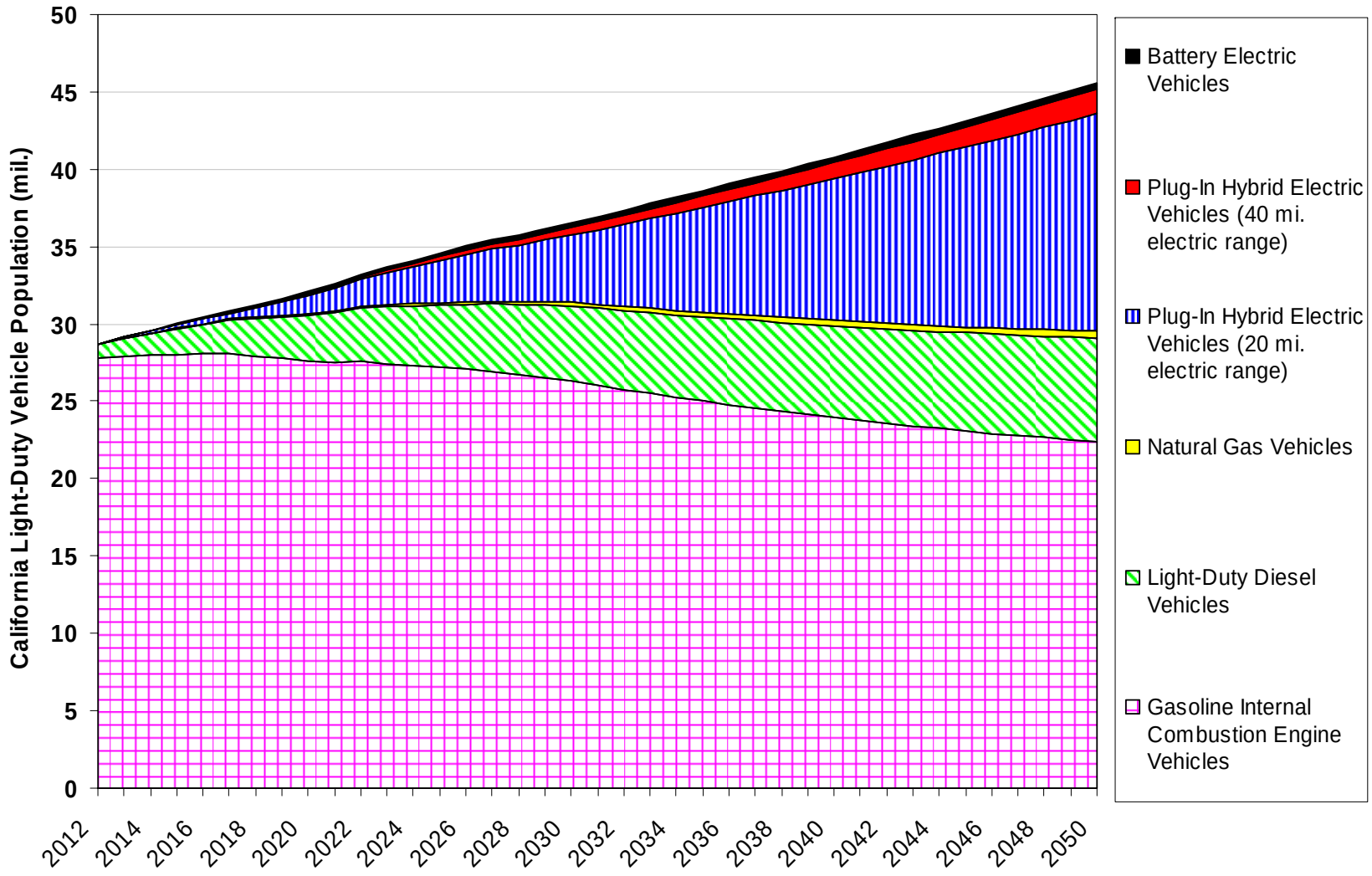
This example is identical to Example 3 (advanced biofuels and hydrogen fuel cells) except that fuel cells are not commercially introduced into the transportation market. Figure 5 shows that PHEVs capture an increasing market share of the new light-duty vehicle market starting in 2012 and continuing through 2050. Fuel cells are also not introduced into the heavy-duty market, and hybrid and PHEV technologies capture some share of this market. All other assumptions for Example 2 are the same as Example 3, including assumptions about battery electric technologies, NGVs, and propane vehicles. Figure 9 presents the vehicle population, fuel consumption, GHG reductions, and comparison to goals for this example. The information is presented in the same format as the previous example.

In Example 2, the light-duty vehicle population is composed mostly of gasoline, diesel, and PHEVs. There are a small number of battery EVs and NGVs. The same caveats hold regarding the split between gasoline and diesel. The biggest difference between the light-duty population estimates is the larger number of alternative-fueled vehicles in the marketplace in this example. This population increase is due to the early introduction of PHEVs and their continued growth, as opposed the initial introduction and subsequent loss of market share to hydrogen fuel cells that is described in Example 3.

Figure 10 illustrates the total fuel consumption for both alternative and conventional fuels that are required to meet the combined light-duty, heavy-duty, and off-road fuel demand. The PHEV example is very similar to the hydrogen example except the hydrogen has been replaced by electricity. Efficiency is slightly larger in the PHEV example since PHEVs are introduced earlier than FCVs, and there is no transition between the two technologies. The PHEV example also offers similar benefits relative to GHG emission reductions and petroleum displacement.

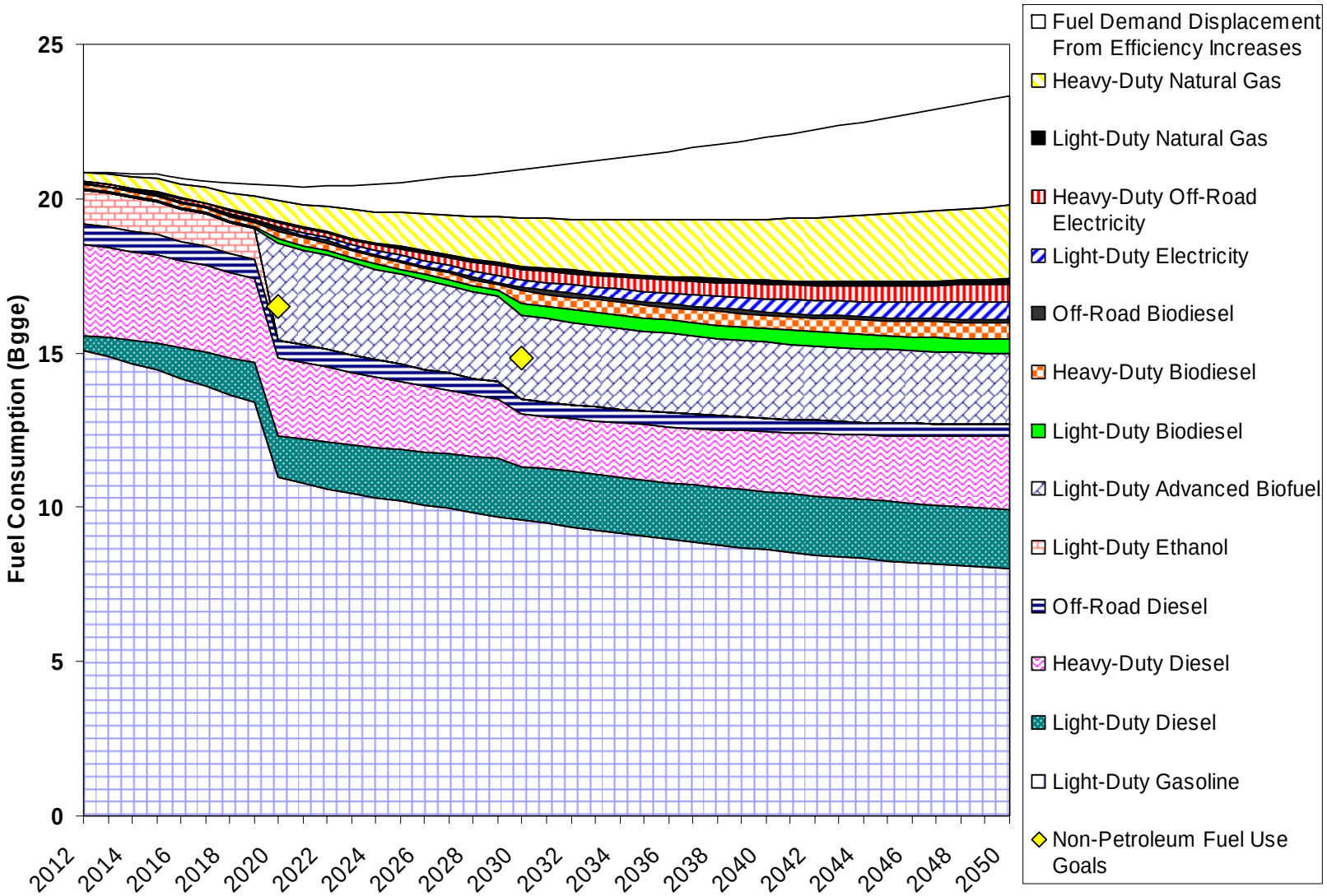
Comparing the light-duty fuel consumption in 2012 with 2050, gasoline is reduced by 8 billion gallons, diesel increased by 2 billion gallons, biofuel increased by 2.3 billion gallons, and electricity increased by 0.6 billion gallons. Corresponding estimates in the heavy-duty sector are: natural gas increases by 2.4 billion gallons, biodiesel increases by 0.6 billion gallons, electricity increases by 0.5 billion gallons, and diesel decreases by 0.6 billion gallons. Efficiency from all sectors improves by some 3.5 billion gallons due to the higher efficiency PHEVs technology. Figure 11 shows the possible GHG emission reductions from this example. Again the results are very similar to the fuel cell example with maximum GHG emission reductions of 77 MMT and the minimum GHG emission reductions of 51 MMT.

Figure 9: Vehicle Population Results for Example 2



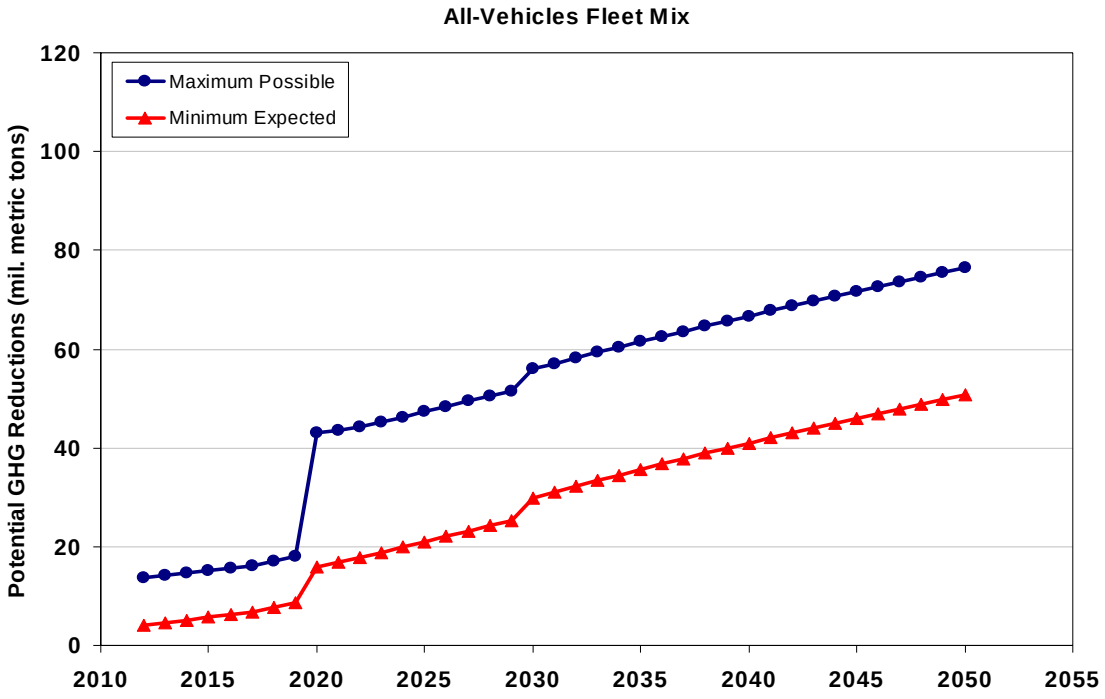
Source: TIAX, LLC

Figure 10: All Vehicles Mix - Fuel Consumption for Example 2



Source: TIAX, LLC

Figure 11: GHG Results for Example 2



Source: TIAX, LLC

Table 6: Results for Example 2

Year	Petroleum Displacement (billions GGE)		GHG Reduction (MMT) *		LCFS (Percent Carbon Intensity)	
	Goal	Example 2 Result	Target	Example 2 Result	Goal	Example 2 Result
2012	---	1.7	---	4 – 14	---	1.1 – 5.2
2020	4	5.2	39	16 – 43	10	5.3 – 17.1
2030	6	7.7	---	30 – 56	---	8.9 – 19.9
2050	---	10.9	202	51 – 77	---	11.7 – 21.2

* GHG Reduction Targets are initial AB 32 and Governor's Executive Order targets, less Pavley GHG reduction estimates.

Source: TIAX, LLC

Table 6 shows how this example compares to the goals of petroleum displacement, GHG emission reduction, and LCFS. The results again are very similar to the fuel cell example. Petroleum displacement goals are achieved. The GHG emission goal in 2020 can be achieved with fuels produced from low-impact GHG feedstocks. Similarly, the LCFS can also be achieved if biofuels are produced from these low GHG feedstocks and conversion processes. As before, the current example will not meet 2050 GHG emission reduction goals. This level of reduction will require that higher-efficiency vehicles and low carbon fuels enter the market sooner and at a higher penetration rate and that VMT is reduced.

Example 3: Advanced Biofuels and Hydrogen Fuel Cell Vehicles

This example assumes that biofuels will be converted to gasoline-like components that can be blended into gasoline and used in the legacy fleet as well as all new vehicles. For analysis purposes, the authors have assumed that advanced biofuels will be blended in at 30 percent by volume with gasoline. This example also assumes that FCVs are developed and subsequently competitive in the marketplace. Other assumptions for the light- and heavy-duty sectors are as follows:

Light-Duty Sector Assumptions

1. Low-level ethanol blends begin at 5.7 percent, progress to 10 percent in 2012, and are phased out as biohydrocarbon components replace ethanol at ever higher blends by 2020.
2. E-85 and FFVs are phased out as advanced biofuels come into the marketplace after 2020.
3. Electric drive technologies advance from PHEV technology to fuel cell technology.
4. Natural gas and battery EVs continue to capture a small light-duty market segment.

Heavy-Duty Sector Assumptions

1. Biodiesel and renewable diesel are blended in at 5 percent starting in 2012, moving to 10 percent in 2020, and to 20 percent in 2030.
2. Natural gas continues to capture market share and grows into wider vehicle and user applications.
3. Propane vehicles also continue in the market but at less volume than natural gas.
4. Hybrid electric drive technologies continue to develop for on-road trucks and other non-road electric drive technologies, including auxiliary marine power and truck refrigeration units.
5. Fuel cell technologies develop and enter the market.

These assumptions were modeled using a simplified vehicle inventory breakdown to obtain vehicle population estimates, petroleum displacement, and GHG reductions.

Figure 12 shows these results for the combined light- and heavy-duty example. Only light-duty vehicle population estimates are shown in this figure. Fuel consumption by alternative is shown for the light-duty, heavy-duty, and off-road sectors. GHG reductions are also estimated for both light and heavy market segments. Table 7 compares goals to the achievements of this example.

In this example, light-duty hydrogen FCVs dominate all other alternative fuel vehicles in the 2050 timeframe. PHEVs in the light-duty sector capture early market share until FCVs are cost-competitive in the marketplace then lose market share to the FCVs. Natural gas captures a small share of the vehicles. In total, alternative fuel vehicles capture all of California's projected vehicle growth. Gasoline and diesel technologies remain relatively constant in the 29 million to 32 million vehicle range. This estimate assumes that light-duty diesel captures a somewhat increasing market share over gasoline vehicles partly to meet California's GHG emission standards.[23]

In the heavy-duty sector, natural gas and diesel account for about three-fourths of the market, with natural gas capturing slightly more than diesel-fueled vehicles in 2050 (these population numbers are not shown in Figure 13). Also included in the heavy-duty sector are hydrogen fuel cells, PHEVs, and propane. The gaseous fuel technologies will most likely capture the short-haul pick-up and delivery market.

Fuel consumption for various technologies in the light, heavy, and off-road sectors is shown in Figure 13. In the light-duty sector, fuel demand is projected to be very flat. Given the aggressive penetration of biofuel blends in the near term, PHEVs in the mid-term, and hydrogen FCVs in the long term, gasoline demand drops by 45 percent relative to the projected demand.

Biofuel consumption grows to some 2 billion GGE as does diesel fuel (although as mentioned above this could be lower depending on gasoline competition). Hydrogen consumption reaches 1.5 billion GGE. Biodiesel grows to about 0.5 billion GGE, and electricity ends up at 0.1 billion GGE, down from a peak of 0.25 billion GGE. Natural gas consumption remains fairly small. A large portion of the efficiency wedge is due to the introduction of the higher-efficiency PHEVs and FCVs.

In the heavy-duty sector, demand is projected to almost double. Today, heavy-duty fuel demand is mostly met with diesel and a small amount of natural gas and propane. This is expected to change with natural gas capturing 36 percent of the demand in 2050. Diesel is projected to meet 32 percent of the demand in this period with biodiesel and hydrogen meeting about 8 percent each. Efficiency improvements from PHEVs and FCVs reduce demand by about 9 percent. Electricity and propane capture the remaining demand.

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[23] Light-duty diesel technology will be competing with improving light-duty gasoline technologies. It is possible that gasoline HCCI-type technologies could have comparable efficiencies as diesel technologies and would capture more market share from the light-duty diesel estimates.

The possible GHG emissions reductions are shown in Figure 14. Two estimates are provided: the maximum possible that represents the maximum GHG reductions for each alternative pathway considered and the minimum possible that represents a low or conservative estimate of the GHG reductions. The only variable in this assessment was the feedstock from which the fuel was derived; no variation in technology was assumed. Using ethanol as an example, the maximum reductions are quantified assuming a cellulosic feedstock, and the minimum reductions assume corn-based production.[24] Similarly, the maximum case for hydrogen fuel cells is hydrogen produced from biomass, and the minimum case is hydrogen produced from natural gas.

As indicated, in 2050 the range of GHG emissions reductions (from minimum to maximum) is between 53-92 MMT of CO_2 equivalents. These GHG emission estimates include only the alterative pathways in this example and do not include any efficiency reductions that will occur in the light- or heavy-duty sectors. The large increase in GHG emission reductions in 2020 is due to the introduction of biofuels in the gasoline pool. For convenience, staff has assumed this will happen in 2020 and has not shown a transition period that may well occur as fuel providers meet the requirements of the LCFS.

Figure 12 shows how well Example 3 compares to the goals of petroleum reduction (or alternative fuel use) goals, GHG emission reduction (compared to transportation sector goals only), and the LCFS. As indicated the example exceeds petroleum reduction targets in both 2020 and 2030. GHG goals for alterative fuels and VMT strategies can be met in 2020 if higher-benefit GHG feedstocks are used in most of the alternative fuels (such as biomass to hydrogen and a biomass-based biohydrocarbon).

The standard will not be met with feedstocks of lower GHG benefit in this example. Of course, increasing PHEV or FCV penetration would increase the carbon intensity from 4.7 percent to the goal of 10 percent. Because there is a large shortfall in meeting the 2050 targets, reaching these goals will most likely require a combination of efficiency strategies, more aggressive use of advanced FCVs, and reduced VMT.

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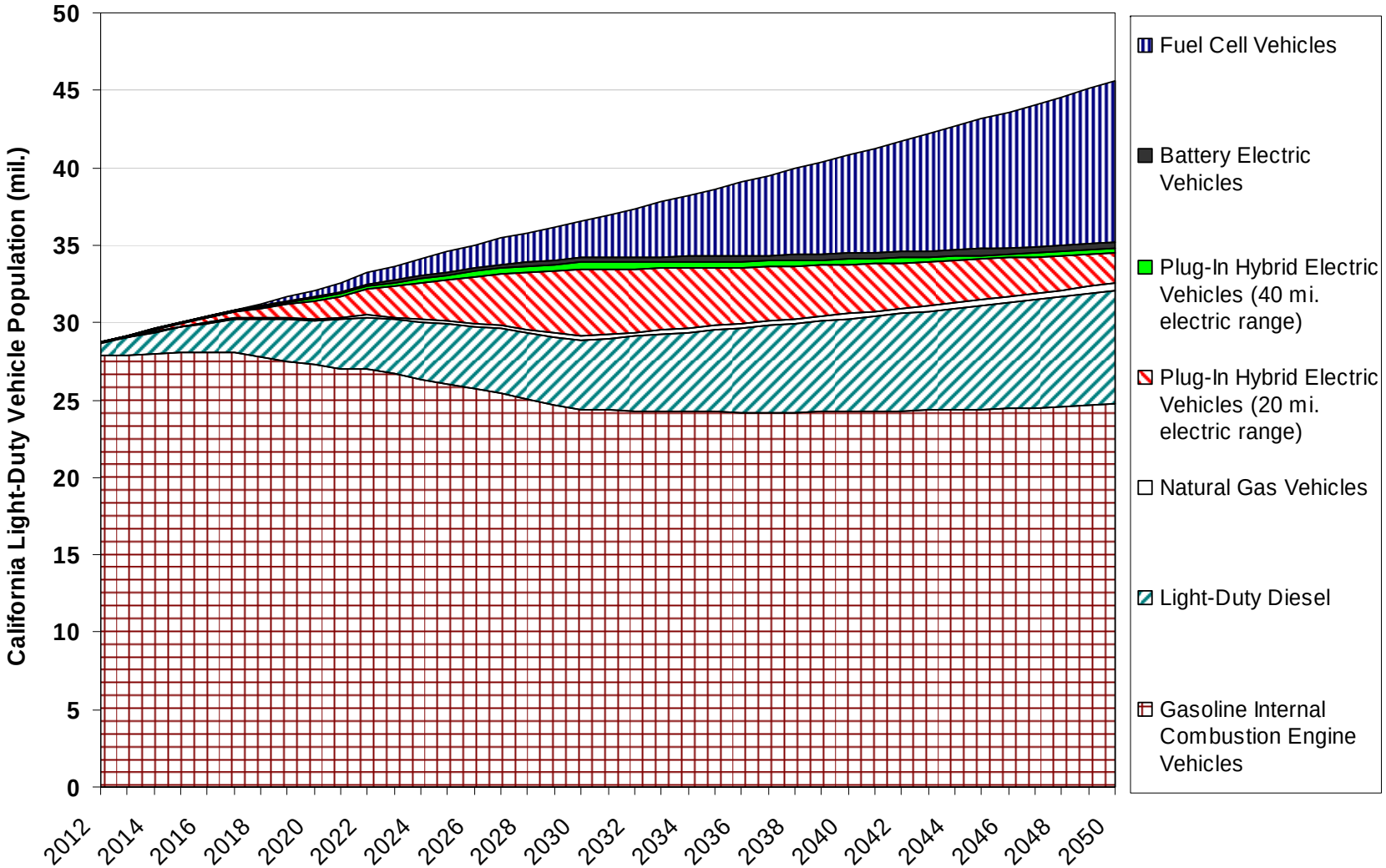
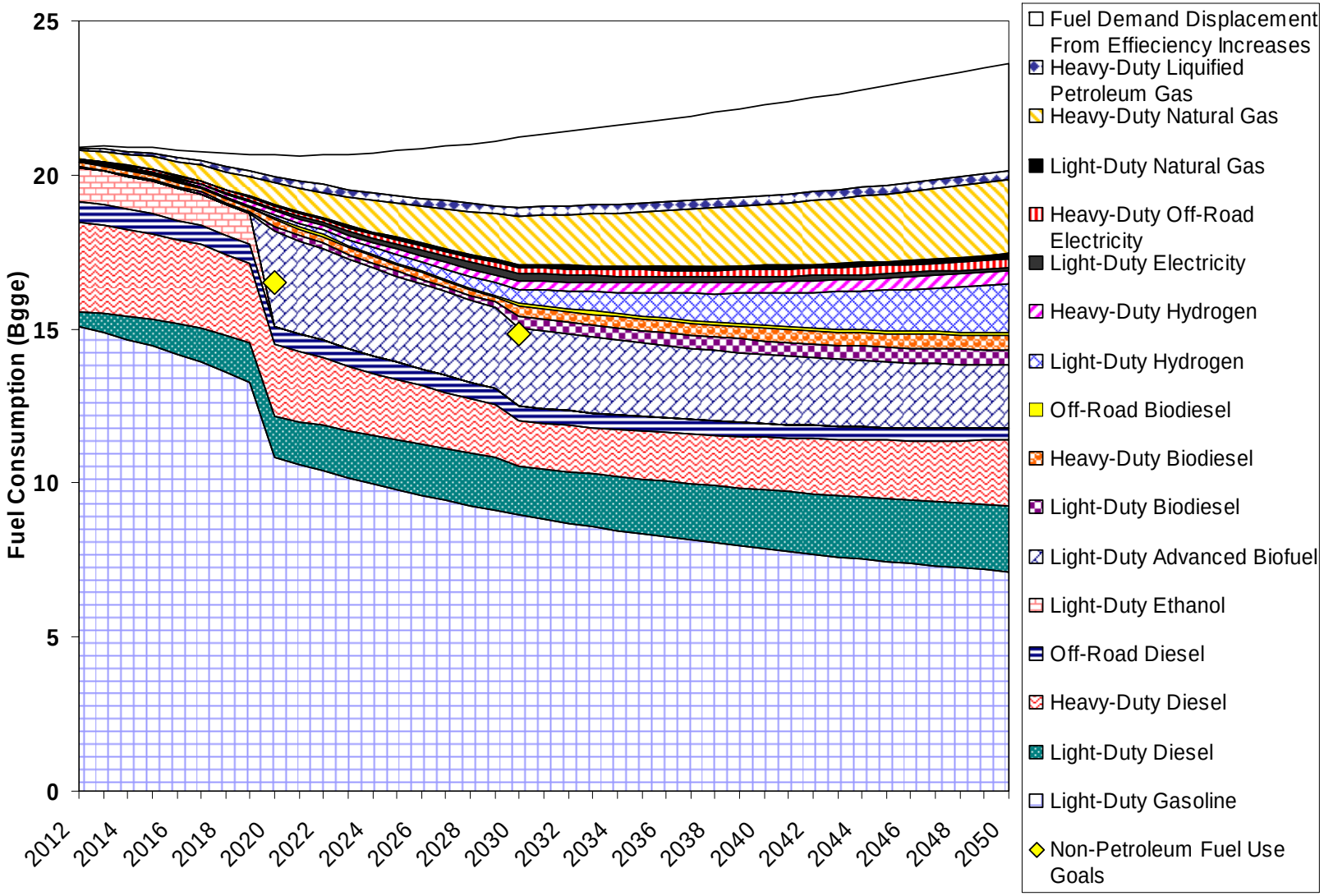
[24] In this analysis, no adverse GHG effects were estimated for land conversion or use, although these effects can be quite large and could substantially reduce any benefit estimated. In this context maximum and minimum estimates are not absolute and are only meant to indicate the range that might be possible.

Figure 12: Vehicle Population Results for Example 3



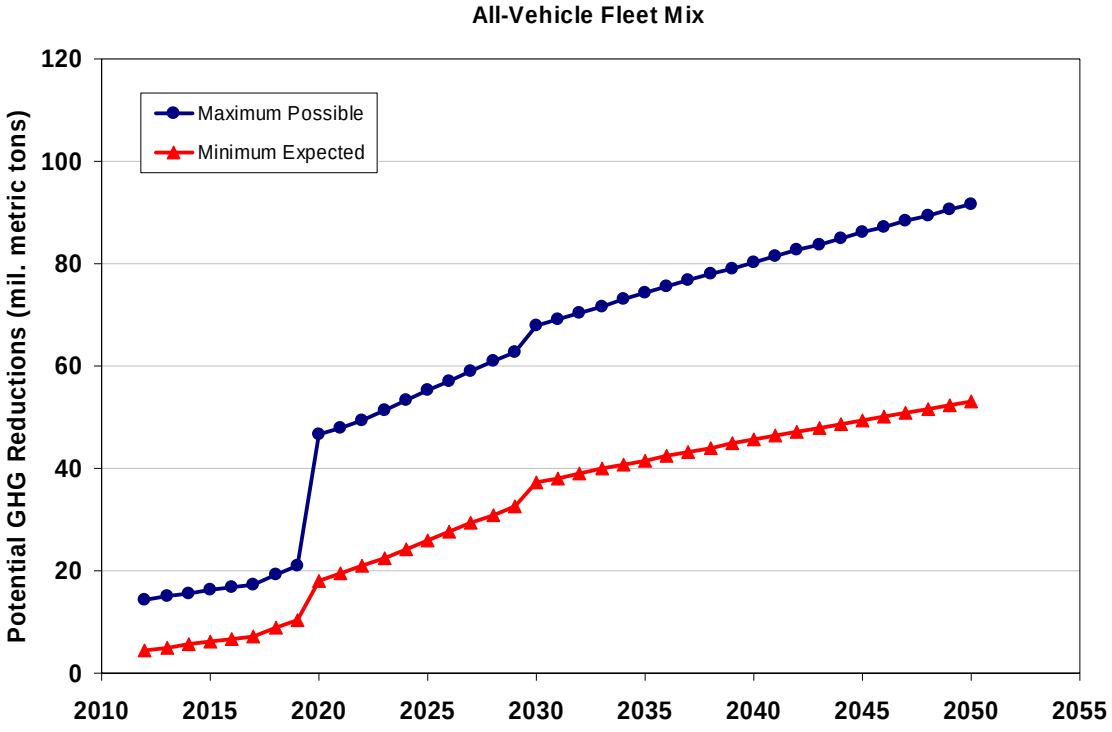
Source: TIAX, LLC

Figure 13: All Vehicles Mix - Fuel Consumption for Example 3



Source: TIAX, LLC

Figure 14: GHG Results for Example 3



Source: TIAX, LLC

Table 7: Results for Example 3

Year	Petroleum Displacement (billions GGE)		GHG Reduction (MMT) *		LCFS (Percent Carbon Intensity)	
	Goal	Example 3 Result	Target	Example 3 Result	Goal	Example 3 Result
2012	---	1.8	---	4 – 14	---	1.1 – 5.3
2020	4	5.6	39	18 – 47	10	5.8 – 18.0
2030	6	8.7	---	37 – 68	---	10.6 – 22.5
2050	---	11.8	202	53 – 92	---	15.0 – 26.6

* GHG Reduction Targets are initial AB 32 and Governor's Executive Order targets, less Pavley GHG reduction estimates.

Source: TIAX, LLC

Although not illustrated in Figure 14, most of the GHG reductions are coming from the light-duty vehicle sector. In this sector, petroleum consumption is reduced by 7.1 billion GGE, and GHG emissions are reduced by 36 to 68 MMT in 2030. In the heavy-duty sector, petroleum is reduced by 4.5 billion GGE, and GHG emissions are reduced by 14 to 21 MMT in 2030. The technologies assumed in the light-duty sector have greater leverage in reducing GHG emissions than in the heavy-duty sector. This is not surprising since a large segment of

the heavy-duty sector shifts to natural gas vehicles, which provide lower GHG emission benefits than vehicles operating on electricity, biomass, and cellulosic feedstocks.

Finally, it appears the LCFS can be achieved in 2020 if some portions of the feedstocks for alternative fuels and gasoline blend components use high-benefit GHG feedstocks.

Example Analysis Summary

The example analysis shows what the contributions of alternative fuels could be in meeting the Plan's alternative fuel use goals of 9 percent in 2012, 11 percent in 2017, and 26 percent in 2022. Comparing these goals to on- and off-road energy projections corresponds to reducing petroleum by 4 billion gallons in 2020 and 6 billion gallons in 2030. All three examples discussed above accomplish this objective. Further, this objective is met without compromising criteria pollutants or adversely affecting other multimedia environmental impacts. All three examples provide substantial GHG emission reduction benefits.[25]

The example analysis clearly illustrates that no single strategy will achieve the level of GHG reductions needed to meet California's goals. At least four major strategies are needed:

- Improved vehicle efficiency
- Biofuels or biofuels components that can be blended into gasoline and diesel fuels
- New vehicle strategies using alternative fuels and advanced technologies
- Reduced vehicle miles traveled

Improved efficiency and biofuels can be implemented in the near term and in combination. The vehicle system includes the powertrain (engine and drivetrain components), vehicle, and the fuel. These need to be integrated and optimized to maximize the benefits of low-exhaust and evaporative emissions of criteria pollutants as well as low GHG emissions not only from the vehicle exhaust but also from the production and distribution of the fuel.

Available engine and vehicle technology can substantially increase vehicle efficiency and lower GHG emissions, albeit at a higher cost. Additional work is needed to develop low-carbon fuels that can be optimized in future engines. It is believed that the LCFS will provide motivation to the fuel and auto industries to develop the next generation of low-GHG fuels for gasoline and diesel fuel vehicles.

Vehicle efficiency improvements as a result of California's GHG emission standards for light-duty vehicles contribute 25 percent of the GHG reduction goals in 2050. These standards level out in 2016 but could be expected to become increasingly stringent in later years. In addition, the heavy-duty sector will be developing technologies that will reduce GHG emissions. Additional savings from vehicles and engines are possible but have not

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[25] See *Full Fuel Cycle Assessment: Well-to-Wheels Energy Inputs, Emissions, and Water Impacts*, California Energy Commission. August 2007, CEC-600-2007-004-Rev.

been included in this analysis. A 25 percent efficiency improvement in diesel fueled vehicles would result in an additional 5 to 20 MMT of CO_2 equivalent reductions.

Biofuels, in the form of ethanol, are being blended into gasoline today at 5.7 percent by volume. This level will likely increase to 10 percent volume by 2012. Biodiesel can be blended into diesel fuels nominally at 5 percent by volume. These blends provide immediate GHG blends since they are used throughout the existing fleet as well as in new vehicles. There is no delay in GHG benefits while alternatively fueled vehicles are introduced into the market. The LCFS will provide additional incentives for the fuel industry to develop low-GHG gasoline and diesel fuels.

Compared to the 2050 reduction target of 253 MMT, blend strategies provide from 8 to 44 MMT of reduction or from 3 to 17 percent, depending on the feedstocks used for biofuels, ethanol, biodiesel, and renewable diesel. The higher-blend reductions are associated with the lower-GHG feedstocks. Additional reductions are possible but somewhat limited by either supply or the maximum volume fraction that can be blended into gasoline or diesel.[26]

Implementing a new alternative fuel vehicle strategy takes a long time compared to gasoline/diesel blend strategies. New vehicle strategies require time for the vehicles to enter the marketplace and for the older vehicles to be retired. Additionally, the implementation of the alternative fuel infrastructure must match the vehicle rollout to minimize stranded infrastructure investments.

Dual fuel technologies such as FFVs or PHEVs are easier to integrate since they can operate on multiple fuels and the fueling infrastructure can be phased in based on vehicle deployment. In this regard, the infrastructure for PHEVs should be the easiest to implement, but even this technology has potential infrastructure needs such as separate metering.

Petroleum reduction and GHG emissions benefits are limited by how fast the vehicles are introduced into the market. Two variables are important. The first is the technology launch date, the point in time when vehicles will enter the commercial market. The second is the penetration rate. It would be very unusual for one alternative fuel to instantaneously become the fuel of choice. More likely there will be a gradual shift in technology from hybrid to plug-in hybrid to fuel cells. All of this takes time and therefore delays the possible benefits of the technologies.

As illustrated in the above three examples, new vehicle technologies can provide GHG emission reduction benefits ranging from 42 MMT to 67 MMT. All examples provide about the same range of benefits. The electric drive examples are comparable on the low end. FCVs, used with PHEVs or FFVs, are incrementally better on the high end (67 MMT vs. 53 MMT) when compared to PHEVs only. These reductions are comparable to the GHG emission reductions resulting from California's GHG emission standards for light-duty vehicles.

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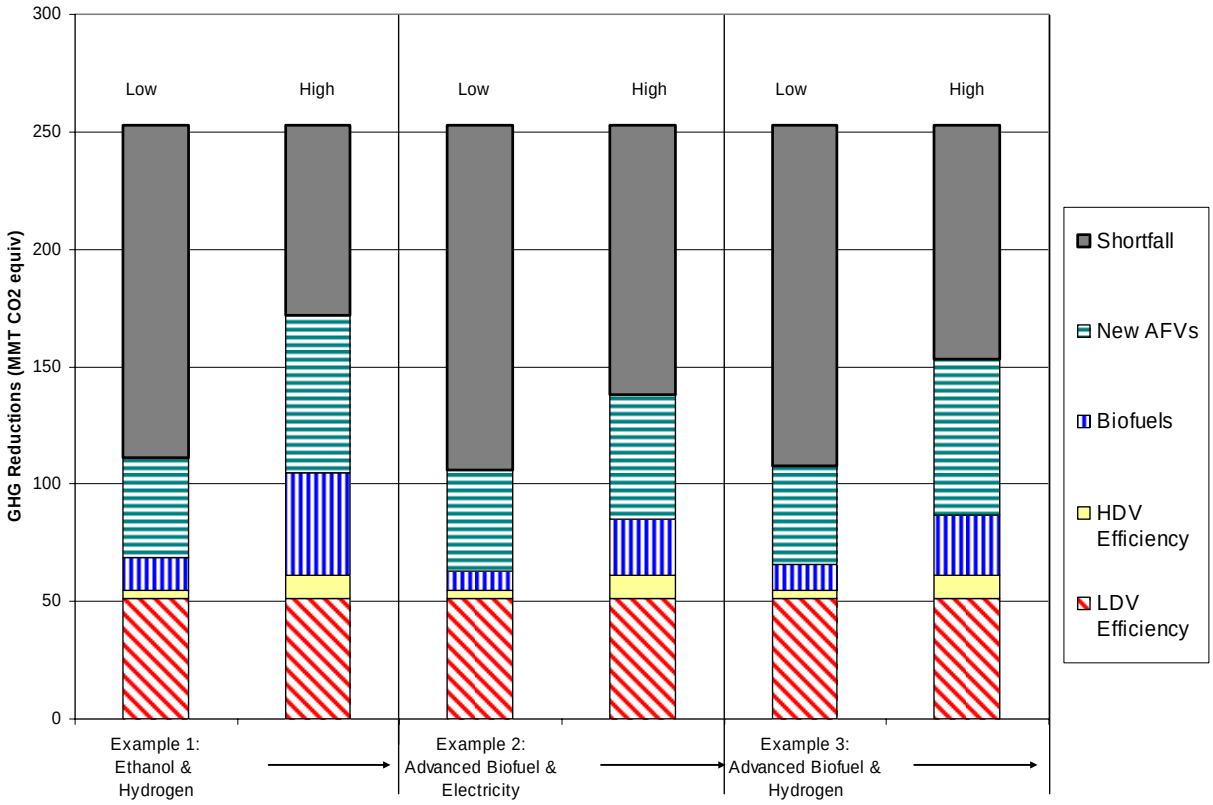
[26] Staff assume a maximum of 30 percent by volume of ethanol or biofuel is blended in gasoline and a maximum of 20 percent by volume of biodiesel or renewable diesel is blended in diesel fuel.

Finally, it is clear from this analysis that technology alone will not be sufficient to achieve the most aggressive GHG goal of meeting 80 percent of 1990 levels. Much work will be required of local agencies in developing ways of reducing VMT. Work is ongoing in a variety of communities to be smarter regarding land use and its effect on vehicle use and emissions. Portland, Seattle, and Sacramento have all either implemented or are implementing various land use strategies that will result in lower VMT.

Figure 15 summarizes how the various examples and the various strategies compare to the goal of reducing transportation GHG emissions by 80 percent of 1990 levels. Clearly none of these alternative fuel examples comes close to achieving the transportation goal of 253 MMT. However, this figure also illustrates how the various strategies complement each other: efficiency, biofuels blends, new alternative fuels, and VMT reduction. It is possible that by aggressively implementing all four strategies, each could be potentially fulfilling one-quarter of the overall goal. Such a strategy would thereby spread the responsibility for GHG reductions among all areas of the transportation sector. The E-85 FFV and hydrogen example is somewhat illustrative of such a breakdown.

Figure 15: Comparison of GHG Reductions Possible by Strategy and Example



Source: TIAX LLC

CHAPTER 6: The 2050 Vision Statement

Alternative fuels alone will not be sufficient to meet California's aggressive 2050 GHG emissions reduction goal. Increasing energy efficiency in the transportation sector and reducing the growth in travel demand are essential components of a holistic strategy to achieve this goal, as well as to further the state's long-term air quality and energy security goals.

This chapter presents a vision for the 2050 timeframe. It is a guide to articulate the other elements needed to achieve the 2050 goals using strategies beyond increased use of alternative fuels. This vision statement will be a barometer that will be used by the agencies and the public to measure the state's progress toward achieving the multiple benefits of alternative transportation fuels well into the future. The objectives of this vision, looking out beyond a 15-year horizon, include:

- The need to define the long-term investments needed to create the necessary supplies and the distribution infrastructure for alternative fuels.
- The desire to illustrate how alternative fuels can, in the long term:
    - Help the transportation sector achieve the state's GHG overall emission goal of 80 percent reduction by 2050.
    - Provide diversity that enhances transportation fuel security.
    - Provide economic benefits through in-state fuel production.
    - Be used in tandem with more efficient vehicles to produce a sustainable transportation future.

To address these questions, the Energy Commission and ARB staff have extended the time horizon from the required 15 years in AB 1007 through 2050. This effort includes a "2050 Vision" that combines three broad strategies as follows:

- Maximize the energy efficiency of vehicle/fuels systems used by Californians;
- Reduce growth in travel demand through transportation efficiency, technology changes in the delivery of goods and services, expanded transit, and more efficient land use patterns; and
- Deploy an increasing mix of low GHG emission alternative and conventional fuels to satisfy the remaining transportation energy demand.

The AB 1007 analysis includes forecasts for five specific "milestone" years: 2012, 2017, 2022, 2030, and 2050. The first three forecast years are required by the legislation, and forecasts for these years are based upon substantial quantitative analysis. The "2050 Vision" is necessarily much more general and at a lower level of analysis and detail. The 2030 analysis helps bridge the gap between 2022 and the longer-term vision for 2050. It has an intermediate level of detail.

Analytical Approach

A "bottom-up" analysis based on the contractor assessments, the Energy Commission and ARB's policy goals, and stakeholder input has formed the basis for the creation of the alternative fuel analyses for 2012, 2017, and 2022. The goals and policies recommended for these timeframes were also guided by:

- The explicit requirements of AB 1007.
- The Governor's Executive Order S-01-07, which established goals and a timeline for a LCFS.
- The Energy Commission's energy policy goals, as expressed in the 2005 *IEPR*.
- The climate protection goals of AB 32.
- The energy diversity goals established in the Governor's Executive Order S-06-06 on Bioenergy.

The 2050 Vision has been developed as a "top-down" assessment, based on established state goals. Principally these include the desire to:

- Reduce GHG emissions to a fraction of today's levels.
- Create sustainable long-term energy sources to meet the state's transportation needs.
- Protect the California economy from overdependency on oil and petroleum products.
- Minimize the economic costs to the state.
- Maximize the economic benefits of producing alternative fuels in the state.

The 2050 Vision anticipates improvements in vehicle efficiency, reductions in energy demand due to improved travel habits, and the widespread use of low GHG-emitting fuels. As a result of these strategies, the 2050 Vision presents a transportation future that greatly reduces the energy needed for transportation, provides that energy through a diverse set of transportation fuels, eliminates overdependency on oil, and achieves an 80 percent reduction in GHG emissions. The 2050 Vision was developed to enable industry, the public, ARB, and the Energy Commission to understand and debate the types of changes that are possible and will likely become necessary to enable an environmentally sustainable transportation system in California.

Although many of the details and policies needed to achieve the 2050 Vision will not be determined within the AB 1007 process or timeframe, the inclusion of a longer-term horizon in the AB 1007 report can serve to initiate a more in-depth discussion. Such a perspective is vital to determine how the strategies and policies included in the AB 1007 report can help achieve long-term energy goals and begin the effort to achieve the 80 percent GHG reduction goal for the transportation sector.

Results of the 2050 Vision Forecast

Staff has developed its top-down assessment on how the widespread use of alternative fuels, efficiency measures, and changes in travel habits would impact transportation fuel demand and diversity, at least within the personal transportation sector. This assessment shows that there are challenging but plausible ways to meet 2050 goals. An 80 percent reduction in GHG emissions associated with personal transportation can be achieved even though population grows to 55 million, an increase of 50 percent.

The following set of measures could be combined to produce this result:

- Lowering the energy needed for personal transportation by tripling the energy efficiency of on-road vehicles in 2050 with:
    - Conventional gas, diesel, and FFVs averaging more than 40 miles per gallon (mpg).
    - Hybrid gas, diesel, and FFVs averaging almost 60 mpg.
    - All electric and PHEVs averaging well over 100 mpg (on a GGE basis) on the electricity cycle.
    - FCVs averaging over 80 mpg (on a GGE basis).
- Moderating growth in per capita driving, reducing today's average per capita driving miles by about 5 percent or back to 1990 levels.
- Changing the energy sources for transportation fuels from the current 96 percent petroleum-based to approximately:
    - 30 percent from gasoline and diesel from traditional petroleum sources or lower GHG emission fossil fuels such as natural gas.
    - 30 percent from transportation biofuels.
    - 40 percent from a mix of electricity and hydrogen.
- Producing transportation biofuels, electricity, and hydrogen from renewable or very low carbon-emitting technologies that result in, on average, at least 80 percent lower life cycle GHG emissions than conventional fuels.
- Encouraging more efficient land uses and greater use of mass transit, public transportation, and other means of moving goods and people.

Table 8 compares current 2005 situation, a business-as-usual 2050 forecast, and the 2050 Vision. The business-as-usual 2050 forecast assumes modest improvements in vehicle efficiency and some use of traditional corn-based ethanol. The 2050 Vision reflects the extensive use of energy efficiency measures, new vehicle technologies, and low GHG emission alternative fuels.

Table 8: Alternative 2050 Forecast of Fuel Used for Personal Transportation

Parameter	2005 Base Year	2050 BAU Forecast	2050 Vision	Units
CA Population	37	55	55	Million people
Annual VMT	320	570	450	Billion-miles
Per Capita VMT	8,600	10,300	8,200	Miles/year
Vehicle Mix				
Gas/Diesel	25	40	4	Millions
FFVs	0.3	4	7	Millions
FCVs & PHEVs	--	>1	28	Millions
Real World Average MPG	20	26	70	Miles/gallon
Energy Demand	16	23	6.4	Billion GGE
GHG Emissions	134	182	23	MMT CO^2
Fuel Mix				
Gas/Diesel	15.3	21	~2	Billion GGE
Biofuels	0.7	1.2	~2	Billion GGE
Electricity and Hydrogen	--	--	~2.5	Billion GGE

Source: ARB

How Could Such a Dramatic Transition Occur?

Transitioning from current trends to the 2050 Vision would require substantial changes in technology, fuel options and availability, urban form, personal travel habits, and government policies. However, it does not require implausible technological evolution or radical changes in lifestyles.

The Major Changes Needed by 2030 Include:

1. Improving the design and efficiency of personal vehicles so that, by 2030, the average new conventional (for example, non-hybrid) vehicle is twice as efficient as today's new cars and small trucks, achieving at least 40 mpg when operated on gasoline, diesel, or biofuels. New hybrids are assumed to be 40 percent more efficient than the comparable non-hybrid vehicle.
2. Fully commercializing PHEVs, hydrogen FCVs, and battery EVs at a price and performance that can command high market shares and with effective fuel efficiencies of 80 mpg (equivalent) or better when operated on electricity or hydrogen.

3. Creating the necessary fuel production technologies and infrastructure expansions so that the needed quantities of biofuels, electricity, and hydrogen can be cost-effectively produced with very low life cycle GHG emissions.
4. Diversifying the fuel delivery infrastructure so that consumers have reliable and convenient access to price-competitive biofuels, electricity, and hydrogen.
5. Implementing "smart growth and redevelopment" policies that lower the need for personal travel in new development and enable residents of existing and new communities to lower auto use.

By 2050 an 80 Percent Reduction in GHG Emissions Could Occur as Follows:

1. Further improving the design and efficiency of new personal vehicles so that, by 2050, the average in-use vehicle achieves 70 mpg and gains half of its fuel energy from electricity or hydrogen sources.
2. Designing most liquid-fueled vehicles sold after 2030 so they can be operated on a flexible mix of biofuels and gasoline or on lower carbon diesel blends.
3. Designing most PHEVs sold after 2030 to be capable of being plugged into the electricity grid and producing efficient and low-carbon electricity so that owners have strong economic incentives to plug in.
4. Lowering the cost of PHEVs, battery-powered EVs, and/or hydrogen FCVs so that they compete for a large share of the vehicle market.
5. Ensuring the fuel delivery infrastructure is fully diversified and provides consumers with reliable and convenient access to cost-competitive, very low GHG emission biofuels, electricity, and hydrogen.
6. Expanding the choice of travel mode for most trips and reducing the need to travel with both technology and more compact urban form (improved land use planning).
7. Increasing use of mass transit and public transportation, as an alternative to personal motor vehicle use.

How Does the Forecast for 2022 in AB 1007 Link with the Vision?

Because the needed transition can occur over four decades, most of the changes outlined above can occur incrementally – provided the recommendations in the AB 1007 and other state policies effectively jump start the move to alternative fuels. Much of the basic technological progress is needed by 2030 because of the 15 years it takes to fully introduce new technologies into the vehicle fleet. To achieve the needed progress by 2030, much of the change must be well underway by 2020, and considerable progress is needed in the 2022 planning horizon required by the AB 1007 legislation.

Setting ambitious goals for the deployment of large amounts of alternative fuels as part of the AB 1007 recommendations and initiating the LCFS are the beginning steps in this process. By 2022, the last milestone year required by AB 1007, the proposed Plan calls for a five-fold increase in the current share of non-petroleum alternative transportation fuels. Via the LCFS, the Plan calls for at least a 10 percent reduction in global warming emissions from transportation fuels. The exact route to these two goals is not clearly defined, but they can be reached only with substantial change in fuel production methods, fuel availability at competitive prices, and vehicle capability. All of these efforts are logical initial steps to the 2050 Vision.

Energy Commission and ARB staff has modeled how these recommendations for 2022 might be met and how California's transportation fuel supply and vehicle inventory could evolve from today to 2022, 2030, and 2050. This is shown in Table 9.

Table 9: Potential Path to 2050 Vision

Parameter	Today 2005	AB1007 2022	Interim 2030	Vision in 2050
Per capita VMT/yr	8,600	8,900	8,600	8,200
Vehicle Mix (millions)				
Gas/diesel	25	20	10	5
FFVs	0.3	5	11	7
FCVs & PHEVs	--	2	11	28
Fleet Avg. MPG	20	26	36	66
Transportation Fuel (BGGE)	16	15	13	7
GHG Emissions (MMT CO2)	134	120	74	23
Fuel Carbon Intensity	0.99	0.89	0.73	0.38
Fuel Mix (% of total energy)				
Gas + Diesel	96%	80%	50%	30%
Biofuels	4%	16%	38%	30%
Electricity + Hydrogen	0	4%	12%	40%

Source: ARB

CHAPTER 7: Economic Analysis

The economics of alternative fuels depend largely on the future price of petroleum fuels. For this analysis, the authors assumed that future gasoline prices would consistently increase and range from $3.66 to $5.49 per gallon in 2050 (in 2007$). Investments in alternative fuels should be compared to existing subsidies for oil, estimated at $65 billion to $113 billion annually.[27]

AB 1007 directs the Plan to "optimize the environmental and public health benefits of alternative fuels…in the most cost-effective manner possible." The legislation also requires that the Plan minimize economic costs to California and maximize the economic benefits of producing alternative fuels in the state.

The Plan addresses these economic requirements in several ways. In a general sense, the Plan minimizes costs to the state by decreasing California's vulnerability to volatile petroleum prices. High gasoline and diesel fuel costs are caused by rising, and increasingly volatile, petroleum prices, which are the result of a shrinking petroleum supply margin. Increasing the availability of non-petroleum fuels will increase this margin, expand consumer choice, and help control price volatility in the transportation fuels market.[28]

In addition, the Plan minimizes the cost to increase the use of each alternative fuel by recommending the least costly feedstock and production pathway for that fuel, given specified reductions in GHG and criteria pollution emissions. This approach does not compare different alternative fuels to one another but compares the different possible methods of producing each fuel.

For example, hydrogen can be produced in several ways, including electrolysis (which can use a variety of electricity generation sources), steam reformation of methane, and gasification. The costs and environmental impacts of these methods were assessed, and steam reformation of methane was determined to be the preferred hydrogen production pathway for AB 1007. All hydrogen included in the alternative fuel examples was therefore assumed to be produced through steam reformation of methane. The Plan also includes the following quantitative economic assessments:

- Capital Cost Assessment
- Consumer Payback Period
- Societal Cost-Effectiveness Analysis
- Macroeconomic Analysis

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[27] *Lives Per Gallon: The True Cost of Our Oil Addiction*, Terry Tamminen, 2007.

[28] It is important to note that alternative fuel prices will also experience volatility to varying degrees, and further investigation of the vulnerability of the various alternative fuels to volatility is warranted. At the very least, diversifying the transportation fuel mix will serve as a hedge against price shocks in any particular fuel market.

The capital cost and consumer payback period assessments reveal the differing cost structures of the various alternative fuels to inform the design of effective state incentives. The societal cost-effectiveness analysis shows that increasing alternative fuel use, as envisioned in the three alternative fuel examples presented in Chapter 5, is likely to provide net benefits to society as a whole, especially in the long term. And the macroeconomic analysis reveals that the public and private investment necessary to increase alternative fuel use will have a small, and most likely positive, impact on real state productivity, personal income, and employment.

The four economic analyses are presented in the sections that follow.

Capital Cost Assessment

Table 10 compares the capital costs required to displace 1 billion GGE with each alternative fuel. As shown, the cost structures of the various alternatives differ widely; for example, the advanced biofuel requires relatively costly production facilities but no vehicle costs (since it will be blended into gasoline and used in conventional vehicles), whereas hydrogen has much lower production facility costs but high vehicle costs. This table does not take into account the prices of the alternative fuels themselves. The interplay of fuel and vehicle prices is explored in the consumer payback period analysis below.

Table 10: Alternative Fuel Capital Costs for Displacing the Equivalent of 1 Billion Gallons of Gasoline (GGE) Per Year in Billion Dollars[a]

	Production Facilities	Distribution Infrastructure	Fueling Stations	Vehicles (incremental)[b]	Vehicle/Fuel R&D
E-85[c]	3.3	1	0.4	0.3	0
Advanced Biofuel	4.5	0.3	0	0	1
Natural Gas[d,e]	0	0	2.1	2.9	2
Propane[e]	0	0	1.8	1.8	0
Electricity[f]	0	0.5	0	20.7	2
Hydrogen	1.0	0.9	2.4	31.7	2

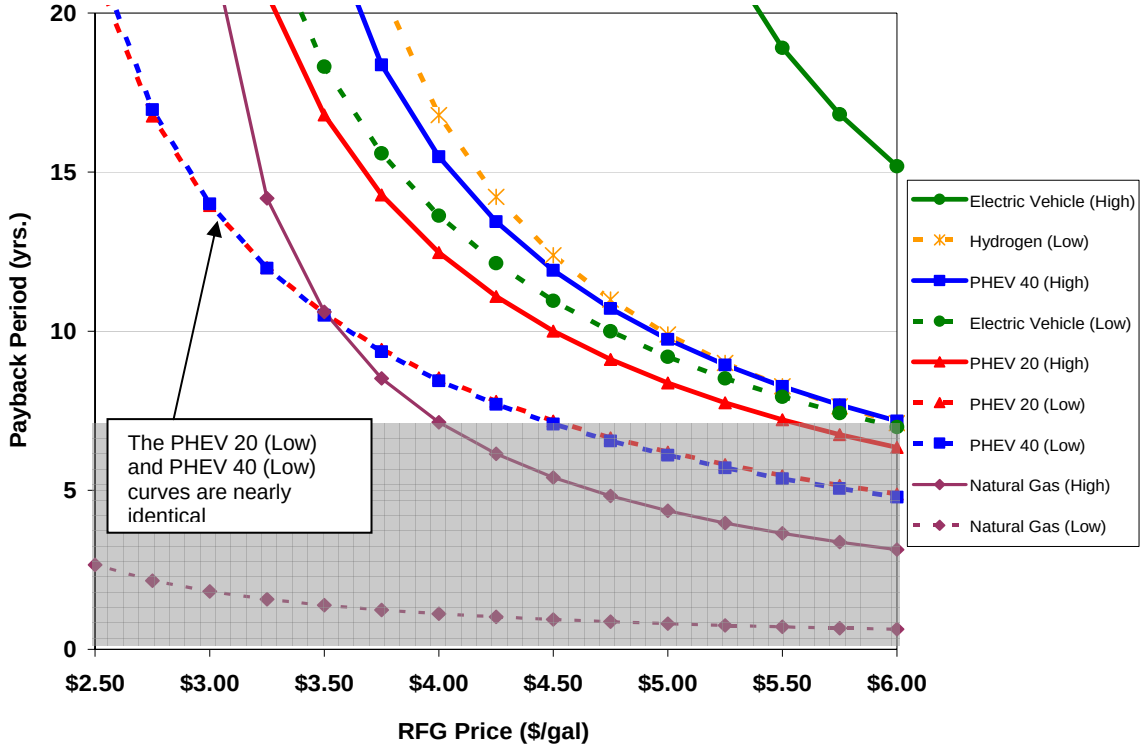
Notes:
a – Normalized to reflect cost required to displace 1 billion GGE gasoline or diesel. Costs are in 2007$ and are not discounted. Costs therefore represent what it would cost *today* to displace 1 billion GGE *today*, if that were technologically and practically feasible. The capital costs in this table should not be added directly to obtain a total capital cost for each fuel, because the privately funded portion of the R&D (R&D) cost is likely to be recovered in the vehicle price.
b – Vehicle costs based on 400 GGE/yr for light duty, 1,200 GGE/yr for medium duty and 10,800 GGE/yr for heavy duty.
c – E-85 distribution infrastructure based on cost to go from E-5.7 to E-10.
d – Vehicle costs based on current estimate of natural gas storage tanks.
e – Most natural gas and propane vehicles are heavy duty vehicles.
f – This analysis for electricity only includes on-road vehicles (light and heavy-duty) and does not include the additional non-road electric drive technologies described in the Electric Drive Storyline. The inclusion of additional non-road technologies from the storyline would likely decrease the capital costs required to displace 1 billion GGE. Distribution costs include $100 per installed meter.

Source: TIAX, LLC

Consumer Payback Period

Figure 16 displays the consumer payback period of light-duty electric, hydrogen, and NGVs. The payback period is a function of vehicle and fuel prices, since these are the costs experienced by the consumer.

Figure 16: Consumer Payback Period of Light-Duty Alternative Fuel Vehicles[29]



Source: TIAX, LLC

Each of these alternative vehicles has a higher purchase price than conventional gasoline vehicles; but if the alternative fuels are less costly than gasoline, the additional upfront cost will be paid back through fuel savings over time. As Figure 16 shows, the payback period depends on the gasoline price: the higher the price of gasoline, the greater the fuel savings associated with the alternative vehicles, and so the shorter the payback period. Two payback period curves are shown for each fuel, with the lower curve (dotted lines) corresponding to low alternative vehicle and fuel price assumptions, and the high end of the range (solid lines) corresponding to higher price assumptions. Consumers are assumed to

[29] Assuming a discount rate of 8 percent, to approximate the rate of return on private investment. PHEV 20 refers to PHEVs with an all-electric range of 20 miles, and PHEV 40 refers to PHEVs with an all-electric range of 40 miles.

require a payback period of no more than seven years (the length of a standard car lease), as indicated by the shaded area in Figure 16. As the figure shows, most alternative vehicles will become attractive to consumers at gasoline prices of $4 to $6/gallon.

When low natural gas fuel and vehicle prices are assumed, NGVs are attractive at all gasoline prices; and when high EV, hydrogen vehicle, and fuel prices are assumed, the vehicle cost assumptions used here result in high consumer payback periods even at gasoline prices of $6 per gallon in the absence of incentives.

Societal Cost-Effectiveness Analysis

A societal cost-effectiveness analysis reveals that the three alternative fuel examples described in this report are all likely to save the state money in the long term. Example 2, which is dominated by an advanced biofuel and PHEVs, is likely to be cost-effective in the near- to medium-term as well. Some alternative-fueled vehicles, most notably hydrogen and electric, are very costly in the near term, even if the value of avoided emissions is taken into account. However, large cost decreases are likely as these technologies mature and achieve increased market penetration. State incentives will be necessary to promote the development and use of these technologies until they reach commercial maturity.

The cost-effectiveness analysis was carried out with regard to two of the goals of the Plan: reduction in petroleum consumption and GHG emissions reduction. Cost-effectiveness was calculated according to the following formulas:

- Cost-Effectiveness of Petroleum Reduction = (Costs – Benefits) / Avoided Petroleum Consumption
- Cost-Effectiveness of GHG Emissions Reduction = (Costs – Benefits) / GHG Emissions Avoided

The "costs" term in these formulas includes retail prices of the alternative fuel and vehicles, as well as infrastructure and R&D costs that are not recovered in the fuel and vehicle prices. The "benefits" term includes the avoided retail costs of petroleum fuel and conventional vehicles as well as the value of the avoided criteria pollution and (in the first formula) avoided GHG emissions.

This approach follows the method used in the Climate Action Team's *Updated Macroeconomic Analysis of Climate Strategies* (September 7, 2007). The "net cost" calculations presented in that report are equivalent to the cost-effectiveness of GHG emissions reduction presented here.

The three alternative fuel examples are described in detail in Chapter 5 of this Plan. In brief: in Example 1, ethanol continues to be used as a gasoline blendstock in the future, both as E-85 (for use in FFVs) and in low-level blends. Light-duty hydrogen FCVs dominate the alternative vehicle market. This example also includes natural gas, propane, and renewable diesel fuels, as well as PHEVs.

Example 2 is similar to Example 1, except that (1) hydrogen FCVs do not achieve market success, and PHEVs dominate the light-duty alternative vehicle market; and (2) an advanced biofuel is developed and replaces ethanol as a gasoline blendstock.

Example 3 is a hybrid of Examples 1 and 2. It assumes that both hydrogen vehicles and the advanced biofuel achieve market success.

A cost-effectiveness range was calculated for each example to reflect the uncertainty associated with the price trajectory of gasoline and diesel, the costs of alternative technologies, and the value of avoided GHG emissions, among other factors. The key assumptions associated with the three cases are presented in Table 11.

Table 11: Range of Assumptions for Cost-Effectiveness Analysis

	Case A	Case B	Case C
Gasoline/diesel price forecast[30]	Low	Medium	High
Value of GHG emissions ($/t$CO_2$eq)[31]	$8	$25	$50
Cost of alternative fuel vehicles	High	Medium	Low

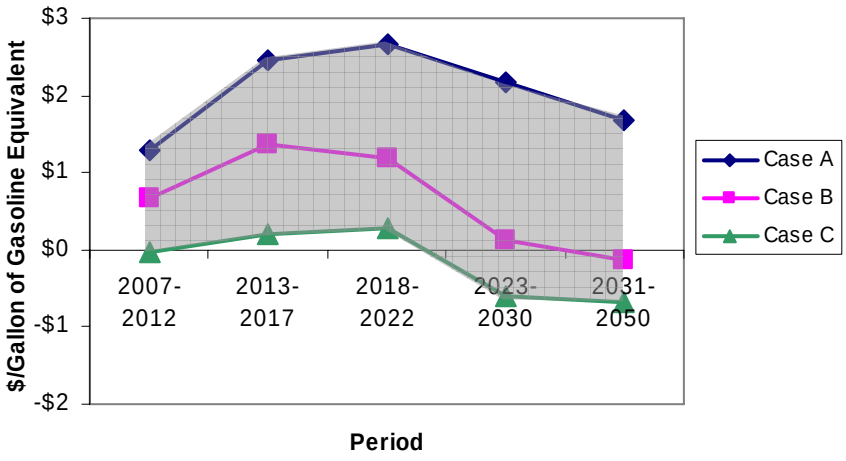
Source: California Energy Commission

Results of the cost-effectiveness calculation for the three examples are presented in Figures 17, 18, and 19. The shaded areas represent the cost-effectiveness ranges. Negative values imply net societal savings compared to gasoline/diesel baseline example. Negative cost-effectiveness values result when fuel cost savings and the value of avoided emissions outweigh the incremental vehicle and infrastructure costs associated with alternative fuels. As these figures show, the low cost end of the range (Case C) is associated with net savings for all examples in nearly all years, and the middle case (Case B) results in net savings by 2050 in Examples 1 and 3, and much earlier in Example 2.

[30] The "medium" gasoline/diesel price forecast used in this Plan is based on the Energy Information Administration's *2007 Annual Energy Outlook* high oil price forecast. The Plan's "low" and "high" price forecasts are 20 percent below and above the medium price forecast, respectively.

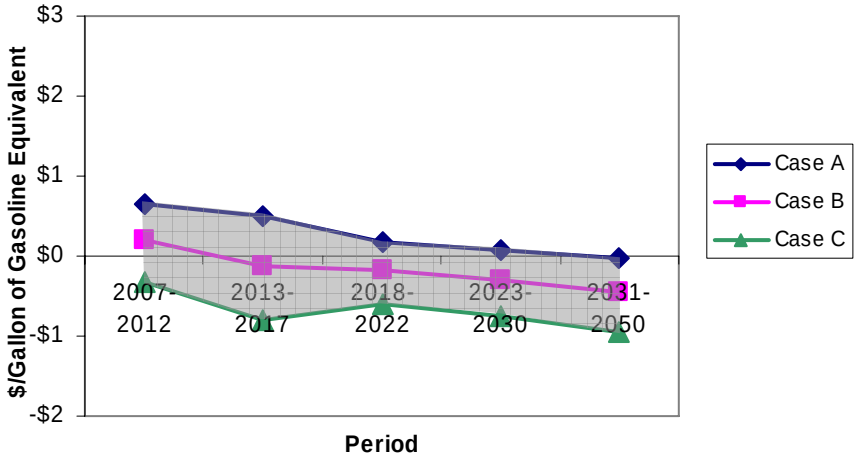
[31] $8/ton is the CPUC GHG "adder" (CPUC Rulemaking 04-04-025, April 2005). $50/ton is the high end of the range of GHG offset values considered by the California Climate Action Team in the *Updated Macroeconomic Analysis of Climate Strategies* (September 7, 2007). All values are in 2007 dollars.

Figure 17: Cost-Effectiveness Range for Example 1



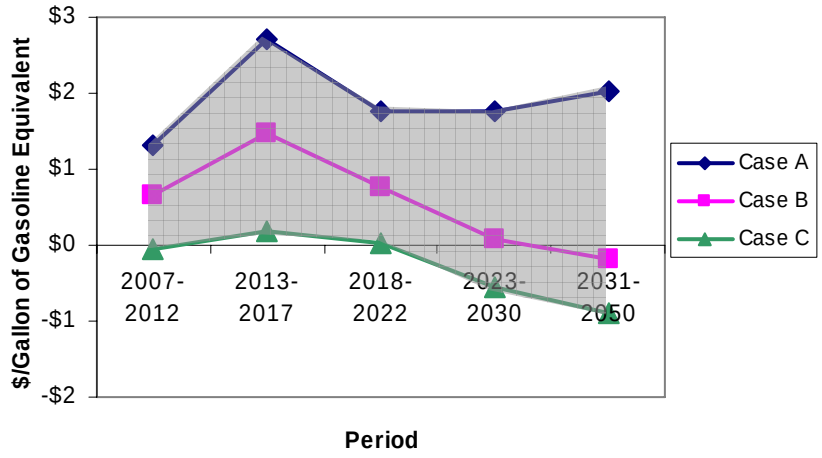
Source: California Energy Commission

Figure 18: Cost-Effectiveness Range for Example 2



Source: California Energy Commission

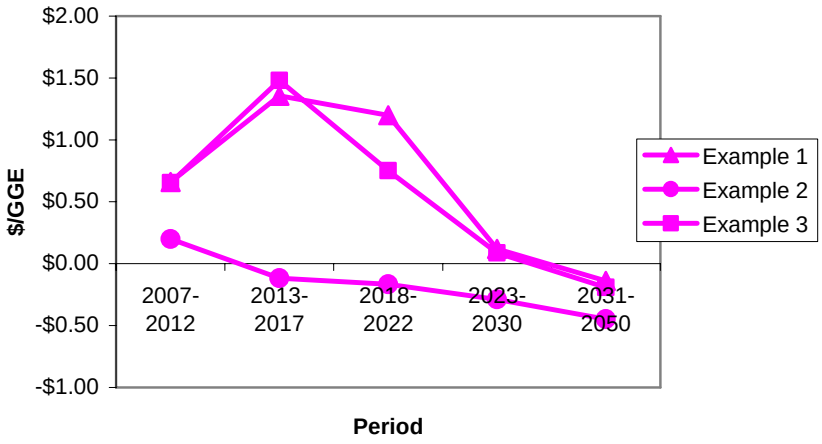
Figure 19: Cost-Effectiveness Range for Example 3



Source: California Energy Commission

Figure 20 compares the cost-effectiveness of the three examples for the medium cost projections (Case B). The three curves in Figure 20 are identical to the middle curves in the three figures above. Under these assumptions, Example 2 is the most cost-effective in all years. However, taking into account the uncertainty associated with future fuel and vehicle prices, the potential cost-effectiveness ranges of the three examples overlap significantly.

Figure 20: Cost-Effectiveness of All Examples, Medium Cost Projections



Source: California Energy Commission

Table 12 and Table 13 present the cost-effectiveness ranges of each alternative fuel, in dollars per GGE and dollars per metric ton of CO_2 avoided, respectively.[32] The overall cost-effectiveness of each example, as presented above, is a function of the cost-effectiveness of each constituent fuel and the quantity of that fuel in the example. Again, negative cost-effectiveness values imply net savings relative to gasoline/diesel.

Table 12: Cost-Effectiveness of Petroleum Reduction (2007$/GGE)

	2007-2012	2013-2017	2018-2022	2023-2030	2031-2050
Hydrogen	$13.40 to $34.80	$13.30 to $32.80	$10.40 to $28.20	$1.40 to $18.90	-$1.00 to $10.90
Electric Drive	$12.60 to $19.20	-$0.10 to $4.70	-$2.40 to $1.60	-$2.80 to $0.90	-$2.70 to $0.90
Renewable Diesel	$1.60 to $2.00	$1.50 to $1.90	$1.40 to $1.90	$1.30 to $1.80	$1.00 to $1.50
Ethanol	$0.65 to $0.90	$0.33 to $0.63	$0.18 to $0.47	-$0.08 to $0.17	-$0.01 to $0.17
Propane	$0.14 to $0.29	-$0.01 to $0.33	-$0.03 to $0.32	-$0.04 to $0.30	$0.08 to $0.32
Natural Gas	-$2.00 to -$1.00	-$2.60 to -$0.90	-$2.70 to -$1.10	-$2.70 to -$1.10	-$2.20 to -$0.90
Advanced Biofuel			-$0.25 to $0.06	-$0.26 to $0.06	-$0.22 to $0.05

Source: California Energy Commission

Table 13: Cost-Effectiveness of GHG Emissions Reduction (2007$/Tonne CO_2eq)

	2007-2012	2013-2017	2018-2022	2023-2030	2031-2050
Hydrogen	$1,700 to $4,200	$1,600 to $3,900	$1,100 to $3,000	$190 to $1,900	-$66 to $1,100
Electric Drive	$1,800 to $2,700	-$30 to $370	-$190 to $160	-$220 to $82	-$220 to $98
Renewable Diesel	$200 to $200	$170 to $170	$140 to $150	$130 to $130	$96 to $97
Ethanol	$250 to $290	$120 to $140	$85 to $110	$22 to $49	$33 to $60
Propane	$160 to $230	$64 to $260	$53 to $260	$45 to $240	$140 to $281
Natural Gas	-$470 to -$250	-$590 to -$210	-$630 to -$260	-$630 to -$260	-$530 to -$210
Advanced Biofuel			$13 to $23	$13 to $22	$11 to $19

Source: California Energy Commission

Each of the fuel categories shown here includes a variety of on-road vehicle types. For example, the Electric Drive category includes light-duty PHEVs, medium/heavy-duty PHEVs, and light-duty battery EVs. The cost-effectiveness values presented are weighted averages of the cost-effectiveness of each of these vehicle types, based on the portion of total fuel used by each vehicle type. In the Electric Drive category, light-duty PHEVs are the most cost-effective category and are also assumed to achieve the highest market penetration of the three vehicle types. However, the higher anticipated costs of medium/heavy-duty PHEVs and light-duty battery EVs affect the cost-effectiveness results for this category.

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[32] The analysis for Electric Drive includes only on-road vehicles (light and heavy-duty) and does not include the additional non-road electric drive technologies described in the *Electric Drive Storyline*. The inclusion of these additional non-road technologies from the storyline would likely improve the cost-effectiveness numbers shown in Tables 12 and 13. Also, assumed significant amounts of publicly funded R&D costs in the early periods act to reduce the cost-effectiveness shown.

Macroeconomic Analysis

The Energy Commission and the ARB used a macroeconomic model to evaluate the statewide impacts of the three examples. The examples all assume significant government incentives to partially offset the costs of alternative vehicles, fuel production, and fueling stations.[33] Overall, considering both public and private sectors, all three examples result in small costs or even net savings (decreased expenditures) in the early years, followed by increased expenditures in later years. The private sector experiences savings in nearly all years. These savings are due to the fact that the private sector saves more in avoided petroleum costs than it spends in additional vehicle and infrastructure costs.

These results are consistent with the results of the societal cost-effectiveness analysis presented above. Cost-effectiveness tends to decrease over time because, though the total costs of the examples increase, these higher costs are associated with even greater quantities of petroleum fuel and GHG emissions avoided.

Table 14: Total Change in Expenditures (Billions of 2006 Dollars)

Example	Sector	2012	2017	2022	2030	2050
Example 1: Ethanol and Hydrogen	Total Economy	0.2	1.0	2.2	7.1	14.3
	Private Sector	-0.4	-0.6	-1.4	-1.4	-4.3
Example 2: Advanced Biofuel and PHEV	Total Economy	-0.3	-0.1	0.1	0.8	5.1
	Private Sector	-0.5	-0.9	-1.2	-1.2	3.6
Example 3: Advanced Biofuel and Hydrogen	Total Economy	0.2	0.7	2.4	7.2	14.2
	Private Sector	-0.5	-0.9	-1.2	-1.3	-4.5

Source: UC Berkeley

All three examples will divert purchases from the state's petroleum refinery sector to the natural gas, propane, chemical, agriculture, and electrical sectors. The projected changes in expenditures in these sectors are presented in Table 15. Negative values represent decreased expenditures in that sector, and positive values represent increased expenditures.

[33] Government funds were assumed to be diverted from other transportation programs. No attempt was made to calculate the negative effects on the state economy of diverting these funds.

Table 15: Change in Expenditures by Sector (Billions of 2006 Dollars)

Example	Sector	2012	2017	2022	2030	2050
Example 1: Ethanol and Hydrogen	Petroleum	-1.8	-5.4	-11.1	-22.2	-42.1
	Natural Gas/Propane	0.6	1.4	2.4	4.3	7.7
	Chemical	0.4	1.4	3.1	6.7	14.8
	Agriculture	0.4	1.8	3.4	6.8	12.3
	Electric	0.0	0.1	0.2	0.4	0.4
Example 2: Advanced Biofuel and PHEV	Petroleum	-1.6	-3.8	-18.3	-22.8	-31.3
	Natural Gas/Propane	0.6	1.4	2.4	4.3	7.7
	Chemical	0.2	0.5	5.3	5.5	6.0
	Agriculture	0.3	0.8	8.6	8.9	9.8
	Electric	0.0	0.1	0.2	0.4	0.9
Example 3: Advanced Biofuel and Hydrogen	Petroleum	-1.7	-4.1	-19.0	-24.6	-36.9
	Natural Gas/Propane	0.6	1.4	2.4	4.3	7.7
	Chemical	0.3	0.8	6.2	7.7	12.9
	Agriculture	0.3	0.8	8.4	8.4	9.2
	Electric	0.0	0.1	0.2	0.4	0.4

Source: UC Berkeley

Projected business-as-usual petroleum sector expenditures range from $53 billion in 2012 to $131 billion in 2050. The avoided petroleum expenditures presented in Table 15 amount to 3 percent of total petroleum expenditures in 2012, increasing to between 24 percent and 32 percent in 2050.

Finally, the effects of the examples on three indicators of economic welfare — state output, personal income, and employment — were assessed. The impacts are very small relative to the size of the state economy and are positive in most years (Table 16). However, it is important to keep in mind that this analysis assumes that state alternative fuel expenditures are shifted from other transportation programs, and the costs associated with reducing expenditures on those programs are not taken into account.

Table 16: Changes in Economic Welfare (Percent Change Compared to Business as Usual)

Example	Sector	2012	2017	2022	2030	2050
Example 1: Ethanol and Hydrogen	State Output	0.06%	0.03%	0.08%	0.02%	0.14%
	Personal Income	0.01%	0.05%	0.13%	0.16%	0.05%
	Employment	0.06%	0.08%	0.14%	0.16%	0.14%
Example 2: Advanced Biofuel and PHEV	State Output	0.06%	0.11%	-0.11%	-0.04%	-0.24%
	Personal Income	0.02%	0.09%	0.04%	0.12%	-0.09%
	Employment	0.05%	0.09%	0.15%	0.15%	0.00%
Example 3: Advanced Biofuel and Hydrogen	State Output	0.08%	0.11%	-0.11%	-0.04%	0.21%
	Personal Income	0.01%	0.09%	0.04%	0.14%	0.08%
	Employment	0.06%	0.09%	0.15%	0.16%	0.15%

Source: UC Berkeley

Overall, the macroeconomic analysis reveals that the public and private sector expenditures necessary to increase alternative fuel use in California will have a small and likely positive impact on the state's economy. The most significant impact will be to shift expenditures from the petroleum sector to a number of other sectors of the economy.

CHAPTER 8: Fuels and Trade Policy

As California moves toward low-carbon fuels, there is a foreseeable risk of collision with nations that have the economic incentive and political will to use trade rules to challenge California's initiatives. Brazil has already signaled its intent to use trade remedies if California measures adversely affect its share of the market for biofuels. Venezuela has already set a precedent using trade rules to challenge U.S. policy on reformulated gas, which affected its share of the market for petroleum fuels.

It makes sense for California and other states to know the rules of the road under trade policy. You can avoid a collision if you know the direction from which it might come.

How Is Trade Policy Relevant to Transportation Fuels?

Opportunities. California's innovations in transportation fuel policy are most likely to succeed as a national and international model if other states, provinces, and countries view them as likely to survive trade disputes. Trade rules are vague and have yet to be applied to biofuels. There is an opportunity to anticipate likely trade arguments against policies under consideration and answer them in advance. Constructive answers include: (1) California has effectively considered a trade rule as it drafted its policy, or (2) the United States can avoid a conflict with trade rules by the way it conducts pending negotiations.

Threats. Trade rules could be used in several ways to divert or block state policy innovations. In the order of least likely to most likely, these include:

Trade disputes. The formal enforcement process for trade agreements begins when another country files a trade dispute, which can result in economic sanctions. Trade disputes are not always filed when there is a case to be made because of their expense in time, money, and political capital. However rare they are, formal disputes can result in trade sanctions that are designed to maximize economic and political pain by targeting innocent industries in the states or districts of congressional leaders.

Federal preemption. Congress has empowered the Executive Branch to enforce trade agreements by suing to preempt state laws that are "inconsistent" with the rules. Preemption battles between states and federal agencies are fairly common in energy and transportation policy. Trade rules are likely to strengthen the legal position of the federal government in such disputes.

Lobbying and political pressure. Trade rules have already been invoked to influence or support political decisions in state capitals. Various actors including multinational companies, foreign governments, and agencies of the federal government may invoke trade rules to lobby against state policies that they perceive to adversely affect their interests.

What Are the Relevant Trade Rules?

In addition to restricting tariffs on goods, trade agreements have expanded to cover services, set limits on domestic subsidies, and impose rules on regulations, including those that are clearly not discriminatory. The most important agreements are those of the World Trade Organization (WTO) with 151 members, but the United States also has regional or bilateral Free Trade Agreements with transportation fuel exporters such as Canada, Mexico, Ecuador, and others. Here is a brief overview of selected WTO trade rules:

Tariffs. There are two U.S. tariffs on ethanol. One is a 54 cents-per-gallon tariff; the other is a 2.5 percent-of-value tariff. There is a vigorous debate over whether the domestic ethanol industry needs protection versus whether the country would benefit more from importing low-carbon, lower-cost ethanol from Brazil. This debate is relevant to the question of whether state-level incentives for ethanol production, conversion, or use would be more or less effective or expensive in the absence of the tariff.

Rules against discrimination. The WTO's General Agreement on Tariffs and Trade (GATT) and General Agreement on Trade in Services (GATS) prohibit discrimination against foreign suppliers of goods and services (national treatment) or against suppliers from particular countries (most-favored nation treatment). These rules prohibit explicit discrimination, and they also prohibit changing the conditions of competition to the disadvantage of certain (not necessarily all) foreign suppliers, even if there is no intent to discriminate.

Rules Limiting Subsidies

Agricultural subsidies. The WTO's Agreement on Agriculture (AoA) limits aggregate subsidies for commodity crops, which could indirectly support production of biofuels made from corn, rice stalks, or soy beans. Brazil recently followed Canada in launching a WTO complaint on grounds that the United States violated its AoA limits. The Brazilian agriculture minister said the case was "about ethanol."

Trade distorting subsidies. The WTO's Agreement on Subsidies and Countervailing Measures (SCM Agreement) prohibits subsidies that cause "serious prejudice" to the industries of another country by either suppressing prices or displacing that country's market share.

Limits on nondiscriminatory law making. One set of trade rules is significant in that they cover measures that (a) do not discriminate and (b) apply primarily to regulation of domestic goods and services. For example:

Goods. The WTO's Agreement on Technical Barriers to Trade (TBT Agreement) requires that regulations must serve a legitimate purpose, be least-trade restrictive, and be based on international standards where they exist or where their completion is imminent. The TBT Agreement also prohibits "disguised barriers," a rule that has been interpreted to require consultation with foreign governments before regulations are adopted.

Services. Negotiations are nearing completion on rules that "discipline" domestic regulation of services, which would cover transportation fuel sectors: distribution, pipeline transportation, and bulk storage. For example, the most recent draft prohibits "disguised barriers" and requires domestic regulations to relate to the service, be based on objective criteria, be pre-established, be as simple as possible, and be under a single authority. Many of these rules create obligations for policy makers that neither the Constitution nor the Congress has imposed on state governments.

Could Policy Options Conflict With Trade Rules?

It is premature to identify potential legal conflicts between trade rules and policy options for transportation fuels, primarily because California officials have yet to select specific options. However, it is possible to flag important or controversial issues based on recent trade disputes or negotiations that are relevant to state policy makers.

Four kinds of policies illustrate the broader range of options that California agencies are analyzing. Comments about trade issues are organized in the sequence of questions that a WTO panel must answer in a trade dispute (Figure 21), which are: (1) Is a measure covered by a trade agreement? (2) If so, is it consistent with trade rules (such as the prohibition on discrimination)? (3) If not, is there a general exception that might excuse the conflict?

Figure 21: Analysis of Consistency with Trade Agreements

Biofuel Production Subsidies

Cash, tax, or in-kind incentives to produce ethanol or biodiesel in California are covered by the SCM Agreement and the AoA.

Conflict with trade rules. If California were to subsidize production of biofuels in California, such a single state's subsidy would probably not be large enough to cause

serious prejudice under the SCM Agreement. However, any WTO dispute using the SCM Agreement (serious prejudice) would likely aggregate all states and all federal subsidies to biofuels. Brazil has already filed a WTO dispute against U.S. crop subsidies under the AoA, and ethanol is presently classified as an agricultural commodity. Brazil has announced its opposition to state subsidies for biofuel production; it may have grounds for challenging such subsidies under either the AoA or the SCM.

Exceptions. There are no general exceptions under the SCM Agreement; they expired after 1999. The AoA does contain exceptions for certain "Green Box" measures; however, none of these exceptions are likely to apply to biofuel production subsidies.

R&D Subsidies

R&D subsidies to develop new biofuels are covered by the SCM Agreement

Conflict with trade rules. So long as the results of research are publicly available and not proprietary, R&D subsidies are not likely to cause serious prejudice under the SCM Agreement. Producers from other countries could benefit from the research.

Exceptions. There are no general exceptions under the SCM; they expired after 1999.

Fuel mixture regulations

Regulations that require a certain fuel mixture (that is, a minimum percentage of ethanol) are covered by GATT. They may also be covered by GATS under the existing U.S. commitment on distribution services and proposed commitments on bulk storage and pipeline transportation of fuels.

Conflict with trade rules. GATT prohibits discrimination generally with respect to "like" products, which enables countries to distinguish between fuels with unlike physical and combustion characteristics. The GATS test of discrimination, which GATS defines as changing the conditions of competition for like services or suppliers, has yet to be interpreted in the context of transportation fuel. In some circumstances, GATT also prohibits different treatment of products within mixtures if the products are substitutable products, as opposed to like products. Gasoline and ethanol are substitutable. Consequently, legal analysis is likely to focus on the nature of discrimination: Does a "renewable fuel standard" or minimum ethanol blend work to the advantage of domestic suppliers or the disadvantage of particular foreign suppliers (that is, petroleum exporting countries)?

Exceptions. GATT provides a general exception for measures that conserve exhaustible natural resources. However, this exception is not available if the measure being challenged works as a "disguised barrier" to trade. Venezuela used the GATT rules against discrimination to win a WTO dispute against regulations on reformulated gas, which worked to the disadvantage of Venezuelan refineries. The WTO Appellate Body ruled that the resource conservation exception applies to protecting the atmosphere, but the conflict with trade rules was not excused because the U.S. regulations functioned as disguised

barriers. The WTO Appellate Body reasoned that the United States had an obligation to consult with Venezuela before implementing the regulations and develop alternative standards that were less trade-restrictive. The fact that the alternatives were more expensive to implement was not relevant under GATT. Under GATS, there is no exception for conservation of resources.

Low-Carbon Fuel Standard

The LCFS Is Covered by GATT, GATS, and the TBT Agreement

Conflict with trade rules. Depending on how the LCFS is used, the same issues flagged for fuel mixtures would apply to the LCFS. Given its novelty, complexity, and likely impact on markets, the LCFS is also likely to be scrutinized under the rules of the TBT Agreement. For example, the TBT Agreement obligates governments to base their regulations on international standards, even if those standards are developed after a domestic regulation is adopted. The International Organization for Standardization (ISO) just approved a committee to start work on standards for ethanol and biodiesel with an explicit focus on how fuels compare in terms of GHG impact. In addition, ISO has recently completed standards on GHG assertions and certification as well as life-cycle assessment. Among the questions to be considered are:

- Are the life-cycle methods being used by California designers of the LCFS consistent with existing ISO standards on life-cycle assessment and GHG certification?
- How can the LCFS be "based on" the "imminent" ISO standards on biofuel performance?
- Even if the LCFS incorporates ISO biofuel standards, will the LCFS be more trade-restrictive than necessary if it uses a longer life cycle (for example, field-to-wheels) than the ISO?
- If the LCFS is criticized by other countries as being trade-restrictive (to either imported petroleum products or biofuels), what kind of consultation would be appropriate to survive a challenge based on the rule that prohibits "disguised barriers"?

Exceptions. While a GATT dispute can be defended under the general exception for conserving natural resources, the TBT Agreement has no general exceptions. Rather, the issue is whether it is inappropriate to follow international standards and whether a measure is necessary to serve a legitimate policy objective. Assuming that controlling GHG emissions is a legitimate objective, the questions to be considered include: Could the United States defend the LCFS on grounds that ISO standards are not sufficient measures of impact on global warming? Could the United States defend the LCFS as least-trade-restrictive if it shifts the burden of certifying compliance to foreign refineries or suppliers?

How can policy makers use knowledge of trade policy?

Deciding on policy options. Trade rules do not outright prohibit the particular policy options that California agencies are considering. The potential for conflict arises in terms of how those options are drafted.

Drafting policy options. As noted above, it is premature to offer trade policy guidance on drafting a given policy option. That would require analyzing a specific proposal in light of specific rules and interpretations by the WTO's dispute settlement body. However, it is possible to lay out the general nature that guidance can take.

Stating policy objectives – This is important considering that public officials from the President on down have stated policy objectives for transportation fuels (such as the need for energy independence from Venezuela or the Persian Gulf region) that express an explicit or implicit purpose of discriminating against certain fuels or source countries.

Using international standards – This obligation applies to all levels of government, and the process of setting international standards on biofuels has begun.

Assessing the risk of legal conflict – The purpose of a careful legal analysis is not simply to avoid any risk of conflict, but rather to avoid unintended conflict by developing drafting options that are less likely to spark a trade dispute while still achieving policy objectives.

Identifying offsets or safeguards – Another way to avoid a conflict is to develop trade negotiating offsets or trade policy safeguards outside a particular measure. An example would be actions that the federal government could take to limit U.S. trade commitments to avoid a conflict or develop ways to facilitate trade, perhaps in other sectors, in consultation with foreign governments.

Consulting with foreign governments – The process of consulting with foreign governments appears to be a trade obligation that the WTO's Appellate Body has read into prohibitions on creating "disguised barriers" to trade.

Engaging U.S. Trade Negotiators

U.S. trade negotiators are working on a range of future trade commitments that could help or hurt policy innovators at the state level. While educating and influencing trade negotiators is best done through multi-state associations and advisory committees, California could play an important role in such state-federal consultation because of its leadership on policy and the influence of its congressional delegation. Pending trade negotiations that could help or hurt innovative policy on transportation fuels are:

New international standards – including ethanol and biodiesel (ISO, Technical Committee 28, petroleum products).

New service sector commitments – including pipeline transportation of fuels and bulk storage of fuels (GATS Council & Trade Negotiations Committee).

New disciplines on domestic regulation – including an objectivity test, a relevance test, a simplicity test, and other disciplines (GATS Working Party on Domestic Regulation).

New prohibited subsidies – including proposals by the United States to prohibit subsidies that would exceed the risk terms of conventional bank financing (SCM Agreement) and negotiations to develop subsidy disciplines for service industries (GATS Working Party on GATS Rules).

Classification of biofuels – including existing classification for tariffs, limits on agricultural subsidies, and sector coverage of trade in services (GATT, AoA, and GATS).

Technical specifications for procurement – including questions about whether provisions for protecting environmental quality are limited to the environmental territory of the purchasing government entity.

New Free Trade Agreements – including chapters on services, investment, and procurement that incorporate or add to the trade commitments listed above.

This discussion of trade policy and transportation fuels is limited to selected examples from a much larger field of trade rules and policy options. Table 17 identifies 18 trade rules from six different agreements and how they apply to categories of policy options.

Table 17: Trade Rules That Cover Fuel Measures

These selected trade rules…			Apply to these transportation fuel policies				
	Rule	**Except?**	**Tariffs**	**Taxes**	**Regulation**	**Mkt. Part.**	**Subsidies**
Tariff schedule							
	E - .54/gal	FTAs	x				
	E – 2.5% ad valorum	FTAs	x				
Prohibition of discrimination							
	GATT – NT taxes/like or substitutable	health, consv		x			
	GATT – NT regs/like or substitutable	health, consv			x		
	GATT – Mixtures/domestic content	health, consv		x	x		
	GATS – NT like services/supplies	health			x	x	x
	GPA – NT goods/services/suppliers	n.a.				x	
	SCM – domestic content (red light)	expired					x
	SCM – serious prejudice (yellow light)	expired					x
	INV – NT investors/investments	subsidies		x	x	x	
Limits on non-discriminatory domestic law making							
	TBT – necessity test/tech regs	no		x	x		
	TBT – use int'l standards	appropriate		x	x		
	GATS – objectivity test	health			x	x	x
	GATS – relevance test	health			x	x	x
	GATS – pre-established	health			x	x	x
	GATS – simplicity test/licensing	health			x	x	x
	GATS – consider int'l standards	health			x	x	x
	INV – minimum standard of treatment	subsidies		x	x	x	

Source: Georgetown University Law Center