California Energy Commission

COMMITTEE REPORT

2010-2011 INVESTMENT PLAN FOR THE ALTERNATIVE AND RENEWABLE FUEL AND VEHICLE TECHNOLOGY PROGRAM

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DISCLAIMER

This report was prepared by the California Energy Commission Transportation Committee as part of the 2010-2011 Investment Plan for the Alternative and Renewable Fuel and Vehicle Technology Program – Docket # 09-ALT-1. The report will be considered for adoption by the full Energy Commission at its Business Meeting on August 11, 2010. The views and recommendations contained in this document are not official policy of the Energy Commission until the report is adopted.

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PREFACE

The increased use of alternative and renewable fuels supports California's commitment to curb greenhouse gas emissions, reduce petroleum use, improve air quality, and stimulate the sustainable production and use of biofuels within California. Alternative and renewable transportation fuels include electricity, natural gas, biomethane, propane, hydrogen, ethanol, renewable diesel, and biodiesel fuels. State investment is needed to fill the gap and fund the differential cost of these emerging fuels and vehicle technologies.

Assembly Bill 118 (Núñez, Chapter 750, Statutes of 2007) created the Alternative and Renewable Fuel and Vehicle Technology Program. This statute, amended by Assembly Bill 109 (Núñez, Chapter 313, Statutes of 2008) authorizes the California Energy Commission to "develop and deploy innovative technologies that transform California's fuel and vehicle types to help attain the state's climate change policies." The Energy Commission has an annual program budget of approximately $100 million.

The statute also directs the Energy Commission to create an advisory committee to help develop and adopt an investment plan. The statute calls for the investment plan to describe how funding will complement existing public and private investments, including existing state and federal programs. The Energy Commission will use the investment plan as a guide for awarding funds. The statute calls for the investment plan to be updated annually.

ABSTRACT

The investment plan for the Alternative and Renewable Fuel and Vehicle Technology Program serves as the guidance document for the allocation of program funding and is prepared annually based on input and advice of the Assembly Bill 118 Advisory Committee. This second investment plan, the *2010-2011 Investment Plan for the Alternative and Renewable Fuel and Vehicle Technology Program*, covers the third year of the program and reflects laws, executive orders, and policies to reduce petroleum use, greenhouse gas emissions, and criteria emissions, increase alternative fuel use, and spur the development of bioenergy sources in California. It details how the California Energy Commission, with input from stakeholders and the Advisory Committee, determined the program's goal-driven priorities coupled with project opportunities for funding. These priorities are consistent with the program's goal "to develop and deploy innovative technologies that transform California's fuel and vehicle types to help attain the state's climate change policies."

The foundation of the *2010-2011 Investment Plan* is the analytical method used in the first investment plan and addresses greenhouse gas reductions for 2020, and to 2050. It provides proposed funding recommendations, based on the alternative and renewable fuel and vehicle technology analyses and identified opportunities. The appendices provide supporting analyses and important references for the development of this plan to help transform California's transportation sector to a low-carbon, cleaner, non-petroleum, and more efficient energy future.

Keywords: California Energy Commission, Alternative and Renewable Fuel and Vehicle Technology Program, alternative transportation fuels, Investment Plan, electric drive, hydrogen, biodiesel, renewable diesel, diesel substitutes, renewable gasoline substitutes, ethanol, natural gas, propane, innovative technologies, advanced fuels, workforce training, vehicle efficiency, sustainability, fueling stations, fuel production, fuel storage and blending, biofuels, biomethane.

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EXECUTIVE SUMMARY

"Now, more than ever, it is clear that clean transportation is the future, and California's policies and companies are leading the way...Our nation-leading green policies are not only creating jobs and inspiring entrepreneurs and innovators to create and grow businesses in California, they are charting the path to a future that doesn't depend on oil, will reduce costs for consumers and leave this world a better place for the next generation." ~ Governor Schwarzenegger June 15, 2010

Transportation fuels is one of the top three energy use sectors in the United States, accounting for two-thirds of the 20 million barrels of petroleum consumed daily. Of that, 65 percent is imported from foreign sources. In California, the transportation sector represents roughly half of all energy consumed and, like the United States, is 95 percent dependent on petroleum. In 2008, California's transportation sector consumed about 15 billion gallons of gasoline and more than 3 billion gallons of diesel fuel. This sector represents approximately 40 percent of the state's greenhouse gas emissions, the largest amount from any sector.

It has been nearly four decades since the 1973 Arab Oil Embargo and the ensuing economic disruption and geopolitical instability. The United States continues to be vulnerable to oil supply disruption and price shocks as a result of our dependence on petroleum, sending almost a billion borrowed dollars a day out of the country for oil imports. This exacerbates the growing trade imbalance and severely dampens economic recovery. In addition to economic and geopolitical risks, we now see how domestic petroleum extraction presents increasing environmental risks as evidenced in the recent Gulf of Mexico oil spill disaster.

The unprecedented events of the past two years that have affected all Californians and the state's economy have challenged the development of non-petroleum transportation fuels and advanced vehicle technologies. The Great Recession of 2008-2009, gasoline price increases in 2008, bankruptcies in the auto industry, financial institution collapses, job losses, and severe capital constraints are among the many events. The de-stabilizing impacts of these events have resulted in creating this challenging environment; while underscoring the importance of the development of alternative and renewable fuel and vehicle technologies for the many public benefits they can provide.

California is positioned to dramatically affect the direction of the nation's transportation sector as it leads the way with landmark state regulations and incentives to decrease petroleum use and greenhouse gas emissions. The *State Alternative Fuels Plan* of 2007 (Assembly Bill 1007, Pavley, Chapter 371, Statutes of 2005), jointly developed and adopted by the Energy Commission and Air Resources Board, presented strategies to increase the use of alternative and non-petroleum fuels for transportation. The *State Alternative Fuels Plan* set goals of reducing petroleum dependence by 15 percent and increasing alternative fuels use by 20 percent, by 2020. The alternative fuels proposed in the plan could achieve these goals and reduce greenhouse gases by 15 percent to 20 percent in the near term. Other important California regulations include the Global Warming Solutions Act of 2006 (Assembly Bill 32, Núñez, Chapter 488, Statutes of 2006), "Zero Emission Vehicle" regulations, the Low Carbon Fuel Standard, the *Bioenergy Action Plan*, the Renewable Portfolio Standard and the *San Pedro Bay Ports Clean Air Action Plan*.

The Alternative and Renewable Fuel and Vehicle Technology Program, created by Assembly Bill 118 (Núñez, Chapter 750, Statutes of 2007), has a crucial role in attaining the state's climate change policies. Through 2014, the Energy Commission will provide incentives of up to $100 million annually through the program to leverage public and private investment in the development and deployment of clean, efficient, and low-carbon alternative fuels and technologies. Assembly Bill 118 also provides up to $50 million per year for the Air Quality Improvement Program, administered by the Air Resources Board, which complements the Energy Commission's investment plan in providing alternative fuel vehicle incentives.

The Energy Commission is required to prepare an annual investment plan to determine funding priorities and opportunities, and describes how program funding will be used to support other public and private investments. The program also provides a foundation for the sustainable development and use of transportation energy and an economic stimulus to create California jobs and businesses by encouraging the invention and production of the technologies and services necessary for the future transportation system. The Energy Commission adopted its first investment plan combining funds from fiscal year 2008-2009 and fiscal year 2009-2010 in April, 2009. This *2010-2011 Investment Plan for the Alternative and Renewable Fuel and Vehicle Technology Program* (Plan) is the funding guide for fiscal year 2010-2011.

Although significant, the funding necessary to transform California's transportation system is greater than what the program provides and requires the Energy Commission to effectively leverage its funding with other agencies and private industry.

2010-2011 Investment Plan Funding Priorities

The Energy Commission will continue to provide funding to accelerate the development and deployment of clean, efficient low-carbon technologies that will achieve several key policy objectives: reducing greenhouse gas emissions and petroleum dependence, and increasing alternative and renewable fuel use, and in-state biofuels production. Achieving these objectives requires a portfolio of fuels and vehicle technologies including developing electric drive and fuel cell vehicles, producing low-carbon biofuels, increasing vehicle efficiency, and continuing deployment of natural gas and propane vehicles.

Funding priorities were analyzed based on the *2050 Vision* goals stated in the *State Alternative Fuels Plan* which specifies scenarios for categories of fuels and light-duty vehicles that could be used over the next 40 years to achieve the 2050 greenhouse gas emission reduction target. These funding priorities are shaped by the program opportunities to achieve the 2020 greenhouse gas emission target and the necessary "trajectory" of continued greenhouse gas emission reductions through 2050. A similar approach was used for medium- and heavy-duty vehicles.

The Plan also evaluates existing public funding that is already developing and deploying alternative and renewable fuel and vehicle technology and assesses where gaps exist and funding is required. Funding required for workforce training, sustainability studies, standards and certification, public education and outreach, and analytical support was also considered.

This Investment Plan recognizes the necessity to leverage existing federal, state, and local funding as well as stakeholder investments. Auto manufacturers, utilities, other stakeholders, and federal and local governments are investing in alternative fuel and advanced vehicle technologies. The Energy Commission intends to leverage these investments to accelerate the introduction and use of these fuels and technologies.

To help develop the *2010-2011 Investment Plan* five stakeholder workshops were held in September and October 2009. The workshops focused on the technologies and markets for electric drive, biofuels, natural gas and propane, hydrogen, and electric drive infrastructure. The *2010-2011 Investment Plan* also considers:

- Program funds that have been awarded to date.
- American Recovery and Reinvestment Act funds awarded to successful California project applicants.
- The effects of the Zero Emission Vehicle regulation modifications, the Low-Carbon Fuel Standard, the *Bioenergy Action Plan*, the Clean Fuels Outlets regulations, the Renewable Fuel Standard, the National Greenhouse Gas and Corporate Average Fuel Economy Standards for Vehicles, the Renewable Portfolio Standard, and the Clean Air Action Plan.

Program Status

The second Investment Plan has benefited from several public workshops, stakeholder comments and proposed project concepts, and funded projects. Using this information the competitive solicitations have resulted in the best projects for alternative and renewable fuels and advanced vehicle technologies. The program funding is heavily oversubscribed, receiving project proposals totaling more than four times the available funding. Greenhouse gas and petroleum use reductions are substantial, and the amount of leveraged public, stakeholder, and venture capital is unprecedented.

One of the major developments since the adoption of the first investment plan has been the American Recovery and Reinvestment Act and the billions of dollars that are being distributed nationally for a broad range of economic stimulus activities. To help California entities successfully compete for available American Recovery and Reinvestment Act funds, the Energy Commission issued a solicitation in April 2009 offering $175 million in cost share funds from the first investment plan government response to a transportation-related American Recovery and Reinvestment Act funding opportunity announcement. The Energy Commission reviewed 108 proposals requesting more than $624 million of program funds and $1.815 billion of American Recovery and Reinvestment Act funds. To date, the Energy Commission has committed $36.5 million to California projects that have been awarded approximately $105.3 million in additional American Recovery and Reinvestment Act funds and that also include $113.3 million in private funds. These funds have gone to:

- Install 3,891 new electric vehicle charging sites.
- Demonstrate over 800 medium- and heavy-duty natural gas and hybrid-electric trucks.

- Develop high energy density lithium-ion batteries.
- Provide public outreach and education to promote the deployment of heavy-duty natural gas vehicles.

With a significant amount of funding still available, the Energy Commission issued a number of additional solicitations and agreements (totaling $124.4 million) for the following purposes:

- Biomethane production facilities: $21.5 million
- Alternative and renewable fuel infrastructure: $9.5 million
- Demonstration of medium- and heavy-duty advanced vehicle technology: $13.8 million
- Manufacturing facilities for electric vehicles, alternative fuel vehicles, vehicle components and batteries: $19 million
- Biofuel production plants: $15 million
- Hydrogen fueling infrastructure: $19 million
- Ethanol production incentive program: $6 million
- Certification of hydrogen dispensing equipment for retail hydrogen fueling stations and establishment of specifications for hydrogen and biodiesel fuels: $4 million
- Establish statewide workforce training and development programs: $15 million.
- Convert state-owned hybrid-electric vehicles to plug-in hybrid-electric vehicles: $600,000
- Technical assistance in administering the Alternative and Renewable Fuel and Vehicle Technology Program: $1 million

As of July 2010, all of the above solicitations are closed. The Energy Commission is preparing to release the following solicitations and agreements, which will account for all remaining funding (totaling $14.65 million) from fiscal year 2008-2009 and fiscal year 2009-2010:

- Medium- and heavy-duty vehicle Center of Excellence: $7 million
- Medium-duty propane school buses and other vehicles: $2 million
- Hydrogen fueling infrastructure for transit: $3 million
- Sustainability studies and certification programs: $2 million
- Technical analysis with the National Renewable Energy Laboratory: $1.2 million
- Spatial analysis for fuel/charging infrastructure establishment with the University of California, Irvine Spatially and Temporally Resolved Energy and Environmental Tool model: $.25 million

Investment Plan Allocations

The allocations in the Investment Plan are based on possible alternative and renewable fuel increases and advanced vehicle technology deployment, petroleum displacement, potential

greenhouse gas reductions, the level of current public and private funding, and feedback from stakeholders. These allocations provide funding for commercial demonstration and deployment in the short-, mid- and long-term to meet program goals. For example, funding is being provided for immediate establishment of electric drive infrastructure for electric vehicles ready to be deployed in 2010 to 2012—the near term. Funding for biofuel feedstock development and improved production methods will provide alternative vehicle fuels for the mid-term, and funding for hydrogen infrastructure will help to meet petroleum and greenhouse gas reduction goals for the long term as commercial volumes fuel cell vehicles are introduced in 2015. The funding allocations for fiscal year 2010-2011 are shown in Table ES-1 and are described below.

Battery Electric Drive

Estimates of cumulative sales of in-state plug-in electric vehicles expected by 2015 range from 125,000 to 450,000, with the most likely estimate between 250,000 and 275,000. To support the accelerated deployment of these vehicles, the Energy Commission is providing $3 million for charging infrastructure and related activities. These funds will be used to both expand and coordinate the state's growing network of public and private charging stations.

The Energy Commission will also provide $14 million in grants and loans for ongoing demonstrations of medium- and heavy-duty electric drive vehicles, including on-road and non-road applications. Incentives for commercialized medium- and heavy-duty vehicles will be provided by the Air Resources Board. Similarly, the Air Resources Board has already announced its intent to provide incentives for commercialized light-duty electric drive vehicles.

Additionally, the Energy Commission is allocating $7.5 million for in-state electric drive manufacturing facilities. California is the home of numerous start-up electric vehicle manufacturers. This funding, properly leveraged with private capital, will allow them to address high initial capital costs, and expand into the broader commercial market.

Hydrogen Electric Drive

Hydrogen vehicles, including fuel cell vehicles, are expected to rapidly expand within the state over the next decade. Based on a recent Energy Commission and Air Resources Board survey of major automakers planning to produce fuel cell vehicles, the Energy Commission is planning for fuel cell vehicle deployments in the hundreds by 2012, in the thousands by mid-decade, and in the tens of thousands by the end of the decade. To support these vehicle deployments, the Energy Commission will offer up to $13 million for hydrogen fueling infrastructure, following the results of its June 2010 hydrogen infrastructure solicitation. This funding will be tailored to automakers' anticipated vehicle rollout schedules, regional needs, and fueling capacity needs prior to the accelerated deployment of fuel cell vehicles in 2015.

As with electric drive vehicles, incentives for light-duty hydrogen vehicles will be available from the Air Resources Board. However, significant deployment of these vehicles is not anticipated before 2015, and they are likely to comprise a small percentage of the Air Resources Board's incentives before then.

Gasoline Substitutes

Gasoline substitutes offer a significant opportunity for reducing both greenhouse gas emissions and petroleum use. The state's Low Carbon Fuel Standard and *Bioenergy Action Plan*, as well as the federal Renewable Fuel Standard, will rely heavily on biofuels (including ethanol) in meeting their targets. Toward this end, the Energy Commission is providing $10 million to expand in-state production for gasoline substitutes. An additional $6.5 million will be provided to expand E-85 dispensers and retail outlets. Given the relatively modest marginal cost for the purchase of flex-fuel vehicles, the Energy Commission is not proposing vehicle funding for this fuel category.

Diesel Substitutes

Much like gasoline substitutes, diesel substitutes offer an immediate opportunity to significantly reduce California's greenhouse gas emissions and petroleum dependence. The same policy drivers that will accelerate gasoline substitutes will also accelerate diesel substitutes. To accelerate the in-state production of diesel substitutes, the Energy Commission will provide $5 million to expand and support California's diesel substitute production plants. The Energy Commission additionally allocates $4 million to support needed fuel terminal and distribution infrastructure for diesel substitutes. This funding will include modifications to existing rack-terminals, enabling them to dispense biomass-based diesel, and expansion of bulk terminal and storage facility capacity.

Natural Gas

In response to greenhouse gas emission reduction targets, volatile petroleum prices, and air quality standards, the Energy Commission expects natural gas to play a significant role in the state's transportation sector. A number of automakers, as part of their loans and grants from the American Recovery and Reinvestment Act, are expected to begin promoting light-duty natural gas vehicles. Additional opportunities remain for expanding the use of medium- and heavy-duty natural gas vehicles in ports and other applications. To capitalize on these opportunities, the Energy Commission is allocating $13 million for natural gas vehicle incentives for light-, medium- and heavy-duty vehicles.

A modest network of fueling infrastructure already exists for natural gas vehicles. However, many of these stations are in need of upgrade, and the funding for these upgrades is not available for certain operators (such as schools and local governments). The Energy Commission is therefore allocating $2 million to upgrade, refurbish or expand natural gas fueling stations for school districts and other public sector facilities.

The production and use of in-state biomethane will further advance state policy in the transportation sector. Biomethane, when produced from waste-based resources or byproducts, possesses one of the lowest carbon intensities of any existing fuel. For these reasons, the Energy Commission is allocating $7 million to promote in-state biomethane production for use in the transportation sector.

Propane

Propane, like natural gas, offers the potential for immediately reducing greenhouse gas emissions, petroleum reductions, and fuel costs for light- and medium-duty vehicles. The prospect of renewably produced propane will further reduce greenhouse gas emissions from propane-fueled vehicles. Propane has been the preferred alternative fuel for rural communities and school districts that would not otherwise have access to an alternative fuel, as propane fueling infrastructure is readily available and affordable. The Energy Commission is allocating $3 million toward light- and medium-duty propane vehicle deployment.

Innovative Technologies and Advanced Fuels

In addition to the previous categories, the Energy Commission is interested in providing funding for other types of projects that can assist the state in meeting its greenhouse gas emission reduction and alternative fuel use goals. This could include, among other things, projects to improve engine efficiencies, develop high-productivity biomass feedstocks (such as algae), and lightweight vehicle materials for multiple vehicle platforms. To ensure adequate funding for these opportunities, the Energy Commission is reserving $3 million for this category. Additionally, the Energy Commission is reserving $5 million for cost-sharing opportunities for highly-leveraged federal solicitations.

Market and Program Development

To ensure the success of this program, the Energy Commission is also allocating funding for non-fuel categories. In support of workforce development and training, the Energy Commission is providing $1 million to expand workers' skills in clean fuels and vehicle technologies. In promoting the commercialization of alternative fuels, the Energy Commission is seeking to minimize any negative environmental impacts. To support this goal, the Energy Commission is providing $2.5 million for sustainability studies. An additional $2.5 million is allocated for marketing and program outreach, aimed at promoting awareness of the program and alternative fuels. Finally, the Energy Commission will provide $6 million for technical assistance and environmental, market, and technology analysis. Much of this funding will assist the program in focusing on funding priorities and identifying preferred opportunities for future funding. This category may also provide funding for full fuel cycle analysis, to assist small companies in developing and demonstrating the carbon intensity of their alternative and renewable fuels and technologies.

Table ES-1: Funding Allocation Summary for FY 2010-2011[2]

	Project/Activity	Funding Allocation for FY (2010-2011)
Battery Electric Drive	Develop and demonstrate advanced on-road and non-road medium- and heavy-duty vehicles	$14 Million
	Infrastructure and related activities	$3 Million
	Manufacturing facilities and equipment	$7.5 Million
	Subtotal	**$24.5 Million**
Hydrogen Electric Drive	Fueling Infrastructure	$13 Million
	Subtotal	**$13 Million**
Gasoline Substitutes	Expansion of E-85 dispensers and retail outlets	$6.5 Million
	Gasoline substitutes production in existing, new and retrofit facilities	$10 Million
	Subtotal	**$16.5 Million**
Diesel Substitutes	Diesel substitutes production	$5 Million
	Bulk terminal storage and blending facilities	$4 Million
	Subtotal	**$9 Million**
Natural Gas	Light-, medium- and heavy-duty vehicles	$13 Million
	Upgrades to natural gas fueling stations	$2 Million
	Biomethane production plants and quality testing	$7 Million
	Subtotal	**$22 Million**
Propane	Light- and medium-duty vehicles	$3 Million
	Subtotal	**$3 Million**
Innovative Technologies and Advanced Fuels	Innovative technologies and advanced fuels	$3 Million
	Federal cost sharing	$5 Million
	Subtotal	**$8 Million**
Market and Program Development	Workforce Development and Training	$1 Million
	Sustainability studies	$2.5 Million
	Program marketing and public education and outreach	$2.5 Million
	Technical assistance and environmental/market/ technology analyses	$6 Million
	Subtotal	**$12 Million**
	Grand Total	**$108 Million**

Source: California Energy Commission

2 The Energy Commission will also fund up to 2 percent (or $2.16 million) of the total allocation for measurement, verification, and evaluation. This amount will be taken from each category on a prorated basis.

Looking Ahead

The Energy Commission will continue to focus on and leverage those technologies that show the most promise and market potential, and will balance that focus with the need to have a robust portfolio approach to technology development. This approach will help address and mitigate investment risks. It will also emphasize investments that provide immediate greenhouse gas reduction and petroleum reduction benefits while developing the technologies and infrastructure needed to compete in the future. As fuels and technologies evolve, the Energy Commission must continually evaluate a clear pathway, with landmarks, to the 2020 and 2050 greenhouse gas reduction goals. The scope of the program may also be expanded to include applications not previously addressed, such as aviation fuel.

Important lessons are learned with each successive investment plan. Although the solicitations were oversubscribed and all funds can be used, the process of disbursing the funds more quickly in the form of block grants will be important in the future. It will also be helpful to involve entities such as air quality management districts, transportation planning agencies, the state's universities, colleges and community colleges, and various other fuel and vehicle consortia as partners in administering funded programs at the local level.

The Energy Commission will continue to use its discretion and best judgment in setting specific allocations, and will maintain flexibility to redirect funding within a fiscal year as emerging conditions (environmental, energy, or economic) require, as noted under section 3108(f) of the program's regulations.

CHAPTER 1: Introduction

The transportation sector has a tremendous role to play in California's energy security and diversity future, as well as the state's efforts to combat climate change. Within California, transportation accounts for roughly half of all energy consumed, and roughly 40 percent of all greenhouse gas (GHG) emissions, the largest of any single sector.[3] Nearly 40 years after the 1973 Arab Oil Embargo, the United States remains vulnerable to oil supply and price shocks as a result of its dependence on imported oil. In addition to the economic and climate risks associated with petroleum dependence, petroleum extraction presents immediate environmental risks, as evidenced in the recent Gulf of Mexico oil spill disaster. Cleaner, more secure alternatives to petroleum exist, but California and the United States have yet to take full advantage of them.

Extraordinary changes have taken place in the economic, political, and energy landscape in the last few years. The California economy, along with the United States economy, is still struggling to overcome one of the worst recessions since the Great Depression. Economic uncertainty, volatile energy prices, and capital constraints have had an adverse affect on green transportation technology development and deployment.[4] Potential investors in alternative and renewable fuels are wary of uncertain fuel price forecasts, and many who would otherwise be willing to invest are hesitant. Gasoline prices are lower, so consumers and businesses are less motivated to buy alternative or advanced vehicle technology than they were when gasoline prices spiked in 2008. They also have less discretionary income to spend on new vehicles.

Over the long term, however, there are positive trends for green transportation. Green transportation employment in California has increased 152 percent since 1995, with the sub-category of alternative fuels jobs increasing 201 percent in that period. [5, 6] Recent private investments in alternative and renewable fuel and vehicle technology such as battery electric and fuel cell vehicles, advanced batteries, charging stations, hydrogen, E-85, and natural gas fueling infrastructure are a sign that alternative transportation technology is increasingly attractive to investors. During this critical phase of emerging green transportation technology development and deployment, government will continue to play an important role in establishing policies that provide long-term market signals and performance standards as well as incentives that encourage private investment in alternative and renewable transportation fuels and technologies.

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3 California Energy Commission, *2009 Integrated Energy Policy Report*, Final Committee Report, December 2009, CEC-100-2009-003-CTF.

4 2010-2011 Investment Plan Biofuels Workshop, September 14-15, 2009.

5 Green transportation employment primarily falls into motor vehicle and equipment jobs and alternative fuels jobs.

6 *Many Shades of Green: Diversity and Distribution of California's Green Jobs*, Next 10 and Collaborative Economics, October 2009.

California will remain dependent on petroleum fuels in the near-term. In 2008, California's transportation sector consumed approximately 15 billion gallons of gasoline and more than 3 billion gallons of diesel fuel.[7] Although the 2008-2009 economic downturn has reduced near-term fuel consumption, projections indicate that without GHG emission reduction policies, over the next 10 years the combined volume of gasoline and diesel consumption will grow by 1.98 percent.[8] This is due largely to increasing diesel demand, as gasoline demand is expected to drop by a small amount over the same period.

Since 2003, California has implemented a number of key policies to reduce GHG emissions, reduce the state's dependence on petroleum, increase the development and use of alternative and renewable fuels and vehicles, and stimulate in-state sustainable biofuel production and use. Transforming California's transportation sector to achieve these objectives will require the well-planned use of state and federal funds to encourage private investment in alternative and renewable fuels and technologies.

Table 1: Summary of Key Policies

Objectives	Goals and Milestones
Petroleum Reduction[9]	Reduce petroleum fuel use to 15% below 2003 levels by 2020
GHG Reduction[10,11]	Reduce GHG emissions to 1990 levels by 2020 and 80% below 1990 levels by 2050
Alternative and Renewable Fuel Use[12]	Increase alternative and renewable fuel use to 11% of on-road and off-road fuel demand by 2012, 13% by 2017, and 26% by 2022
In-State Biofuels Production[13]	Produce in California 20% of biofuels used in state by 2010, 40% by 2020, and 75% by 2050

Source: California Energy Commission

7 *Fuel Taxes Division Statistics and Reports - Board of Equalization* http://www.boe.ca.gov/sptaxprog/spftrpts.htm

8 Transportation Energy Fuel Demand Forecast in support of *2009 IEPR*, low demand case.

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

10 Assembly Bill 32 (Núñez, Chapter 488, Statutes of 2006).

11 Governor's Executive Order S-3-05.

12 *State Alternative Fuels Plan*, Final Adopted Report, CEC-600-2007-011-CMF, December 2007.

13Governor's Executive Order S-6-06.

As a means of achieving these policies Assembly Bill (AB) 118, (Núñez, Chapter 750, Statutes of 2007) created the Alternative and Renewable Fuel and Vehicle Technology Program. The statute, amended by Assembly Bill 109 (Núñez, Chapter 313, Statutes of 2008), authorizes the Energy Commission to develop and deploy alternative and renewable fuels and advanced transportation technologies to help attain the state's climate change policies. Accordingly, the Energy Commission is providing incentives to accelerate the development and deployment of clean, efficient, low-carbon alternative fuels and technologies. The Energy Commission has an annual program budget of approximately $100 million for projects that:

- Develop and improve alternative and renewable low-carbon fuels.
- Reduce California's use and dependency on petroleum transportation fuels and increase the use of alternative and renewable fuels and advanced vehicle technologies.
- Optimize alternative and renewable fuels for existing and developing engine technologies.
- Produce alternative and renewable low-carbon fuels in California.
- Decrease, on a full fuel cycle basis, the overall impact and carbon footprint of alternative and renewable fuels and increase sustainability.
- Expand fuel infrastructure, fueling stations, and equipment.
- Improve light-, medium-, and heavy-duty vehicle technologies.
- Retrofit medium- and heavy-duty on-road and non-road vehicle fleets.
- Expand infrastructure connected with existing fleets, public transit, and transportation corridors.
- Establish workforce training programs, conduct public education and promotion, and create alternative and renewable fuel and vehicle technology centers.

The statute requires the Energy Commission to prepare an investment plan to determine funding priorities and opportunities, and describe how program funding will be used to complement other public and private investments. The Energy Commission adopted its first investment plan combining funds from fiscal year (FY) 2008-2009 and FY 2009-2010 at the April 22, 2009, Business Meeting. The statute also requires the Energy Commission to adopt a new investment plan each year. This *2010-2011 Investment Plan for the Alternative and Renewable Fuel and Vehicle Technology Program* (*2010-2011 Investment Plan*) is the funding guide for FY 2010-2011.

To implement the priorities of the investment plan, the Energy Commission has authority to employ various funding mechanisms including grants, loans, loan guarantees, revolving loans, and other appropriate financial measures. Public agencies, private businesses, public-private partnerships, vehicle and technology consortia, workforce training partnerships and collaboratives, fleet owners, consumers, recreational boaters, and academic institutions and others are eligible for funding.

New financing options will be available through agreements between the Energy Commission and the California Alternative Energy and Advanced Transportation Funding Authority (CAEATFA) and the California Pollution Control Financing Authority (CPCFA), with the goal of using AB 118 funds to encourage private investment in worthy alternative fuel, vehicle, and infrastructure projects.

The CAEATFA bond program allows the Energy Commission to use AB 118 funds to help program applicants gain access to credit in the commercial bond market. Program funds are used to reduce bond issuance costs and provide credit enhancements in an effort to obtain more favorable financial terms for borrowers. Institutional investors are the source of debt financing using industrial development or tax exempt bond mechanisms. CAEATFA also provides sales tax exemptions to purchase zero emission vehicle manufacturing equipment.

The California Capital Access Program (CalCAP), managed by the CPCFA, is a loan guarantee program helping small businesses gain access to loans by depositing public funds into a loan loss reserve account. These funds are accessible by lenders if borrowers default, providing some guarantee of the borrower's creditworthiness. Eligible applicants to the AB 118 program will be directed to the CPCFA's list of partner commercial banks, where they can apply for a loan through the CalCAP program.

Reaching the GHG and petroleum reduction goals will require additional steps beyond alternative and renewable fuels deployment. The California Energy Commission's 2050 analysis shows that the state cannot meet transportation's GHG reduction "fair share" by fuel switching and advanced vehicle technologies alone.[14] Better land use and transportation planning will also be required that improves mobility, increases transit, biking, and walking infrastructure, and reduces the need for vehicle travel to meet the state's 2050 target.

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14 The transportation sector's "fair share" emission reduction target is not established by statute, but is the calculated emission reduction target for the transportation sector (or in this case for light-duty vehicles) based on the sector's contribution to the state's total GHG emissions. In other words, since the transportation sector is responsible for 38 percent of statewide GHG emissions, its "fair share" emission reduction is 38 percent of the total reduction needed to meet 2020 and 2050 policy goals.(page 5 of CEC-600-2009-008-CMF)

CHAPTER 2: Determining Priorities and Opportunities

The Energy Commission developed a goal-driven analytical method for establishing funding priorities and opportunities for the program to achieve the 2020 GHG emission target and examine the necessary "trajectory" of continual climate change emission improvements to achieve the 2050 target.

This method was based on the *2050 Vision* developed as part of the *State Alternative Fuels Plan* that was jointly adopted by the Energy Commission and the California Air Resources Board (ARB) in December 2007.[15] The *2050 Vision* represents a plausible scenario that specific categories of fuels and light-duty vehicles would be introduced and used over the next 40 years to achieve the 2050 target. A similar analytic approach was developed for medium- and heavy-duty vehicles and used in a two-step process allocating a percentage of available funds.

The first step established the potential relative contributions of each fuel and vehicle category to meeting the 2020 and 2050 GHG targets, according to one scenario. (See Appendix A.) The Energy Commission's most recent fuel demand forecast was used as a base and then incorporated the effects of the "Pavley" regulations, the Low Carbon Fuel Standard (LCFS), and the assumptions for reduction in vehicles miles traveled.

The California Conventional and Alternative Fuel Response Simulator (CALCARS) model was used to establish a "business as usual" baseline fuel demand projection. The baseline included gasoline, diesel, and hybrid vehicles. From this baseline, the analysis established a plausible scenario for the introduction and use of alternative and renewable fuels and advanced vehicle technologies through 2050.

The second step determined the existing public and private funding already in place to develop and deploy alternative and renewable fuels and vehicle technology and where gaps exist and funding is needed. Only public funding is assessed; for private funding, last year's analysis was used, which will be updated in future investment plans. This step also addresses other funding for other important categories such as workforce training, sustainability studies, standards and certification, public education and outreach, and analytical support. A new category, "Innovative Technologies and Advanced Fuels," is also included in this plan.

In the *2010-2011 Investment Plan*, the Energy Commission continues to rely on this core analysis to determine the relative contributions of various fuels and technologies toward achieving the 2050 GHG emission targets. The analysis has been updated to incorporate the Energy Commission's most recently adopted fuel demand forecast that has expanded baseline projections that include natural gas, propane, fuel cell, battery electric, plug-in hybrid-electric, biodiesel, and flex fuel (E-85) vehicles. In addition, the analysis uses updated full fuel-cycle carbon intensity values for alternative and renewable fuels using different feedstocks. These

15 *State Alternative Fuels Plan*, Final Adopted Report, CEC-600-2007-011-CMF, December 2007.

updates improve the accuracy and resolution of emerging fuel and technology effects in GHG reduction. A more detailed description of these changes can be found in Appendix A.

Consistent with the LCFS, the alternative and renewable fuels that are expected to contribute to petroleum and GHG reduction all result in lower carbon intensity compared to the gasoline and diesel intensity baselines. These GHG reductions are more than double the required LCFS 2020 reduction of 10 percent and occur 10 years earlier. (See Appendix A for details.)

The *2010-2011 Investment Plan* includes information obtained from five stakeholder workshops held in September and October of 2009. The workshops focused on the technologies and markets for electric drive, biofuels, natural gas and propane, hydrogen, and electric drive infrastructure. The *2010-2011 Investment Plan* also takes into account program funds that have been awarded to date, American Recovery and Reinvestment Act (ARRA) funds awarded to successful California project applicants, and the effect of the Zero Emission Vehicle (ZEV) regulation modifications, the LCFS, the *Bioenergy Action Plan* (BAP), the Clean Fuels Outlets regulations, the Renewable Fuel Standard, the National Greenhouse Gas and the Corporate Average Fuel Economy (CAFÉ) Standards for Vehicles, the Renewables Portfolio Standard (RPS), and the Clean Air Action Plan (CAAP).

Pathway to 2020 and 2050

An array of fuels and technologies is required to achieve the 2050 goal. There are very few technologies that individually have the potential to achieve 80 percent GHG reductions. Many of the fuels and technologies needed to meet program objectives exist in the market today and offer a tangible bridge to fuel-vehicle technologies that can achieve 2050 goals; others require additional development and substantial cost reductions to be competitive.

Plug-in hybrid-electric vehicles, battery-electric vehicles, and hydrogen fuel cell vehicles are being aggressively developed by automakers and will be entering the market in increasing numbers over the next several years. Electric charging and hydrogen fueling stations will need to be put in place to accommodate the roll-out of these vehicles. Hybrid-electric technologies are finding success in light-duty vehicles and have considerable potential for medium- and heavy-duty truck applications. More development work is needed to overcome high cost premiums due to low market-entry production volumes and to reduce carbon emissions through the use of plug-in electric technologies and alternative fuels.

Ethanol is currently blended in gasoline at about 1 billion gallons per year in California and represents the largest volume of alternative or renewable fuel in use today. Flexible fuel vehicles also are produced today and are capable of using gasoline, E-85, or any blend level in between. Biodiesel and renewable diesel also are being used in various applications. Researchers are developing other biofuels with a low carbon footprint that can be more easily blended with gasoline and diesel fuels. Investments are needed to construct facilities to produce so-called “second generation” biofuels using energy crops, algae, and current waste streams

such as landfills, agricultural wastes, and forest residues. The potential to use waste resources within California to produce alternative and renewable fuels is immense and will be an important key to GHG reductions.[16]

Propane and natural gas have found important applications in the medium- and heavy-duty truck and transit sectors and may see expanded use for light-duty cars and trucks. Other combinations of technologies are in various stages of the research, development, demonstration and deployment cycle, including hydraulic hybrid applications in medium- and heavy-duty vehicles and hybrid electric in heavy-duty vehicles and transit buses. Examples of these options are beginning to find their way into the marketplace. Furthermore, these vehicles will provide a pathway for deeper GHG reductions with the development of biomethane and renewable propane.

Developing and deploying advanced fuels and vehicles will not be enough. Investments will be necessary to establish certification and standards for fuels and vehicles, construct advanced fuel and vehicle production facilities, meet work force training needs, and educate and inform the public. However, public funding alone is an unsustainable strategy in the long term to support the development of alternative fuels, vehicles, and infrastructure.

The Energy Commission will focus on and leverage technologies that show the most promise and market potential and will balance that focus with the need to have a robust portfolio approach to technology development. This approach will address and reduce investment risks. It also will emphasize investments that provide immediate lower carbon and GHG and petroleum reduction benefits while developing the technologies and infrastructure to compete in the future. In this and future investment plans, the Energy Commission will re-evaluate the status of fuels and technology as they evolve and chart a course of investment with landmarks to the 2020 and 2050 GHG reduction goals. This will maximize the return on investment of current funds and minimize the risk of perpetual subsidies for alternative fuels and technologies.

Status of Program Funding

The Energy Commission allocated $176 million in the first investment plan. Since the adoption of the first investment plan in April 2009, the Energy Commission has committed approximately $20.6 million to:

- Establish statewide workforce training and development programs: $15 million.
- Convert state-owned hybrid-electric vehicles to plug-in hybrid-electric vehicles: $600,000.

16 *An Assessment of Biomass Resources in California, 2007.* PIER Collaborative Report from the California Biomass Collaborative March 2008, California Energy Commission. Contract No. 500-01-016.

- Technical assistance in administering the Alternative and Renewable Fuel and Vehicle Technology Program: $1 million
- Certification of hydrogen dispensing equipment for retail hydrogen fueling stations and establishment of specifications for hydrogen and biodiesel fuels: $4 million

The Energy Commission is also providing approximately $36.52 million as match funding to approximately $105.3 million of ARRA funds and $113.3 million of private funds to:

- Install 3,891 new electric vehicle charging sites.
- Demonstrate more than 800 medium- and heavy-duty natural gas and hybrid-electric trucks.
- Develop high-energy-density lithium-ion batteries for vehicles.
- Provide public outreach and education to promote the deployment of heavy-duty natural gas vehicles (NGV)

The details of the ARRA funding commitment are discussed in the next section. The Energy Commission offered the 2008-2010 AB 118 funds to leverage as much federal funding for California as possible. After accounting for this opportunity, however, there remained significant uncommitted program funding from the first investment plan. Therefore, in November 2009, the Energy Commission released three focused solicitations for approximately $45.2 million. The proposals received in response to these program opportunity notices (PON) were scored, and the aggregated levels of awards are listed in Table 2. (A more detailed breakdown of each proposed awards is provided in the appropriate fuel section of Chapter 3.)

Table 2: Awards From PON-09-003, -004 and -006

PON	Description of Projects (# of projects)	Proposed Award
PON 09-003	Production of biomethane from waste feedstocks for compressed natural gas (CNG) and liquid natural gas (LNG) transportation use (4)	$21,479,499
PON 09-004	Medium- and heavy-duty vehicles using alternative fuels or advanced technologies (8)	$9,967,977
PON 09-006	Electric vehicle charging stations and upgrades (5)	$3,200,000
	Ethanol fueling stations (1)	$1,000,000
	CNG/LNG fueling stations and upgrades (10)	$5,741,388
	Biomass-based diesel infrastructure (3)	$3,858,612
Total		**$45,247,476**

Source: California Energy Commission

Since then, the Energy Commission has released four additional PONs, totaling up to $59 million, for the following:

- Manufacturing plants for electric vehicles, alternative fuel vehicles, vehicle components and batteries (PON-09-605): $19 million.
- Biofuel production plants (PON-09-604): $15 million.
- Hydrogen fueling stations (PON-09-608): $19 million.
- An ethanol production incentive program (PON-09-607): $6 million.

An additional $9 million in forthcoming solicitations will be for:

- A medium- and heavy-duty electric drive vehicle Center of Excellence: $7 million
- Medium-duty propane school buses and other vehicles: $2 million.

The remaining funds of $6.45 million will be for interagency agreements and other arrangements for:

- Examination of best management practices and sustainability certification programs for imported fuels and fuels produced in California: $2 million
- Hydrogen fueling infrastructure for transit applications: $3 million
- Technical analysis with the National Renewable Energy Laboratory : $1.2 million
- Expand the capabilities of the University of California (UC), Irvine Spatially and Temporally Resolved Energy and Environmental Tool (STREET) model: $.25 million

The American Recovery and Reinvestment Act of 2009

One of the major developments since the adoption of the first investment plan was the implementation of ARRA and the resulting billions of dollars of federal stimulus funding that are being distributed nationally for a broad range of economic stimulus activities. To date, more than $33 billion of ARRA funds have been awarded.

President Obama signed ARRA into law on February 17, 2009, to stimulate the economy, create jobs, and address a variety of critical areas of national concern.[17] One of the areas targeted for the economic stimulus was energy.

The initial announcement of federal funding opportunities in March 2009 for alternative and renewable fuels and advanced vehicles immediately preceded the adoption of the Energy

17 US Department of Energy. "Recovery and Reinvestment," http://www.energy.gov/recovery.

Commission's first investment plan. To help California entities successfully compete for available federal funds, the Energy Commission issued a solicitation (PON-08-010) in April 2009 offering $175 million[18] of program funds from the first investment plan as cost share to those who were submitting proposals to the federal government in response to a transportation-related ARRA funding opportunity announcement.

The Energy Commission reviewed 108 proposals requesting more than $624 million of program funds and $1.815 billion of ARRA funds. Of the 108 applications, 38 percent were applying to the federal Clean Cities solicitation, 35 percent were for transportation electrification, 12 percent for biorefineries, and 10 percent for battery and component manufacturing. The remaining applications were for Transit Investments for Greenhouse Gas and Energy Production (TIGGER) and Advanced Research Projects Agency-Energy (ARPA-E).

To date, the Energy Commission has committed $36.5 million to California projects that have been awarded approximately $105.301 million in additional ARRA funds. These projects also include $113.281 million in additional private funds. Table 3 shows ARRA funds awarded to date for alternative and renewable transportation projects with and without AB 118 match funds.

The ARRA awards that were made to California include 3,191 electric charging sites,[19] 442 medium-duty LNG vehicles, and 123 plug-in Class 2-5 hybrid-electric vehicles.

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18 This amount was later reduced to $156 million. Four million dollars for standards and certification and $15 million for workforce training and development had already been committed for specified entities in the *2008-2009 Alternative Fuels Investment Plan*.

19 Includes 1,041 public Level 2; 1,000 commercial Level 2; 1,000 home charging; and 50 Level 3 charging station.

Table 3: ARRA Awards With AB 118 Match in California (In Millions)[20]

Program	Federal Funds Available	ARRA Awards with AB 118 Match			ARRA Awards w/o AB 118 Match
		ARRA Awards	AB 118 Match Funds	Private/ Other Match	ARRA Awards
Transportation Electrification	$400	$75.025	$17.070	$53.182	$3[21]
Clean Cities	$300	$26.276	$18.450	$59.770	$6
ARPA-E	$400	$4.000	$1.000	$0.329	$12
Adv Battery Manufacturing	$2,000	$0	$0	$0	$0
Diesel Emission Reduction	$300	$0	$0	$0	$27
Applied RDD&D	$2,500	$0	$0	$0	$14
TIGGER	$100	$0	$0	$0	$18
Integrated Biorefinery	$483	$0	$0	$0	$45
Efficient Class 8 Trucks and Adv Tech for LD Vehicles	$115-$240	$0	$0	$0	*[22]
Algal/Adv Biofuels Consortia	$85	*[23]	$0	*[24]	$.4
Totals	$6,683-6,808	$105.301	$36.52	$113.281	$125.4

Source: California Energy Commission

20 Most of these numbers change periodically, so some will be out of date by the time of publication.

21 Funding is an estimate of California's share of multistate projects.

22 A total of $187 million was awarded to major heavy-duty truck and passenger vehicles companies, and at this time it is unknown how many of the vehicles will come to California.

23 Total award of $44 million nationwide but California portion is not yet available.

24 California portion not yet available.

As of November 2009, total nationwide transportation awards totaled more than $2.8 billion. Nationwide, excluding California, infrastructure funding was awarded for: 30 biodiesel (B20), 112 E-85, 146 natural gas (of which 133 were compressed natural gas [CNG]), 253 propane, and 2 hydrogen stations; 1,571 electric charging sites; and 50 truck stop electrification projects. Vehicle purchases funded nationally, excluding California, included 2,647 natural gas, 2,576 electric drive/hybrid electric, and 3,256 propane vehicles.[25] These nationwide awards provide support to the industry that also provides vehicles for California use. In this regard, California ultimately will benefit from more robust vehicle and infrastructure manufacturing industries in other states.

Reducing California's Petroleum Dependence

In 2003, the Energy Commission and the ARB jointly adopted a strategy to reduce California's dependence on petroleum. In response to AB 2076 (Shelley, Chapter 936, Statutes of 2000), 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 influencing the federal government to double the fuel economy of new vehicles. The Energy Commission and ARB showed that the combined corporate average fuel economy standards for new passenger cars and light trucks can be doubled in a cost-effective manner and without sacrificing safety or consumer choice. The report also contained a recommendation to increase the use of non-petroleum fuels to 20 percent of on-road fuel demand by 2020 and 30 percent by 2030. The Energy Commission incorporated the findings of the joint report into the *2003 Energy Report* and recommended that the Governor and Legislature adopt the goals and strategy as state policy.

State Alternative Fuels Plan

The *State Alternative Fuels Plan* was jointly prepared by the Energy Commission and the ARB in response to AB 1007 (Pavley, Chapter 371, Statutes of 2005), and adopted by the two agencies in December 2007. The plan contains recommendations to stimulate the use and production of alternative and renewable transportation fuels and vehicle technologies in California. The plan also highlights the need for state government incentive investments of over $100 million per year for 15 years to spur the development of these alternative fuels to reach cost parity with gasoline and diesel vehicles and petroleum fuel infrastructure. In addition, the plan recommends that the state adopt alternative fuel use goals of 9 percent by 2012, 11 percent by 2017, and 26 percent by 2022. The plan provides a foundation for the types of investments that will be made by the Energy Commission in this and future investment plans.

25 Recovery Act Announcements, 2009.

Air Quality Improvement Program

The ARB is responsible for administering the AB 118 Air Quality Improvement Program (AQIP) which provides up to $50 million per year for grants to fund clean vehicles and equipment, air quality research, and workforce training. [26]

Both AQIP and the Energy Commission's program were established by the same legislation and provide opportunities for complementary funding strategies. For example, unlike the Energy Commission, ARB cannot fund infrastructure for alternative and renewable fuels. The Energy Commission, therefore, is making significant investments in fueling and electric charging stations and fuel storage facilities.[27] Both agencies can fund vehicle technology development and commercial deployment. The Energy Commission, however, is largely funding the former while ARB is providing incentives for the latter with a focus on electric drive and ZEVs. The Energy Commission is providing vehicle deployment incentives, but only for natural gas and propane vehicles.

As part of the FY 2008-2009 state budget, the Legislature directed that FY 2008-2009 AQIP funds be used for a new ARB Truck Loan Program to assist truckers affected by the ARB regulations adopted in December 2008: the Statewide In-Use Truck and Bus Regulation and the Heavy-Duty Vehicle Greenhouse Gas Emission Reduction Measure. About $35 million is available for this program, which supplements ARB's existing grant incentive programs. Loans will be available for the purchase of new or used trucks, diesel emission control devices, and the United States Environmental Protection Agency (U.S. EPA) SmartWay technologies.[28] ARB's Truck Loan Program is designed to leverage state dollars to maximize funding opportunities and to provide credit access to truckers, so they can take early action in upgrading their fleets. The program was rolled out in the spring of 2010 with loan opportunities for truckers available in the following months.

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26 "AB 118 Air Quality Improvement Program," http://www.arb.ca.gov/msprog/aqip/aqip.htm and http://www.arb.ca.gov/msprog/aqip/meetings/aqip_workshop_presentation_120809.pdf

27 In compliance with governing statutes and regulations adopted by the ARB, projects funded by the ARB or Energy Commission must complement, and not interfere with, efforts to achieve and maintain air quality standards. Additionally, in compliance with regulations adopted by the ARB, the Energy Commission must provide supplemental evaluations of localized health impacts for any projects requiring permits. These evaluations are to ensure that projects funded by the Energy Commission do not result in disproportionate health impacts to communities with low incomes or minority populations. This information will be posted and available for public review at least 30 calendar days before being presented in a publicly noticed meeting. Source: Health and Safety Code, Chapter 8.9, Section 44271(b), and California Code of Regulations, Chapter 8.1, sections 2343 (b)(2) and (c)(c)(a).

28 The 2009-2010 AQIP Funding Plan page 6 explains how FY 2008-09 funds were directed to the truck loan program. ARB did not develop a funding plan for FY 2008-09 due to time constraints. The Legislature codified financial assistance for truck loans in HSC Section 44274.7. The original funding amount was $42 M, but based on revenues generated during that fiscal year, only $35 M was available.

For FY 2009-2010 total AQIP funds of about $30 million[29] are allocated to hybrid truck and bus vouchers ($20.4 million), zero-emission and plug-in hybrid light-duty vehicle rebates ($4.1 million), lawn and garden equipment replacement ($1.6 million), zero-emission agricultural utility terrain vehicle rebates ($1.1 million), and advanced technology demonstrations (about $2 million).

The AQIP 2010-2011 funding plan was adopted in June 2010. The AQIP 2010-2011 plan allocates up to a total of $40 million to: hybrid truck and bus vouchers ($25 million); clean vehicle rebate project ($5 million); lawn and garden equipment replacement ($1 million); zero-emission agricultural utility terrain vehicle rebate project ($0.5 million); off-road hybrid technology pilot ($3 million for this new project); and advanced demonstration projects ($5.5 million).[30]

The Energy Commission will consider supplementing funding for vehicle deployment incentives through the AQIP pending a review of the need for additional funding, and the necessity and sufficiency of the incentives.

Zero Emission Vehicle Regulation

The ZEV regulation was adopted in 1990 as part of the ARB's Low Emission Vehicle Program and has been modified several times since then. It requires large automakers to produce certain percentages of "pure zero" emission and "near-zero" emission vehicles for sale in California. The goal of the ZEV regulation is to meet California's air quality goals and has resulted in the introduction of new vehicle technologies in California. As a result of the ZEV regulation, over 1 million Californians are driving partial zero and advanced technology partial zero-emission vehicles (PZEV and AT PZEV).

Automakers may comply using a variety of different types of ZEVs. While required to produce a minimum number of pure ZEVs, manufacturers can meet their remaining obligation with a variety of vehicle technology options including PZEV (partial or "near zero" ZEVs; advanced gasoline vehicles), AT PZEV (advanced technology PZEV; hybrids, NGVs), and Enhanced AT PZEV (hydrogen internal combustion engines and plug-in hybrid electric). ARB is preparing regulatory changes that move the PZEV and AT PZEV categories from the ZEV program to the Low Emission Vehicle (LEV) and Pavley programs by 2020.[31]

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29 The ARB approved a funding plan for $42.3 million in April 2009 based on funds appropriated in the FY 2009-2010 state budget, however ARB expects about $30 million will be available for AQIP projects based on revised revenue projections.

30 ARB *Proposed AB 118 Air Quality Improvement Program Funding Plan for Fiscal Year 2010-11*, http://arb.ca.gov/msprog/aqip/fundplan/AQIP_FP_JUNE%202010-FINAL.pdf

31 AB 1493 (Pavley, Chapter 200, Statutes of 2002), known as the Pavley Bill, requires the ARB to adopt regulations for the reduction of GHG emissions from motor vehicles. More information is available on the ARB's website: http://www.arb.ca.gov/cc/ccms/ccms.htm.

Zero Emission Bus Regulation

The ARB's Zero Emission Bus (ZEB) regulation was adopted in 2000 as part of the Transit Fleet Rule. It affects only large transit agencies with more than 200 buses and includes a 15 percent fleet ZEB purchase requirement. Ten agencies are affected, with six in Northern California and four in Southern California. Two compliance paths are offered: the diesel path (2011-2026 timeframe for purchase requirement) and the alternative fuel path (2012-2026 time frame for purchase requirement), which includes fuel cell buses and battery-operated buses.

Low Carbon Fuel Standard

Governor Arnold Schwarzenegger established the LCFS by Executive Order S-01-07 in January 2007, and the ARB adopted standards and protocols on April 23, 2009 . The LCFS establishes carbon intensity (grams CO_2e/MI) standards that fuel producers and importers must meet each year beginning in 2011. The 10-year LCFS schedule requires a gradual reduction in average carbon intensity for the first several years, beginning January 1, 2011, then steeper reductions, year-to-year over the remaining years, concluding with a 10 percent carbon intensity reduction by 2020. The LCFS will be reviewed periodically to update advances in low-carbon fuels, production technologies, and full cycle assessments.

Bioenergy Action Plan

On April 25, 2006, Governor Schwarzenegger issued Executive Order S-06-06, which established targets for the use and production of biofuels and biopower and directed state agencies to work together to advance biomass programs in California. The Bioenergy Interagency Working Group is working to meet the goals of the *Bioenenergy Action Plan* (BAP) [32] which include maximizing the contribution of bioenergy toward achieving the state's petroleum reduction, climate change, renewable energy and environmental goals. The Executive Order established targets to increase the production and use of bioenergy, including ethanol and biodiesel fuels from renewable resources. For biofuels, the state's goal is to produce a minimum of 20 percent of its biofuels within California by 2010, 40 percent by 2020, and 75 percent by 2050. Regarding the use of biomass for electricity, the goal is for 20 percent of the state's Renewables Portfolio Standard targets for renewable generation for 2010 and 2020 to be met with biomass resources.[33]

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32 Publication number CEC-600-2006-010, July 2006.

33 The *2010 Bioenergy Action Plan* is under development. Workshops were scheduled for June and September with possible adoption of the *Bioenergy Action Plan* in November 2010.

Renewable Fuel Standard

The Energy Policy Act of 2005 established the federal Renewable Fuel Standard (RFS) Program. The United States Congress gave the U.S. EPA the responsibility to coordinate with the United States Department of Energy (U.S. DOE), the United States Department of Agriculture (USDA), and stakeholders to design and implement the RFS program. With the passage of the Energy Independence and Security Act (EISA) of 2007, Congress made several important revisions to the RFS.

As of January 1, 2010, the new RFS-2 increased the total renewable fuel required to be used as transportation fuel from 9 billion gallons in 2008 to 36 billion gallons by 2022. Of the four standards, the cellulosic biofuel requirement grows most significantly at 100 million gallons in 2010 to 16 billion gallons in 2022, 1 billion gallons more than corn-based ethanol (15 billion gallons that year).[34]

Parties (refiners, importers, and blenders) have minimum yearly calculated volumetric blending obligations that gradually rise between 2009 and 2022. Not surprisingly, the RFS-2 will increase demand for ethanol and biodiesel. Companies can generate Renewable Identification Number (RIN) credits for excess renewable fuel use, which may be purchased or sold for compliance purposes.

National Greenhouse Gas and Corporate Average Fuel Economy Standards for Vehicles

On September 15, 2009, the U.S. EPA and the United States Department of Transportation's (DOT) National Highway Traffic Safety Administration (NHTSA) proposed a historic national program that would dramatically reduce GHG emissions and improve fuel economy for passenger cars, light-duty trucks, and medium-duty passenger vehicles for model years 2012 through 2016.

The combined U.S. EPA and NHTSA standards require these vehicles to meet an estimated combined average emissions level of 250 grams of carbon dioxide (CO_2) per mile, equivalent to 35.5 miles per gallon (MPG) if the automobile industry were to meet this CO_2 level solely through fuel economy improvements.[35] Together, these proposed standards would reduce CO_2 emissions by an estimated 950 million metric tons and 1.8 billion barrels of oil over the lifetime of the vehicles sold under the national program (model years 2012-2016).

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34 The RFS includes four categories including Biomass-Based Diesel, Cellulosic Biofuel, Total Advanced Biofuel and Total Renewable Fuel. RFS eligible corn-based ethanol is the difference between Total Renewable Fuel and the sum of the other three categories. Source: EPA Table "RFS2: 4 Separate STDS."

35 A/C and tailpipe emissions represent an additional potential CO_2 savings of 1 3.5 percent of fuel economy standards.

Under this proposed national program, automakers will be able to build a single light-duty national fleet that satisfies all requirements under both the national program and the standards of California and other states, while ensuring that consumers still have a full range of vehicle choices.[36] Automakers will also be able to earn, trade, and bank credits if their fleet average is better than the standard for that year. Certain vehicle types, including battery electric vehicles, plug-in hybrid electric vehicles, fuel cell vehicles, and (for a limited number of model years) flex-fuel vehicles, will earn additional credits compared to conventional vehicles.

Renewables Portfolio Standard

California's Renewables Portfolio Standard (RPS) was established by Senate Bill 1078 (Sher, Chapter 516, Statutes of 2002), and amended by Senate Bill 107 (Simitian and Perata, Chapter 464, Statutes of 2006) and Senate Bill 1036 (Perata, Chapter 685, Statutes of 2007). It requires electric corporations to increase procurement from eligible renewable energy resources by at least 1 percent of their retail sales annually, until they reach 20 percent by 2010. In Executive Order S-14-08, the Governor established a more aggressive goal of 33 percent by 2020. This higher goal is a key strategy for meeting the state's GHG emission reduction targets[37] and has implications for potential GHG reductions for electric vehicles.

On September 15, 2009, Executive Order S-21-09 ordered that the ARB, under its Assembly Bill 32 (Núñez, Chapter 488, Statutes of 2006) authority, adopt a regulation consistent with the 33 percent renewable energy target by July 31, 2010. The ARB is also directed to work with the California Public Utilities Commission (CPUC), the Energy Commission, and the California Independent System Operator to encourage the creation and use of renewable energy sources built upon the RPS program and may increase the target and accelerate and expand the time frame based on a thorough assessment of relevant factors.[38]

Clean Air Action Plan

On November 20, 2006, the Port of Los Angeles and Port of Long Beach both adopted the San Pedro Bay Ports Clean Air Action Plan (CAAP).[39] The goal of the CAAP is to reduce port-

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36 United States Environmental Protection Agency, "Regulations and Standards," http://www.epa.gov/oms/climate/regulations.htm.

37 Energy Commission, "Renewables Portfolio Standard (RPS) Proceeding – Docket # 03-RPS—1078," http://www.energy.ca.gov/portfolio/, and California Public Utilities Commission, *California Renewables Portfolio Standard*, http://www.cpuc.ca.gov/PUC/energy/Renewables/index.htm.

38 Office of the Governor, "Executive Order S-21-09," http://www.gov.ca.gov/executive-order/13269.

39 Port of Los Angeles, "San Pedro Bay Ports Clean Air Action Plan," http://www.portoflosangeles.org/environment/caap.asp.

related air pollution, including particulate matter, nitrogen oxide, and sulfur oxide, by at least 45 percent by 2012. As part of the CAAP, the ports are implementing a Clean Trucks Program[40] (CTP), which aims to reduce heavy-duty drayage truck-related air pollution by 80 percent by 2012. Part of the CTP requires the scheduled phase-out of trucks that do not meet the 2007 federal emission standards. Beginning January 1, 2010, pre-1994 diesel trucks and certain non-retrofitted 1994-2003 trucks will be banned from use in the ports. About 7,000 drayage trucks in the ports already meet federal emission standards, 1,500 trucks that have received funding were delivered in April 2010, and an additional 500-600 of the 2004-2006 trucks will require replacement by 2012.[41]

Both ports also offer incentives for fleet owners to replace older trucks with newer, cleaner trucks. In particular, the Alternative Fuel Vehicle Funding Program, funded by the ports, the South Coast Air Quality Management District (SCAQMD), and ARB (with Proposition 1B funds), offers $50 million to provide incentives for the purchase of natural gas trucks for use within either of the ports.

40 Port of Los Angeles, "Clean Truck Program," http://www.portoflosangeles.org/ctp/idx_ctp.asp.

41 Energy Commission staff conversation with Thomas Jelenic, March 24, 2010.

CHAPTER 3: Funding Allocation

The sections below describe the state of the technologies and markets for each category of alternative and renewable fuels and vehicles: electric drive, hydrogen, gasoline substitutes, diesel substitutes, natural gas, and propane. It also includes a new category called "Innovative Technologies and Advanced Fuels." The "Market and Program Development" category encompasses workforce development and training, sustainability studies, outreach and marketing, and program analytical and technical support. Based on the current funding landscape, the status of the alternative and renewable fuels and advanced vehicle technologies and markets, and the status of market and program development, the Energy Commission presents the following observations and recommended funding allocations.

Battery Electric Drive

Electric drive (EV) applications include hybrid-electric vehicles (HEV), plug-in hybrid-electric vehicles (PHEV), and battery electric vehicles (BEV) in light-, medium-, and heavy-duty applications.[42] (Plug-in electric vehicles [PEV], as used in this document, include both PHEVs and BEVs, but not HEVs.) In 2008, there were approximately 350,000 light-, medium- and heavy-duty electric drive vehicles registered in California for on-road use. The majority of these EV vehicles were HEVs. Currently, 10 automakers are producing light-duty HEVs, and as many as 110,000 of these vehicles are being added to the market in California each year. Department of Motor Vehicle (DMV) data for 2008 shows less than 15,000 of California's EV vehicles were BEVs, of which approximately 10,000 were low-speed neighborhood electric vehicles (NEVs), a decrease from the more than 23,000 BEVs registered in 2004. There are less than 500 PHEV conversions in the current EV vehicle population. Changes in the 2008 ZEV program encourage the production and deployment of PHEVs by adding a new vehicle category for compliance: Enhanced AT PZEVs, to meet up to 70 percent of the "pure" ZEV requirement in the near-term (2012 to 2014) and up to 50 percent in the medium-term (2015 to 2017). ARB estimates up to 25,000 PHEVs per year will be deployed between 2012 and 2014.[43]

The number of PEVs in California over the next five years is expected to increase substantially, but projections vary significantly as evidenced in Table 4.

42 While fuel cell vehicles (FCVs) also use electric drive, they are not addressed in this section. Refer to the Hydrogen section instead.

43 *2008 Proposed Amendments to the California Zero-Emission Vehicle Program Regulations*, Staff Report, California Air Resources Board, February 8, 2008.

Table 4: Projections of PEV Deployments

	2013	2015	2020
Morgan Stanley		250,000 PHEVs	
Sothern California Edison			576,000 BEVs
Plug in America	47,455 BEVs		
California Electric Transportation Coalition		450,000 BEVs and PHEVs	

On the forefront of the California BEV rollout, Nissan Motor Company has taken over 5,000 reservations for the Nissan Leaf BEV in California, and will likely see that number at least double by the end of the year.[44] By 2011 Nissan could deliver 5,000 to 10,000 electric drive vehicles to California. Tesla Motors will also continue sales of its Roadster and plans to begin production of its four-door Model S sedan at the re-opened New United Motor Manufacturing Inc. (NUMMI) plant in Fremont, California, in 2012. [45] Tesla has delivered over 1,200 Roadsters to customers worldwide, and plans to produce its Model S with an initial 20,000 vehicle production in 2012. Other original equipment manufacturers (OEMs) are preparing for commercial production and sales in California.[46]

Medium- and heavy-duty trucks, buses, and non-road vehicles can saturate market niches earlier than passenger vehicles at a much lower level of manufacturing (3,000 to 5,000 per year) to achieve cost-competitiveness with diesel vehicles. Hybrid electric designs are being offered for sale in limited volumes. Technology improvements and demonstrations will reduce costs and broaden market availability. Also, GHG emissions can be further reduced by introducing alternative and renewable fuels in hybrid-electric truck hybrid applications, demonstrating advanced hydraulic technology, electrifying on-board vehicle accessories, and demonstrating plug-in electric and battery electric trucks.

Installation of electric charge infrastructure will support the anticipated commercialization of electric drive vehicles. Both private and public charge points, along with potential upstream electrical system infrastructure upgrades, will support the widespread use of PEVs. Utilities are developing charging strategies, procedures and special rates that meet the needs of vehicle

44 Source: Tracy Woodard, Nissan (number of reservations as of June 7, 2010.). The reservations are divided among four regions: San Francisco Bay Area (1,900), Los Angeles (1,800), San Diego (1,000), and Sacramento (250).

45 A total of 1,200 Roadsters were sold in 2009 (Source: Tesla CEO Elon. Musk November 8, 2009)

46 General Motors (GM) will deliver 100 Chevrolet Volt vehicles to utilities in 2010. (Source: GM at Los Angeles Auto Show in December 2009.) Fisker Automotive expects to have sales of up to 115,000 vehicles nationwide by 2015.

recharging and grid reliability. Infrastructure equipment will need to be standardized, on and off the vehicle.

Widespread use of electric drive technology may require:

- Consumer acceptance of commercially available light-duty vehicle models.
- Increased manufacturing scale and continued battery research, to bring down the cost per kilowatt hour (kWh) of electric vehicles' batteries.
- Cost-competitive electric vehicles and electric vehicle components, absent subsidies, and accounting for the lower cost of electricity as a fuel.
- Adequate charging infrastructure including residential, workplace, and public access charging.
- Public familiarity with battery recharging and replacement, and vehicle performance.
- Smart charging capability to allow for better load management, reduced "on-peak" generation, and lower infrastructure costs.

Light-Duty Vehicles

Widespread usage of PEVs is an integral component to achieving California's low-carbon transportation goals. Using California's present electricity grid, the full fuel-cycle emissions of BEVs using today's California electricity grid are 65 percent to 70 percent lower than the emissions of conventional gasoline vehicles.[47] As California shifts to an increasingly renewable electricity generation system, BEVs will account for fewer GHG emissions on a full fuel-cycle basis. Full fuel cycle emissions of PHEVs are estimated to be 50 percent lower than conventional gasoline vehicles, depending on the proportion of miles driven in electric mode, which is a function of installed battery capacity and driver behavior.

The benefits of high efficiency, reduced GHG and other criteria emissions, attractive vehicle attributes, and fuel diversity are among the primary motivations for pursuing PEV technology. In addition, state policy including the ZEV mandate is driving the timing of industry investments. The ZEV mandate currently applies only to the six largest automakers: Ford, General Motors (GM), Chrysler, Honda, Nissan, and Toyota. Several OEMs are testing PHEV models, and Toyota's goal is to have a Prius PHEV on sale for retail consumers by 2011.[48] In addition, 8 other existing automakers and 15 start-up companies plan to release PEVs during this time frame.

Under the ARRA, Ford received $5.9 billion in loans from the U.S. DOE to help it retool its plants to produce 13 fuel-efficient models, including as many as 10,000 EVs per year beginning

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47 ARB, "Low Carbon Fuel Standard Program," http://www.arb.ca.gov/fuels/lcfs/lcfs.htm.

48 Jeffrey Ross, "Toyota Releases Details on Toyota Prius PHEV" http://www.autotropolis.com/autotropolis-columns/car-tech/toyota-releases-details-on-toyota-prius-phev.html.

in 2011. Nissan received $1.6 billion in loans to retool its Tennessee plant to make EVs.[49] In August 2009, Ford, GM, Chrysler, and others received $2.4 billion in federal grants to encourage the development of HEVs and PEVs. The grants include $1.5 billion for battery makers, $500 million for companies developing electric motors and drive components, and $400 million to test a recharging system for electric cars.

A main barrier to penetration of light-duty PEVs is vehicle purchase price, mostly due to high battery cost. Several California battery manufacturers are pursuing advances in battery technology to make them with lower costs, lighter in weight, and with higher energy densities that can provide longer range driving. Among other approaches, nanotechnology is being applied to develop high-energy-density lithium-ion batteries.[50] Charging costs are expected to be less in comparison to most internal combustion vehicles operating on gasoline. The cost of electricity as a fuel is typically 70 percent to 80 percent below the cost of gasoline per mile traveled.[51] However, battery replacement costs may offset some of these savings.

For consumers unfamiliar with BEV technology, the location of chargers, implications of limited driving range, and battery replacement cost will also be primary areas of concern. Accordingly, consumer education will be essential to familiarizing consumers with EV technology.

The federal tax rebate of up to $7,500 and the AQIP rebate of up to $5,000 for PEVs will both help to encourage and accelerate the deployment of zero-emission vehicles in California. Single-occupant access to the high-occupancy vehicle (HOV) lanes also provides a desirable incentive for BEVs.

The ARB, through its AQIP, is providing $4.1 million in its 2009-2010 funding plan as purchase incentives for PEVs on a "first-come, first-served" basis. The 2010-2011 funding plan provides up to $5 million for this category. Therefore, the Energy Commission is not proposing to provide incentives in this *2010-2011 Investment Plan*, but will continue to provide for vehicle charging infrastructure as described below.

Medium- and Heavy-Duty Vehicles

There are nearly 1 million medium- and heavy-duty vehicles registered in California on the road and a half-million registered in other states that are operating in California.[52] Hybrid-electric and hydraulic-hybrid technologies on medium- and heavy-duty vehicles can potentially reduce GHG emissions 60 percent on a full fuel-cycle basis compared to conventional diesel

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49 The 1.3 million square foot battery manufacturing facility will be capable of producing 200,000 advanced-technology batteries annually. The adjacent vehicle assembly plant, which will produce the Nissan LEAF, will be capable of producing 150,000 cars annually. Source: www.nissanusa.com/leaf-electric-car.

50 The 2009 R&D 100 award given to Envia Systems and Argonne National Laboratory for highest energy and cycle life of all lithium-ion battery systems available in the market for electric vehicles.

51 *State Alternative Fuels Plan*, Final Adopted Report, CEC-600-2007-011-CMF, December 2007.

52 DMV data.

vehicles. Hybrid electric trucks use the engine to recharge the batteries, which assists the engine and auxiliary functions. Hydraulic-hybrids use a hydraulic pump and motor to capture regenerative braking and offer a power boost to the engine and auxiliary functions. Refuse trucks, drayage trucks, package delivery vans, utility trucks, transit and school buses, and harbor craft are the most practical applications due to their unique duty cycles. Deeper emissions and petroleum reductions can be achieved by combining PHEV technology with alternative and renewable fuel engines.

Presently, fewer than 600 commercial hybrid trucks are on the road today. However, at least 15 companies are developing hybrid-electric technologies, and at least four companies are developing hydraulic-hybrid technologies. The primary obstacle facing this industry is the high incremental cost of the trucks. The incremental costs for medium- and heavy-duty HEV trucks in the ARB's Hybrid Truck and Bus Voucher Incentive Program (HVIP) range from $20,000 for trucks 8,500 to 10,000 lbs. to $70,000 for trucks over 38,000 lbs.[53] To facilitate commercial market introduction, next generation plug-in hybrid and battery electric trucks will benefit from continuing proof-of-concept demonstrations.

ARRA funded 2,576 HEVs and 100 BEVs for demonstration in the medium- and heavy-duty vehicle classes nationwide. The funding will evaluate technical feasibility and build customer familiarity through a nationwide demonstration.

The Energy Commission and ARB are coordinating the use of their respective AB 118 funds for the development and deployment of advanced on-road medium- and heavy-duty vehicles. The ARB has allocated $20.4 million for FY 2009-2010 for a voucher program that will provide incentives for the purchase of commercially available medium- and heavy-duty vehicles. The ARB is also providing up to $25 million for this category for FY 2010-2011 in its AQIP Funding Plan.

The Energy Commission's funds will be used to demonstrate technology advancements in medium- and heavy-duty BEV and PHEV vehicles as well as hybrid-electric, hydraulic-hybrid and fuel cell applications. Under the FY 2008-2010 investment plan, program funds will match ARRA funding to provide a demonstration of 123 medium-duty PHEVs, primarily in Central and Southern California. Additionally, the Energy Commission, based on a solicitation from November 2009 (PON-09-004), will fund the following projects for advanced medium- and heavy- duty vehicle development and demonstration.

53 Joe Calavita, Air Resources Board, electronic communication, April 29, 2010. The HVIP will be administered and implemented by a partnership between ARB and CALSTART; updates on the HVIP implementation manual are available at http://www.arb.ca.gov/msprog/aqip/hvip.htm.

Table 5: Medium- and Heavy-Duty Hybrid and Electric Vehicle Projects Funded by the Program

Solicitation	Project Description	Proposed Award
PON-08-010	Medium-duty PHEV commercial fleet demonstration and evaluation	$5,000,000
PON-09-004	Commercial truck platform demonstration, incorporating a natural gas engine and hybrid electric drive	$2,100,000
PON-09-004	Hydraulic-hybrid drivetrain implementation in delivery trucks	$750,000
PON-09-004	Demonstration of a truck with a Class 8 hybrid electric system and intercooled recuperated 350 kW microturbine	$1,458,735
PON-09-004	Battery-electric bus demonstration	$888,595
PON-09-004	Class 4 electric vehicle demonstration	$1,345,552
PON-09-004	Hybridization of utility service vehicles demonstration	$494,678
PON-09-004	Design, develop and deploy a range-extended electric vehicle powertrain for medium-duty truck applications	$1,153,053
Total		**$13,190,613**

Source: California Energy Commission

In addition to these projects, the Energy Commission will fund up to $7 million for an advanced medium- and heavy-duty vehicle Center of Excellence. The center, in close partnership with the Energy Commission, will serve as a central entity to identify strategic opportunities to develop and demonstrate advanced technologies and fuels, as well as plan, coordinate, evaluate, fund, and manage projects in California to accelerate the introduction of a broad array of advanced vehicle technologies and fuels across all sectors of the medium- and heavy-duty market.

Electricity also has the potential to displace diesel fuel and reduce criteria and GHG emissions in a number of non-road markets including forklifts,[54] truck refrigeration and auxiliary power units, port cold ironing, and truck-stop electrification (TSE). Electrifying truck engines and non-road applications offers significant criteria pollutant and GHG emission reduction benefits, as well as fuel savings and other efficiency improvements.[55] However, the high upfront capital costs to purchase and install equipment inhibit the widespread adoption of these technologies.

ARRA funding provided more than $22 million for 50 TSE projects outside California, expanding the network of TSE availability for the more than 76,000 long-haul trucks that travel

54 The Energy Commission is using both indoor and outdoor BEV forklifts within this context.

55 California Energy Commission. *2009 Integrated Energy Policy Report.* CEC-100-2009-003-CMF. December 2009. http://www.energy.ca.gov/2009_energypolicy/index.html.

into and throughout California. In 2006, California had seven truck stops that featured TSE infrastructure and services. However, California has more than 300 truck stop sites and 20,000 truck parking spots that are candidates to switch to TSE and use electricity instead of fuel burning auxiliary power units for cabin power. TSE costs about $10,000 per parking stall.

Technology improvements and demonstrations of on-road and non-road medium- and heavy-duty vehicles will reduce manufacturing costs, broaden market availability and significantly reduce GHG emissions. To provide for ongoing demonstrations of on-road and non-road medium- and heavy-duty vehicle technology advancements, the Energy Commission will allocate $14 million in grants and loans in this *2010-2011 Investment Plan*.[56]

Charging Infrastructure

Installation and upgrades of electric charging infrastructure will need to keep up with the expected roll-out of PEVs. California currently has 413 stations with 1,300 public access electric charge points. [57, 58] A charging point consists of a single charge outlet, while a charging site (or station) may offer multiple charging points. While this existing network of public access charge points is important for the legacy fleet of PEVs, some of these stations will need to be upgraded to include Society of Automotive Engineers (SAE) J1772-compliant connectors to charge new PEVs. In addition, a larger, more strategic network of new electric charging stations will be needed to support the number of new PEVs expected to be introduced into the market over the next few years. This will include charging infrastructure for single- and multi-family residences, business and municipal fleets, commuter corridor locations, and charge points for medium-duty and heavy-duty electric trucks and transit buses.

There are three voltage levels for recharging PEVs: Level 1 is ordinary household current at 120 volts; Level 2, at 240 volts, is used in residences for washers and dryers, although some older homes do not have adequate Level 2 wiring; and Level 3 direct current (DC) charging, at 360 volts, is rarely found in residences, but is necessary for quick charges. For the Nissan Leaf with a 100-mile range (24 kWh battery pack), recharging at Level 1 (110 volts at 15 amperes [amps]) provides only 4 to 5 miles of range per hour of charging.[59] Level 2 (220 volts at 40-60 amps) recharging provides 12 to 15 miles of range per hour of charging. A Level 3 DC charging system (360 volts at 100 amps) recharge provides 80 miles of range with one hour of charging.[60]

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56 This includes vehicles that utilize the following technologies: battery electric, hydrogen fuel cell, hydrogen internal combustion and other advanced technologies.

57 Alternative Fuels & Advanced Vehicle Data Center, *Electric Fueling Stations in California*, http://www.afdc.energy.gov/afdc/progs/ind_state.php/CA/ELEC.

58 *EV Charger News*, http://www.evchargernews.com.

59 All Cars Electric. *2011 Nissan Leaf: Batteries*. http://www.allcarselectric.com/blog/1033848_2011-nissan-leaf-batteries

60 Presentation to the Energy Commission staff by Nissan, June 3, 2010.

The average cost for Level 2 residential infrastructure "smart charging" equipment is approximately $4,066[61] depending on a variety of cost drivers.[62] The total installed average cost of a residential charger is approximately $5,789, accounting for expenses such as charging equipment, installation labor, permits, materials, freight and taxes. [63] Certain cost drivers such as a new panel upgrade may increase the installation cost by an average of 50 percent.[64] Consumers who purchase residential charging equipment may receive a tax credit of up to $2,000 for charging equipment placed into service through December 31, 2010. The average cost for Level 2 commercial charging equipment is $4,066. The total average installed cost of Level 2 commercial charging infrastructure is about $7,112.[65] A federal tax credit of up to 50 percent of the cost of commercial charging equipment placed in service after January 1, 2009, (not to exceed $50,000) will also be available through the end of 2010. Credits may apply to each location for multiple sites. The primary installation cost drivers are panel upgrades, length of conduit, panel size, whether the location is detached or not, wall versus pedestal charger, extent of special work such as trenching and pouring, and time-of-use meter costs.[66] According to some OEMs an ideal residential consumer rebate would be $500 to $1,000 for installation.[67]

Residential charging has the significant benefit of encouraging charging during periods of off-peak electrical demand. However, a complete charging network will require access to both residential and non-residential charging. Level 2 public access and commercial sites would provide vehicle owners the opportunity to extend their range by charging while the vehicle is parked at work or commercial lots. Level 3 charging sites can relieve drivers of range anxiety on longer trips and provide quick charging capability on freeway corridors between major metropolitan areas.

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61 Energy Commission estimate based on budget numbers in EV proposals from PON-08-10 and PON-09-06.

62 Cost drivers include panel upgrades, conduit length, panel size, attached vs. detached garage, indoor vs. outdoor installation, wall vs. pedestal mounted chargers, special work such as coring, boring and trenching, and time-of-use meter. (Clean Fuel Connection, Presentation at Plug-In 2010 Conference 7/28/10)

63 Enid Joffe, Clean Fuel Connections, (Presentation at Plug-In 2010 Conference 7/28/10). Clean Fuel Connection's 2009 survey data indicates an average residential installation cost of $1,723 ($964 for labor, $550 for materials, $155 for permits and $54 for tax on materials).

64 Average cost of an installation requiring a new panel is $2,685 compared to $1,793. (Clean Fuel Connection, Presentation at Plug-In 2010 Conference 7/28/10)

65 Energy Commission estimate based on EV proposal budgets from PON-08-10 and PON-09-06. The average cost for installation for commercial chargers is $3,046.

66 Cal ETC, submitted to docket 09-ALT-1, May 25, 2010.

67 Alex Keros, General Motors, CPUC/CEC/ARB Joint Agency Workshop on Alternative-Fueled Vehicle Rulemaking 3/16/10.

Public access and commercial charging, however, will increase the demand for electricity during peak periods. The addition of "smart" components to the charging equipment will coordinate the vehicle's charging and user preferences with the needs of the power grid. Smart chargers will ensure utilities can measure and control charging and optimize electricity transmission and distribution. Users may receive a lower rate for charging if the utility is allowed to control the timing of the charging to maximize benefits to the grid.[68] Additionally, impacts to the grid can be mitigated by offsetting the increased demand for electricity by improving local energy efficiency and/or installing photovoltaic systems.

The CPUC is required to evaluate and implement policies relating to PEVs and adopt rules by January 1, 2011.[69] On August 20, 2009, the CPUC filed an Order Instituting Rulemaking. The rulemaking will "consider tariffs, infrastructure and policies needed for California investor-owned electric utilities to ready the electricity system in a consistent, near-term manner for the projected statewide market growth of light-duty electric vehicles throughout California."[70] Similarly, electrical utilities have already begun to anticipate the needs and impacts of PEVs on the grid. Each investor-owned electric utility and some municipal electric utilities already offer special time-of-use rates for customers who purchase a PEV. This reduced off-peak rate incentivizes customers to recharge during off-peak hours, when excess generation and transmission capacity (and renewable wind capacity in particular) is available.[71]

Beyond potential electrical grid issues, the permitting, installation, and inspection of residential charging stations need to be seamless. This process will vary for each community and for each installation, but on the whole, it is complex, costly, and protracted. For example, the average residential installation time between ordering and installing charging equipment is over four weeks.[72] Although the actual charging panels may take a few hours to install, the entire process depends on a series of site visits including the utility company, licensed electrician, city permitting office, and city building inspector. It is common for delays to occur between steps, increasing installation time from a few days to several weeks. Other states and cities are adopting strategies to minimize the time needed for permitting. For example, New York City

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68 For more information on metering issues, see the CPUC's Alternative Fuel Vehicle Proceeding (R.09-08-009) at: http://www.cpuc.ca.gov/PUC/hottopics/1Energy/090814_ev.htm

69 SB 626 (Kehoe, Chapter 355, Statutes of 2009)

70 CPUC, Order Instituting Rulemaking to Consider Alternative-Fueled Vehicle Tariffs, Infrastructure and Policies to Support California's Greenhouse Gas Emissions Reductions Goals. http://docs.cpuc.ca.gov/word_pdf/FINAL_DECISION/106042.pdf.

71 E-mail from Matthew Crosby, CPUC, June 15, 2010.

72 Enid Joffe. Clean Fuel Connection, CPUC/CEC/ARB Joint Agency Workshop on Alternative-Fueled Vehicle Rulemaking, March 16, 2010.

does not require inspections under its electrical code, which uses a "permit for minor electrical work" for the installation of electrical circuits for residential charging.[73]

The OEMs are very interested in simplifying and streamlining this process and recommend a national installation process.[74] Local government jurisdictions often lack knowledge about the permitting process for vehicle charging, and many permit and inspection offices face workforce reductions due to declining budgets, thus exasperating the problem of timely permitting.[75] Additionally, potential PEV owners will need assistance in determining the electrical suitability of their residence or commercial structure to accommodate the installation of a charging system. To facilitate the rollout of electric vehicles in the next few years, these complex installation challenges must be addressed.

Another option to accommodate charging needs is the battery switch station (BSS), where a discharged battery pack is replaced with a fully charged battery pack. BSS enables third-party battery ownership, ease of battery replacement for servicing, and use in secondary applications. Since most charging will be done at home, work, and in public spaces, BSS deployment is not required on the same scale as the current gasoline infrastructure. High-mileage fleets such as taxicabs could use BSS within and between cities. BSS deployment, similar to natural gas station deployment, could initially follow major freeway corridors. At this time, however, the Energy Commission does not propose funding for battery swap stations due to a lack of vehicle manufacturer support.

Determining the number of charging sites needed to accommodate even the initial roll out of PEVs requires an understanding of both the number of vehicles expected over the coming years and the appropriate balance between residential charging and public charging requirements. In the case of the PEV market, estimating either these parameters is inherently uncertain and speculative. However, some initial work on these issues is already underway.

Projections of how many PEVs will be on the road even in the near term is limited. Nissan estimates the number of their PEV deployments to be 1,000 in Los Angeles, 1,000 in San Diego, 1,300 in the Bay Area and 250 in Sacramento by 2011. GM expects over 1,000 Chevy Volt extended range EVs in the Bay Area by the end of 2011. In addition, Toyota, Chrysler, Mitsubishi, Fisker, Ford, and Tesla will be entering the market in the following years, but no public estimates are available.

Charging infrastructure deployment also needs to consider an "appropriate" number of public and workplace charging stations to encourage public adoption of PEVs and support the

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73 Title 27, Chapter 3 Electrical Code of the New York City Electrical Code, Electrical Permit Application ED-16A.

74 Alex Keros, General Motors, CPUC/CEC/ARB Joint Agency Workshop on Alternative-Fueled Vehicle Rulemaking, March 16, 2010.

75 Bob Hayden, City of San Francisco, CPUC/CEC/ARB Joint Agency Workshop on Alternative-Fueled Vehicle Rulemaking, March 16, 2010.

development of a competitive market for public charging services. Until PEVs gain some level of market share, private sector investments in public charging will be quite limited due to the uncertainties of utilization and revenue potential. For example, the CPUC estimates that one home charging and 0.5 public charging capacity is needed for each vehicle. However, with 75 percent to 90 percent of the charging occurring at home, each public charger will average only 30 to 72 minutes of use per day. These charging levels are unlikely to be profitable for private financing.[76] Nissan, Ford, GM and Chrysler similarly estimate that there is a need for one home charger and 0.3 public chargers per vehicle.

The Energy Commission's role in nurturing the development of the nascent EV industry is important. If the projections of EV deployment shown in Table 4 are realized, however, the investment needed to keep pace with infrastructure demand will far exceed the Energy Commission's available funds. Consideration will need to be given for a business case for EV charging infrastructure, especially for public charging.

To facilitate the development of EV infrastructure throughout the state, organizations such as "Ready, Set, Charge!" are beginning to coordinate efforts between EV regional areas. "Ready, Set, Charge!" is convening representatives of utilities, auto and electric vehicle supply equipment (EVSE) OEM's, regional and local governments, and EV organizations to develop statewide solutions to EV infrastructure challenges such as installation process streamlining and consumer awareness.[77] This will link EV infrastructure development efforts in the metropolitan regions of Los Angeles, San Diego, the Central Coast, the Bay Area, and the Sacramento area.

Although some challenges remain, charging infrastructure is needed as PEVs are expected to begin market introduction in 2010 and 2011 timeframe. The Energy Commission has awarded approximately $15.3 million for electric charging infrastructure projects that was allocated in the first investment plan. This funding will allow the upgrade of existing charging sites and installation of electric charging stations in all major metropolitan areas where PEVs are expected to be initially introduced by the automakers. Table 6 provides a summary description of these projects.

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76 CPUC, Preliminary Staff response to PEV charging criteria questions, June 14 2010

77 "Ready, Set, Charge California!" A Statewide Action Plan to Support Regional EV Readiness, May 11, 2010, Co-Sponsors: Electric Power Research Institute (EPRI), Clean Fuel Connections, EV Communities Alliance, GM.

Table 6: EV Infrastructure Projects Funded by the Program

Solicitation	Project Description	Proposed Award
PON-08-010	Nissan and Electric Transportation Engineering Corporation will deploy 1,000 BEVs in San Diego and install up to 1,000 Level 2 residential chargers, up to 1,300 Level 2 commercial chargers, and up to 60 Level 3 fast chargers in San Diego and the adjacent transportation corridor.	$8,000,000
PON-08-010	Coulomb Technologies, Clean Fuel Connection, and California Car Initiative will install 1,290 networked EV charging stations in San Francisco, Sacramento, and Los Angeles. Coulomb's chargers will have smart grid capabilities, as well as Web services to enable drivers to find available stations.	$3,417,000
PON-08-010	The Sacramento Municipal Utility District will demonstrate and test 34 Chevrolet Volt PHEVs in their fleet applications and install Level 3 DC chargers at SMUD's facility. The chargers will be integrated with SMUD's Advanced Metering Infrastructure system to collect data on electrical grid impacts and charging time.	$553,000
PON-08-010	The Sacramento Municipal Utility District will demonstrate and test 20 Chrysler PHEVs in their fleet applications and install Level 3 DC chargers at SMUD's facility. The chargers will be integrated with SMUD's Advanced Metering Infrastructure system to collect data on electrical grid impacts and charging time.	$100,000
PON-09-006	Clipper Creek will update 635 existing chargers statewide to the SAE-J1772 standard and install meters, as directed by the local utility, so that usage can be monitored and eventually coordinated with the local utility.	$1,900,000

PON-09-006	Foothill Transit will build two quick-charge stations for up to 12 electric buses that will have the capacity to recharge a battery from 10 percent to 95 percent in 10 minutes or less. The project will provide information on battery life and performance.	$200,000
PON-09-006	Los Angeles County Metropolitan Transportation Authority will install 15 new chargers and upgrade 5 existing chargers at end-of-the-line parking lots.	$415,185
PON-09-006	City of Reedley will install three charging stations as part of a Central Valley Transportation Center. The center will include a learning center and education center component to train current and future vehicle technicians on the latest technologies.	$180,400
PON-09-006	The Association of Bay Area Governments will install 135 charging stations as part of the Bay Area EV Corridor Project.	$504,415
Total		**$15,270,000**

Source: California Energy Commission

California currently has 1,300 public charge points. In the above projects, the Energy Commission is funding more than 4,000 residential charging installations and public charge points. The deployment of new charging stations funded by the Energy Commission is being done in coordination with regionally based plans and will include advanced smart grid technologies.

The Energy Commission also funds the PHEV and BEV Research Center at the UC Davis Institute of Transportation Studies. The center will study consumer behavior and grid-connected vehicles, ways to restructure the cost of automotive batteries, and the optimal interaction between plug-in vehicles and smart grid systems.[78] The Energy Commission also will engage stakeholders in a broader effort to prepare a statewide plan to ensure that charging infrastructure issues are addressed in a consistent manner from region to region and to guide the magnitude and geographic distribution of program funds.

The Energy Commission proposes $3 million in grants and loans in this investment plan to fund home charging, public charging, and a range of issues related to electric vehicle community readiness including education, workforce training and staffing of local government entities, and strategic planning for the establishment of electric vehicle infrastructure in California. Given a ratio of 1 home charger and 0.3 public chargers for each PEV, this amount will be expected to

78 For more information, refer to the center's website, http://phev.its.ucdavis.edu/.

provide the necessary charging support for 1,136 new PEVs.[79] This allocation is very conservative in comparison to anticipated vehicle deployments, and may need to be adjusted in the future.

Battery Reuse

Battery reuse occurs when an electric vehicle's battery is removed and repurposed for a second application after its retirement from the vehicle. To accelerate the implementation of PHEVs or BEVs, and to promote the growth of the battery market, the Energy Commission's Public Interest Energy Research (PIER) Transportation Program Area is identifying and evaluating potential reuse strategies for vehicle traction batteries, known as "Battery Second Use."

Several strategies discussed in a recent PIER paper could hasten the early commercialization of electric vehicles in California.[80] They include: battery downsizing, standardization, and leasing, with shortened initial vehicle deployment and repurposing/downcycling into stationary use for grid-support services. These strategies, based on minimizing the battery size and cost by re-defining "battery life," combined with strategies for capturing later-stage battery value in stationary applications, can help to reduce the estimated initial lease prices of new plug-in vehicle batteries. Electric utilities may value repurposed vehicle batteries as storage devices for nighttime power from renewables and delivery devices for peak needs, especially if such devices help to avoid building new power plants. Post-vehicle, stationary "battery-to-grid" (B2G) applications can also provide meter benefits for customers, offer demand-response services, improve utility operation, help defer costly grid upgrades, and support the profitability and penetration of wind power and other carbon-reduction measures.

PIER Transportation, working with the UC Davis Plug-In Hybrid and Electric Vehicle Research Center, is advancing battery recycling within the Second Life Applications and Value of "Traction" Lithium Batteries request for proposals (RFP), which will include actual and simulated transactions between a household energy storage appliance (HESA) and the electricity system using real or proposed smart grid protocols. The center recently solicited the RFP to research possible second use applications and requirements for used automotive lithium-ion batteries. Applications that can use transportation batteries in complementary or secondary applications may help to build the market for automotive lithium batteries and extend the usable life and value of the batteries.

Manufacturing

Encouraging manufacturers of PEVs and their components to locate or expand their operations in California has the potential to create several thousand green jobs and substantial benefits to

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79 These estimates are based on an estimated cost of $5,789 per residential charger and $7,112 per public charger. They also assume a federal tax credit of 50 percent, and Energy Commission coverage of 50 percent of the remaining cost.

80 Williams, Brett D, and Timothy E. Lipman. 2010. *Strategies for Transportation Electric Fuel Implementation in California: Overcoming Battery First-Cost Hurdles*. California Energy Commission, PIER Transportation Program Area. CEC-500-2009-091.

the state's economy. For example, at its peak production before it closed the NUMMI plant in Fremont, California, employed 4,500 high-skilled laborers and up to 35,000 supply chain workers in a joint venture between GM and Toyota. In a recent announcement, Toyota said it will partner with Tesla Motors Inc. to develop and build electric cars at the plant in Fremont. The long-term job growth potential is up to 10,000 jobs between suppliers and factory workers.[81]

Several California manufacturers produce batteries and component parts for automakers, components for the electronics industry, and stationary power storage systems for military and industrial customers. In addition, several start-up vehicle manufacturers have emerged in California and begun developing prototype and early market EVs. However, difficulties in raising upfront capital can impede these manufacturers from developing and expanding the plants and assembly lines to make advanced EV components and produce electric and alternative fuel vehicles for commercial sales.[82]

Under the FY 2008-2010 program funding, the Energy Commission will award $19 million for a combination of grants for pre-development stages of manufacturing plants and loans to help finance assembly and production plants that make vehicles, batteries, electric propulsion systems, and other components in California. This solicitation would encourage investment in California-based manufacturing and assembly plants that produce alternative fuel vehicles and components that help the state meet its GHG emissions and petroleum fuel demand reduction targets. The Energy Commission will collaborate with the CAEATFA to establish loan mechanisms and facilitate sales tax exemptions for the purchase of equipment to manufacture ZEVs. The Energy Commission is reviewing proposals to cost-share the development and expansion of manufacturing and assembly plants in California that produce electric vehicles, alternative fuel vehicles, and batteries and component parts for electric vehicles, including other alternative fuel vehicles.[83]

California utilities estimate that California will represent 25 percent of the national purchases of light-, medium-, and heavy-duty EVs. As a result of the ARRA solicitation process and follow up interviews with stakeholders, the Energy Commission intends to provide manufacturing incentives of $7.5 million in the form of grants and loans. This will ensure that California manufacturers are established to fulfill demand from California customers seeking electric drive vehicles. California will benefit economically from the local production of vehicles and components. This funding will likely result in 20,000 to 30,000 California-manufactured PEVs

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81 "Toyota to Invest $50 million in Tesla Electric Car Plant," *Sacramento Bee*, May 20, 2010.

82 Although the U.S. DOE awarded nearly $1.7 billion nationwide for vehicle and battery manufacturing incentives, no California firm was selected for federal ARRA economic stimulus funding during 2009. However, the ARRA funds that were awarded nationwide will still have a large impact on the nation's ability to manufacture electric vehicles and components and will in turn impact California's market for electric drive vehicles.

83 As part of its earlier ARRA cost-sharing solicitation, the Energy Commission is providing $1 million toward a project to develop advanced anodes and cathodes that will increase the energy density of lithium-ion batteries.

sold per year within five years. Additionally, by 2014 battery sales will likely reach 100,000 per year within California primarily for medium-duty and heavy-duty auxiliary power units. At these levels it is expected that battery cost will drop by up to 50 percent from current market rates, thereby increasing the competitiveness of PEVs compared to conventional vehicles. Repayments from revolving loans could reduce the need for annual allocations, and within five years, the need for manufacturing incentives could be eliminated, reduced, or based only on loans and loan guarantees. Conversely, if California incentives are not provided in the near term, customer demand will be met by products manufactured primarily outside California. [84]

Table 7: Battery Electric Drive Funding Summary for FY 2010-2011

Develop and demonstrate advanced on-road and non-road medium- and heavy-duty vehicles	$14 Million
Infrastructure and related activities	$3 Million
Manufacturing facilities and equipment	$7.5 Million
Total	$24.5 Million

Source: California Energy Commission

84 All data in this paragraph was taken from the Energy Commission Electric Drive Workshop, and debriefing meetings with applicants after the ARRA solicitations. The Energy Commission staff hosted all meetings.

Hydrogen Electric Drive

Hydrogen fuel cell vehicles (FCVs) generate electricity through an electrochemical process, using hydrogen as the fuel, to generate electricity to power an electric motor, which drives the vehicle. When the hydrogen is converted to electricity in a fuel cell, the only by-products at the vehicle are heat and water.

Hydrogen can be derived from a number of sources, including natural gas, biomass, and renewable energy. Currently, the vast majority of hydrogen is produced through the reformation of natural gas. Hydrogen produced in this manner and used in an FCV can reduce GHG emissions by 56 percent and petroleum consumption by 99.7 percent[85] when compared to California's reformed gasoline used in a conventional vehicle.

Hydrogen vehicles are expected to play a modest but important role in meeting the state's 2020 GHG emission reduction goal, but will be a more significant factor in meeting the state's 2050 goal. Today, although it is commonly used for industrial processes, very little hydrogen is produced for use as a vehicle fuel. Early FCV deployments by automakers, coupled with strategic investments in hydrogen fueling infrastructure, are necessary steps in supporting early commercialization. The ZEV and ZEB programs administered by the ARB also promote the adoption of hydrogen technologies in the marketplace. These efforts will demonstrate the market readiness of the technology, and will also lead to significant cost reductions as economies of scale are realized. The use of renewable sources of hydrogen such as biomass and biomethane will further reduce the life-cycle GHG emissions.

Senate Bill (SB) 1505 (Lowenthal, Chapter 877, Statutes of 2006) requires that, on a statewide basis, no less than 33.3 percent of the hydrogen produced for, or dispensed by, fueling stations that receive state funds be made from renewable energy resources. The ARB is developing regulations to clarify elements of SB 1505 for a possible October 2010 adoption.

During the transition to a commercial market, government and private investments in hydrogen fueling infrastructure will be essential to complement the roll-out of light-duty and transit FCVs. These investments will be needed to establish strategically located hydrogen fueling stations that will fuel the early FCVs. While hydrogen is expected to become cost-competitive with gasoline on a per-mile basis when serving large numbers of vehicles, early infrastructure will benefit from a balance of government incentives and regulatory approaches. To maximize customer convenience and leverage private funds, the infrastructure should be supplemented by strategic, retail-oriented placement (market development) and co-funding of these initial stations. A focused and disciplined method is needed that includes all available "tools" for leveraging funds (such as public-private partnerships, joint ventures, "anchor" stations in cluster communities,[86] co-locating of fueling with CNG/other alternative fuels). A

85 *State Alternative Fuels Plan*, Final Report. December 2007. CEC-600-2007-011-CMF. See Table 3.19.

86 Cluster areas in Northern California include Sacramento and the Bay Area. Clusters in Southern California include Santa Monica, Torrance, Irvine, Newport Beach. These early-adopter areas are

crucial element of this effective strategy is to combine high-volume fuel use with multiple users to help create the best business case and stimulate station owners/operators to co-invest. This also enables the stations' ongoing future operation.

The ARB is evaluating a number of approaches to provide policy incentives to energy companies who invest in ultra-low-carbon fuels including hydrogen. This includes, for example, the use of credit multipliers under the LCFS or the Clean Fuels Outlet as part of the ZEV program. On December 10, 2009, the ARB directed staff to investigate the potential for these mechanisms. Decisions on any proposed changes are expected in late 2010. These regulatory tools have the potential to create a clear business model for private investment in hydrogen infrastructure as vehicle numbers grow.[87]

Lastly, to establish hydrogen fuel as a commercial option in the future, a regulatory standard for retail dispensing of hydrogen is necessary to enable hydrogen to be sold in California on a per-unit retail basis. Under an interagency agreement with the Energy Commission, the California Department of Food and Agriculture's (CDFA) Division of Weights and Measurement Standards (DMS) will undertake the steps necessary to create such a standard.

Light-Duty Vehicles

The benefits of high efficiency, reduced GHG and other criteria emissions, fuel diversity, and attractive vehicle attributes are the primary motivations for automakers pursuing fuel cell and other electric drive vehicle technologies. In addition, state policy including the ZEV mandate is driving the timing of industry investments. (See Appendix B for a detailed description of the ZEV program.) While the volumes are currently low, FCVs are expected to move from the current demonstration stage to early commercial volumes within the next decade. Table 8 shows the range of numbers of vehicles that the ARB estimates could be rolled out under ZEV compliance options and under the LCFS base case scenario.

Table 8: FCV and ZEV Deployment Estimated Ranges (ZEV Mandate Requirements)

	2010-11	2012-14	2015-17
"Gold" FCVs (ZEV compliance)	0 to 250	0 to 5,357	0 to 25,000
"Gold" ZEV (Total FCV & BEV)	0	0 to 25,000	0 to 50,000
FCV (LCFS base case scenario)	0 to 1,400	0 to 9,000	0 to 45,000

Source: California Energy Commission

identified by UC studies and according to the California Fuel Cell Partnership's 2009 Action Plan http://www.cafcp.org/sites/files/Action%20Plan%20FINAL.pdf.

87 Ogden, Joan et al. *Roadmap for Hydrogen and Fuel Cell Vehicles in California: A Transition Strategy Through 2017*. Institute of Transportation Studies, University of California, Davis. December 21, 2009.

In early 2009, the California Fuel Cell Partnership (CaFCP) prepared its first action plan to develop a commercial market for FCVs in California by 2015.[88] The plan contained a survey of automakers conducted in late 2008 to determine timing and location of their deployment of FCVs in California. Both the action plan and survey have since been updated.[89] The first line in Table 9 shows the estimated FCV deployment according to the CaFCP's more recent voluntary survey. The second line in Table 9 shows the results of an Energy Commission/ARB joint survey of automakers' written FCV deployment commitments.[90]

Table 9: Estimates of OEM Vehicle Deployment Numbers (Cumulative)

	2009	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**…**	**2018**
CaFCP December 2009 Survey				450			4,200		53,907
	2009	**2010**	**2011**	**2012**	**2013**	**2014**	**…**	**2017**	**…**
Energy Commission/ARB November 2009 Survey	93	192	330	495	769	1,839		47,809	

Source: California Energy Commission, CaFCP

Table 10 provides anticipated FCV deployment by major metropolitan areas, as identified in the Energy Commission/ARB joint survey. As demonstrated, the vast majority of these vehicles will be deployed in the identified cluster communities. It is also apparent, however, that OEMs have an interest in expanding vehicle placements into non-cluster areas in the future.

88 CaFCP, *Hydrogen Fuel Cell Vehicle and Station Deployment Plan: A strategy for Meeting the Challenge Ahead*. http://www.cafcp.org/sites/files/Action%20Plan%20FINAL.pdf

89 CaFCP, *Hydrogen Fuel Cell Vehicle and Station Deployment Plan: A strategy for Meeting the Challenge Ahead: Progress and Next Steps.* http:/www.cafcp.org/sites/files/FINALProgressReport.pdf

90 Both surveys were conducted confidentially, and the data is aggregated to protect the specific details of individual automakers' deployment plans. The numbers provided are only for those manufacturers who responded to the survey and only for the years reported, and may not represent the total number of vehicles planned.

Table 10: FCV Deployment by Major Metropolitan Areas (Cumulative)

	2009	2010	2011	2012	2013	2014	2015-2017
Los Angeles Area (4 clusters)	52	105	175	257	372	849	18,349
Los Angeles Area (Other)	16	30	57	88	117	382	9,115
San Diego		4	8	8	23	33	1,100
Bay Area cluster	9	20	34	48	91	264	11,145
Sacramento cluster	9	17	25	38	60	117	1,942
Other	7	16	31	56	106	194	6,158
Total	93	192	330	495	769	1,839	47,809

Source: California Energy Commission

Prior to the anticipated commercialization of FCVs toward 2015, FCV cost estimates are difficult to assess. Recent third-party engineering analysis estimates the cost of fuel cell systems produced in high volume at $4,800-$6,400 for an 80 kW system based on 2008 technology.[91] Toyota anticipates releasing a commercial FCV by 2015 that, as a general estimate, may cost approximately $50,000.[92] Vehicle and component manufacturers are working hard to drive down the manufacturing cost of the vehicles before early commercialization to assimilate the lower production cost associated with high volume vehicle manufacturing. For FCVs weighing less than 8,500 pounds, an $8,000 federal income tax credit is available if the vehicle was placed into service on or before December 31, 2009. The tax credit decreases to $4,000 if the vehicle is placed in service after that date, through 2016.

The ARB allocated $4.1 million for light-duty FCV incentives in its AQIP 2009-2010 funding plan, and up to $5 million in the AQIP 2010-2011 funding plan.[93] Under ARB's funding criteria, a fully functioning FCV, such as the Honda Clarity FCX, would be eligible for a $5,000 rebate per vehicle. In addition to funding incentives, light-duty FCVs are also granted access to HOV lanes.

91 National Renewable Energy Laboratory, *Fuel Cell System Cost for Transportation – 2008 Cost Estimate*, http://hydrogendoedev.nrel.gov/pdfs/45457.pdf

92 Bloomberg. *Toyota Targets $50,000 Price for First Hydrogen Car (Update2).* http://www.businessweek.com/news/2010-05-06/toyota-targets-50-000-price-for-first-hydrogen-car-update2-.html.

93 For the 2010-2011 funding plan, ARB has indicated that two FCV models may be eligible as ZEVs under the CVRP if funding is continued. The Honda Clarity and the Mercedes B-Class could be eligible if they are leased to customers in a three-year lease agreement.

Heavy-Duty Vehicles

California has pursued development and deployment of alternative-fueled and hydrogen fuel cell transit buses through regulations and incentives for more than 10 years. Over this time, many developments have advanced hydrogen fuel cell transit bus technologies for the benefit of the state and the nation. Hydrogen fuel cell buses can reduce GHG emissions from 26 percent to 86 percent compared to conventional diesel buses, depending on the method of hydrogen production.[94] Fuel cell transit buses also reduce particulate matter and air toxics associated with diesel.

Since 2004, the ARB directed its staff to develop fuel cell bus (FCB) demonstration programs in the Bay Area and in Southern California. The HyRoad Program, led by AC Transit in Oakland/Emeryville, will roll out 12 hydrogen FCBs by January 2011.[95] In addition, the ARB co-funded two FCBs with SunLine Transit in Twentynine Palms. Please see the Introduction section of this document for details on the ZEB program.

In the July 2009 ARB meeting, staff was directed to delay the ZEB purchase requirement due to technology readiness issues, and a two-to-three year delay is likely. In addition, the ARB plans to develop cost-differential purchase metrics to re-evaluate and re-institute the schedule for purchase requirements, and to report back to the Board by July 2012. The reasons for the delay of the purchase requirement include the higher than expected cost differential compared to conventional diesel and other alternative fuel technologies, as well as the continued development to improve reliability, durability and commercial readiness of the transit bus technologies. [96]

Vision Motor Corporation in Southern California (headquartered in Santa Monica) is developing hydrogen fuel cell hybrid heavy-duty drayage trucks for goods movement in and around ports. Additional testing, validation, and demonstration are needed to prepare the technology for commercial demonstration or deployment.

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94 Based on *Detailed California Modified GREET Pathway for Compressed Gaseous Hydrogen from North American Natural Gas Version 2.1.* California Air Resources Board http://www.arb.ca.gov/fuels/lcfs/lcfs.htm and *Full Fuel Cycle Assessment: Well-to-Wheels Energy Inputs, Emissions, and Water Impacts.* Consultant Report. 2007. California Energy Commission CEC-600-2007-004-REV. Numbers are for compressed hydrogen based on grams/mile basis, with energy efficiency ratios included: on-site grid electrolysis: 26 percent; on-site 70 percent renewable electrolysis: 63 percent; on-site natural gas reforming: 56 percent; on-site natural gas reforming using 33 percent landfill gas as feedstock: 66 percent; on-site natural gas reforming using 100 percent landfill gas as feedstock: 86 percent. (All values % GHG reduction compared to California reformed gasoline baseline.)

95 *AC Transit for the Environment*. http://www.actransit.org/environment/hyroad_main.wu.

96 SunLine Transit Agency. Chandler, K. and L. Eudy. February 2007. *Hydrogen-Powered Transit Buses: Preliminary Evaluation Results*. Table 7, pg. 33, Table 10, pg. 36, and Appendix. February 2007. http://www.nrel.gov/hydrogen/pdfs/41001.pdf

In addition, other related "bridging" technologies are being developed for hydrogen. For example, blending up to 30 percent hydrogen with natural gas and hydrogen-compressed natural gas (H/CNG) fuels reduces emission and improves operational results in trucks, buses, and vans. Hydrogen-fueled internal combustion engines (HICE) offer another bridging technology with the potential to reduce GHG and criteria emissions although the lower efficiency of combustion engines relative to fuel cells reduces their benefits. Depending on commercialized FCV costs, HICE may be a viable transition option from existing conventional vehicle technology.

Under ARRA, limited funding was provided for heavy-duty hydrogen vehicle incentive programs, including hydrogen fueling infrastructure (to fuel hydrogen fuel cell buses in Connecticut). The Federal Transit Administration has made a significant contribution (12 fuel cell buses) to the AC Transit's HyRoad hydrogen bus program.

A federal tax credit for fuel cell technology is available for $10,000 to $40,000 for heavy-duty vehicles, based on the weight of the vehicle. The credit may be claimed for vehicles placed in service after December 31, 2005, and purchased on or before December 31, 2014.

The SCAQMD also serves as an important funding partner, reserving approximately 13 percent of its $16.6 million in Clean Fuels Program funding for hydrogen and fuel cells. This is mostly intended for research and development in transit and heavy-duty applications, with the goal of improving air quality. Co-funding demonstration/test fleet projects through the AQMDs is already in progress as explained in the ZEB section above. Additionally, ARB is currently reviewing, monitoring and reassessing components of the AQIP to potentially fund and support hydrogen FCBs in future funding plans.

As stated in the electric drive section, the Energy Commission may consider funding for hydrogen trucks in FY 2010-2011. If allotted, this will come from funds reserved in the battery electric drive section for medium- and heavy-duty vehicles. (See the battery electric drive section for more details.)

Non-Road Applications

A recent report for the US DOE identified at least two near-term markets for non-road use of hydrogen fuel cells: forklifts in warehousing and distribution centers and airport ground support equipment (which include certain classes of forklifts).[97] Fuel cell forklifts are considered to have near-term market potential because they provide zero emission operation, eliminate the need for battery storage space, allow rapid refueling, and do not lose power during operation. The ability to rapidly refuel is especially attractive for multi-shift applications. Indoor and outdoor air quality concerns are another important reason for preferring fuel cell forklifts over combustion engine forklifts in the workplace. A number of material handling site owners have already indicated a willingness to provide co-funding for such applications. The U.S. Department of Defense, through the Defense Logistics Agency, has a large fuel cell forklift

97 *Full Fuel-Cycle Comparison of Forklift Propulsion System*, Argonne National Laboratory, ANL/ESD/08-3, October 2008.

demonstration program underway at distribution depots throughout the country. Argonne National Laboratory has estimated that about 50,000 battery electric forklifts have been sold each year from 2005 to 2007 representing a large market potential for this emerging technology. In some cases, infrastructure to serve non-road applications could also adequately serve light-duty vehicle applications. Finding such locations may be a challenge but would offer opportunities to leverage funding and increase capacity for multiple use stations.

The Energy Commission does not intend to fund non-road applications in FY 2010-2011, but acknowledges their importance and potential to further fuel cell technology. This does not preclude funding for non-road application fueling infrastructure, if it can be combined with transportation fueling infrastructure (discussed below). The ARB AQIP funding plan for FY 2009-2010 includes $2 million for non-road applications, for example, agricultural and lawn/garden equipment, marine vessels, locomotives, and other off-road equipment, which may include hydrogen fuel cell applications; the funding plan for FY 2010-2011 allocates up to an additional $5.5 million for this category.

Infrastructure

Subsequent to the prior investment plan, the Energy Commission sought to provide adequate funding ($22 million) for the cost-shared establishment of needed hydrogen infrastructure based on the information available from public agencies, public and private organizations, and other stakeholders. The Energy Commission sought collaborations and participation with all involved entities and stakeholders. Some of these activities include:

- Collaborations with the CaFCP, ARB, the Institute of Transportation Studies (UC Davis), National Fuel Cell Research Center (UC Irvine), and the National Renewable Energy Laboratory (NREL)
- Partnerships with air quality management districts and other public agencies, such as the Clean Air Technology Initiative[98]
- Development and approval of an interagency agreement with the CDFA DMS for the establishment of hydrogen fuel quality standards and the certification "type approval" for a retail hydrogen dispenser for use at retail stations in California
- Discussions with industrial gas companies on the strategic development of hydrogen fueling infrastructure to accommodate the planned roll-out of FCVs and FCBs in California
- Discussions with OEMs and the administration, with the ARB, of a survey of expected FCV rollouts with specification of timing, location, and numbers of vehicles to be deployed over the next several years

98 Participants include the U.S. EPA, U.S. DOE, ARB, South Coast Air Quality Management District, and the San Joaquin Valley Air Pollution Control District.

Based on these collaborations and discussions, the Energy Commission has noted that the evolving landscape for hydrogen fueling infrastructure involves several important factors for success.

- Approximately 12-24 months are required to establish a hydrogen fueling station.[99] This represents a significant decrease from previous estimates. To emphasize a strong interest in reducing this time frame, the Energy Commission's June 2010 solicitation (PON-09-608) for hydrogen fueling stations included an incentive for those proposals that complete their projects closer to 12 months.
- Currently all existing stations have only 350 bar dispensing pressure, with the exceptions of two stations which also provide dispensing at 700 bar (UC Irvine and Burbank). New stations will be expected to offer both 350 and 700 bar fueling options to serve all vehicles.
- The cost to build a new hydrogen station with a minimum dispensing capacity of 100 kilograms per day ranges from $2 million to $3 million.[100] (More precise estimates of these costs will be available upon review of the Energy Commission's hydrogen infrastructure solicitation.) These costs show signs of decreasing as the industry develops new, innovative production, distribution, and retail supply strategies that are more cost-efficient, including larger capacity stations.
- The Energy Commission is overseeing an assessment of all existing hydrogen fuel stations, and this assessment will help determine whether existing stations (including those stations scheduled to cease operation) can continue to be used in the future. Existing stations located outside designated clusters may hold strategic value as "connector" stations.
- Funding from AQMDs and other local authorities, as well as private industry partners, could significantly enhance the efforts to establish infrastructure, further easing the deployment of FCVs.
- As with other alternative fuels, public funding alone is an unsustainable strategy in the long term to support the growing development of an extensive hydrogen fueling infrastructure in California as FCV deployments approach commercialization. ARB is evaluating changes to the existing Clean Fuels Outlets regulation for ZEVs and the potential to use credit multipliers under LCFS and encourage fuel and charging infrastructure development. These complementary policies hold substantial promise for the development of needed hydrogen infrastructure, if approved.[101]

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99 "Hydrogen Fuel Station Building and Permitting," Presentation by Mike Mackey, P.E., General Physics Corporation, hosted by the California Fuel Cell Partnership on October 2009.

100 *California Hydrogen Highway Network: CaH2Net – Summer 2009 Update*. California Air Resources Board, http://www.hydrogenhighway.ca.gov/update/summer09.pdf.

101 At its December 10, 2009, Board meeting, members of the Air Resources Board directed ARB staff to investigate the potential for using these mechanisms and to report back to the board in December 2010.

A recent assessment of the hydrogen fueling stations established over the past several years, illustrated in Table C-2 of Appendix C, shows that most active stations are located in the greater Los Angeles area.[102] Of the original 25 dispensing stations, 3 are (or will soon be) operated by transit agencies, 5 by automakers, and 3 by universities. Five of the stations are publicly accessible and available. Of the remaining 20 stations, an independent evaluation is being conducted to determine their potential to be adaptable to public access if funding or leases can be provided (and if they are in strategically beneficial locations).

The ARB has awarded funding to seven fueling station projects over the past two years. These are expected to come on-line in 2010 or 2011. Most of these have 100 kg or more capacity (up to 140 kg), average 33 percent renewable hydrogen, and will be equipped with 350 bar and 700 bar dispensing capability to allow for fueling newer and older model FCVs.

The best way to ensure adequate fueling infrastructure is to focus funding for stations in designated clusters (and other compelling and strategic locations outside those clusters), and for critical transit demonstrations. In order to facilitate the early market, infrastructure needs to provide both adequate coverage (in number and location of stations) and capacity (in number of vehicles served by each station). Toward this end, Table C-1 of Appendix C matches the vehicle deployments provided by OEMs in the joint Energy Commission/ARB survey to existing and expected hydrogen fueling stations. By assuming an average fuel demand of one kilogram of hydrogen (roughly equivalent to 1 gallon of gasoline) per day for each passenger FCV, Table C-1 also identifies the years and regions when fueling deficits are anticipated.[103] This supply and demand table errs on the conservative side, as it includes only stations with committed funding. Additionally, the analysis assumes that once committed funding is exhausted and the agreement is completed for an existing station, the station is no longer available. This may not be true in all cases, as some stations will likely continue to operate. Finally, the analysis also does not include private stations funded by specific OEMs, which may have restricted access for other OEMs' vehicles.

The numbers presented in Table C-1 depict early fueling deficits in the Santa Monica and Irvine clusters in Southern California. These begin as early as 2010, and persist through the 2014 time frame. In Northern California, a fueling deficit arises in Sacramento in 2011, as the West Sacramento CaFCP station loses its committed funding. Through 2013, however, these three

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These regulatory tools may offer an attractive and viable compliment to public incentives funding, providing needed balance to the existing vehicle-oriented ZEV mandate. Considering the exponential growth of the vehicle volumes projected in 2015-2017, this three-pronged approach of cost-shared station establishment incentives, station establishment mandates and regulatory credits for "early actions," will provide the best, most balanced chance for mid- term and long-term ZEV mandate success.

102 CaFCP hydrogen fueling station tracking documentation. August 2009 update.

103 FCVs are expected to represent the vast majority of hydrogen-based vehicles deployed in California. However, hydrogen internal combustion engine vehicles can also utilize the same fueling infrastructure.

clusters represent the only areas with anticipated fueling deficits.[104] Fueling deficits rapidly accelerate statewide in 2014, as the number of FCVs on the road more than doubles, and the funding commitments for seven ARB-funded stations come to an end.

To address the projected fueling deficit, the Energy Commission is providing $19 million from the first investment plan in the hydrogen infrastructure solicitation to ensure ample hydrogen availability at publicly accessible fuel dispensing locations. As a condition of funding, each proposal must provide a letter of support from at least one OEM, detailing the link between a proposed station(s) and anticipated FCV deployments. The solicitation provides additional incentives for stations that use more renewable hydrogen content than required (33 percent), are completed in an accelerated time frame of less than 18 months, and/or exceed the minimum 100 kg/day capacity level. The Energy Commission will invest its funds in a capital-efficient manner that maximizes hydrogen throughput at each station and provides customer convenience through strategic placement. The stations established from this solicitation are expected to be operational within two years and should contribute to eliminating some of the regional fueling deficits identified in Table C-1.

Specifically, the Energy Commission anticipates that this funding could establish more than 10 additional retail stations, upgrade and expand the capacity of existing stations, and help establish needed transit demonstration fueling capabilities. It may be possible to establish more than 1,000 kg/day fueling capacity. If this capacity were optimally distributed according to the regions listed in Table C-1, it would eliminate the fueling deficit through 2013 and make substantial inroads into the fueling deficit of 2014. Additionally, the Energy Commission intends to provide $3 million in funding (along with $1.1 million provided from the ARB) to upgrade the AC Transit Fuel Cell Bus Station in Oakland. This key project is part of the 12 bus demonstration in the San Francisco Bay Area - the largest such project in the United States.

In 2009, the CaFCP's Action Plan identified a need for approximately 40 publicly accessible hydrogen stations in California by 2014-2015 to meet the demand of thousands of customers driving FCVs and to launch the early FCV market.[105] Eight new hydrogen stations will come online in 2010-2011, funded in large part by the ARB's hydrogen program. In 2010, the CaFCP released the *Progress and Next Steps* report, which identifies a need for an additional 7 new and 4 upgraded or expanded stations to come online by the end of 2011.[106] (This does not include any new or upgraded stations as a result of the Energy Commission's recent hydrogen infrastructure solicitation.)

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104 The "Other" region in Table C-1, made necessary by some OEMs not committing their vehicle deployments to the identified clusters, exhibits a moderate fueling deficit, which may be difficult to address. Fortunately, only a fraction of vehicles fall into this "Other" category.

105 California Fuel Cell Partnership, "*Action Plan: Hydrogen Fuel Cell Vehicle and Station Deployment Plan: A Strategy for Meeting the Challenge Ahead,"* http://www.cafcp.org/sites/files/Action%20Plan%20FINAL.pdf

106 California Fuel Cell Partnership, "*Progress and Next Steps Report: Hydrogen Fuel Cell Vehicle and Station Deployment Plan: A Strategy for Meeting the Challenge Ahead*," http://www.cafcp.org/sites/files/FINALProgressReport.pdf

Based on manufacturer product plans, vehicle numbers are expected to double between 2011 and 2013. The Energy Commission's recent solicitation is expected to result in the building or upgrading of approximately 8 to 10 stations providing an additional 800 to 1,000 kg/day of hydrogen to support approximately 800 cars. These stations will begin coming on-line in late 2012 – early 2013 and will be necessary for manufacturers to successfully place their planned numbers of FCVs and will provide customers the assurance and confidence they need to purchase or lease FCVs.

FCV placements statewide are expected to double again between 2013 and 2014, to 1800 vehicles. When this occurs, approximately 1,000 kg/day will be required to keep pace with light duty infrastructure needs.[107] In addition, the Federal Transit Administration, in partnership with California, is considering supporting a Southern California Regional Fuel Cell Hybrid Bus program that will require infrastructure support which could include a station upgrade and a new station. To meet these needs, the Energy Commission is providing $13 million that will be made available to supply additional volumes needed for 2013 to 2015 hydrogen vehicle deployment.

Table 11: Hydrogen Electric Drive Funding Summary for FY 2010-2011

Fueling Infrastructure	$13 Million
Total	$13 Million

Source: California Energy Commission

107 It is also expected that technical experience gained by hydrogen suppliers from previous funding rounds will result in larger capacity stations (300 – 500 kg/day) and subsequent cost reductions in $/kg.

Gasoline Substitutes

Liquid fuels used in spark ignition engines will continue to be needed to meet California's light-, medium and heavy-duty transportation needs. Due to the Federal RFS and California's LCFS, renewable and low-carbon liquid biofuels will play an increasing role in meeting this need.[108] These regulations will require the use of existing first generation biofuels and increasingly cellulosic and other advanced biofuels (commonly referred to as "second generation" biofuels). A variety of second generation biofuels are being pursued using both bio-chemical and thermo-chemical processes including bio-methanol, ethanol, bio-butanol, mixed alcohols, biocrude, and "renewable gasoline" which can be used in existing vehicles without modification.[109] This portfolio of first and second generation gasoline substitute biofuels is the linchpin of the strategy to establish increasing use of low-carbon renewable and alternative fuels by the 2020 to 2022 time frame.[110]

Currently, first generation ethanol is the primary commercial renewable gasoline component used in California's reformulated gasoline (CaRFG), blended up to 10 percent by volume. E-85, a mixture of 85 percent ethanol and 15 percent gasoline hydrocarbons, is a higher ethanol content biofuel for FFVs.[111] About 1 billion gallons of first generation ethanol were used to make CaRFG in 2008 while less than 1 million were used to make E-85.

The demand for renewable fuel in California is expected to triple between now and 2022 to meet the Energy Commission's current gasoline demand forecasts and the "fair share" renewable fuel use requirements of the federal RFS. In the process, carbon reduction goals

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108 The Renewable Fuel Standard mandates specific volumes of renewable fuels be blended in transportation fuels. California's "fair share" is about 11 percent of national requirement or about 3 billion gallons (as ethanol) by 2022. ARB's LCFS program expects advanced low-carbon biofuel to play the largest role among biofuels options in achieving the 10 percent carbon intensity reduction goal in 2020.

109 Details of some technologies and processes can be found on multiple company websites. See examples such as Amyris, Cobalt Biofuels, Coskata, Fulcrum Bioenergy, GEVO, LanzaTech, Blue Sun Energy, SWAN Biomass, and many others. Stage of development can be laboratory bench scale to small-scale pilot project and demonstration.

110 The current capacity of "first generation" corn based ethanol production in the United States is 13.3 billion gallons at 212 facilities. See www.ethanolproducer.com, 3/11/10 plant list. California plants while mostly idle (four out of five facilities) are candidates for use of second generation biofuel processes given California's large and diverse mixture of waste biomass resources

111 Unlike other states, California refiners and blenders use California reformulated gasoline blendstock to make E-85 fuel. California Renewable Blendstock for Oxygenate Blending (CARBOB) or "unfinished" California gasoline) is the most readily available hydrocarbon(s) component at petroleum products terminals for the 15 percent "gasoline" portion of E-85.

under California's LCFS will increasingly drive fuel suppliers and blenders to secure second generation, lower-carbon biofuel supplies.[112, 113]

The LCFS requires an average carbon intensity reduction of 10 percent for all transportation fuels by 2020. Further, the RFS requires that of the total renewable fuels requirement more than 50 percent be "advanced" biofuels by 2022. This can be done by developing and deploying new biofuel production facilities, as well as repurposing existing corn-ethanol facilities to use second generation feedstocks that achieve advanced biofuel status under RFS and contribute to LCFS goals. Increased in-state biofuels production would also create the opportunity to produce biofuels with a much lower GHG impact through improved production efficiencies and the use agricultural and forest-based waste streams and sustainably produced low-carbon bioenergy crops. On a full fuel-cycle basis, using non-food feedstocks and state-of-the-art best practice biofuel production could result biofuels with 80 percent or more GHG emissions reductions relative to gasoline.

Light-Duty Vehicles

Significant use of renewable fuel in accordance with the aggressive RFS timeline can be achieved primarily through the use of renewable ethanol mixtures in light-duty vehicles over the next three to four years.[114] The federal RFS fair share biofuel use requirements for California can be achieved over the next 13 years with significant growth in the number of FFVs, concurrent growth in the number of retail and fleet outlets and supporting distribution infrastructure, and the use of E-85 and increasingly second generation biofuels likely including cellulosic and advanced alcohols and biogasoline.[115]

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112 Corn-based ethanol provides biofuel "floor" requirements in the early years of the national RFS program. Increasingly, cellulosic and other advanced biofuels are expected to characterize California in-state production from new facilities over the next 10 years. Staff believes that some advanced biofuels such as bio-butanol and other bio-oxygenated (such as mixed alcohols/ethers) and non-oxygenated hydrocarbons ("biogasoline") are likely to come to commercial status within this period. Any "new" transportation fuel will need to undergo a multimedia environmental fate and transport assessment and be approved by the California Environmental Policy Council before commercial introduction under the LCFS regulations.

113 California Air Resources Board, *Proposed Regulation to Implement the Low Carbon Fuel Standard; Initial Statement of Reasons,* March 5, 2009. ARB staff projects first generation and advanced biofuels to contribute from 60 percent to 89 percent of the total carbon content (intensity) reductions in gasoline by 2020 based on scenario analyses.

114 Use of ethanol and methanol in heavy-duty vehicles is not currently a widespread commercial-scale practice in the United States.

115 Technical issues concerning manufacturer's ability to achieve new car emissions certification requirements are constraining new sales of FFVs in California in the coming years. For the 2010 model year, Chrysler is withholding two FFV models from the California market and 10 other states who have adopted California Emissions standards. GM's 2010 FFV Impala is available only on request at dealerships. If not specified FFV, dealers will sell the gasoline super ultra low emissions version of the

Assuming ethanol is used to meet the RFS goals, California's existing fleet of 400,000 FFVs would have to increase by at least 2.8 million vehicles (and perhaps more depending on CaRFG demand) by 2022 if consumers owning FFVs use E-85 100 percent of the time. This number doubles to 5.6 million vehicles if consumers use E-85 only 50 percent of the time. California's FFV growth depends on accelerated manufacturing and deployment by multiple automakers to achieve these production volumes for the California market. Currently, Detroit automakers are producing enough FFVs to meet consumer demand nationwide and are on track to achieve 50 percent of their new car offerings as FFVs in 2012. However, these manufacturers are also beginning to withhold FFVs from the California market and other states adopting California vehicle emissions standards due to challenges in meeting California's new car and light truck PZEV emissions certification standards.[116] Each manufacturer must comply with a decreasing fleet average non-methane organic gas emission standard[117] over time that will require all vehicles to achieve the super-ultra-low emissions (SULEV) tailpipe standard and zero evaporative emissions standards. Other manufacturers are not positioned to adequately fill this future potential gap of FFVs, and all manufacturers must find technical solutions to overcome the PZEV emissions certification hurdle.

Achieving federal and California ambient air quality standards and reducing toxic air contaminant emissions through increased use of E-85 and emerging second generation biofuels such as biobutanol, mixed alcohols and long chain hydrocarbons is a likely strategy to achieve LCFS objectives and federal RFS objectives simultaneously.[118] Despite the hurdles for FFVs in the California market, no funding is recommended for FY 2010-2011. While FFVs, including additional components, add modestly to the cost of a new vehicle, automakers are currently and have historically priced product line FFVs the same as their gasoline counterpart vehicles. Assuring continued growth of California's FFV population and access to this strategy will

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Impala to California consumers. Personal communication with Coleman Jones of General Motors Corporation.

116 Cullen, Kevin, "Fuel Economy & Emissions: Ethanol Blends vs. Gasoline" General Motors Powertrain Engineering. Presented at the U.S. DOE Biomass R&D TAC Meeting – September 10, 2007, and Ambrozaitis, Giedrius, "Comments of the Alliance of Automobile Manufacturers On the Florida Department of Environmental Protection Proposed Rulemaking to Adopt the California Low Emission Vehicle Program (CA LEV)," August 11, 2008.

117 The non-methane organic gas standard is ARB's "hydrocarbon" standard adjusted for ozone reactivity of fuel molecules. For example, oxygen containing molecules (such as ethanol, methanol, and butanol) have lower ozone reactivities than most hydrocarbons (such as benzene, gasoline components). Thus, "alcohol" cars can emit more "hydrocarbons" under the ARB non-methane organic gas standards, yet have the same ozone forming effect as a gasoline car emitting fewer gasoline "hydrocarbon" emissions.

118 The California Air Resources Board has recently initiated informal regulatory discussions on LEVIII amendments with automakers and the public. Discussion of proposed changes to the LEV regulations address several issues pertinent to the special challenges faced by the manufacturers in certifying FFVs to California Standards. See www.arb.ca.gov/msprog/levprog/leviii/leviii.htm

require additional investments by manufacturers. PIER funding will initiate testing of second generation biofuels, biobutanol, mixed alcohols, and others in existing California FFVs at the University of California, Riverside Center for Environmental Research and Technology (CE-CERT).

Fueling Infrastructure

Until second generation biofuels that are compatible with existing retail infrastructure and vehicles become available, it is expected that increasing volumes of ethanol will be needed to meet the RFS and LCFS goals. This can be accommodated either by increasing the percentage of ethanol blended into all CaRFG (currently capped at 10 percent by volume), or by increasing the amount of E-85 used in FFVs. The E-85 strategy assumes FFV emissions certification issues and manufacturer's concerns are resolved within the next one or two years through investments made by manufacturers' and public funding.

Currently, E-85 dispensers are sparsely distributed within California. To provide adequate availability of E-85 for consumers and businesses operating FFVs, the 43 existing retail and fleet fueling facilities should be expanded over the next few years.[119] These facilities represent only 0.4 percent of 10,400 retail gasoline outlets presumed to be operating today. Los Angeles and San Francisco Bay regions are notably lacking, while Sacramento region boasts the highest number of E-85 dispensers per capita.

The federal government, as part of the EISA (2007), allows an investment tax credit of up to 50 percent for alternative fuels infrastructure applicable to E-85 installations, up to $50,000.[120] Funding offerings are not expected from the ARB's AQIP or from regional air districts.

At least four business models are being employed in California to meet perceived latent demand for E-85.[121] The Energy Commission estimates that up to $100,000 is sufficient program funding to leverage a new E-85 dispenser and associated new underground equipment including fuel tank, given an estimated total cost of $250,000 per underground installation. New above-ground installations are less costly, so up to $50,000 is considered an appropriate level of

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119 Analysis of dispenser needs for E-85 to achieve RFS obligation under gasoline demand scenarios (assuming the RFS is met through the use of ethanol)—900 dual-hose dispensers placed at retail stations represent about 10 percent coverage; 1,800 dispensers would be 20 percent of all retail gasoline outlets assuming 9,000 operational gasoline retail stations in the 2016 to 2022 time frame. This assumes a gradual decline in the number of retail outlets from 10,500 presumed to be operating in 2009 due to declining California gasoline demand forecasts (*2010 IEPR*).

120 Staff has assumed that FY 2008-2010 cost-sharing funds ($4 million) will supplant U.S. DOE ARRA funds in the event that Pearson Fuels declines federal funds or otherwise fails to execute an agreement to spend ARRA funding.

121 In California, Propel, Pearson Fuels, Nella Oil Company, DMC Green Inc., and Interstate Oil among others have developed most of the existing E-85 stations. Some details of the business approach are available on each company website.

state funding. Forty-three E-85 dispensers are established and operating in California, and at least 75 more will be added through federal funds and FY 2008-2010 program funding.

Table 12: Ethanol Stations Funded by the Program

Solicitation	Project Description	Proposed Award
PON-08-010	Build and operate 75 E-85 retail stations throughout California	$4,000,000
PON-09-006	E-85 retail stations (number as yet undecided)	$1,000,000
Total		**$5,000,000**

Source: California Energy Commission

A FY 2010-2011 program funding allocation of $6.5 million in grants will provide 65 additional underground dispenser installations, assuming a cost-shared level of $150,000 by program applicants. This will contribute to 183 dispensers statewide, or roughly the first 10 percent of the 1,800 dispensers needed to achieve the upper bound of the "adequate consumer availability" goal.[122] A funding allocation of $6.5 million for E-85 dispensers provides a reasonable balance between one-time ARRA funding and immediate needs to increase E-85 fuel availability to at least 400,000 FFVs operated by consumers and fleets in California. In the future, policy incentives (such as the LCFS) will be critical to creating a sustainable market for fueling infrastructure.

Existing Ethanol Production Capacity

California has seven ethanol production plants — five corn-based ethanol plants and two smaller food and beverage waste processing plants.[123] When fully operational, these plants have a combined production capacity of about 250 million gallons per year, representing about 25 percent of California's current ethanol demand. However, all five of the modern corn-based ethanol plants were idle for most of 2009 due to adverse market conditions. Only one is now in

122 Fuel price and availability have been shown to be the two most important variables affecting consumer use of alternative fuel in bi-fuel (flexible fuel) alternative fuel vehicles. Source: David L. Greene, *Survey Evidence on the Importance of Fuel Availability to Choice of Alternative Fuels and Vehicles*. Oak Ridge National Laboratory, DOE Contract # DE-AC05-96OR22464, November 11, 1997. To achieve a 1,800 dispenser installation goal (20 percent) by the end of the AB 118 Program, about 270 E-85 dispensers would need to be installed each year. To achieve the lower goal of 900 stations (10 percent), 121 stations per year would be required. Appropriate alternative fuel pricing at California E-85 retail outlets is expected to positively affect FFV owner's choice of E-85 over CaRFG, market conditions permitting. Periodic evaluation of gasoline and ethanol wholesale market conditions conducted by Energy Commission staff will advise future investment plan decisions in this regard.

123 California's five conventional corn "dry mill" ethanol plants are located in the San Joaquin Valley, while the two smaller plants are located in Southern California. The California Cheese Company ceased operations at its Corona plant and laid off all 700 workers in late 2007. Parallel Products' plant in Rancho Cucamonga continues to process brewery and beverage processing wastes as it has since 1984.

operation. In 2008, 86 percent of California's ethanol needs were met by imports of ethanol from corn-based plants in the Midwest while in-state plants provided 10 percent. Foreign ethanol imported via California ports provided the remaining 4 percent.[124] With the in-state production industry idled for most of 2009, jobs, tax revenue, and local income were lost.[125]

In-state ethanol production using Midwest corn brought by rail to California plants has a measurable GHG advantage over average Midwest ethanol. Given current demand for ethanol blending into CaRFG at a rate of about 1.4 billion gallons per year, importing Midwest ethanol increases GHG emissions when California plants aren't operating. California plants produce ethanol that, on a full fuel-cycle basis, has about 20 percent fewer GHG emissions than the average corn-based ethanol shipped in by rail from the Midwest.[126] California's ethanol producers currently use natural gas for process energy (rather than the average Midwestern mix of coal and natural gas) and distribute "wet grains" to dairies and cattle feed lots. Newer production facilities (with higher process efficiency) combined with energy savings of not drying distillers' grains gives California plants an inherent lower energy use (and carbon footprint) benefit when compared to average size and age Midwest plants.[127]

The California Ethanol Production Incentive Program (CEPIP) solicitation (PON-09-607) is intended to help the idled California corn-based biorefineries resume production under current and possible future adverse market conditions. This $6 million solicitation includes provisions requiring in-state biorefineries to begin the transition to lower-carbon feedstocks and more efficient operations and process technologies (such as biochemical and thermochemical cellulosic conversion). The CEPIP will provide incentives on a per-gallon basis only when the "ethanol crush spread" (a measurement of the difference between the value of a gallon of ethanol and its feedstock price) falls below a threshold of 55 cents-per-gallon. If the ethanol

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124 Foreign ethanol usually comes to California from Caribbean, Latin, and South American nations under reduced or no tariff international agreements as well as from the North American Free Trade Agreement (NAFTA) partners Mexico and Canada. These agreements do not include Brazil, the world's second largest ethanol producer; however, Caribbean nations can upgrade hydrous Brazilian ethanol (minus the 54 cent per gallon U.S. tariff) for import into the United States under a 7 percent quota tied to corn based U.S. ethanol production in the previous calendar year. Other nations are subject to a 54 cent-per-gallon U.S. import tariff and ad valorem tax.

125 Staff projects ethanol production in 2009 of 31 million gallons or 13 percent of California's installed capacity. If this projection holds, then just 3.1 percent of California's estimated 1 billion gallon ethanol demand in 2009 will have been provided by California plants.

126 California ARB analysis using the California version of the GREET model estimates average Midwest corn ethanol full fuel-cycle pathway GHG emissions about 25 percent higher than California plants that distribute wet distillers grains locally, while selling the ethanol to California refiners and blenders.

127 California's five dry mill ethanol plants were built in 2005, 2006 and 2008(3). These state-of-the-art plants will have to continue to invest in efficiency upgrades just as the Midwest "baseline" plants have to keep their edge and remain competitive in the marketplace. The LCFS is a regulatory driver to increasingly move California plants to lower carbon feedstocks, advanced process technologies, and biomethane as a replacement for natural gas.

crush spread rises above $1, the producer is required to reimburse the CEPIP. The continued funding for an individual producer is contingent on the producer's continued compliance with established milestones for carbon intensity reduction and alternative feedstock use.

Fuel Production

The LCFS and the federal RFS will drive renewable fuel production and use in California through 2022.[128, 129] California's fair share of the Total Renewable Fuel use obligation under RFS2 requires growth in biofuel demand of about 2 billion gallons by 2022. The assumption is that ethanol will continue to be the primary biofuel for the next several years to meet the RFS and LCFS. When added to the current volume of 1 billion gallons that is blended into CaRFG today, total demand for ethanol in 2022 could be as much as 3.0 billion to 3.2 billion gallons per year. To comply with this requirement, California should plan for up to 164 million gallons of new ethanol supply each year to satisfy the demand for gasoline and, increasingly, E-85 blending.

Between 2010 and 2012, CaRFG will shift from a 6 percent (E-6) to a 10 percent (E-10) ethanol-in-gasoline blend. The blending limit for ethanol under the Clean Air Act is currently 10 percent. This equates to about 1.5 billion gallons of ethanol annually. Further increases to higher blending levels (for example, E-15) are limited by the so-called "blending wall" in federal statute.[130] Therefore, unless there is a near term breakthrough in the production of biofuels compatible with existing infrastructure such as renewable gasoline, the use of E-85 is the only practical way to meet RFS requirements.[131] If this scenario becomes reality, then consumer use of E-85 must grow to about 12 percent of California's gasoline demand to meet the state's RFS2 fair share requirement.

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128 Staff estimates of future transportation fuels supply and demand forecasts include ethanol, E-85, and biodiesel use obligations under the EISA; roughly equal volumes of ethanol blend E-10 and E-85 would be needed to meet the 2022 volume targets; WebEx Western States Coordination Meeting presentation, October 29, 2009, Fossil Fuels Office, Fuels and Transportation Division, California Energy Commission.

129 The Renewable Fuel Standard (RFS) Program was authorized under the Energy Policy Act of 2005 and amended in the EISA of 2007. Among other requirements of the RFS Program, the former "RFS1" and latter "RFS2"require mandatory biofuels use. "RFS2" fuel use obligations are much more aggressive than those of "RFS1," culminating at 36 billion gallons nationwide in 2022.

130 The Clean Air Act Amendments of 1990 established a limit of 3.7 weight percent oxygen in gasoline as the upper limit of oxygen content. This limit corresponds to 10 percent by volume (not weight) ethanol blending in gasoline. Other oxygen containing blending components such as methanol, butanol or Methyl Tertiary Butyl Ether (MTBE) have different corresponding volumetric blending levels corresponding to the 3.7 weight percent limitation (for example, butanol is 16 percent by volume).

131 The Federal Environmental Protection Agency, Department of Energy, oil and automotive manufacturers (Coordinating Research Council), and other affected industries are evaluating issues surrounding the use of ethanol blends greater than 10 percent. In addition, U.S. ethanol industry interests have petitioned EPA under Section 211 (f) of the Clean Air Act waiver process to allow an increase to 15 percent ethanol blending in gasoline.

A mix of in-state produced ethanol, Midwest ethanol, and foreign-sourced ethanol is currently being used in California. California is uniquely positioned, however, to use vast in-state cellulosic and other low-carbon feedstocks and produce at least 80 percent of its fair share of RFS2 biofuels from feedstocks other than corn. California has significant waste streams from the agricultural, municipal, and forest sectors that are available for use as feedstocks for advanced biofuels with low-carbon content.[132] This has the potential to contribute to achieving the RFS requirement of more than 50 percent of these new types of low-carbon biofuels by 2022. Specialty bioenergy crops such as "energy cane," sweet sorghum, and perennial grasses can be grown on marginal soils to produce very low-carbon biofuels (with 75 percent and higher reductions from the petroleum baseline) using some conventional, developing, and demonstration phase conversion technologies.

California's LCFS identifies a major role for low-carbon biofuels, particularly those with very low full fuel-cycle carbon emissions.[133] The LCFS requires transportation fuel providers (obligated parties) that make, buy, sell, distribute, or trade transportation fuels to decrease the carbon content of CaRFG and California diesel 10 percent by 2020. The LCFS differs from the RFS regarding biofuels in that it has no prescriptive production pathway, feedstock, or renewable fuel use volumetric requirements. Obligated parties under the LCFS can supply other transportation fuels including hydrogen, electricity, and natural gas as well as other means to meet carbon reduction requirements.[134] Several compliance scenarios in the LCFS documentation illustrate different mixes of alternative fuels to meet the 10 percent GHG reduction target by 2020. In one LCFS scenario, ARB staff estimates that 18 cellulosic

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132 The California Biomass Collaborative projected for 2010 biomass potential of 86 million bone dry tons (BDT)/yr gross and 36 million BDT/yr technically recoverable biomass in California. Source: www.Biomass.ucdavis.edu/reports.html *An Assessment of Biomass Resources in California, 2007* Draft Report, PIER Collaborative Report, March 2008. Using an average CBC value of 82 gals of ethanol derivable from each BDT of a mix of biomass wastes and residues yields a technical potential in 2010 of 2.9 billion gallons of ethanol. CBC source "California Biofuel Goals and Production Potential,"2007.

133 The LCFS uses the metric of "carbon intensity" to quantify measurement of and establish numerical requirements of grams carbon dioxide equivalent per megajoule (MJ)of energy content of all fuels on a lower heating value (LHV) basis (that is gCO2-eq/MJ). In-state based California ethanol produced at corn dry mills distributing wet distillers grains to feed lots has a carbon intensity value of 80.7 CO2-eq/MJ while a corresponding Midwest corn-based ethanol based on 20 percent coal/natural gas process heat with drying of the distillers grains has a carbon intensity of 99.4 gCO2-eq/MJ, about a 20 percent carbon reduction advantage when produced in California.

134 "The federal RFS would deliver only about 30percent of the GHG benefits of the proposed regulation, and does little to incent fuels such as natural gas, electricity or hydrogen. California's LCFS is designed to complement the federal RFS2." Excerpt from Executive Summary, Page ES-5, *Proposed Regulation to Implement the Low Carbon Fuel Standard*, Volume I, Staff Report: Initial Statement of Reasons, California ARB, March 5, 2009.

biorefineries, 6 corn ethanol biorefineries, and 6 new biodiesel or renewable diesel refineries could be needed by 2020 to meet the increased demand for low-carbon content biofuels.[135]

Like all modern ethanol plants, California plants are candidates for efficiency upgrades and conversion to low-carbon feedstocks using available California biomass wastes and sustainably produced bioenergy crops. For example, if biogas were substituted for natural gas in California's ethanol plants, ethanol carbon content would be on the order of 50 percent lower than conventional Midwest ethanol. One such project is underway at Calgren Renewable Fuels Pixley ethanol plant.[136]

At the Energy Commission's *2010-2011 Investment Plan* Biofuels Workshop, several project developers described strategies to produce very low-carbon intensity biofuels (80 percent to 90 percent and greater reductions from CaRFG baseline) at competitive prices in California. These strategies include:

- Fractionation of feedstocks into multiple value-added products including ethanol, renewable diesel, green electricity, and other co-products.
- Development of specialty bioenergy feedstocks such as energy cane, sweet sorghum and perennial grasses that can be grown on marginal, non-food crop soils.
- Capital investments to increase biorefinery production outputs to meet shifting and new market demands, similar to the production strategy used by petroleum refiners.[137]

Lack of capital and debt financing is impeding biofuel plant development and upgrades at some existing plants. If capital and debt financing were readily available, California's existing plants and planned plants now on hold could move forward to initiate use of California's biomass wastes and other alternative low carbon feedstocks such as sweet sorghum, citrus wastes, sugar cane, and sugar beets. Many in-state developers of advanced biofuels projects are positioned to provide technology specifically designed to convert agricultural, forest, and municipal waste streams to transportation fuel.

California's in-state biomass waste stream feedstocks are substantial. According to the California Biomass Collaborative, the annual, technically recoverable feedstocks include 8 million bone dry tons (BDT) of agricultural residues, 9 million BDT of municipal solid waste,

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135 California Air Resources Board, *Proposed Regulation to Implement the Low Carbon Fuel Standard: Initial Statement of Reasons*, March 5, 2009.

136 Testimony of Dolores Santos, AB 118 2010-2011 Investment Plan Biofuels Workshop, September 14-15, 2009, California Energy Commission, Sacramento, California.

137 Testimonies of David Rubenstein of California Ethanol and Power, Brian Pellens of Great Valley Energy, and Bob Walker of Swan Biomass, AB 118 2010-2011 Investment Plan Workshop, September 14-15, 2009, California Energy Commission, Sacramento California.

and 14 million BDT of woody biomass from forest fuels management and other timber production waste streams.[138]

To meet the in-state production milestone for 2010 as identified in California's BAP, the state needs to restart the largely idle and corn-based in-state production capacity of 240 million gallons per year (MGPY). This modern infrastructure will serve as the basis for California's shift to cellulosic and other low-carbon feedstocks. To achieve the BAP production goals in 2020, 20 plants with average production capacity of 47.5 MGPY would need to be built. Forty plants in the commercial range of 15 to 30 MGPY may more fairly represent the size of emerging cellulosic and other low-carbon ethanol production plants. Thus, a mix of 20 to 40 plants with capacities ranging from 24 to 47.5 MGPY is possible. The market capital required to build the first two or three plants will be at least $250 million because advanced biofuel and cellulosic ethanol production technologies are unproven at commercial scale. However, capital costs will decrease as the new plants come on line. The Energy Commission estimates initial capital costs to be $7 to $15 per installed gallon capacity in 2010 and 2011, $5 to $10 per installed gallon capacity in 2012 and 2013, and $3 to $6 per installed gallon capacity up to 2020.[139]

The U.S. DOE has released solicitations totaling $570.5 million in funding through the ARRA in two biofuel technology categories: Integrated Biorefinery Production and Algal/Advanced Biofuels Consortia. No U.S. DOE awards were made for California-based biorefinery facilities under the former. In June 2010, U.S. DOE announced $24 million for the latter nationwide, including $9 million for the Consortium for Algal Biofuels Commercialization in San Diego. In addition to these project funds, the federal government also offers a 10 cent per gallon (first 15 million gallons) production incentive for small ethanol producers. Based on an estimate of 31 million gallons of anhydrous ethanol produced in 2009, California's producers may be eligible for additional funding depending on market conditions. Blenders will be eligible for an additional $14 million in federal incentives when making CaRFG or E-85.

Using funds from FY the FY 2008-2010 investment plan funding cycle, the Energy Commission is preparing to fund critical opportunities for producing in-state ethanol and other biofuels. The Biofuel Production Plant solicitation (PON-09-604) is expected to provide $14.9 million for feasibility and project development grant and loan funding advanced biorefinery projects that have been described in the *2010-2011 Investment Plan* workshops or discussed with Energy Commission staff.

Development funding is essential to develop new biofuel facilities and restart advanced feedstock ethanol projects, in order to prove the technical and economic feasibility of emerging feedstocks and new processes for biofuels production. For this reason, the Energy Commission will allocate $10 million in grants, loans, and other funding mechanisms available through the CAEATFA and CalCAP to 1) the CEPIP, 2) project feasibility, feedstock and pre-plant

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138 *An Assessment of Biomass Resources in California, 2007,* PIER Collaborative Report from the California Biomass Collaborative, March 2008, California Energy Commission Contract No. 500-01-016.

139 Energy Commission staff estimate based on a variety of sources.

development activities for high-efficiency-low-carbon new and retrofitted advanced biofuel production technologies, and 3) construction of new and retrofitted advanced biofuel production facilities that will achieve lower carbon ethanol and other gasoline substitutes. Given a broad range of potential funding needs for each project, this amount could fund 10 to 20 projects.

Table 13: Gasoline Substitutes Funding Summary for FY 2010-2011

Expansion of E-85 dispensers and retail outlets	$6.5 Million
Gasoline substitutes production in existing, new and retrofit facilities	$10 Million
Total	$16.5 Million

Source: California Energy Commission

Diesel Substitutes

Diesel substitutes are defined as biomass-based diesel fuels including biodiesel and renewable diesel, as well as specific feedstock- and process-based diesels such as algae-based diesel, biomass-Fischer-Tropsch diesel, and diesel from thermal depolymerization of industrial and food processing waste. Of these fuels, only biodiesel is commercially available in California and the United States today.

Biodiesel refers to a non-petroleum-based diesel made from vegetable oils or animal fats using a process called transesterification. This is a simple process that blends bio-oils and a catalyst to make a biodiesel fuel, which is often blended with conventional petroleum-based diesel. In 2008, California used 50 million gallons of biodiesel.[140] Today, California has the potential to expand its biodiesel use to 200 million gallons within the industry-accepted blend of 5 percent biodiesel and 95 percent conventional diesel (also known as B5) without requiring modifications to vehicles and downstream infrastructure.

Renewable diesel can be made from a variety of feedstocks and is typically processed in a refining facility where the feedstocks are transformed into a diesel fuel through hydrocracking and hydrogenation. The refinery-based process produces a renewable diesel fuel that is chemically identical to diesel fuel, requiring no modifications for infrastructure or diesel engines.

Biomass Fischer-Tropsch diesel can be made from agriculture waste, green waste, food waste, or forest residue. Through a gasification process, the biomass is converted into diesel and naphtha. The final diesel product has superior fuel qualities and can be used in any blend level with conventional diesel fuel and infrastructure.

Biochemical processes for fuel production are being researched by several companies (such as Amrys, Solazime, Jiangsu Yuehong Chemical Co., Ltd.). Biochemical processes vary considerably, and the final fuel product specifications are as varied as the processes and are in the beginning stages of development. Energy Commission staff will continue to monitor these promising technologies.

Algae-derived diesel is a pre-commercial, research-phase effort that involves growing algae in ponds or in containers that either reacts with sunlight and CO_2 or is fed sugar to reproduce and create oils for later separation and use in any biomass-based diesel process. Algae is an especially attractive fuel source for diesel, gasoline, and aviation fuel, since the process does not require arable land and results in a fuel with up to an estimated 80 percent reduction in GHG emissions compared to petroleum-based diesel.[141] Additionally, algae-derived diesel may have

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140 *Renewable Fuels: Standards, Supply and Demand Projections, & Infrastructure*, Gordon Schremp, California Energy Commission presentation, October 29, 2009

141 *The Addition of Algae and Jatropha Biodiesel to GHGenius*" (S&T)2 Consultants Inc., September 30, 2009.

a significant potential to replace conventional fuels due to its ability to produce up to 30 times more oil per unit of growth area than land plants.[142]

Diesel substitutes could be significant contributors to reduce GHG emissions in California's transportation sector. Depending on the feedstock, biomass-based diesel fuels reduce GHG emissions 50 percent to 88 percent compared to conventional diesel fuel.[143] Additionally, the 50 million gallons of biodiesel used in California in 2008 had the estimated emissions reductions (with the exception of nitrogen oxide [NOx], which increases) shown in Table 14.[144]

Table 14: 2008 Estimated Emission Reductions From 50 Million Gallons of Biodiesel Compared to Conventional Diesel

	Particulate Matter	**Hydrocarbons**	**Carbon Monoxide**	**NOx**	**SO_2[145]**
Percentage Reductions	47%	67%	48%	-10%	100%
Emission Reductions (lbs)	252,000	282,000	2,780,000	-775,000	221,000

Source: National Biodiesel Board

The ARB's Research Division is investigating biodiesel NOx impacts, and its staff released a draft biodiesel NOx mitigation plan. The staff draft biodiesel NOx mitigation plan relies on blending renewable diesel or a common cetane improver to render biodiesel's NOx emissions neutral, requiring no further mitigation. An ARB hearing and regulation on this is anticipated in 2010.

Biodiesel is a near-term option, but it requires bulk storage and rack modifications to expand beyond its current 20 million gallon level. Ultimately, biodiesel is expected to supply less than 10 percent of California's diesel demand due to feedstock supply limitations. In the mid-term, renewable diesel is envisioned to become a commercial product, be comingled with petroleum diesel, flow through the existing pipelines and dispensed from petroleum storage and rack terminals. In the long term, renewable diesel can also use the separate and dedicated storage and blending facilities established for biodiesel.

It is expected that most renewable diesel would be produced at refineries on the coast, and the fuel transported via pipeline throughout the state. Concurrently, most biodiesel is envisioned to

142 NREL, *Aquatic Species Project Report FY 1989-90*. January 1992, pg. 3.

143 *EPA Lifecycle Analysis of Greenhouse Gas Emissions from Renewable Fuels*. EPA-420-F-10-006. February 2010. http://www.epa.gov/otaq/renewablefuels/420f10006.htm. Also based on ARB's LCFS look up tables available at http://www.arb.ca.gov/fuels/lcfs/121409lcfs_lutables.pdf. December 14, 2009.

144 Based on an emissions calculator provided by the National Biodiesel Board at http://www.biodiesel.org/tools/calculator/default.aspx

145 Sulfur dioxide (SO_2)

be produced in the Central Valley or in more remote locations, and areas not served by the pipelines connected to major refineries.

The key obstacles for biodiesel are economic viability due to high feedstock costs and the lack of California bulk infrastructure. To become a more viable fuel option, California will need strategic deployment of blending and storage terminals to increase the availability of biodiesel and renewable diesel to customers. Additional progress will be needed to produce fuels from renewable feedstocks (including algae and the organic fraction of municipal waste sources) and purpose-grown crops, as well as to demonstrate the market viability of these sources. Resuming the federal subsidy of $1 per gallon may spur biodiesel's economic viability in the short term and by the federal RFS and the California LCFS in the long term. In addition, automakers and engine manufacturers will need to show widespread acceptance of higher biodiesel blend concentrations for use in all diesel vehicles. California has several compelling reasons to increase in-state production and use of biomass-based diesels:

- Significant emission reductions from lower carbon intensity.
- Along with biomethane, biomass-based diesel represents one of the most effective alternative fuels for reducing GHG emissions. It also provides a significant petroleum diesel gallon displacement, thereby diminishing California's dependence on petroleum.
- In-state biodiesel production plants are needed to ensure California's "fair share" biofuel use of 60 million gallons per year by 2022 as specified in the RFS of the EISA.[146]
- The LCFS identifies a major role for biofuels, such as biomass-based diesel, in achieving the 10 percent carbon intensity reduction target. Biofuels are projected to contribute 60 percent to 89 percent of the carbon intensity reductions.[147] Up to 30 new biorefineries could be needed in California to meet the LCFS carbon intensity reduction requirements for diesel fuel.[148]
- California has biomass waste streams from agricultural, municipal, and forest sectors available for the production of biofuels with low carbon intensity. Bioenergy specialty crops such as algae, jatropha, and canola can be grown on marginal land to produce biofuels using conventional conversion technologies.
- To meet the 2010 in-state production goal in California's BAP, the state needs to restart its largely idle in-state production capacity of 68 MGPY. In-state production increases

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146 Staff estimates of future transportation fuels supply and demand forecasts for biodiesel use obligations under EISA used in the Transportation Energy Forecast for the *2009 Integrated Energy Policy Report (2009 IEPR).*

147 California Air Resources Board, *Proposed Regulation to Implement the Low Carbon Fuel Standard: Initial Statement of Reasons*, March 5, 2009.

148 Staff finds 1.4 billion gallons of soybean biofuel is needed at 68 g GHG/MJ by 2020. Assuming 50 million gallons per plant, 28 plants would be needed. Conversely, 8 yellow grease plants would be needed; however, there is not enough yellow grease in California to fuel 8 plants. Based on staff analysis done in support of the *2009 IEPR*.

California jobs and economic benefits and reduces GHG emissions by minimizing imported fuel transport costs and impacts. California needs to add 115 million gallons of new capacity to meet the 2020 BAP goal.

Biodiesel/Renewable Diesel Fuel Use and Vehicles

In 2008, 1.1 million on-road diesel vehicles were registered in California, consuming 2.8 billion gallons of diesel. Off-road diesel demand adds an additional one billion gallons. Heavy-duty and off-road vehicle applications use over 92 percent of all diesel fuels and therefore represent the key market for biomass-based diesel fuels.[149] Biodiesel has unique fuel properties that require a unique American Society for Testing and Materials (ASTM) D-6751 fuel specification. It also has special handling, storage, and use requirements. This fuel poses challenges with vehicles and engine durability, fuel plugging, variable fuel quality, and cold weather properties.

Renewable diesel has less variable fuel properties than biodiesel and complies with ASTM D975 (petroleum diesel fuel) or ASTM D396 (home heating oil).[150] These characteristics are favored by engine manufacturers. Based on current ASTM specifications, renewable diesel fuels are not anticipated to require any vehicle modifications or preventative maintenance.

Today, the main barrier to expanded B20 use is the 20 cent to 40 cent per gallon higher price for B20 than standard diesel. Future renewable diesel fuels are expected to encounter the same higher price challenge as biodiesel because both use the same expensive feedstocks. Since 1992, most diesel fleets obligated to meet federal alternative fuel use requirements use B20 as the lowest-cost compliance option.[151] Most major medium- and heavy-duty diesel engine vehicle manufacturers accept blends of up to B20 in their vehicles, which are also accepted as an alternative compliance option for the federal alternative fuel vehicle purchase requirements.[152] Federal fleets required to use an alternative fuel in medium- and heavy-duty vehicles provided sufficient market opportunity for some manufacturers to build B20 compatible vehicles in limited models. These medium- and heavy-duty engines were not subject to the aggressive emission reductions required of light-duty vehicles since the 2004 model year, but the 2010 heavy-duty diesel engine standards will be as stringent as the 2004 light-duty standard.

All light-duty diesel cars and pickup trucks can use B5 blends without voiding manufacturers' warranties. However, new light-duty diesel vehicles are susceptible to biodiesel's engine-oil-dilution and have critical emission control needs. As a result, vehicle manufacturers are

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149 Emerging Fuels and Technologies Office, Total Fuel Use Analysis of DMV population and fuel demand. G. Yowell.

150 National Biodiesel Board. *Biodiesel, Renewable Diesel & Co-Processed Diesel*. http://www.biodiesel.org/pdf_files/fuelfactsheets/Co-Processing%20One%20Pager.pdf.

151 The Energy Policy Act of 1992, EPAct 1992 regulations require that federal, state, and alternative fuel provider fleets build an inventory of alternative fuel vehicles.

152 National Biodiesel Board, OEM statement, http://www.biodiesel.org/resources/oems/default.shtm.

currently not recommending higher blends for use in new light-duty vehicles although some are conducting research that may enable future B20 acceptance. Since renewable diesel blends of up to 90 percent meet conventional diesel standards, light-duty diesel vehicle manufacturers are not likely to be as concerned with higher blends of renewable diesel as they are with higher blends of biodiesel.[153]

In November 2008, ASTM International adopted new biodiesel standards for B5, B20, and B100 blends to address the fuel quality problems identified in the recent past. The Energy Commission is funding additional work to develop and perform test methods for the development of national standards for biodiesel blends greater than 20 percent by volume.[154] Compliance with the recently established ASTM B5 standard would provide the opportunity to triple biodiesel use.

In 2008, 1.6 million gallons of biodiesel were sold at 39 retail stations within California. Of these 1.6 million gallons, 1 million gallons were sold as part of B20 blends, and 250,000 gallons were sold as B99 blends.[155] The majority of fuel was used by non-retail facilities such as commercial fleets, governmental entities, private card locks, and rental companies, most of which relied on B20 blends.

Funding for vehicle demonstrations is not recommended for biodiesel vehicles. The producers of some new biomass-based diesel fuels are requesting vehicle demonstration funds. These demonstrations will allow for pre-commercial identification and correction of any deleterious engine effects that might otherwise dissuade light-duty vehicle manufacturers. While the Energy Commission will continue to monitor this opportunity, it is not currently allocating any program funds for this purpose.

Fuel Production

California has 11 biodiesel plants with a combined annual production capacity of 87 million gallons. Due to the industry's inability to compete with petroleum-based diesel prices, these plants likely produced less than 25 million gallons in 2009. Six plants, representing one-third of the state's biodiesel production capacity, are idle due to their price disparity.[156] The BAP requires a minimum of 20 percent of biofuels to be produced within California by 2010 and 40 percent by 2020. With an estimated diesel demand of 5.25 billion gallons by 2020, a minimum of 200 million gallons of biomass-based diesel and other biofuels are needed, requiring an in-state plant expansion of up to 115 million gallon.[157]

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153 Renewable diesel engine testing finds that blends up to nearly 90 percent have the ability to meet ASTM 975 Standards, Preliminary Results from Neste and Conoco Phillips Testing, 2003-2007.

154 This task is $523,000 out of $4 million agreement with Department of Food and Agriculture.

155 Source: California Energy Commission, Petroleum Industry Information Reporting Act data.

156 Docket comments by the California Biodiesel Alliance, February 16, 2009.

157 5.25 million gallons x 20% for LCFS x 20% for BAP.

Biodiesel plants use recycled cooking oil (yellow grease) as their lowest-cost and lowest GHG feedstock and use more expensive—and typically higher GHG—feedstocks such as soybean, palm, and a variety of plant and animal oils. To reach higher production volumes of lower carbon biodiesel, second generation feed sources and plants are necessary like biomass-based cellulose, waste, and algae. Second generation plants will need assistance as they move into pilot and pre-commercial scale plant sizes. Expansion of both first and second generation fuel production is needed to reach the 2020 goals. Building biofuel plants is one of the most effective and fastest ways to reach the goals of the BAP, and directly supports California's economy.

A federal $1 per gallon incentive for biodiesel production began in 2002 and expired on December 31, 2009. The ARB's LCFS program has a gradual phase-in, and will not significantly impact the market demand for biodiesel for another two years. Accordingly, fuel producers will have little motivation to invest in ensuring these plants' continued operation in the short-term without the federal production incentive.[158] The LCFS should provide a 10-cent to 75-cent per gallon market price premium for biofuels providing 40 percent to 90 percent GHG reduction in a $20-$60/metric ton GHG market, respectively.

On November 12, 2009, U.S. DOE and the USDA announced $24 million in funding in Biomass Research and Development grants to produce biofuels. Of these funds, $1.6 million was awarded to a California firm. The ARB does not fund infrastructure, and California's regional air quality management districts have not awarded funds in this area. The Energy Commission allocated $13 million for Biofuel Production Plants with FY 2008-2010 funds in a solicitation released in April 2010. Proposals are being reviewed, and awards are scheduled to be announced in July.

For FY 2010-2011, the Energy Commission is proposing $5 million dollars in grants and loans for diesel substitute fuel production.

Fuel Terminal Storage and Blending

For California to reach the 2050 GHG emission reduction goals and other near-term goals, all biomass based diesel sources must have access to California's market. Biomass-based diesel use must, at a minimum, expand to half a billion gallons by 2015 and one billion gallons by 2030. Maximizing in-state and domestic supplies is the first priority but may not be sufficient to reach the goals if unfavorable market conditions persist.

Consequently, the continued growth of biomass-based diesel produced and used in California may depend on establishing bulk storage and terminal blending facilities for importing biofuels and feedstocks. California imports approximately 62 percent of its transportation fuels from domestic and foreign sources, and this amount continues to grow for petroleum and biofuels alike.[159] Biodiesel and renewable diesel will require bulk terminals to receive and store the large

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158 As of July 2010 Congress has not yet reinstated the incentive.

159 Schremp, Gordon, Aniss Bahreinian, Malachi Weng-Gutierrez. *Transportation Energy Forecasts and Analyses for the 2009 Integrated Energy Policy Report,* Draft Staff Report. California Energy Commission CEC-600-2009-012-SD.

volumes of bio-oils required to competitively produce renewable diesel. ARB's LCFS carbon intensity and sustainability requirements will ensure that future imported renewable fuels are sustainably grown and provide lower carbon intensity.

Nearly all bulk receiving terminals are located with access to marine ports, railroads, and pipelines sufficient to move the fuel volumes into the 4 billion gallon per year diesel market. Adding biofuel capacity and modifying existing bulk terminals to accept biofuels are critical to biofuels' expanded future use.

Terminal blending racks are used to store bulk volumes of unblended fuels and dispense blended fuels for trucks to deliver to retail, fleets, and farm customers. California terminal racks are not modified to accept biodiesel fuels. Biodiesel terminal rack modifications can lead to a significant expansion of biofuel volumes due to the ease, lower-cost and time to load the fuels compared to today's method. In California, biodiesel fuels typically experience after-plant transport costs of 15 cents to 50 cents per gallon, compared to 9 to 12 cents for gasoline and diesel fuel.[160] These higher transportation costs should be eliminated with the establishment of appropriate rack terminal modifications to accept the biofuel.

Currently, financial institutions are not funding biodiesel infrastructure projects. Funds from sources such as the federal government, ARB, or local air quality districts have not been made available for biodiesel infrastructure investments. The Energy Commission's program funds alone are not sufficient. However, program funds used as a grant or loan guarantee may be able to leverage funds from other financial institutions to minimize the risk for companies to make improvements in advance of economic necessity.

For FY 2008-2010, the Energy Commission allocated $4 million for blending and storage terminal projects as part of a broader solicitation for alternative and renewable fuel infrastructure in November 2009. From this solicitation, approximately $3.86 million has been awarded as identified in Table 15.

Table 15: Diesel Substitute Infrastructure Funded by the Program

Solicitation	Project Description	Proposed Award
PON-09-006	Port of Stockton biodiesel fuel terminal	$1,999,379
PON-09-006	Two biodiesel blending facilities	$1,790,000
PON-09-006	Bulk biomass dispenser adjacent to San Jose pipeline terminal	$69,223
Total		**$3,858,602**

Source: California Energy Commission

160 Tellurium's comments made at the Energy Commission workshop November 2009.

For FY 2010-2011 the Energy Commission is allocating $4 million, including possible loans and loan guarantees, to expand the number of terminal blending facilities capable of handling biodiesel fuels. California has more than 100 rack-terminals requiring modifications to dispense biomass-based diesel. Modification costs are estimated to be $500,000 to $3.0 million per site. Making these modifications would reduce retail prices of biomass-based diesels and increase biodiesel throughput. An allocation of $4 million dollars could fund one fifth of the terminal modifications at 20 percent of the total conversion cost, assuming $1 million/terminal total conversion cost.

Table 16: Diesel Substitutes Funding Summary for FY 2010-2011

Diesel Substitute Production	$5 million
Bulk Terminal Storage and Blending Facilities	$4 million
Total	$9 million

Source: California Energy Commission

Natural Gas

Natural gas (methane) in compressed or liquefied form has been used as motor fuel in California for more than 20 years. It is used in a broad range of transportation applications, from personal light-duty vehicles to transit buses and freight movers. The Energy Commission forecasts California's use of natural gas in the transportation sector will increase by 150 to 180 percent by 2030 from the 2007 demand of 150.1 million therms, increasing the need for additional fueling infrastructure.[161] California has more than 400 CNG and LNG stations, more than 30 percent of which provide public access.

In 2008, there were almost 35,000 NGV registered in California. Approximately 28 percent of the vehicles were medium- and heavy-duty vehicles, mostly CNG-powered buses. Medium- and heavy-duty NGVs can also replace diesel vehicles in port drayage, refuse hauling, transit, delivery vehicles, and more. NGVs, along with hybrid diesel trucks, are an important recommended strategy to achieve black carbon, NOx, and GHG reductions.[162] With regulatory requirements to reduce diesel pollution in communities next to ports and rail yards fully in effect by December 31, 2012, natural gas may be the only viable alternative fuel option in the near- to mid-term.

Natural gas is competitively priced with gasoline, typically costing consumers between 27 percent less to 5 percent more than gasoline. Based on the fuel economy of previous NGV models (through 2009), natural gas costs the consumer between 24 percent less and 21 percent more than diesel. However, new natural gas engines have significantly improved fuel economy, and these new designs are close to matching the fuel economy of diesel engines. Based on these improved fuel economies, natural gas would range from costing 44 percent less to being equivalent in cost on a diesel-energy-equivalent basis. Vehicles operating on conventional CNG reduce petroleum fuel use by 99 percent and reduce GHG emissions by 29 percent relative to gasoline and by 21 percent relative to diesel on a full fuel cycle basis (although some criteria pollutants can be higher than their new diesel vehicle counterparts).[163]

While natural gas is generally regarded as a non-renewable alternative fuel, CNG and LNG can also be derived from biomethane gas. Biomethane is produced through anaerobic digestion of organic matter and is chemically and structurally identical to natural gas. The use of biomethane in CNG and LNG vehicles has tremendous GHG reduction potential, reducing emissions by 70 percent to 88 percent.[164] More than 70 landfills, 23 wastewater treatment

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161 California Energy Commission, *2009 Integrated Energy Policy Report,* CEC-100-2009-003-CMF, December 2009, http://www.energy.ca.gov/2009_energypolicy/index.html.

162 *Advanced Technology to Meet California's Climate Goals: Opportunities, Barriers & Policy Solutions*, California ETAAC Advanced Technology Sub-Group, December 14, 2009.

163 Staff comparison of 2007 and 2009 model year heavy-duty engine ARB Executive Orders.

164 The ARB's January 2009 GREET model analysis estimates biomethane feedstocks dispensed in a LNG/CNG fueling station and used in a natural gas passenger vehicle would result in GHG emissions of

facilities, and more than 12 dairies in California are now capturing biomethane emissions and using them for electricity generation, heating, or alternative fuel production.[165, 166, 167] Biomethane from California waste streams may be able to produce 120 billion cubic feet of gas (bcf) or 60 bcf of pure biomethane, comparable to 0.44 billion diesel gallon equivalent.[168] The capture of fugitive biomethane from landfills, dairy waste, and municipal waste streams not only displaces petroleum, but also prevents its release into the atmosphere.[169, 170]

Another use for biomethane that will likely be seen in California in the near future is as an input to the production of other alternative fuels. For example, biomethane can be used to replace natural gas in the production of ethanol, reducing the carbon intensity of ethanol by as much as 66 percent.[171] Also, technology now exists to convert natural gas or biomethane directly into hydrogen for fuel cell use. Moreover, methane (natural gas and biomethane) can be blended with hydrogen (hythane and H/CNG), further extending the potential benefits of both.

Vehicles operating on natural gas can reduce GHG emissions by as much as 30 percent compared to gasoline and diesel vehicles on a full fuel-cycle basis. However, the use of biomethane in the same vehicles has an even greater GHG reduction benefit, reducing emissions by as much as 97 percent.[172]

Given that biomethane can lead to such substantial GHG reductions and can use existing waste streams, it will not be surprising to see additional biomethane production facilities come on-line given California's aggressive biofuel and GHG reduction mandates and goals.

11.3 to 28.5 g/MJ or approximately a 70 to 88 percent reduction compared to California gasoline. Biomethane used in medium- and heavy-duty vehicles would result in similar reductions compared to diesel.

165 US EPA Landfill Methane Outreach Program, http://www.epa.gov/lmop/index.htm.

166 *Opportunities for and Benefits of Combined Heat and Power and Wastewater Treatment Facilities*, Eastern Research Group Inc., Energy and Environmental Analysis Inc., April 2007

167 Personal Communication, Allen Dusault of Sustainable Conservation, December 16, 2009

168 Biomethane Summit, Westport Innovations Presentation, June 23, 2009

169 California Air Resources Board (ARB), Detailed California-Modified GREET Pathway for Compressed Natural Gas (CNG) from Landfill Gas, available at http://www.arb.ca.gov/fuels/lcfs/lcfs.htm

170 "An Overview of Landfill Gas Energy in the United States — Presentation," U.S. Environmental Protection Agency (US-EPA) Landfill Methane Outreach Program (LMOP) June 2009

171 Presentation by Calgren at Energy Commission's AB 118 Investment Plan Workshop for Biofuels, September 14-15, 2009.

172 The ARB's January 2009 GREET model analysis estimates biomethane feedstocks dispensed in a LNG/CNG fueling station and used in a natural gas passenger vehicle would result in GHG emissions of 2.7 g/MJ or approximately a 97 percent reduction compared to California gasoline. Biomethane used in medium- and heavy-duty vehicles would result in similar reductions compared to diesel.

One of the biggest barriers to the penetration of natural gas in the marketplace is the lack of public access fueling infrastructure. Until this problem is addressed, the use of NGVs will likely be confined to the medium- and heavy-duty class of vehicles, which can use predetermined CNG/LNG stations on a regular route.

Light-Duty Vehicles

Approximately 25,200 light-duty NGVs are on the road in California, accounting for about 12 percent of natural gas use in the transportation sector.[173] The Energy Commission estimates that an additional 6,100 light-duty OEM and retrofitted NGVs will be deployed during the FY 2009-2010 period and 2,450 during the FY 2010-2011 period.[174] Retrofitted conventional vehicles account for only 10 percent to 15 percent of the overall light-duty NGV population.[175]

Honda is the only OEM that retails a light-duty passenger NGV in the United States. However, 20 other manufacturers worldwide also make light-duty NGVs. GM has nine models available for markets outside the United States, but, along with other manufacturers, the company is taking a wait-and-see position while evaluating United States incentives and infrastructure.[176]

All light-duty NGV engines are basically converted gasoline engines, including the engines in OEM NGVs, which are based on previously existing gasoline engine families that have been redesigned or simply modified for natural gas operation. California regulations prohibit the after-market conversion of emission-controlled vehicles with retrofit systems to operate on an alternative fuel, such as natural gas, unless the retrofit systems have been evaluated and certified by the ARB. Two firms (Baytech and BAF) have ARB certification to produce kits for converting light-duty conventional vehicles to light-duty NGVs.[177, 178] Baytech offers various GM light- and medium-duty vehicles on an aftermarket basis (including pickups, vans, and cutaways). BAF offers natural gas Ford Crown Victoria (used for taxis), as well as E-350 passenger/cargo vans and F-150/250/350 pickup trucks. A third firm, NaturalDrive Partners, is seeking certification from ARB for its retrofits.[179] California-based Imperial Machine Products Company (IMPCO) sells approximately 13,000 natural gas and propane conversion kits per

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173 Energy Commission staff estimate based on Department of Motor Vehicles data for 2008. (G. Yowell).

174 CALCARS.

175 Estimate by Clean Energy December 1, 2009.

176 California Natural Gas Vehicle Coalition, *Natural Gas Vehicles: A Key Path to 2020 and 2050 GHG Reductions*, http://www.cngvc.org/pdf/CNGVC_factsheet_KeyPath.pdf.

177 Presentation by SCAQMD on September 3, 2009. Titled "Clean Fuels Program Advisory Group." http://www.aqmd.gov/TAO/ConferencesWorkshops/Retreats/9-2009_LoriBerard.pdf.

178 ARB no longer certifies conversion equipment, but they do certify converted vehicles and engines.

179 Ibid.

month to the world market, but none in California, primarily because of the expense required to comply with current ARB certification.[180, 181] Table 17 shows the costs of these conversions.

Table 17 Natural Gas Conversion Costs by Vehicle Model[182]

Vehicle Type	Conversion Cost
Ford Crown Victoria/Lincoln Town Car/Mercury Marquis with 13 gasoline gallon equivalent (GGE)	$13,500
Sierra/Silverado 1500/2500HD pick-up truck with 20 GGE	$15,500
F150/250/350 pick-up truck with 30 GGE	$18,500

Source: California Energy Commission

Nationwide, the ARRA includes multiple elements to advance alternative fuel and vehicle technologies. The Clean Cities program, as part of the ARRA, was a significant portion of federal activity in 2009 promoting NGVs.[183] Worldwide, 20 manufacturers including GM and Ford provide NGVs with a total of 9.8 million vehicles on the road in September 2008.[184]

Although California received no ARRA funds in the light-duty natural gas sector, the funding of light-duty NGVs elsewhere in the nation will encourage the development of additional NGV models by OEMs. Since the California NGV market generally depends on the same OEMs as the rest of the nation, California's NGV market stands to benefit from a stronger nationwide market.

Federal tax credits are available for the Honda Civic GX, which is the only light-duty NGV currently produced by a major OEM in the United States market. The difference in price between the Honda Civic GX ($25,340) and a gasoline equivalent Honda Civic DX ($15,655) is $9,685.[185] A $4,000 federal tax credit is available for vehicles capable of using only CNG or LNG

180 Presentation by Tim Standke, IMPCO at the "Natural Gas and Propane Workshop" on September 18, 2009.

181 Mike Eaves, CA NGV Coalition, presentation to the Energy Commission, March 23, 2007.

182 Stephe Yborra, NGV America, "Frequently Asked Questions About Converting Vehicles to Operate on Natural Gas," http://www.ngvc.org/pdfs/FAQs_Converting_to_NGVs.pdf.

183Other federal activities in 2009 included: Formation of Congressional Natural Gas Caucus; Tax Extenders Act of 2009 (H.R. 4213) extending the natural gas fuel tax credit by one year; a $5 million budget appropriation for U.S. DOE for NGV RD&D; the Natural Gas Vehicle Research, Development, Demonstration, and Deployment Act of 2009 (H.R. 1622) for $30 million annually for five years.

184 Pike Research, October 19, 2009. http://www.pikeresearch.com/newsroom/17-million-natural-gas-vehicles-will-be-on-the-road-by-2015.

185 Manufacturer's Suggested Retail Price 2009.

that partially offsets this incremental cost. As an additional incentive, light-duty CNG vehicles are permitted to use California's HOV lanes.

The natural gas conversion of a light-duty vehicle is given a federal tax credit of up to 80 percent of the cost gap, up to a maximum credit of $4,000.[186] Using the Ford Crown Victoria model as an example, the net cost of a converted light-duty NGV would equal the original vehicle cost ($18,000) plus the cost of the conversion ($13,500) minus the tax credit ($4,000), or approximately $27,500.

Federal grants and loans to encourage and expand the markets for light-duty NGVs commenced in early 2010. This large influx of funds to the vehicle manufacturers is expected to result in expanded NGV offerings as early as 2011 to 2013 (based on a federal three-year agreement term).

In coordination with the Energy Commission, the ARB has taken the primary responsibility for providing light-duty vehicle deployment incentives. The ARB's Clean Vehicle Rebate Program is not expected to provide funding for light-duty NGVs for FY 2010-2011, due to an expected high demand for rebates for light-duty PHEVs and BEVs. However, light-duty NGVs can provide an immediate opportunity for significant GHG emission reductions and petroleum reduction. To address this opportunity, Energy Commission and ARB staff have discussed the possibility of having the ARB administer light-duty NGV rebates as part of the Clean Vehicle Rebate Program using Energy Commission funding. Toward this end, the Energy Commission will allocate a portion of its $13 million allocation for NGVs specifically toward light-duty NGV deployment rebates. These rebates will serve both to accelerate NGV deployment and to publicly demonstrate the viability of light-duty NGVs for individual consumers' use.

Medium- and Heavy-Duty Vehicles

Medium- and heavy-duty NGVs are an important element of the NG fleet consuming 88 percent of the natural gas used by NGVs. In 2008, 9,674 medium- and heavy-duty NGVs represented 1 percent of these vehicle classes operating in California. Transit and school buses represent 74 percent of the natural gas population (7,144), and refuse trucks represent 10 percent (1,000) of the population. Sixteen years after NGVs' first introduction into bus fleets, they make up 10 percent of these fleets. Eight years after NGVs' introduction into refuse truck fleets, NGVs make up 7 percent of these fleets.[187] Transit and school buses were the first vehicle types to make extensive use of alternative fuels and diesel particulate filters.

The most likely future markets for medium- and heavy-duty NGVs are short- and medium-haul applications, pick-up and delivery, and general freight.[188] Clean Energy, a natural gas supplier, foresees applications for the entire range of medium- to heavy-duty trucks. Kenworth, Peterbilt,

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186 NGV America, "Fact Sheet: Federal Incentive for Natural Gas Vehicles," http://www.ngvamerica.org/pdfs/FederalVehicleTaxCredit.pdf

187 DMV vehicle registration data.

188 Westport; Cummins.

Freightliner, and Volvo/Mack offer heavy-duty natural gas trucks for the California market, and all have an additional cost barrier as compared to diesel truck counterparts. All refuse truck manufacturers and all transit bus manufacturers (Gillig, the most recent addition) offer natural gas platforms, and an even wider variety of heavy- and medium-duty engines are under development. Heavy-duty NGV costs are roughly $70,000-$80,000 higher than for a Class 8 heavy-duty conventional diesel truck.

The purchase of Class 8 drayage trucks is the single greatest factor affecting the demand for medium- and heavy-duty NGVs in California for the next few years. About 500 heavy-duty Class 8 trucks use LNG for port applications within the state. Penetration is greatest in Southern California, where local air district and port policies have provided incentivizes for more activity.[189] The Clean Air Action Plan (CAAP) adopted by the Ports of Los Angeles and Long Beach is a major driver for these large purchases. As part of the CAAP, the ports are implementing a Clean Trucks Program (CTP), with a goal of reducing heavy-duty drayage truck-related emissions by 80 percent by 2012. A section of the CTP requires the scheduled phase-out of trucks, and certain non-retrofitted 1994-2003 trucks will be banned from use in the ports. About 7,500 diesel drayage trucks in the ports already meet federal emission standards, 1,500 diesel trucks that have received funding were delivered in April 2010, and an additional 500-600 of the 2004-2006 trucks will require replacement by 2012.[190] Consequently, there is opportunity to replace 500 non-compliant diesel trucks with natural gas immediately and many more later on for the Ports of Los Angeles and Long Beach.

Nationwide, ARRA funds were awarded for at least 325 medium- and heavy-duty NGVs.[191] Since these manufacturers would also provide vehicles for a California market, the ARRA funding may strengthen the vehicle offerings for California. Funding for medium- and heavy-duty NGVs has not been made available as part of the ARB's AQIP.

In conjunction with ARRA funding, the Energy Commission is funding a project to deploy 180 LNG drayage trucks for the Ports of Los Angeles and Long Beach. The San Bernardino Association of Governments will also receive funds for 262 heavy-duty LNG trucks and two LNG fueling stations. These projects will receive a combined $11.5 million of program funds, along with $17 million of ARRA funds. Additional funding, as part of a separate solicitation (PON-09-004), is being provided for the development, demonstration, and commercial launch of an advanced natural gas engine. [192] These activities are summarized in Table 18.

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189 Pete Price, Price Consulting, e-mail, November 16, 2009.

190 Energy Commission staff conversation with Thomas Jelenic, March 24, 2010

191 An additional 2,322 NGVs were identified for funding, but not identified as to vehicle class.

192 As part of PON-09-004, funding is also being provided to other medium- and heavy-duty NGVs that incorporate electric or hybrid applications. These are identified in the earlier electric drive section.

Table 18: Medium- and Heavy-Duty NGV Projects Funded by the Program

Solicitation	Project Description	Proposed Award
PON-08-010	San Bernardino LNG trucks	$9,308,000
PON-08-010	Ports of Long Beach and Los Angeles drayage trucks	$5,142,000
PON-09-004	Development, demonstration and commercial launch of an advanced natural gas heavy-duty engine	$1,777,364
Total		**$16,227,364**

Source: California Energy Commission

A review of the projects requested in conjunction with the ARRA funding provides an insight into the areas in California where natural gas technology is used. NGV proposals fell into three regional categories: Southern California, the Bay Area, and Central California. The Southern California region had the largest number of proposals, with two projects receiving funding. Other areas represent additional opportunities for future solicitations.

Offsetting the incremental cost of medium- and heavy-duty NGVs in California is an excellent strategy to reduce GHG emissions. Given the increasing demand for natural gas medium- and heavy-duty vehicles, new emission standards, the need for zero-emission technologies, and the high incremental cost of natural gas medium- and heavy-duty trucks, the Energy Commission will allocate $13 million in grants for light-, medium- and heavy-duty NGVs for FY 2010-2011. These grants will help defray the differential costs of these vehicles, after all other incentives are accounted for.

Infrastructure

The natural gas fueling infrastructure consists of seven types of fueling facilities:

- CNG home refueling appliances
- Small-capacity CNG stations
- Medium-capacity CNG stations
- Large-capacity CNG stations
- Large-capacity LNG stations
- CNG dispensers added to existing gasoline stations
- Combined CNG and LNG station

The number of natural gas stations in California increased from approximately 375 in January 2007 to approximately 400 in September 2009.[193] Thirty percent of these stations are publicly accessible, and 30 dispense LNG. Small-, medium-, and large-capacity CNG stations (compressors and dispensers) can be added to existing gasoline stations, or built as "stand-alone" CNG stations. The former is the cheaper option, since existing land, concrete infrastructure, and canopy can be used. For example, the Galileo Nanobox is a self-contained

193 Telephone conversation with Mike Eaves on October 23, 2009.

system that can be added to fuel islands anywhere.[194] It is also possible for a single station to dispense both CNG and LNG, and in fact LNG can be gasified to CNG with conventional pumps with less energy than it takes to compress pipeline gas to CNG.[195]

CNG stations can be divided into two groups: time fill and fast fill. Time fill stations are cheaper to construct but require several hours to fill a vehicle. Fast fill stations can refill a vehicle in minutes, but the costs associated with these stations are considerably higher. Fast fill dispensers are the only practical dispensers for use in public access natural gas stations. Table 19 presents Energy Commission estimates of current natural gas infrastructure costs.

Table 19: Natural Gas Infrastructure Costs

Infrastructure Type	Estimated Costs
Small CNG Station with fast fill[196]	$400,000
Medium CNG Station with fast fill[197]	$600,000
Large CNG Station with fast fill[198]	$1.7 million
Large LNG Station[199]	$1.7 million
Combined CNG (with fast fill) & LNG Station	$2 million

Source: California Energy Commission

Nationwide, ARRA funded 133 CNG stations and 13 LNG stations. These additional stations add to, but do not substantially affect, infrastructure along vehicle corridors that would extend the range of NGVs.

In response to the Energy Commission's first solicitation in conjunction with the ARRA, the Southern California region had the largest number of proposals, over half of which were for the construction of natural gas fueling infrastructure.[200] In November 2009, the Energy Commission also issued a grant solicitation with $5.6 million available for CNG and LNG fueling stations.

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194 Presentation by Michael Eaves, Clean Energy "Natural Gas Fueling Infrastructure" at the "Natural Gas and Propane Workshop" on September 18, 2009.

195 *2008-2009 Investment Plan*.

196 Defined as a capacity of less than or equal to 500 standard cubic feet per minute (scfm).

197 Defined as a capacity of 100 to 2,000 scfm.

198 Defined as a capacity greater than 2,000 scfm.

199 Defined as a capacity greater than 15,000 gallons of LNG.

200 Southern California region comprises the entire greater Los Angeles area, up to Santa Barbara and south to San Diego and the Mexican border.

The proposed awards from these solicitations are summarized in Table 20. Additionally, SCAQMD allocated $2 million for natural gas infrastructure in the previous fiscal year.

Table 20: Natural Gas Infrastructure Funded by the Program

Solicitation	Project Description	Proposed Award
PON-09-006	Sun Valley LNG/CNG refueling station	$489,040
PON-09-006	Oakland LNG infrastructure	$470,600
PON-09-006	Ontario CNG infrastructure	$300,000
PON-09-006	Sacramento transit CNG fueling equipment	$500,000
PON-09-006	Coachella Valley regional LNG infrastructure	$500,000
PON-09-006	San Fernando Valley CNG stations	$195,600
PON-09-006	SCAQMD CNG and LNG fueling stations	$2,600,000
PON-09-006	Central Valley Transportation Center in Reedley	$300,000
PON-09-006	Lemoore CNG fueling station	$200,000
PON-09-006	San Diego CNG fueling station upgrade	$186,148
Total		**$5,741,388**

Source: California Energy Commission

For FY 2010-2011, the Energy Commission allocates $2 million in grants for the upgrading of existing fueling stations. There are approximately 400 natural gas fueling stations in California, representing significant investments of both public and private funds. The life expectancy of the tanks and equipment varies depending on the materials used and the quality of the gas. The cost of upgrading equipment can be prohibitive, particularly for schools and local governments encouraged to convert their fleets to NGVs. State funding will relieve these public agencies of this financial burden and maximize the use of existing infrastructure.

Biomethane

When organic matter is treated with heat and bacteria over time, a biogas is produced. Once created, biogas can be converted to biomethane by removing impurities such as CO_2, hydrogen sulfide, and water.

Biomethane can be used as an energy source in transportation, power generation, and combined heat and power application, including:

- Direct use as a fuel and heat source for boilers or industrial heat.
- Injection into utility-operated natural gas pipeline systems for use by residential, commercial, and industrial customers, and for use in powering combined cycle natural gas electricity generating stations.
- Blended or enhanced with hydrogen, further extending its GHG benefits, or used as a feedstock in hydrogen production.

- Refined into gasoline and diesel via gas-to-liquid technologies.
- Compressed into CNG or liquefied into LNG for use in transportation applications.

The technologies needed for the production of biomethane as a transportation fuel are "off the shelf" technologies that are generally well-developed, commercialized, and carry a "zero technology risk."[201] Biomethane is fully compatible with California's existing natural gas infrastructure and can be used by all vehicles equipped to operate on natural gas.

Biomethane in California will most likely be sourced from dairies, landfills, wastewater treatment facilities, local or regional standalone anaerobic digester plants, agricultural residues, woody biomass from forest fuels management activities, and diverted organic material from municipal solid waste streams.[202] This is important because biomethane derived from waste stream feedstocks has the lowest carbon intensity value of any commercially viable alternative transportation fuel. CNG and LNG derived from dairy waste and landfill gas can have anywhere from a 70 percent to 88 percent GHG emission reduction from the petroleum diesel baseline.[203] Capturing biomethane from these sources is a particularly important GHG reduction strategy, as methane is 21 times more potent than carbon dioxide as a GHG.

The technical feasibility of deriving both CNG and LNG from landfill gas has already been commercially demonstrated. Currently more than 70 landfills in California are using captured methane emissions as an energy source, and at least two of those are producing biomethane to be used as a transportation fuel. At the Frank R. Bowerman Landfill in Orange County, Prometheus has a plant that will produce 40,000 gallons of LNG from waste biogas by 2010.[204] In Livermore, the Altamont Landfill is currently the world's largest landfill gas to LNG project in the world and is producing 13,000 gallons of LNG daily to be used in Waste Management's refuse trucks.[205] Other landfills working to capture biomethane include Kiefer Landfill and Puente Hills Landfill. In particular, the organic fraction of municipal solid waste, currently

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201 Investment Plan Staff Workshop on Biofuels, CalStart, September 15, 2009.

202 Should California's existing waste streams be committed entirely to biomethane production, they could provide roughly 24 billion cubic feet of additional biogas potential annually source: *An Assessment of Biomass Resources in California, 2007*: California Biomass Collaborative, PIER Collaborative Report, Contract No. 500 01 016. January 2008.

203 Carbon Intensity value for C/LNG derived from dairy or landfill waste can range anywhere from 11.3 to 28.5 grams of CO2 equivalent / MJ. Source: Air Resources Board Low-Carbon Fuel Standard website.

204 Prometheus Energy, *Liquid Natural Gas, LNG, from Landfill Gas* .http://www.prometheus-energy.com/whatwedo/landfillgas.php.

205 Biomethane Summit, Linde Presentation, June 23, 2009.

comprising up to 40 percent of all waste being landfilled in California, could be diverted for biomethane production.[206]

Dairies could use biomethane for off-road agricultural vehicles such as tractors, combines, and threshers, as well as on-road vehicles including pickup trucks and milk trucks. A current working example of onsite biomethane use is at the Hilarides Dairy located in Lindsey, California. The Hilarides Dairy originally collected biogas for onsite electricity generation but has since expanded to become the first dairy in the United States to power milk trucks with manure derived biomethane. These milk trucks are Peterbuilt trucks that have been converted to CNG and drive a 300-mile round-trip route from Lindsey to Hillmar, California.[207]

With proper environmental safeguards, biomethane has the potential to tap the state's large forest woody biomass waste streams that will be generated as forest fuels management projects are implemented. Forest biomass residues in California are estimated to be about 14.2 million BDT per year.[208] The development of new and improved technologies for biogas production from forest biomass is accelerating.

Biomethane can also be used as a process fuel in the production of other alternative fuels such as ethanol. For example, California ethanol production facilities could substitute the use of fossil natural gas with renewable biomethane in its production process to significantly reduce carbon emissions by as much as 66 percent when compared to California ethanol production using natural gas.[209]

Biomethane will be entering the natural gas market, and due to the current low price of natural gas, it will be difficult for biomethane to compete on a production cost basis.[210] The biomethane industry is hampered by capital constraints, and a number of California biomethane projects are now stalled. These projects are having difficulties securing financing due to the uncertainty of how the economics of a biomethane industry will play out in California.

Gas quality testing and certification is an expensive process with no certainty over who should pay for it–biogas developers, natural gas utilities, or other third parties. For biomethane from new feedstocks such as agricultural residues and food waste to be able to enter the natural gas pipeline, extensive gas quality testing must be performed. This testing can be very costly and

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206 Letter from Mark Leary, Deputy Director, Department of Resources, Recycling and Recovery. Dated March 9, 2010.

207 Biomethane Summit, Sustainable Conservation Presentation, June 23, 2009.

208 *An Assessment of Biomass resources in California, 2007*: California Biomass Collaborative, PIER Collaborative Report, Contract No. 500 01 016. January 2008.

209 Presentation by Calgren at Energy Commission's AB 118 Investment Plan Workshop for Biofuels, September 14-15, 2009.

210 Last year the average retail diesel price was $2.58 per gallon, and natural gas was $1.81 per diesel gallon equivalent. Source: Energy Commission Staff Analysis of statewide, retail fuel prices.

the natural gas utilities have currently exhausted their gas testing funds allotted for this purpose.[211]

Biomethane is the lowest carbon intensity alternative fuel readily available in California. Although the production potential for biomethane is significant, few biomethane or biogas projects are operational in California. The most common feedstock in use is landfill gas, although at least one dairy and one agricultural waste facility exist in the state. The landfill gas projects are likely to have a capacity of roughly 4 million to 7 million gallons of LNG per year and estimated capital costs in the area of $12 million to $20 million. The few agricultural waste projects vary substantially in both capital cost and feedstock, making numeric estimates difficult.

At least 10 California projects, soliciting more than $46 million of program funds, were proposed under the Energy Commission's ARRA cost-sharing solicitation to either produce biomethane as a transportation fuel (either as CNG or LNG) or produce biomethane as a process fuel. No awards were funded by ARRA or the Energy Commission under that solicitation. In addition, ARB is not making biomethane investments during its first or second rounds of AQIP funding.

Biomethane production for transportation use was initially allocated $10 million in the FY 2008-2010 investment plan. That amount was later increased to $21.5 million in response to the strong project proposals presented by energy developers at the *2010-2011 Investment Plan* workshop. To date, four biomethane production projects have been awarded a proposed $21.5 million in Energy Commission funding. All of these projects use a different form of waste feedstocks. As a condition of funding, the biomethane produced must be used for transportation fuel or as a process fuel in the production of other alternative fuels.

Table 21: Biomethane Projects Funded by the Program

Solicitation	Project Description	Proposed Award
PON-09-003	Biomethane production from municipal wastewater sludge digesters	$1,830,132
PON-09-003	Anaerobic digestion of rendering waste to produce biomethane	$3,956,150
PON-09-003	Anaerobic digestion of dairy manure to produce biogas, for use in the production of ethanol	$4,672,798
PON-09-003	Bio-LNG production from landfill gas wells	$11,020,419
Total		**$21,479,499**

Source: California Energy Commission

211 Initial research for new biomass feedstocks will cost between $340,000 and $500,000 as a one-time expense, and then each project will require ongoing gas sampling which is estimated at $20,000 per month. These numbers are subject to increase with more complex feedstocks. Brennan, Ken. "Re: PG&E Gas Quality Testing Cost Estimate." Private communication to Leslie Baroody. November 18, 2009.

To establish biomethane for transportation fuel as an industry in California, grants and incentives must offset high capital costs. Because this is a relatively new industry in the midst of a recession, California will have to ensure supportive government policies and additional financial incentives. In light of $46 million in project proposal requests and the $21.5 million in the recent solicitation, funding is still a substantial need. Consequently, the Energy Commission is allocating $7 million in grants and loans for FY 2010-2011 to help establish a biomethane industry in California. The allocation will focus on projects that use a variety of waste feedstocks, including but not limited to dairy, landfill, wastewater, agricultural, forest residues, and the organic fraction of municipal solid waste streams, as well as a variety of process technologies. Potential areas for funding include:

- Projects that wholly or partially produce biomethane for direct use as a transportation fuel.
- Projects that use biomethane as a process fuel in the production of another low-carbon alternative fuel, such as ethanol facilities using biogas as a replacement for natural gas in the ethanol production process.
- Projects that use biomethane as a feedstock for the production of another low-carbon alternative fuel, such as gas-to-liquid technologies.
- Biomethane feedstock and project feasibility studies for future biomethane capital projects in California; this could include feasibility studies of modifications to existing biogas facilities.
- Gas quality testing for new feedstocks.
- Gas for injection into pipelines for electricity production.

Table 22: Natural Gas Funding Summary for FY 2010-2011

Light-, Medium- and Heavy-Duty Vehicles	$13 Million
Upgrades to Natural Gas Fueling Stations	$2 Million
Biomethane Production Plants and Quality Testing	$7 Million
Total	$22 Million

Source: California Energy Commission

Propane

In the early 1980s, propane was the leading alternative fuel in California with more than 200,000 propane vehicles operating in the state. Despite its availability, less costly infrastructure, and price competitiveness, propane fuel use and vehicle availability declined. Nevertheless, propane continues to be an attractive motor fuel for medium-duty vehicle fleets and will likely grow as more applications become available over the coming years, bolstering its role in achieving California's climate change goals.[212]

Propane offers significant and immediate petroleum use reductions and moderate GHG emission reductions. Propane can be produced as a byproduct of either natural gas processing or petroleum refining. For light-duty vehicles, or any gasoline-fueled vehicles, propane produced from natural gas processing reduces GHG emissions by 20 percent compared to gasoline—slightly better than petroleum-derived propane. For heavy-duty vehicles using diesel fuel, propane offers a slight GHG reduction relative to diesel.[213]. In the future, propane could be produced from renewable resources. Renewable propane would provide much greater benefits, with emission reductions reaching up to 90 percent.[214]

According to the Western Propane Gas Association, California consumed approximately 491 million GGE of odorized propane in 2008. Fifty-five million to 63 million GGE of this consumption was used specifically for on- and off-road vehicles.

Propane is attractive in terms of pricing compared to both diesel and petroleum. If federal excise tax credits for propane use continue to be available in the future, propane will be a viable option for fleets. According to the U.S. DOE, the average cost for propane is $2.69 per gallon, or $3.40 per GGE.[215] The federal government also offers a fuel use tax credit of $.50 per GGE, which acts as an incentive to propane users to offset the energy loss with the use of propane in vehicles.

Additionally, case studies conducted in Canada and Texas show significant savings for propane vehicle fuel and maintenance costs. As a result, fleets have become increasingly interested in using propane fueled vehicles.[216] While the propane market will likely grow nationwide in the next few years with the increased availability of engine options and vehicles, this growth will

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212 Survey information provided by CleanFuel USA and Western Propane Gas Association.

213 *Fuel-Fuel Cycle Assessment: Well to Wheels Energy Inputs, Emissions and Water Impacts: State Plan to Increase the Use of Non-Petroleum Transportation Fuels*. CEC-600-2007-004-REV, revised August 1, 2007. For heavy-duty, see also TTW US EPA Heavy Duty Certification Data (2000, 2003, 2005, 2008 and 2010 model years) at http://www.epa.gov/oms/certdata.htm#largeng.

214 CA-GREET analysis conducted by staff.

215 U.S. DOE ERRE July 2009 Price report. Does not include excise tax credit.

216 Propane Facts, "Reliable and Accurate Research and Case Studies of Propane From Canada and Around the World," http://www.propanefacts.ca/Studies/canadian/reports/fullreport/201/1362/.

not affect California's market without the appropriate certification from the U.S. EPA and the ARB. While fleet owners are interested in propane because of its emission and cost benefits, there are no funding opportunities available now for vehicle purchases with the exception of the federal school bus incentives. With program funding for incremental vehicle cost and the introduction of more ARB-certified vehicle options, propane can be a near-term, viable alternative fuel option for business owners.

Propane is a viable option for California in its efforts to meet GHG reduction goals for 2020. While propane has a role in attaining these goals because of its low cost and availability, it will not likely be a dominant fuel in the market in later years as new technologies and cleaner fuels begin to expand their markets and become more commercially available. Nonetheless, propane is the fuel of choice for some fleets that are beginning to transition to cleaner fuels. With the hopeful emergence of renewable propane in the coming years, propane can maintain its role in the alternative fuels market and in supporting California's long-term petroleum and GHG reduction efforts.

Light-Duty Vehicles

The Roush-converted Ford F-150, 250, and 350 trucks are the only three light-duty propane vehicles certified by the U.S. EPA and ARB. Roush anticipates that the E-150, 250, and 350 cutaway vans will be certified by the ARB in late summer 2010, and these vans have already attracted interest from several fleet owners.[217]

The incremental cost for purchasing a light-duty propane vehicle ranges from $7,000 to $12,000. The average incremental costs for the trucks are approximately $9,000, while the average incremental costs for the cutaway vans are slightly higher, averaging $11,000. Roush anticipates that a $3,000 per vehicle incentive is needed to generate sales and stimulate the growth of the light-duty propane market.[218]

With the emergence of new propane vehicles in 2010, interest in using light-duty vehicles as part of delivery, airport, and utility fleets is increasing. Roush predicts that there will be approximately 150-175 light-duty propane trucks and 350-500 vans available in the California market just for the remainder of 2010, with that number continuing to grow through 2011 based on fleet interests. Given the new models, current propane fuel pricing, and reasonable buy-down costs for these vehicles, funding availability will help ensure the purchase of an alternative-fueled vehicle over a gasoline or diesel vehicle.

Other states across the nation already widely use propane in their public fleets, which demonstrates the market-readiness of propane vehicles. Recently Texas was awarded $25.5 million for propane vehicle and infrastructure development. Of the 882 vehicles being deployed, 645 of these vehicles will be light-duty vehicles for use by public school and business fleets. Market-readiness for these vehicles will allow them to serve as an early action in

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217 Curtis Donaldson, CleanFuelUSA, personal conversation, September 18, 2009.

218 Todd Mouw, Roush, e-mail, September 8, 2009.

reducing GHG emissions in the transportation sector. It is recommended that funding be used to support the expanded use of light-duty propane vehicles.

Medium-Duty Vehicles/Retrofits

Most propane vehicles are retrofits. Propane is viewed as an economical retrofit option for delivery trucks, shuttle buses, and school buses. Sales of the propane school buses continue to increase. Approximately 350 buses have been distributed within the past year and a half, and with continued interest, potential orders for new buses are estimated at 150. While there is still interest in purchasing these buses, given the current economic climate and budget cuts in education, many school districts are relying on funding to cover the incremental costs of these buses. Propane is especially beneficial to rural communities and school districts that may not otherwise have access to an alternative fuel.

Only three companies offer propane retrofits for gasoline engines today: Baytech, Bi-Phase Technologies, and Clean Fuel USA. All of the retrofits offered by these companies are for medium-duty GM engines (6.0 and 8.1 liter models). These kits can be used in various applications but are primarily used for business fleets such as utility trucks, delivery trucks, and airport fleets.

The incremental costs for these systems depend on the application for which the system is being used. The price ranges and federal incentives are listed in Table 23. Systems in the $7,500 price range are typically for applications that include trucks, while the incremental costs for shuttle and school buses are around $20,000. Typically, these incremental costs can be quickly recovered through fuel savings and maintenance costs as shown in case studies conducted by the Texas Railroad Commission. The case studies show that several school districts in Texas have realized savings of up to $400,000 per year when they have converted their school bus fleet to propane. Not only are the fuel savings significant, but the cost of maintaining a propane school bus is less than that of its diesel counterpart, which also contributes to the savings associated with operating propane school buses.[219]

Table 23: Medium-Duty Propane Vehicle Cost Summary

Incremental Vehicle Cost	$7,500-$20,000
Federal Incentives	• 50% of cost to replace school bus meeting 2010 U.S. EPA emission standards • 25% of cost to replace school bus meeting 2007 U.S. EPA emission standards

Source: California Energy Commission

219 Railroad Commission of Texas, "Propane Commercial Uses," http://www.propane.tx.gov/commercial/index.php.

In 2009, GM halted production of the propane-fueled 8.1L engine. Only a limited number of these engines are currently available for sale. However, CleanFuel USA anticipates that a successor to this engine will be available in the third quarter of 2010.[220] Additionally, Cummins Engine Co. offers a propane-fueled version of its standard 5.9L engine, known as the B-LPG Plus.

The medium-duty market accounts for a majority of California's propane vehicle usage because of the variety of available applications. However, with the lack of funding incentives, businesses are hesitant to make the large upfront investment to convert their fleets to propane. Consequently, program funding for the incremental vehicle cost is essential to the overall success of propane in the transportation fuel market. The investment is expected to stimulate additional engine development and increased vehicle offerings and fuel usage while leveraging private investment in the base cost of the vehicles and infrastructure upfits.

Heavy-Duty and Non-Road Vehicles

Currently no heavy-duty propane vehicles or engines have been certified for use in the United States. A large engine (HD 7.6 L) for heavy-duty vehicles is currently being developed by CleanFuel USA and will likely be certified by the U.S. EPA and ARB by the third quarter of 2010 or early 2011.[221] Consequently, propane is not likely to enter into the heavy-duty market until 2011. The cost of this engine has not yet been determined.

Propane is already successfully used in off-road applications such as forklifts. Several thousand forklifts in California run on propane. According to the Propane Education Research Council, the cost of a propane forklift is usually between $16,000 and $24,000,[222] which is comparable to a gasoline-powered forklift and nearly $10,000 cheaper than a diesel forklift, while offering additional advantages over a diesel-run forklift. For example, propane forklifts require less maintenance and are able to run for several thousand hours before they need significant service. Additionally, propane forklifts have lower emissions than gasoline or diesel forklifts so they are more suitable for use in environments with limited air circulation. Very little additional infrastructure is needed to support propane forklifts; propane suppliers can maintain on-site storage tanks for fleets or operate cylinder exchange programs. While propane forklifts may provide fewer emission benefits than hybrid or all-electric forklifts, they will continue to be successful in this off-road market, especially in rural communities, because of their practicality and cost-competitiveness with conventional forklifts.

Funding will not be considered for heavy-duty or non-road vehicles until heavy-duty propane vehicles are certified for use in California.

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220 Curtis Donaldson, CleanFuel USA, September 9, 2009.

221 Curtis Donaldson, CleanFuel USA, e-mail, October 9, 2009.

222 Propane Education and Research Council, http://www.propanecouncil.org/enginetemplate.aspx?id=6358.

Fuel Production

Approximately 60 percent of propane used in California is produced in California refineries, depending on seasonal demand. California is typically a net exporter in the summer and, depending on the weather, can be a net importer in the winter. Imported propane typically comes from Texas, the Midwest, and Canada.

While not yet commercially available, renewable propane could be a good alternative fuel option in the future. Studies are being conducted on the generation of renewable propane at Mississippi State University and Massachusetts Institute of Technology. Brazil is also doing extensive research on renewable propane and its potential to serve as a viable fuel option for vehicles.

Renewable propane can be derived from algae, row crops, and wood.[223] Both high-pressure and catalytic cracking have been used as processes for extracting renewable propane from various feedstocks. The derivation of renewable propane requires little additional energy and results in a product that contains the same energy content as propane derived from petroleum.

The Propane and Education Research Council (PERC) is supporting work specifically for the continued development and expansion of renewable propane. According to Greg Kerr, PERC director of research and development (R&D), PERC is reviewing a report it commissioned from the Gas Technology Institute to study the technical and economic feasibility of different technologies and methods to generate renewable propane. For 2010, PERC has allocated at least $600,000 for the further study and development of renewable propane. If the Energy Commission had R&D funds available for the continued study of the feasibility of renewable propane, PERC would do its best to leverage its funds with the state funds. Energy Commission staff will continue to monitor the progress of renewable propane and considers it a promising alternative fuel option in future years.

Infrastructure

Propane retail infrastructure is already widely available and can easily be expanded as demand for propane as a transportation fuel increases. Approximately 189 propane fueling stations are already in place in California, according to the U.S. DOE's alternative fuel and advanced vehicle data center. California has the second largest number of accessible propane fueling stations in the nation, which can already support an expanded vehicle market with funding for light- and medium-duty vehicles.[224]

Infrastructure for propane vehicle fueling could expand quickly, as existing propane dispensing stations can be used for vehicle fueling through the addition of fuel capacity, a tank pump, and metering equipment. With the addition of this equipment, virtually any propane tank/station in

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223 California Energy Commission, *2009 Integrated Energy Policy Report,* CEC-100-2009-003-CMF, December 2009, http://www.energy.ca.gov/2009_energypolicy/index.html, page 162.

224 Alternative Fuels & Advanced Vehicles Data Center, "Alternative Fueling Station Total Counts by State and Fuel Type," http://www.afdc.energy.gov/afdc/fuels/stations_counts.html.

California can be retrofitted to meet a propane vehicle's needs. This will facilitate the increasing demand for propane as a transportation fuel in the years ahead.

The Energy Commission will not provide funding for propane fueling infrastructure in the *2010-2011 Investment Plan*, since sufficient federal incentives are in place to support the infrastructure needs in California. Funding for infrastructure may be considered in the future, as the propane market grows.

The Energy Commission will allocate $3 million in grants for light- and medium-duty propane vehicles for the *2010-2011 Investment Plan*. This funding will be used to fund the conversions of between 130 and 200 vehicles to propane, as well as for the buydown costs of purchasing new vehicles. Based on the demand for propane vehicles, this amount of funding will not cover costs for all anticipated demand; however, this funding will likely stimulate the market demand for propane vehicles in the coming years. This funding will create opportunities for fleets to transition quickly and efficiently to alternative fuel use. Propane is readily available and affordable and provides both immediate GHG emission benefits and energy independence because all propane used in California is domestically produced. Many fleet owners already consider transitioning to propane as a viable option for their fleets. With the additional incentives provided through this program, more public and private fleets will make the transition, especially with more vehicle options becoming available in late 2010. Additionally, if renewable propane becomes commercially available, it will provide emission benefits comparable to some of the most effective GHG emission reduction fuels. Providing funding for propane vehicles will ensure that California does not inadvertently preclude the potential market for renewable propane in the future.

Table 24: Propane Funding Summary for FY 2010-2011

Light- and Medium-Duty Vehicles	$3 Million
Total	$3 Million

Source: California Energy Commission

Innovative Technologies and Advanced Fuels

The previous sections of this *2010-2011 Investment Plan* identified high-priority investments related to specific fuels and vehicles as well as analytical and outreach strategies. The statute establishing the Alternative and Renewable Fuel and Vehicle Technology Program also gives the Energy Commission authority to make public investments in opportunities not specifically identified in the annual investment plan including: projects that optimize alternative and renewable fuels for existing and developing engine technologies; control systems and vehicle/fuel integration systems; advanced internal combustion engines that result in at least 40 percent efficiency improvements; lightweight materials; energy storage; battery recycling and reuse; engine and fuel optimization, electronic and electrified components, idle management technology, and aerodynamic retrofits that decrease fuel consumption.

The Energy Commission is interested in developing a program to co-fund discrete projects that accelerate the development and commercialization of technologies and systems that might include strategies to:

- Improve the efficiency of petroleum- and nonpetroleum-fuel engines to increase fuel savings and GHG emission improvements above the current levels (20-30 percent) in electric hybrid and hydraulic hybrid vehicles.
- Improve the design of key vehicle components including high-pressure fuel tank designs, compressors, electronic controllers, motors, fuel cells, batteries, and other components to increase vehicle performance and efficiency.
- Improve the design of key alternative fuel infrastructure components including above and below-ground fuel storage, dispensers, and safety systems.
- Improve vehicles operations through improved controls and on-board diagnostics.
- Integrate smart grid electricity systems with electric vehicle recharging.
- Develop performance tests, instrumentation, drive cycle protocols, accelerated durability testing, and other technology applications to lower cost and shorten time required to comply with engine, fuel, and vehicle certifications.
- Develop alternative materials and production processes for advanced vehicle battery manufacturing and stimulate business practices that encourage the use of vehicle battery and other storage technology in secondary markets and recycle/reuse opportunities.
- Develop high-productivity biomass feedstocks, such as algae and perennial grasses, which can offer significant GHG benefits and be used to produce “renewable crude oils” or gasoline and diesel fuel substitutes.
- Develop low-carbon intensity aviation fuels.
- Develop or demonstrate renewable methanol fuel.
- Lightweight materials that have application across multiple vehicles platforms.
- Demonstration of personal rapid transit systems.

Projects could include feasibility studies, market research, early market demonstrations, competitions, performance and certification tests, incubator programs, X-PRIZE Foundation and other similar awards,[225] research consortiums such as "Centers of Excellence," recruitment of financial investors or a combination of such activities. The Energy Commission is allocating $3 million for projects involving innovative technologies and advanced fuels as described.

Additionally, the federal government is increasingly providing funding opportunities for innovative low-carbon fuels and vehicle technology research, development, and deployment through agencies such as U.S. DOE, U.S. EPA, U.S. DOT, and the USDA.[226] California's ability to capture these funds will rely significantly on the ability of the state to partner with organizations and institutions to develop and cost-share proposals to the federal agencies. Accordingly, the Energy Commission will provide $5 million in funding as a cost-share for proposals to the federal government.[227] Proposals for cost-share will be evaluated based on their financial leverage and overall consistency with program goals.

Table 25: Innovative Technologies and Advanced Fuels Funding Summary for FY 2010-2011

Innovative Technologies and Advanced Fuels	$3 Million
Federal Cost Sharing	$5 Million
Total	$8 Million

Source: California Energy Commission

225 The X PRIZE Foundation is an educational nonprofit organization that promotes public competitions to encourage accelerated technological development.

226 For example, the USDOE "Fuels from Sunlight" Innovation Hub solicitation to develop fuels directly from sun-light will provide $120M over five years to the winning proposal.

227 The Energy Commission will also consider funding for highly leveraged proposals with local governments.

Market and Program Development

Additional categories for funding are specifically mentioned in statute and are important to the success of the program. These categories are workforce development and training, sustainability studies, outreach and marketing, and program analytical and technical support.

Workforce Development and Training

On September 26, 2008, Governor Schwarzenegger signed Assembly Bill 3018 (Núñez, Chapter 312, Statutes of 2008), establishing the California Green Collar Jobs Council, to develop a comprehensive approach to address California's emerging workforce needs specifically with its budding "green" economy. This council is a collaborative effort among environmental, workforce development and educational state agencies, and California's local workforce development community, including private employers, labor unions, and financial institutions. The council is an opportunity for state agencies and other stakeholders in the workforce development community to collaborate across traditional organizational restraints and address barriers associated with workforce development as well as program expansion to meet industry needs.

In keeping with this spirit, the Energy Commission, the California Employment Development Department (EDD), the Employment Training Panel (ETP), and the California Workforce Investment Board (CWIB), in collaboration with the council, are leading a partnership of state agencies, educational institutions, local workforce investment boards, community and labor organizations and employers to deliver 21st century training programs for workers with all levels of experience. This collaborative effort, known as the Clean Energy Workforce Training Program (CEWTP), combines funding from the ARRA for the State Energy Program (SEP), the Alternative and Renewable Fuel and Vehicle Technology Program, Workforce Investment Act Governor's Discretionary Fund, and private and local entities to create what is believed to be the nation's largest green job workforce development program.

The CEWTP offers California opportunities to develop workforce training programs leading to long-term employment in a new, emerging, low-carbon fuels market. These programs provide education and training for people who are preparing to leave school to join the workforce, want to enter or re-enter the workforce, or just advance in their current career paths. They must recognize and respond to the needs of an industry undergoing significant change and strive to form commitments and partnerships between the environmental community, labor unions, private sector industries, workforce development programs, primary and secondary education systems, and government.

Current Workforce Training Programs

In its first investment plan, the Energy Commission allocated $15 million in funding for workforce training and development. These funds are being used to support the broader CEWTP initiative. Specifically, the Energy Commission has entered into the following interagency agreements to access existing programs and expertise necessary to develop a sustainable workforce:

- EDD Interagency Agreement: The Energy Commission provided $4.5 million to expand and develop local workforce development and training services that focus on job skills needed for alternative and renewable fuel and vehicle technologies. In addition to service delivery, EDD will also provide workforce needs assessments and reports through its Labor Market Information Division and facilitate Regional Industry Cluster development and implementation through the CWIB's Industry Clusters of Opportunity effort. EDD and CWIB are the state's lead agencies over an extensive workforce development and training system and are well-positioned to assess, coordinate, and deliver the services required to meet clean transportation workforce needs. By partnering with the EDD and CWIB, the Energy Commission takes advantage of their extensive workforce training delivery network to meet the training needs of employers at the local level and their labor market data resources to develop a clear picture of future clean transportation workforce needs.
- California Community Colleges Chancellor's Office (CCCCO) Interagency Agreement: The CCCCO system offers an accessible and affordable means of education and training. In addition, community colleges are capable of rolling out training modules quickly and can offer short-term courses and certificate programs. Approved in June 2009, this $4.5 million interagency agreement delivers industry needs assessments and high-level advanced transportation industry studies through the CCCCO's Centers of Excellence. Training module development and delivery is provided through CCCCO's Advanced Transportation Technologies and Energy Program (ATTE) directly to students at the community colleges.
- ETP Interagency Agreement: The Energy Commission has allocated $6 million to fund training contracts to expand workers' skills in clean fuels and vehicle technologies. The Energy Commission approved an interagency agreement with ETP in May 2010. The performance-based training contracts established through this agreement will provide training specific to California's emerging green transportation industry and meet the program's workforce training objectives. ETP training will primarily target incumbent workers, with skills upgrade training, and training is provided in conjunction and concurrent with employer training efforts. On June 25, 2010, ETP awarded the first five projects under the program, totaling $1.8 million to train over 600 workers. ETP has received inquiries for AB 118 funding from close to 40 potential contractors indicating considerable demand in green transportation training. ETP anticipates the need for additional funding to address this demand as early as the first quarter of 2011.

Future Potential Partnerships

Staff will research opportunities to support programs designed to address the needs of disenfranchised young adults as well as programs developed in conjunction with colleges and universities for continuing education. A few examples of promising programs to be evaluated are highlighted below.

One target population not addressed by the previous workforce training effort is at the high school level and specifically targets non-college-bound students interested in pursuing green careers and transportation technologies. Funding training programs that prepare students for careers in alternative fuels and advanced vehicle technologies can lead youth to pursue careers in these green industries. A few entities that have demonstrated successful and enduring programs are offered by the California Regional Occupation Centers and Programs, the CCCCO Career Advancement Academies, and the California Department of Education's Partnership Academy program. Staff recommends evaluating this area for future potential funding.

In addition, numerous California universities and colleges have developed advanced transportation and environmental sustainability certificate and degree programs. For example, the UCs at Berkeley, Davis, Irvine, and Los Angeles have developed the Institute of Transportation Studies and are considered the world's leading centers for transportation research, education, and scholarship. The University of Southern California's School of Policy, Planning and Development offers a summit on ensuring the growth of California's transportation workforce with the intention of developing workers for today's challenges and tomorrow's jobs. Staff recommends evaluating these and other areas for future potential funding.

By recognizing and responding to the needs of an industry undergoing significant change, the Energy Commission and its workforce development partners are leading the country in economic recovery. Through these partnerships with California's education, training, workforce development, and economic development professionals, the Energy Commission leverages program resources and augments workforce training programs to meet the workforce needs of California's growing clean transportation industry.

Given a significant allocation of $15 million to these activities in the first year of the program, the Energy Commission is allocating up to $1 million in funding for this area in FY 2010-2011 to sustain the Employment Training Panel's existing efforts in this funding cycle. The Energy Commission expects to provide funding for this area in future years as the performance data and needs assessment results from early investments become available.

Standards and Certification

It is essential that California uphold and improve upon its existing environmental standards as new alternative and renewable fuels and advanced vehicle technologies are demonstrated and deployed. These new fuels and advanced vehicle technologies will require that standards and certifications be researched and adopted for the fuels and vehicles themselves, equipment, engines, fuel storage, and fleet and retail dispensing systems. Once these standards and certifications are established, methods and protocols will be determined for responsible state and local agencies to use as they assure compliance and enforcement, while assuring straightforward, reasonable, and timely certification and approval processes. Examples of such needed support include the current program funding of $4 million for the CDFA's DMS for "type-approved" retail fuel dispensers for hydrogen and fuel quality standards for hydrogen and biodiesel blends.

The mission of DMS is to assure consumer confidence in conventional and alternative fuels for retail and commercial fuel dispensing. Typically, DMS is the lead agency (with ARB) for the development of fuel quality standards and commercial fuel measurement standards. Presently there is no approved commercial or retail hydrogen dispenser for fueling vehicles. Consequently, hydrogen cannot be sold in California on a retail per-unit basis. A similar situation existed nearly 15 years ago for natural gas fueling dispensers. DMS must establish and enforce testing procedures and quality standards for commercial measurement of hydrogen for vehicle and other refueling applications. In addition, DMS has adopted California regulations which limit contaminates in hydrogen known to be harmful to fuel cells, but these quality standards for gaseous hydrogen have not yet been developed by a national standards development organization, such as ASTM or SAE. Additionally, biodiesel fuel concentrations greater than 20 percent are not legal for sale in California unless authorized under DMS's Developmental Engine Fuel Variance Program. Biodiesel blends and pure biodiesel may be sold under controlled conditions in a fleet environment.

Under an interagency agreement with the Energy Commission, DMS will work with other organizations to develop national standards for hydrogen fuel, sampling procedures, testing protocols, and commercial/retail dispensers. DMS will conduct research to support the development of standards that will allow biodiesel blends greater than 20 percent to be available for sale in California in a retail setting. The work will be conducted over three years, commencing in 2010. Additional funding will be required in 2013 to complete the hydrogen standards (currently estimated to be a five-year endeavor).

In 2008, the California State Water Resources Control Board (SWRCB) enacted a policy requiring independent third-party certification. The SWRCB certifies that the fuel stored is not contaminated or out of compliance with the established ASTM fuel specification (the alternative fuel is as labeled B5, B20, or E-85 and the fuels, or fuels with additives, meet established standards for aquatic toxicity). In addition, the SWRCB mission is to reduce the risk of an unauthorized release of fuel to the environment by ensuring that the fuels stored are the same fuels tested by Underwriters Laboratories (UL) for material compatibility (the fuels stored meet ASTM specification) and that the underground storage tank (UST) does not exhibit indications of material incompatibility (corrosion and products of elastomer degradation). Permitting of USTs for storage of biodiesel fuel in concentrations greater than 5 percent have been stymied due to a lack of UL-certified USTs. Recently, an emergency regulation was enacted to provide a 36 month variance allowing up to B20 use in California until certification is obtained.[228] During this variance period the fuels industry should begin immediately funding and certifying the UST's.

Due to biodiesel fuel's complexities and the lack of established testing protocols certification progress has been slow. State funding is needed to help industry further develop, negotiate, and secure protocols for approval of biodiesel and biodiesel blends infrastructure (such as tanks,

228 State Water Resources Control Board, http://www.waterboards.ca.gov/ust/regulatory/biodiesel_regs.shtml.

piping, dispensers, and so forth) with the various state, federal, and industry users, and to execute the testing needed to secure the approvals for the California market. To the greatest extent possible, the testing will be done on a generic basis and made available to all interested California parties for their use. Individual companies will need to do their own testing after the protocols are established.

Most retail diesel fuel dispensers and USTs use materials that are certified to be compatible with biodiesel. In addition, terminals and storage facilities require certification for biomass based diesel fuels. However, the USTs have not received the required independent testing organizations certification of the complete system.

Depending on industry efforts to identify protocols and testing required by various regulatory agencies and individual companies, staff will assess funding needs for biomass-based diesel fuel infrastructure third-party certification for underground storage tanks in future investment plans.

Sustainability Studies

The Energy Commission is the first major government energy agency in the country to make transportation energy project funding decisions based on specific sustainability goals and evaluation criteria. The Energy Commission is required to "establish sustainability goals to ensure that alternative and renewable fuel and vehicle projects, on a full fuel-cycle assessment basis, will not adversely impact natural resources, especially state and federal lands." In response to this statutory directive, the Energy Commission developed the following sustainability goals to identify and promote transportation-related GHG reduction projects that are exemplary in sustainability and environmental performance and that can serve as national and international models:

- The first sustainability goal is the substantial reduction of life-cycle GHG emissions associated with California's transportation system to help meet California's 2020 and 2050 targets as defined in Health and Safety Code Section 38550 and the Governor's Executive Order S-03-05.
- The second sustainability goal is to protect the environment, including all natural resources, from the effects of alternative and renewable fuel development and promote the superior environmental performance of alternative and renewable fuels, infrastructure and vehicle technologies.
- The third sustainability goal is to enhance market and public acceptance of sustainably produced alternative and renewable fuels by developing, promoting, and creating incentives for the production of such fuels in accordance with certified sustainable production practices and standards as established by government agencies, academic institutions, and nongovernmental organizations.

Biofuels (referred to as renewable fuels under the federal RFS) are projected to play a critical role in meeting the GHG reduction goals for the state's transportation sector, and the

production and use of biofuels must grow substantially to meet RFS fuel use requirements. California currently consumes about 1 billion gallons of ethanol a year and 50 million gallons of biodiesel fuel. The demand for renewable fuel calculated in California must triple between now and 2022 to meet California "fair share" requirements of the federal RFS. Currently, ethanol represents the majority of transportation fuel carbon reduction requirements envisioned for California gasoline under California's LCFS. Absent any breakthroughs in advanced biofuels (such as renewable gasoline), ethanol could increase to more than 3 billion gallons per year by 2022, while biodiesel could increase to more than 200 million gallons per year. The Energy Commission recognizes that the transition to large volumes of alternative and renewable fuels needed to help meet the state's GHG reduction goals from the transportation sector must be managed properly to avoid environmentally and socially destructive production practices.

There is increasing concern about the potential for land use change associated with the development of biofuels and bioenergy crops. As a result, the ARB's LCFS program regulations require indirect land use changes to be accounted for in the GHG emissions calculation for fuel pathways involving bioenergy crops for feedstocks. Commodity-scale crops grown on arable land that can also be used for food or animal forage, such as corn and soy beans, are most likely to trigger land use changes as their production increases.[229] The Energy Commission includes the indirect land use change estimates into the fuel pathway GHG emissions estimates used during evaluation of AB 118 funding proposals.

The Energy Commission also strongly supports the development of an environmentally sustainable in-state bioenergy industry so that California can benefit economically from in-state biofuels production. Staff also identified and developed feedstocks and production technologies for use in California that fully integrate elements that will lead to the long-term development of low-carbon, sustainably produced biofuels.

For internationally produced biofuel feedstocks, staff continues to assess the major international initiatives and sustainable certification programs that are in development. The Energy Commission is working with the ARB and other stakeholders to decide how to evaluate international certification programs to determine if they will meet California's goals and standards for sustainable production. The Energy Commission recently joined the Roundtable on Sustainable Biofuels.

In the first investment plan, the Energy Commission recommended that $4 million be used for sustainability research. Two million dollars from this allocation will be spent on forest biomass sustainability research to implement the sustainability work plan developed by the Energy

229 The concept of "land use change" is that land contains carbon in the soil and vegetation that is released as CO2 when it is cleared and/or tilled for planting bioenergy crops. Land use change can either be "direct" as when bioenergy crops use previously idle land or "indirect" as when, for example, commodity crops previously used for food, such as corn, are instead used for energy production. This reduction in supply of the commodity crop will increase prices and induce further land clearing to make up for that demand resulting in GHG emissions. The ARB has developed land use change emissions estimates for corn ethanol and soy biodiesel.

Commission for the Interagency Agency Forestry Working Group[230] to develop consistent definitions and standards for sustainable woody biomass from California's 40 million acres of private and public land forests. Substantial technical and scientific field work will be needed to establish sustainability definitions and standards for the emerging woody biomass fuels industry. The remaining $2 million was shifted to technical projects. For FY 2010-2011, the Energy Commission is allocating $2.5 million in grants or contracts for sustainability research and technical support in the categories described below. At this time, sustainability research funding is not available through any other California regulatory programs such as AQIP or the federal ARRA program.

The Energy Commission plans to:

- Develop more precise tools to measure sustainability attributes and characteristics of projects proposed for funding.
- Create sustainability indicators for biofuel feedstocks and biorefineries, including historical land uses, soil quality, water use and waste water discharge, and biodiversity and sensitive ecosystems.
- Identify best management practices for bioenergy crops.
- Analyze the effectiveness of current sustainability regulations, goals, and evaluation criteria, and to investigate existing sustainability frameworks for regulatory and non-regulatory programs.

Next, sustainability assessments need to be expanded from the project level to the regional level to develop a more comprehensive understanding of how increased bioenergy crop production in California could be integrated into existing cropping mixes without adversely affecting food crop or animal feed production, agricultural water use, or wastewater discharges. These studies could include the assessment of the environmental performance of current crops and regional assessments of energy crop expansion (such as Imperial Valley sugarcane, San Joaquin Valley sugar beets and sweet sorghum, or Sacramento Valley sweet sorghum). Similar regional studies for bioenergy crops such as algae and perennial grasses may also be needed as the commercial viability of these crops and their associated process technologies mature. Specific studies are also needed on water use, wastewater discharge, land use, and fertilizer and pesticide inputs.

To ensure that water use reduction measures and best management practices are used in the production of biofuels, investigative studies are also needed that quantify water use for different types of biofuel production processes and for bioenergy crops. Examining water best management practices and emerging technologies that reduce water use and waste discharge could also be beneficial.

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230 The Interagency Forestry Working Group was convened by the California Natural Resources Agency and California Environmental Protection Agency to develop consistent metrics for forest carbon accounting and sustainability definitions and standards for the energy and climate change programs at the California Air Resources Board and California Energy Commission.

Finally, California will likely continue to depend on imported biofuel feedstocks and finished products to help meet GHG goals for the transportation sector. Investigating international environmental issues will be critical to ensure that all fuels used in California are sustainably produced. In-country field assessments of industry practices for the harvest and production of Southeast Asia oil palm, cane ethanol and oil palm in Brazil and greater South America, and African oil palm are needed to meet this goal. It is also important that there are field tests of international sustainability programs and third-party audits of international biofuels and feedstocks subject to sustainability certification programs along with examinations of habitat conservation and restoration efforts for areas affected by plantation development. Assessments of sustainability standards, protocols, and the efficacy of using sustainability certification programs in the United States and internationally could be very helpful in determining which sustainability certification programs are most relevant to California's regulations and transportation needs.

Program Marketing and Public Education and Outreach

In 2009, the Energy Commission initiated a communication plan during the first year of the program. This plan sets the stage for the 2010-2011 development of a comprehensive message and media campaign that will reach targeted audiences in the most effective and efficient manner as projects are rolled out.

So far, the most effective method of public marketing and outreach for the program has been in reaching members of industry that are likely to seek funding assistance. Workshops held by the Energy Commission during the development of the investment plan, as well as those describing guidelines for various funding opportunities, have been generally well-attended. Additionally, there has been no shortage of requests for funding from the Energy Commission among stakeholders.

Prior to the planning, development, or construction of any projects funded by the Energy Commission, many stakeholders must navigate complex local and state permitting processes. Occasionally, the processes of local governments are protracted by active citizens who may be suspicious of the installation or expansion of any projects in their vicinity. To expedite these processes, the Energy Commission must also coordinate with local governmental agencies to provide current industry, regulatory, and sustainability information that will assist with the public discourse.

Much of the challenge in implementing a program such as the Alternative and Renewable Fuel and Vehicle Technology Program lies in increasing awareness of the program's existence among the varied public and private entities that can benefit from funding opportunities derived from the legislation and assist the Energy Commission in reaching program goals. This broad-audience challenge can be lessened by the development of an awareness campaign that is crafted to focus marketing and outreach efforts on those entities identified in the program's investment plan. The Energy Commission will further enhance this targeted campaign by leveraging contract services with use of the expertise and resources available within the Energy

Commission. The 2010 outreach and marketing effort will consist of a coordinated internal effort primarily focused on outreach and contracted services focused on marketing and media.

Outreach Plan

As part of an outreach plan, marketing materials such as fact sheets, brochures, and press kits will be developed. These outreach materials will offer simple, straightforward information about the program and highlight the funding priorities identified in the investment plan. The Energy Commission will also coordinate press releases and events highlighting funding opportunities and report on projects as they develop in the field.

A program-specific website will be developed to promote involvement in program funding opportunities and to increase participation in funded projects. The website will also provide linkage to agencies with parallel missions, such as ARB's Drive Clean Campaign and the Bureau of Automotive Repair's Drive Healthy information site and other government agencies offering information about complementary programs or events.

In addition, the Energy Commission will continue participation in high profile, regional alternative fuel auto shows and expositions that leverage opportunities to inform interested entities and stakeholders of the program's existence and funding opportunities.

Marketing and Media

A targeted multimedia campaign is required to reach the businesses, fleet managers, universities, and environmental organizations targeted in the investment plan. A public awareness and marketing firm will be secured to develop audience specific print, radio, television, and cable ads and to negotiate media buys that maximize exposures to the program's targeted audience. The Energy Commission estimates that $2.5 million in grants or contracts will be necessary to meet this desired level of media and marketing.

The Energy Commission received requests for almost $30 million in education and outreach related activities funding in conjunction with ARRA solicitations. Two proposals received $550,000 in funding. To support what appears to be an underserved program area, the Energy Commission allocates a total of $2.5 million in grants or contracts to this area.

Technical Assistance and Environmental/Market/Technology Analysis

The Energy Commission will need continuous updates of the status of vehicle technology and fuels, market analyses, financing trends, and other factors that impact the introduction and growth of alternative and renewable fuels in California to monitor the progress of funding decisions and develop future, annual investment plans. Ongoing refinement of analytical methods, such as full fuel-cycle analysis models, will be needed to evaluate the potential GHG emission and other environmental impacts of new fuel and vehicle technology options. The Energy Commission has allocated $6 million in grants or contracts to fund this technical assistance and analytical work, which is likely to include the following:

- Ongoing technical support is needed to establish the life-cycle scale GHG emissions for new and emerging alternative fuel pathways that have not yet been analyzed in the LCFS program or through the Energy Commission's existing contract with Life Cycle

Associates. The AB 118 program will need additional technical and training support with the California-GREET model as it is expanded and updated to include new climate-changing gases, new fuel pathways, and sustainability parameters such as water.

- Full fuel-cycle analysis for new fuel pathways, to assist small companies in developing and demonstrating the carbon intensity of their alternative and renewable fuels.
- Spatially and Temporally Resolved Energy and Environmental Tool (STREET) represents UC Irvine's modeling approach for identifying, analyzing, and understanding the interplay between GHG, criteria pollutant emissions, water usage, and energy intensity generated from displacing existing transportation fuels and technologies. The Advanced Power and Energy Program (APEP) group under Professor Scott Samuelsen at UC Irvine has developed this integrated model, software, and simulation to predict environmental and resource usage impacts of current and proposed transportation scenarios. Current and past funding sources for the APEP include U.S. DOE, Toyota, Air Products, Honda, Nissan, ARB, and the Energy Commission. Similarly, the Sustainable Transportation Energy Pathways (STEPs) program at UC Davis has developed a number of sophisticated hydrogen infrastructure models and case studies for specific US areas. These STEPs studies often utilize detailed GIS databases such as road networks, census data for population distribution, urban traffic distribution, and locations of gasoline stations and other energy infrastructure in order to design, site and determine costs for the most appropriate hydrogen infrastructure for the given region or city. This analysis is based upon a model that uses US census data to determine hydrogen demand and an idealized city model to estimate the delivery system layout for trucks and pipeline delivery. The model determines the lowest-cost pathway for each city and allows comparisons of the cost, emissions and energy efficiency for a given hydrogen pathway for all cities. The Energy Commission is interested in the hydrogen infrastructure capabilities of these models, and proposes to fund this work to expand into other alternative fuels and their infrastructure aspects. The Energy Commission anticipates funding $975,000 over three years ($325,000 per year) for this work to enable the Energy Commission to make decisions on program funding allocations for alternative fuel infrastructure. For example, the model will produce vehicle rollout scenarios to aid in deciding sustainable locations of fueling stations.
- Technical assistance in the development of future investment plans to ensure the most effective use of program funding. The Energy Commission will need technical assistance in developing research and market-transformation recommendations for future investment plans. Future funding allocations will require reliable assessments of current fuel and vehicle markets. These market assessments will then be compared against preferred market scenarios defined by policy objectives. Subsequent analyses of the gap between present markets and preferred scenarios will identify the barriers to the development and deployment of clean and efficient low-carbon technologies. This will also identify possible funding opportunities to overcome these market barriers and provide guidance on the preferred method for determining funding allocations.

- A possible agreement with NREL's Center for Transportation Technologies Systems to provide technical support services for the program, in particular, market assessments of advanced vehicle fuels and technologies, fuels research, criteria, and GHG emissions characterization and improvement, biofuels production and use, hydrogen vehicle technology evaluation and infrastructure needs, and the ongoing work the laboratory is presently engaged in regarding scenario planning to achieve climate change, petroleum reduction, and air quality goals in the state.
- Program measurement, verification and evaluation (MV&E) efforts. Statute requires the Energy Commission to evaluate the program's efforts in the 2011 Integrated Energy Policy Report, and in subsequently adopted reports. The goals of MV&E are to provide accountability and ensure effective administrative and financial performance of the program and its funding recipients. The Energy Commission will examine: 1) the expected benefits of the projects in terms of air quality, petroleum use reduction, greenhouse gas emissions reduction, technology advancement, and progress towards achieving these benefits; 2) the overall contribution of the funded projects toward promoting a transition to a diverse portfolio of clean, alternative transportation fuels and reduced petroleum dependency in California; 3) key obstacles and challenges to meeting these goals identified through funded projects; and 4) recommendations for future actions.

Table 26: Market and Program Development Funding Summary for FY 2010-2011

Sustainability Studies	$2.5 Million
Program Marketing and Public Education and Outreach	$2.5 Million
Technical Assistance and Environmental/Market/Technology Analyses	$6 Million
Total	$11 Million

Source: California Energy Commission

CHAPTER 4: 2010-2011 Investment Plan Funding Allocations

The allocations in the *2010-2011 Investment Plan* are based on an analysis of the potential GHG reductions, the relative contributions of each fuel and vehicle category to meeting the 2020 and 2050 GHG emission reduction targets and energy security policies, the level of public and private funding, feedback from stakeholders, an analysis of proposals received, and the potential economic impact on the California economy of each funding category.

The *2010-2011 Investment Plan* will seek to leverage existing federal, state, and local funding as well as stakeholder investments to accelerate the introduction and use of these fuels and technologies. The Energy Commission will focus on and leverage those technologies that show the most promise and market potential while balancing the need to have a robust portfolio approach to technology development. This approach will reduce investment risk and emphasize investments that provide immediate lower carbon and GHG and petroleum reduction benefits.

Once the funding allocation is approved, the investments and dollar amounts will be itemized under each category in Table 27 on the following page.

Table 27: Funding Allocation Summary for FY 2010-2011[231]

	Project/Activity	Funding Allocation for FY (2010-2011)
Battery Electric Drive	Develop and demonstrate advanced on-road and non-road medium- and heavy-duty vehicles	$14 Million
	Infrastructure and related activities	$3 Million
	Manufacturing facilities and equipment	$7.5 Million
	Subtotal	**$24.5 Million**
Hydrogen Electric Drive	Fueling Infrastructure	$13 Million
	Subtotal	**$13 Million**
Gasoline Substitutes	Expansion of E-85 dispensers and retail outlets	$6.5 Million
	Gasoline substitutes production in existing, new and retrofit facilities	$10 Million
	Subtotal	**$16.5 Million**
Diesel Substitutes	Diesel substitutes production	$5 Million
	Bulk terminal storage and blending facilities	$4 Million
	Subtotal	**$9 Million**
Natural Gas	Light-, medium- and heavy-duty vehicles	$13 Million
	Upgrades to natural gas fueling stations	$2 Million
	Biomethane production plants and quality testing	$7 Million
	Subtotal	**$22 Million**
Propane	Light- and medium-duty vehicles	$3 Million
	Subtotal	**$3 Million**
Innovative Technologies and Advanced Fuels	Innovative technologies and advanced fuels	$3 Million
	Federal cost sharing	$5 Million
	Subtotal	**$8 Million**
Market and Program Development	Workforce Development and Training	$1 Million
	Sustainability studies	$2.5 Million
	Program marketing and public education and outreach	$2.5 Million
	Technical assistance and environmental/market/ technology analyses	$6 Million
	Subtotal	**$12 Million**
	Grand Total	**$108 Million**

Source: California Energy Commission

231 The Energy Commission will also fund up to 2 percent ($2.16 million) of the total allocation for measurement, verification and evaluation. This amount will be taken from each category on a prorated basis.

APPENDIX A: 2050 Vision Light-Duty Vehicle GHG Emission Reduction

Relative GHG Reductions

Light-Duty Vehicles

This analysis evaluates one potential scenario where the light-duty vehicle segment can reduce GHG emissions in a partially successful attempt to meet "fair share" reduction targets for 2020 and 2050. The transportation sector's "fair share" emission reduction target is not established by statute but is the calculated emission reduction target for the transportation sector (or in this case for light-duty vehicles) based on the sector's contribution to the state's total GHG emissions. In other words, since the transportation sector is responsible for 38 percent of statewide GHG emissions, its "fair share" emission reduction is 38 percent of the total reduction needed to meet 2020 and 2050 policy goals.

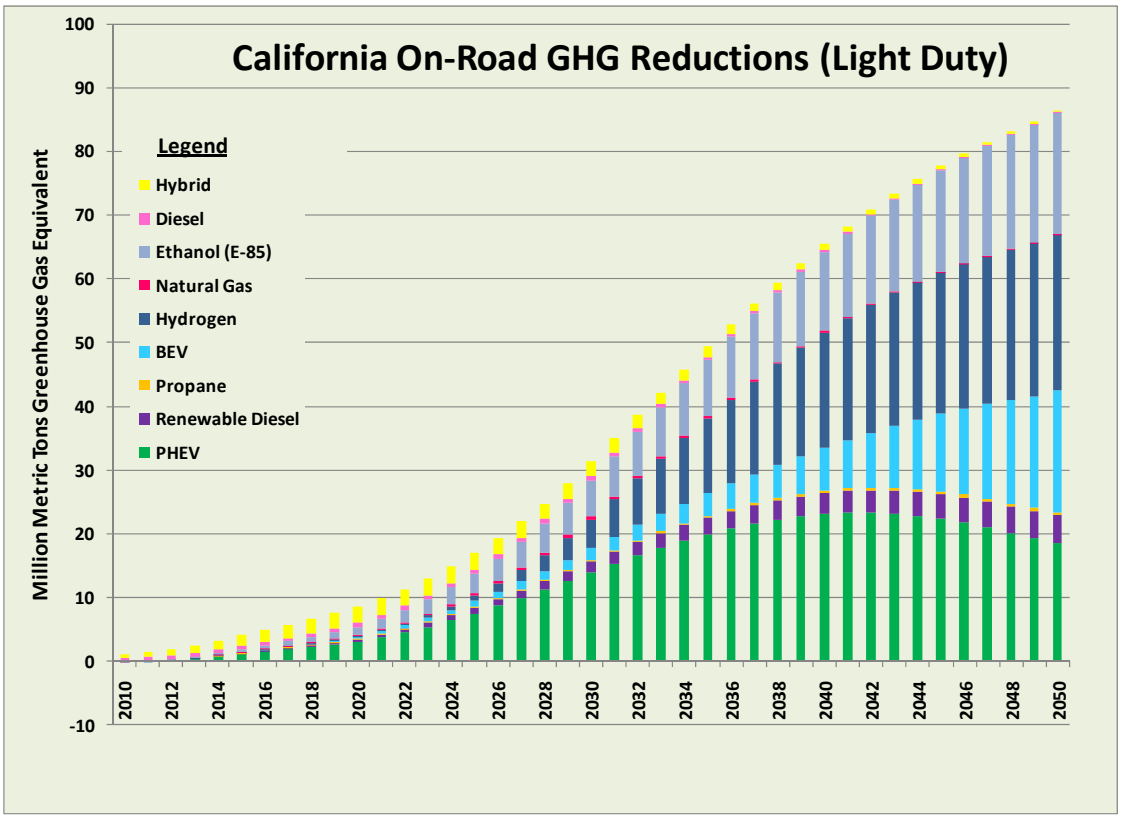
The objective was to work backward from the *2050 Vision* to depict the alternative and renewable fuel and vehicle pathways that may be needed to meet the GHG emissions reduction statutory requirement of AB 32 and to be consistent with the trajectory needed to meet the 2050 target as well. Chapter 6 of the *State Alternative Fuels Plan* describes this vision.[232] The major attributes of this *2050 Vision* are that:

- Most vehicles in 2050 would achieve a fleet-average of 60 miles per gallon; electric-drive vehicles would achieve a fleet-average of 80 miles per gasoline gallon equivalent
- The 2050 fuel mix would consist of electricity and hydrogen (40 percent), biofuels (30 percent) and petroleum fuels (30 percent)
- Vehicle miles traveled of light-duty vehicles would decrease by 20 percent in 2050
- The carbon intensity for alternative fuels used in the vehicle populations in 2050 would be reduced by 50 percent relative to 2010 alternative fuels. Gasoline fuel would also be reduced by 50 percent carbon intensity relative to 2010. In addition, gasoline would be reduced from use in 99 percent of all light-duty vehicles to only 10 percent of all vehicles. The 50 percent carbon intensity reduction is consistent with the reduction methods used in the *State Alternative Fuels Plan.*
- The carbon intensity of ethanol is reduced by 80 percent in 2050 relative to today's value. This change in carbon intensity is based on updated feedstock data.

Figure A-1 shows the contribution of each of these fuel and vehicle categories toward meeting the total light-duty GHG emissions reduction target through 2050.

232 *State Alternative Fuels Plan*, Final Adopted Report. CEC-600-2007-011-CMF, December 2007.

Figure A-1: 2050 Vision Light-Duty Vehicle GHG Emission Reduction[233]



Source: California Energy Commission

Conclusions for Light-Duty Vehicles

Drawing upon data shown in Figure A-1, staff calculated the percentage contribution of each fuel/vehicle type to total light-duty GHG emission reductions for this potential scenario. These percentages, shown in Table A-1 below, were calculated by adding GHG reductions for each category in 2020 and in 2050 and dividing the individual totals for each category by the total GHG reductions. Vehicle efficiency measures, such as tire pressure programs and tire tread standards, low-friction engine oils, and solar-reflective automotive paint and window glazing, were not included in the estimates below. These measures have an estimated potential reduction in 2020 of more than 4.8 million metric ton carbon dioxide equivalent ($MMTCO_2e$).[234] These vehicle efficiency measures are expected to primarily affect light-duty vehicles. For this

233 Reductions are from all alternative fueled vehicles. Numbers are based on a scenario of vehicle penetrations above the 2009 CALCARS baseline. Fuel categories from the previous investment plan have been broken down into their individual fuels to avoid confusion about actual carbon intensities of these fuels. Super-ultra-low has been broken down into hydrogen, BEV, and PHEV. Ultra-low is now Ethanol and low carbon is now CNG and propane. Fuel economy improvements have been broken down and added to their respective fuels.

234 *Climate Change Draft Scoping Plan*, Measure Documentation Supplement, California ARB, 2008.

analysis, the additional GHG reductions as a result of potential vehicle efficiency measures were not included in the calculations shown below.

Differences in assumptions between the *2010-2011 Investment Plan* analysis and the ARB's analysis are:

- ARB evaluated each fuel (and the associated vehicle technology) independently to determine no single approach reached the 2050 goal. A portfolio approach was then evaluated. The Energy Commission analysis evaluated each fuel independently, and the evaluations do not reflect interactions in a marketplace.
- The Energy Commission analysis assumes that both hydrogen vehicles and battery electric vehicles will succeed in approximately equal numbers by 2050.
- The Energy Commission analysis uses a larger number of FFVs in the future.

The results of the analysis lead to the following percentages for each of the categories evaluated.

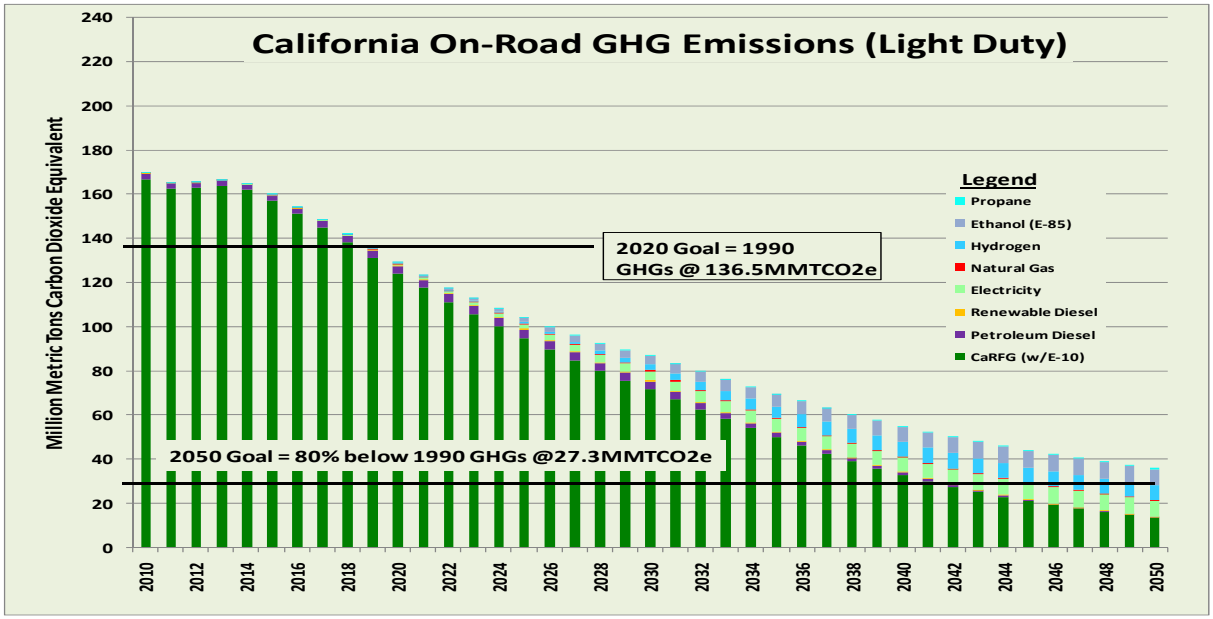
Table A-1: Light-Duty Alternative Fuel GHG Emissions Reductions (2020 and 2050)

Category	2020 GHG Emission Reduction ($MMTCO_{2e}$)	2020 GHG Emission Reduction (Percent)	2050 GHG Emission Reduction ($MMTCO_{2e}$)	2050 GHG Emission Reduction (Percent)
Hybrid	2.57	28%	0.4	0.48%
Light-Duty Diesel	0.54	6%	0.07	0.08%
Biomass-Based Diesel	0.35	4%	4.36	5%
Propane	0.08	1%	0.46	1%
Ethanol (FFV)	2.17	23%	18.35	22%
Battery EV	0.35	4%	18.15	22%
PHEV	2.98	32%	17.77	21%
CNG	0.16	2%	0.1	0%
Fuel Cell Vehicle	0.1	1%	23.26	28%
Total Reductions	**9.3**	**100%**	**82.92**	**100%**

Source: California Energy Commission

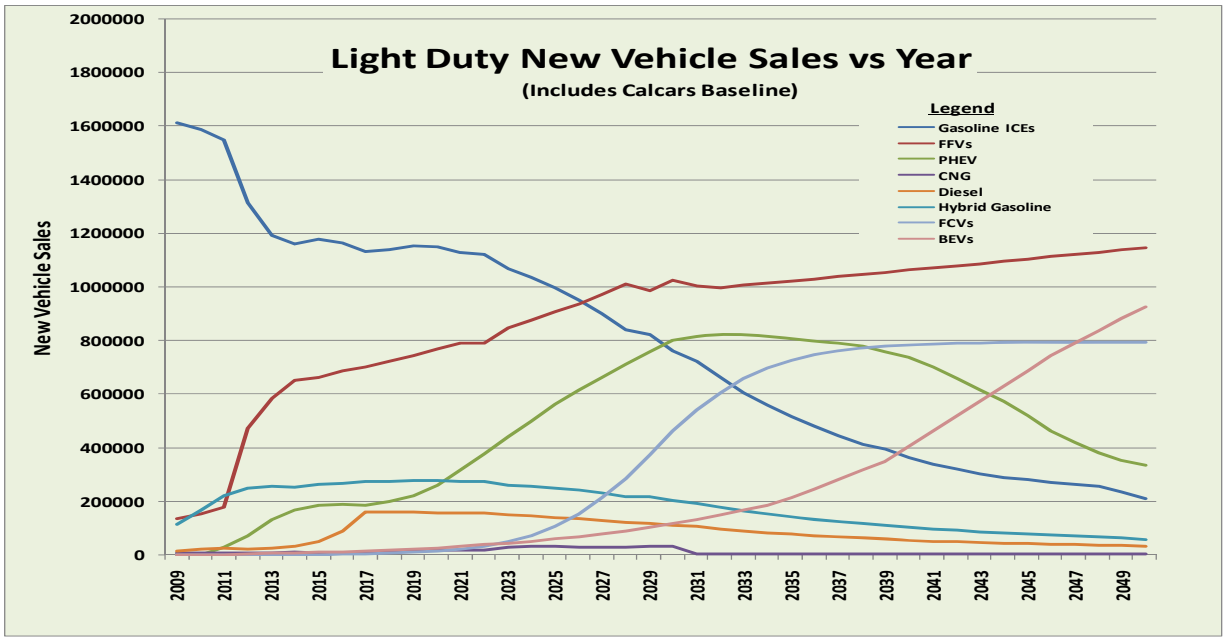
Using these estimates, Figure A-2 shows the effectiveness of this scenario in meeting the fair share 2020 and 2050 GHG reduction targets for the light-duty vehicle sector. As the figure shows, the emission reductions achieved by these measures nearly meet the 2020 goal but are not adequate to reach the 2050 goal. Figure A-3 shows the vehicle sales trends that would generate the emissions shown in Figure A-2.

Figure A-2: California Light-Duty Vehicle GHG Emissions



Source: California Energy Commission

Figure A-3: California Light-Duty New Vehicle Sales Including Scenarios



Source: California Energy Commission

Medium- and Heavy-Duty Vehicles

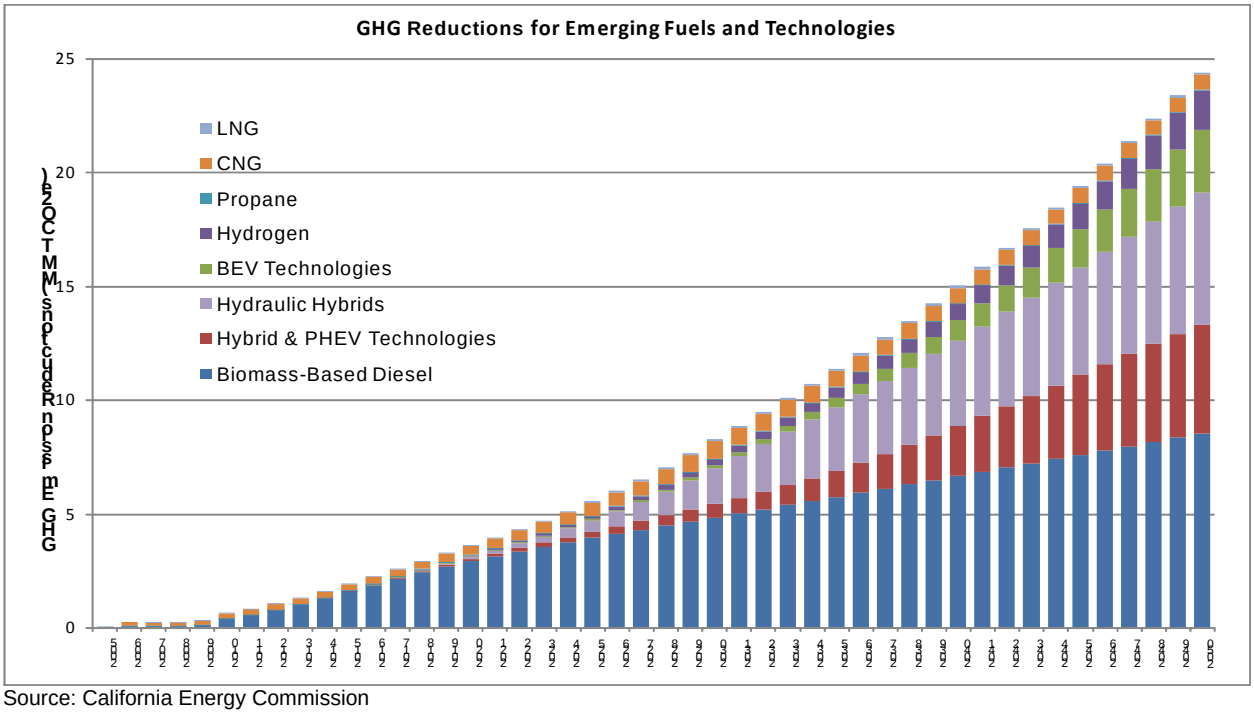
This analysis extends the evaluation of the *2050 Vision* for light-duty vehicles to medium- and heavy-duty vehicles. The emerging fuels and vehicle technologies included in this analysis are renewable diesel, hydraulic hybrids, battery-electric hybrids, full-electric vehicles, FCVs, propane, CNG, and liquefied natural gas (LNG) vehicles.

The total GHG reduction from medium- and heavy-duty vehicles is developed by adding GHG reductions for all categories over the 2009 to 2020 and 2009 to 2050 periods, and then specific percentages of the total are derived for each category eligible for program funding.

As in the light-duty assessment, the GHG emission reduction scenario presented here was "unconstrained" in that projections had no limitations for cost, fuel supply, or biomass feedstock availability placed upon them, even though the updated fuel and technology market information is influenced by costs and considers barriers to market penetration. Still, these fuels and vehicle technologies were evaluated independently and do not reflect interactions in a competitive marketplace. The Energy Commission used a simple accounting method to calculate the estimated emission reductions over a 42-year period for the medium- and heavy-duty vehicles and fuels based on market information developed in the preparation of the AB 1007 *State Alternative Fuels Plan*. The final GHG emission reduction scenario used in this evaluation assumed the moderate market development penetration estimates of the emerging fuels and vehicle technologies in the four categories.

Figure A-4 shows how each fuel/vehicle category contributes to achieving the total medium-/heavy-duty GHG emission reductions through 2050.

Figure A-4: Estimated GHG Reductions from Each of the Categories



Source: California Energy Commission

Medium- and Heavy-Duty Vehicle Analysis Conclusions

The medium- and heavy-duty results displayed in Table A-2 below reflect the initial evaluation of GHG emission reductions from the different categories needed to meet the state's climate change requirements and goals for 2020 and 2050. The ARB's LCFS was not applied.

Table A-2: 2020 and 2050 Medium- and Heavy-Duty GHG Emissions Reductions

Category	2020 GHG Emission Reduction ($MMTCO_{2e}$)	2020 GHG Emission Reduction (Percentage)	2050 GHG Emission Reduction ($MMTCO_{2e}$)	2050 GHG Emission Reduction (Percentage)
Biomass-Based Diesel	6.3	87%	12.0	44%
Hybrids (PHEV & Hydraulics)	0.2	3%	8.6	31%
Battery Electric Vehicle	0.01	0%	2.5	9%
Fuel Cell Vehicle	0.07	1%	1.9	7%
Propane	0.03	0%	0.3	1%
CNG	0.53	7%	1.7	6%
LNG	0.11	1%	0.5	2%
Total Reductions	**7.2**	**100%**	**27.6**	**100%**

Source: California Energy Commission

Combined Results — Light-, Medium-, and Heavy-Duty Vehicles

Staff determined final, overall percentages by combining the light-duty vehicle GHG emissions reductions with those from the analysis of medium- and heavy-duty vehicles. The final GHG emission reduction percentages for meeting California's 2020 and 2050 GHG emission reduction goals, for the designated categories, are displayed in Table A-3 below.

Table A-3: Summary of GHG Emissions Reductions for Light-, Medium-, and Heavy-Duty Vehicles (2020 and 2050)

Category	2020 GHG Emission Reduction ($MMTCO_{2e}$)	2020 GHG Emission Reduction (Percentage)	2050 GHG Emission Reduction ($MMTCO_{2e}$)	2050 GHG Emission Reduction (Percentage)
Biomass-Based Diesel	6.7	40%	16	15%
Light-Duty Diesel	0.5	3%	0.1	0.1%
Hybrids (PHEV & Hydraulics)	5.7	35%	27	24%
Battery Electric Vehicle	0.36	2%	21	19%
Fuel Cell Vehicle	0.17	1%	25	23%
Propane	0.11	1%	0.7	1%
CNG	0.69	4%	1.8	2%
LNG	0.11	1%	0.5	0.5%
Ethanol (FFV)	2.17	13%	18	17%
Total Reductions	**16.5**	**100%**	**110.5**	**100%**

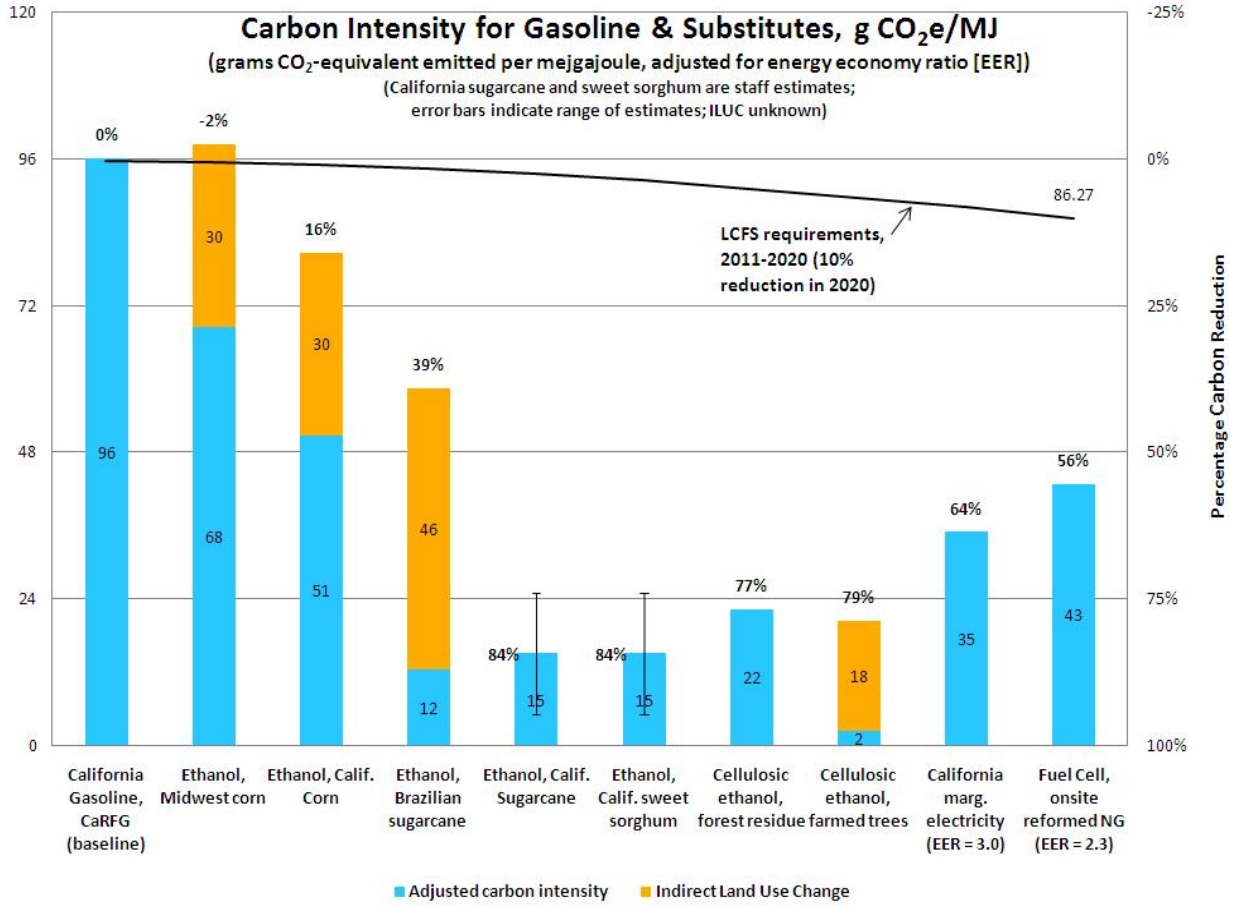
Source: California Energy Commission

With this analysis the Energy Commission reaffirmed that the 2050 GHG reduction targets were plausible. However, any combination of options could achieve similar results. This analysis did not consider cost or consumer preferences, which, if considered, would materially change the technology choices.

Measurement of GHG Reduction (Carbon Intensity)

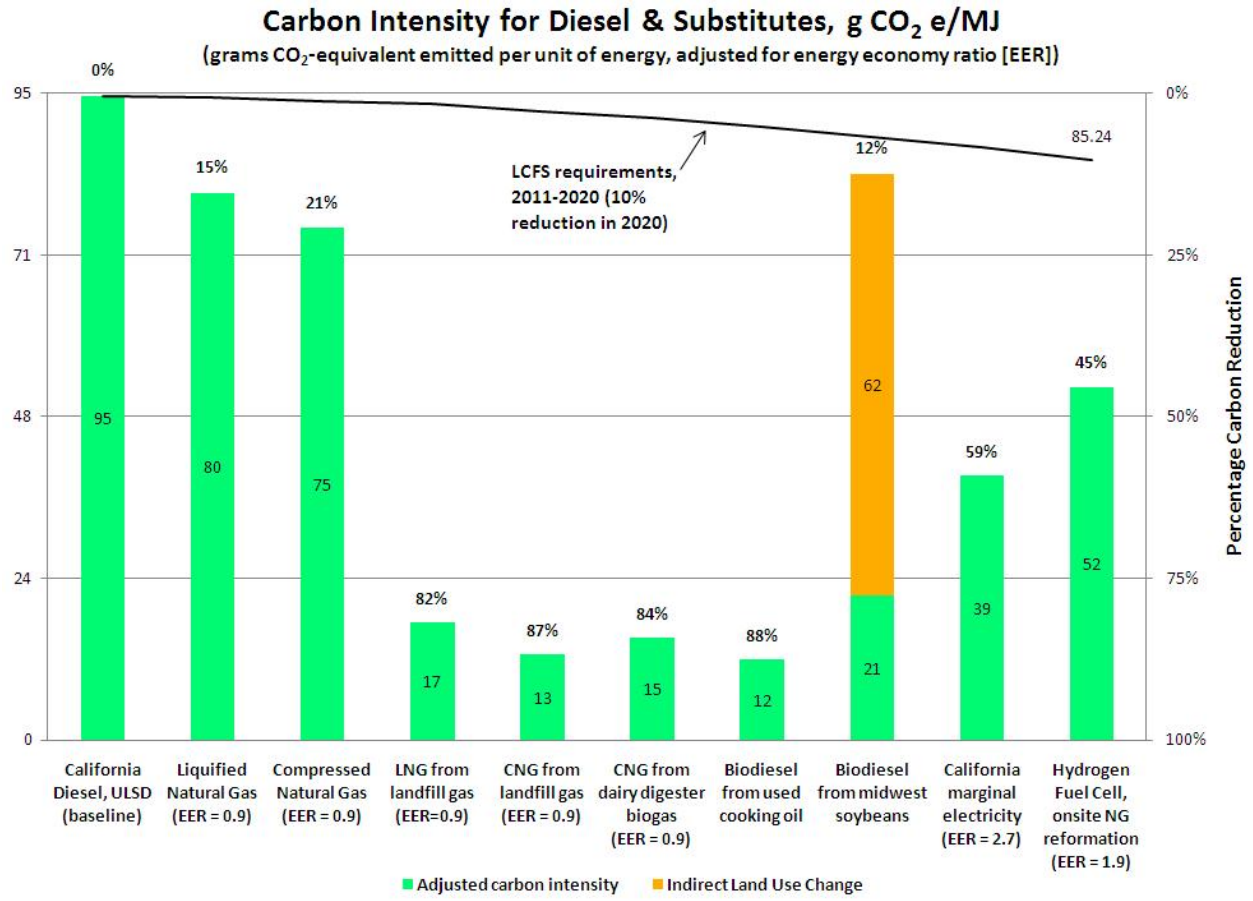
It is important to define "GHG reduction" for the various fuel pathways since GHG reduction is one of the primary objectives of AB 118. Emissions of carbon dioxide and other GHGs are measured by carbon intensity (or GHG intensity) in units of carbon dioxide-equivalents per megajoule of energy (CO2-eq/MJ). Carbon intensity values for alternative fuels are calculated with what is known variously as a well-to-wheels, full fuel-cycle, or lifecycle analysis. Well-to-wheels measures the amount of carbon released during all phases of production and use of a vehicle fuel. It is important to remember that the production of the fuel contributes to the carbon intensity. For example, the production of electricity and hydrogen ultimately releases GHGs into the atmosphere. However, because of their inherently higher efficiency, electric drive fuel paths are afforded an energy efficiency ratio (EER) of two to three times the internal combustion engine (ICE) efficiency baseline, thereby making those pathways very attractive on an overall GHG-per-mile comparison. See Figures A-5 and A-6 below for the carbon intensity for gasoline and substitute fuels.

Figure A-5: Carbon Intensity for Gasoline and Substitutes



Source: California Air Resources Board LCFS.

Figure A-6: Carbon Intensity for Diesel and Substitutes



Source: California Air Resources Board LCFS website.

A full fuel-cycle analysis may be performed with the "Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation" package, more commonly known as GREET. It counts the emissions and energy expended starting from the extraction point (well) and captures all direct (and later indirect) emissions as the fuel is processed, transported, sold, and used by the final consumer. In California, a version known as CA-GREET is used which includes default values and calculations particular to California. This is an Excel® spreadsheet-based model that calculates carbon intensity for fuel production inputs specified by the user. For gasoline, a well-to-wheels analysis would include the carbon released during oil drilling, transportation of the oil, refining the oil into gasoline, transporting and distributing the gasoline, and combustion of the gasoline in a vehicle engine. Corn or sugarcane ethanol would include carbon released from farming; producing agricultural inputs such as pesticide, herbicide, and fertilizer; transporting the harvested crop; refining it into ethanol; and transporting and distributing the ethanol. For ethanol or other biofuels, the CA-GREET model does not include combusting the fuel.

The carbon in the fuel is biogenic in origin: It was in the atmosphere, but through photosynthesis became part of the plant that was then converted into ethanol, and when it is combusted in the vehicle engine, the carbon returns to the atmosphere where it had been a few months earlier.

In response to concerns about the potential for land use change associated with the development of biofuels and bioenergy crops, the ARB's LCFS program regulations require indirect land use change GHG emissions to be added to the direct emissions calculated for fuel pathways involving bioenergy crops for feedstocks. Commodity scale crops that can also be used for food or animal forage, such as corn and soy beans, are most likely to trigger land use changes as their production increases. The Energy Commission includes the indirect land use change estimates into the fuel pathway GHG emissions estimates used during evaluation of AB 118 funding proposals.[235]

235 The indirect land use change figures presented here are current as of February 2010 but are subject to revision by the ARB.

APPENDIX B: Zero Emission Vehicle Regulation

The ZEV regulation was first adopted by the ARB in 1990 as part of the Low Emission Vehicle Program. Although it has been modified several times over the years, it still remains an important program for meeting California's air quality and GHG emission reduction goals and has spurred many new technologies that are being driven on California's roads today. The regulation's intent has consistently been to have zero-emission technologies on the roads on a mass scale as soon as possible.

As part of the ZEV regulation, large automakers are required to produce a certain number of "pure" zero emission and "near-zero" emission vehicles for sale in California as a percentage of their overall sales. This percentage increases over time, from 11 percent in model years 2009-2011 to 16 percent in model years 2018 and beyond. Automakers are awarded credits toward meeting their requirements through the sale of different levels of vehicle technologies, as categorized in Table B-1.[236]

Table B-1: Types of ZEVs Included in the Regulation

Category	Vehicle Acronyms	Technologies
Zero Emission Vehicle	ZEV	Battery; hydrogen FCV
Enhanced Advanced Technology Partial Zero Emission Vehicle	Enhanced AT PZEV	An ATPZEV using a ZEV fuel, such as electricity or hydrogen. (Examples: plug-in hybrids or hydrogen internal combustion engine vehicles)
Advanced Technology Partial Zero Emission Vehicle	AT PZEV	Hybrid; CNG; methanol fuel cell with near zero emissions and extended emissions system warranty
Partial Zero Emission Vehicle	PZEV	Extremely clean conventional vehicle with extended 150,000 mile warranty for the emissions system and zero evaporative emissions

Source: California Energy Commission

Vehicles using the higher categories of technologies are worth more credits toward satisfying the ZEV requirements than those using the lower categories of technologies. Additionally, within the ZEV technology category, there are six different "types" with their own number of credits per vehicle, based on a particular vehicle's range and fueling capabilities.

236 ARB, "Overview of the California Zero Emission Vehicle Program," http://o3.arb.ca.gov/msprog/zevprog/factsheets/overview.pdf

The ZEV program continues to bring innovative, clean technologies to California's roads. Many of these cars, such as hybrids, have become widely accepted, like the Toyota Prius and Honda Civic Hybrid. More advanced technology vehicles have also been deployed throughout the state, though these are often not yet at a commercial phase of deployment. While early commercial demonstrations of FCVs are currently underway with growing numbers of vehicles expected in the near term, the ARB believes, as well as many manufacturers, that FCVs will be commercially viable in the 2015 to 2020 timeframe. Battery electric vehicles are also progressing quickly, with new improvements in lithium battery technology. The following table represents the number of vehicles deployed through 2008.[237]

Table B-2: Statewide Vehicle Deployments by ZEV Category Through 2008

ZEV Category	Technology Type	Vehicles Deployed
ZEV	Fuel cell	250
ZEV	Battery electric	4,800
ZEV	Neighborhood electric	28,000
AT PZEV	Hybrid or CNG	258,000
PZEV	Low-emission conventional	1,156,000

Source: California Energy Commission

Updates to the ZEV Regulations

Traditionally, the ZEV regulation has been based on reducing criteria pollutant emissions. In March 2008, the ARB directed its staff to reassess the ZEV regulation, keeping in mind California's long-term air quality and GHG emission reduction goals, and to return with an update and recommendation by the end of 2009. On December 11, 2009, the ARB convened to review these materials.[238] Based on this hearing, the ARB staff has begun regulatory development and will release proposed modifications to the ZEV regulation in late fall 2010. These modifications may include the following:

- Closer alignment of the ZEV regulation with the state's 80 percent GHG emission reduction target for 2050.

237 Ibid.

238 A summary of the ARB staff's assessment can be found at: http://www.arb.ca.gov/msprog/zevprog/2009zevreview/zevwhitepaper.pdf

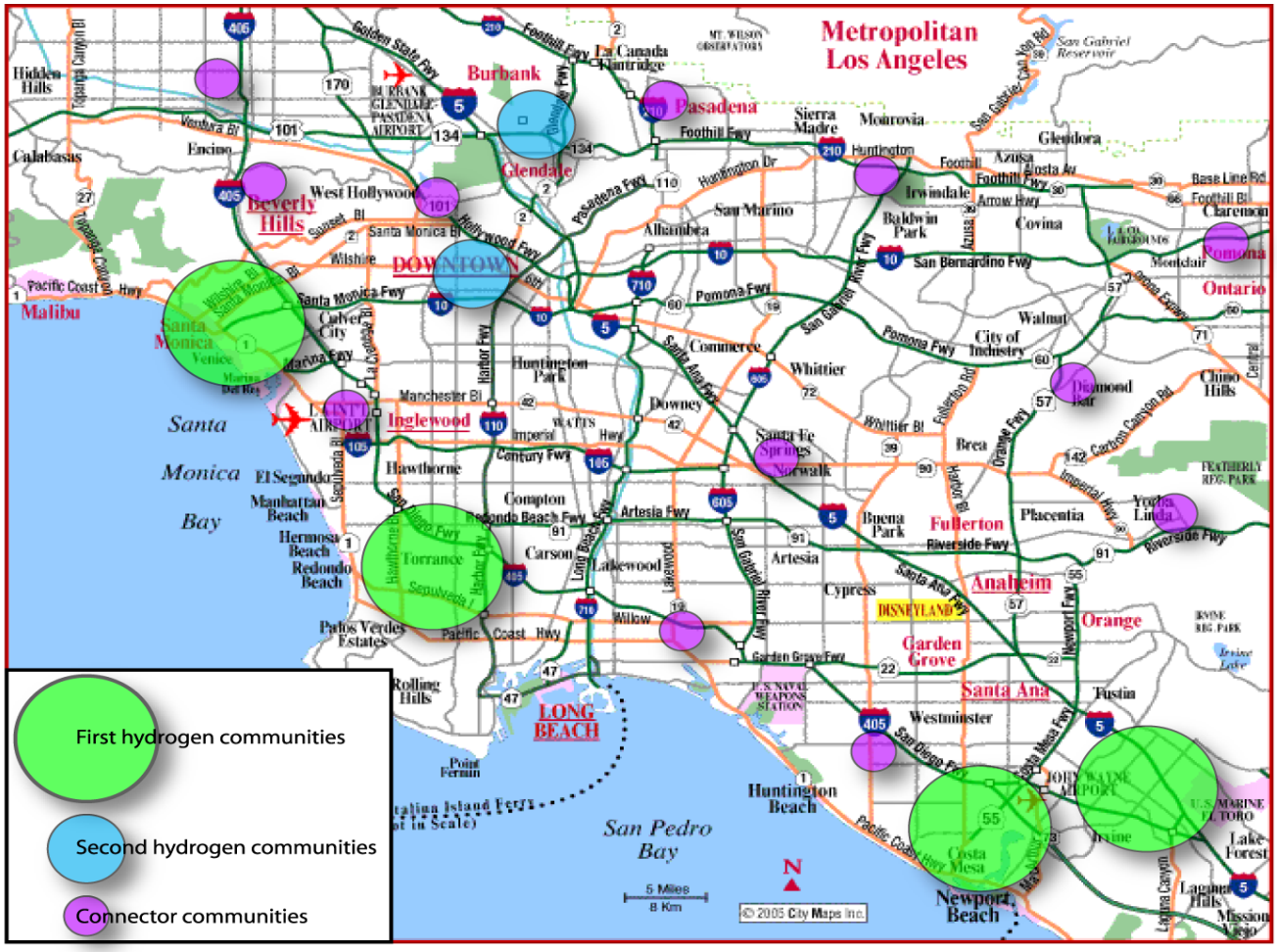
- A renewed focus on pre-commercial development vehicle technologies (such as ZEVs and Enhanced PZEVs), rather than technologies that already have demonstrated their market potential (such as PZEV and AT PZEV).
- Moving PZEV and AT PZEV vehicle technologies out of the ZEV program and into the Low Emission Vehicle (LEV) program for criteria pollutant and GHG reductions.

APPENDIX C: California Hydrogen Early Adopter Cluster Communities

To maximize benefit while minimizing costs, early "cluster communities" for passenger vehicles with clusters of retail hydrogen stations have been identified in four Southern California communities (Santa Monica, Irvine, Torrance, and Newport Beach) and two Northern California regions (Sacramento and the Bay Area), with additional stations to support the next identified communities and a network of connector stations. (See map below for a conceptual map of Southern California cluster communities.)

Placing the first wave of stations will affect the locations for the second wave. Vehicles may be more popular in one community than in another. With input from annual surveys of automakers about the numbers and locations of their vehicles, it can be ensured that the next wave of stations will be constructed at the most desirable and effective locations.

Figure C-1: Southern California Hydrogen Early Adopter Cluster Communities



Source: California Energy Commission

Table C-1: Hydrogen Fuel Demand and Capacity

Year	Region[239]	Cumulative Vehicle Rollouts (From Table 9)	Hydrogen Demand (Kg/day)[240]	Hydrogen Capacity (Kg/day)	Additional Hydrogen Needed (Kg/day)
2010	Santa Monica (LA cluster)	25	25	0	25
	Torrance (LA cluster)	25	25	0	25
	Newport Beach (LA	23	23	0	23
	Irvine (LA cluster)	32	32	25	7
	Los Angeles (non-clusters)	30	30	54	0
	San Diego	4	4	0	4
	Bay Area (cluster)	20	20	0	20
	Sacramento (cluster)	17	17	100	0
	Other	16	16	100	0
	Total	192	192	279	104
2011	Santa Monica (LA cluster)	45	45	0	45
	Torrance (LA cluster)	45	45	150	0
	Newport Beach (LA	38	38	100	0
	Irvine (LA cluster)	47	47	25	22
	Los Angeles (non-clusters)	57	57	330	0
	San Diego	8	8	0	8
	Bay Area (cluster)	34	34	180	0
	Sacramento (cluster)	25	25	0	25
	Other	31	31	100	0
	Total	330	330	885	100
2012	Santa Monica (LA cluster)	73	73	0	73
	Torrance (LA cluster)	64	64	150	0
	Newport Beach (LA	53	53	100	0
	Irvine (LA cluster)	67	67	0	67
	Los Angeles (non-clusters)	88	88	330	0
	San Diego	8	8	0	8
	Bay Area (cluster)	48	48	180	0
	Sacramento (cluster)	38	38	0	38
	Other	56	56	0	56
	Total	495	495	760	242

239 "Regions" are composed of the stations listed in Table C-2

240 "Hydrogen demand" and "hydrogen capacity" are for passenger vehicles and do not account for transit vehicles or transit fueling capacity.

Year	Region[239]	Cumulative Vehicle Rollouts (From Table 9)	Hydrogen Demand (Kg/day)[240]	Hydrogen Capacity (Kg/day)	Additional Hydrogen Needed (Kg/day)
2013	Santa Monica (LA cluster)	107	107	0	107
	Torrance (LA cluster)	91	91	150	0
	Newport Beach (LA	70	70	100	0
	Irvine (LA cluster)	104	104	0	104
	Los Angeles (non-clusters)	117	117	330	0
	San Diego	23	23	0	23
	Bay Area (cluster)	91	91	180	0
	Sacramento (cluster)	60	60	0	60
	Other	106	106	0	106
	Total	769	769	760	400
2014	Santa Monica (LA cluster)	193	193	0	193
	Torrance (LA cluster)	180	180	50	130
	Newport Beach (LA	208	208	0	208
	Irvine (LA cluster)	268	268	0	268
	Los Angeles (non-clusters)	382	382	30	352
	San Diego	33	33	0	33
	Bay Area (cluster)	264	264	0	264
	Sacramento (cluster)	117	117	0	117
	Other	194	194	0	194
	Total	1,839	1,839	80	1,759

Source: California Energy Commission, California Fuel Cell Partnership

Table C-2: Hydrogen Fuel Stations

Station	Region	Passenger Vehicle Capacity (Kg/day)	Transit Vehicle Capacity (Kg/day)	Pressure (Mpa)	Operational Status	Funded Through
Oakland - AC Transit	Bay Area Cluster	0	150	35	Transit only; closing Sept 2010	Thru Q3 2010
San Jose - Santa Clara VTA	Bay Area Cluster	0	0	35	Currently closed	Thru 2009
Emeryville - AC Transit	Bay Area Cluster	60	200	35/70	Expected - 24/7 public access	Q3 2010-2013
San Francisco - SFO Airport	Bay Area Cluster	120	0	35/70	24/7 public access	Q3 2010-2013
Irvine - UCI	LA Cluster - Irvine	25	0	35/70	24/7 public access	Thru 2011
Irvine - UCI	LA Cluster - Irvine	0	0	35	No public access	N/A
Newport Beach	LA Cluster - Newport Beach	100	0	35/70	24/7 public access	Q2 2010-2013
Santa Monica	LA Cluster - Santa Monica	0	0	35	Limited public access	Thru 2010
Torrance - Honda	LA Cluster - Torrance	0	0	35	No public access; OEM only (Honda)	N/A
Torrance - Honda	LA Cluster - Torrance	0	0	35	No public access; OEM only (Honda)	N/A
Torrance	LA Cluster - Torrance	0	0	35/70	No public access; OEM only (Toyota)	N/A
Torrance	LA Cluster - Torrance	50	0	35/70	24/7 public access	Q4 2010-???
Harbor City	LA Cluster - Torrance	100	0	35/70	24/7 public access	Q2 2010-2013
Diamond Bar - SCAQMD	LA Non-Cluster	12	0	35	Limited public access; plans for upgrade and continuation	Thru 2010
Ontario	LA Non-Cluster	0	0	35	No public access	Thru 2010
Santa Ana	LA Non-Cluster	0	0	35	No public access	Thru 2010

Station	Region	Passenger Vehicle Capacity (Kg/day)	Transit Vehicle Capacity (Kg/day)	Pressure (Mpa)	Operational Status	Funded Through
Chino	LA Non-Cluster	0	0	35	No public access; OEM only (Hyundai)	Thru 2010
Culver City	LA Non-Cluster	0	0	70	No public access; OEM only (GM)	N/A
Los Angeles - LAX	LA Non-Cluster	0	0	70	No public access; OEM only (GM)	N/A
Los Angeles - CSU LA	LA Non-Cluster	60	0	35/70	Expected - 24/7 public access	Q4 2010-2013
Fountain Valley	LA Non-Cluster	100	0	35/70	24/7 public access	Q2 2010-2013
Westwood - UCLA	LA Non-Cluster	140	0	35/70	24/7 public access	Q1 2011-2013
Burbank	LA Non-Cluster	116	0	35/70	Currently closed; expected to reopen	N/A
West LA	LA Non-Cluster	30	0	35	24/7 public access	Thru ???
Riverside	LA Non-Cluster	12	0	35	24/7 public access	Thru 2010
Thousand Palms	Other	60	100	35	24/7 public access	Thru 2012
Arcata - HSU	Other	0	0	35	Limited public access	N/A
Oceanside - Camp Pendleton	Other	0	0	35	Delayed opening with limited public access	Opening TBD
West Sacramento - CaFCP	Sacramento Cluster	100	0	35	Daylight hours public access	Thru 2010
Davis - UCD	Sacramento Cluster	0	0	35	Currently closed	Thru 2009

Source: California Fuel Cell Partnership, California Energy Commission

GLOSSARY

APEP	Advanced Power and Energy Program (UCI)
AQIP	Air Quality Improvement Program
ARB	California Air Resources Board
ARPA-E	Advanced Research Projects Agency-Energy
ARRA	American Recovery and Reinvestment Act
ASTM	American Society for Testing and Materials
AT PZEV	advanced technology partial zero-emission vehicles
ATTE	Advanced Transportation Technologies and Energy Program
B2G	battery-to-grid
BAP	*Bioenergy Action Plan*
BCF-	billion cubic feet
BDT	bone dry tons
BEV	battery electric vehicles
BSS	battery switch station
CA LEV	California Low-Emission Vehicle Program
CAAP-	Clean Air Action Plan
CAEATFA	California Alternative Energy and Advanced Transportation Funding Authority
CaFCP	California Fuel Cell Partnership
CAFÉ	Corporate Average Fuel Economy
Cal ETC	California Electric Transportation Coalition
CalCAP	California Capital Access Program
CalCars	Clean Fuel Connection and the California Car Initiative
CALCARS	California Conventional and Alternative Fuel Response Simulator
CaRFG	California's reformulated gasoline
CCCCO	California Community Colleges Chancellor's Office
CE-CERT	Center for Environmental Research and Technology
CEPIP	California Ethanol Production Incentive Program
CEWTP	Clean Energy Workforce Training Program
CDFA	California Department of Food and Agriculture
CFER	California Fuel Ethanol Reserve
CNG	compressed natural gas
CO_{2-}	carbon dioxide
CO2-eq/MJ	carbon dioxide-equivalents per megajoule of energy
CPCFA	California Pollution Control Financing Authority
CPUC	California Public Utilities Commission
CTP	Clean Trucks Program
CWIB	California Workforce Investment Board
DC	direct current
DMS	Division of Weights and Measurement Standards
DMV	Department of Motor Vehicle (California)

DOE	Department of Energy
DOT	Department of Transportation
E-85	85 percent ethanol blend fuel mixture
EDD	California Employment Development Department
EER	energy efficiency ratio
EISA	Energy Independence and Security Act
ETEC	Electric Transportation Engineering Corporation
ETP	Employment Training Panel
EV	electric drive
EVSE	electric vehicle supply equipment
FCB	fuel cell bus
FCV	fuel cell vehicles
FFV	flexible fuel vehicles
FTA	Federal Transit Administration
FY	fiscal year
GGE	gasoline equivalent gallons
GHG	greenhouse gas
GM	General Motors
GREET	greenhouse gases, regulated emissions, and energy use in transportation
H/CNG	blend of hydrogen and compressed natural gas
HESA	household energy storage appliance
HEV	hybrid-electric vehicles
HICE	hydrogen internal combustion engine
HOV	high-occupancy vehicle lane
HVIP	Hybrid Truck and Bus Voucher Incentive Program
ICE	internal combustion engine
IEPR	Integrated Energy Policy Repot
kWh	kilowatt hours
LCFS	Low-Carbon Fuel Standard
LEV	low emission vehicle
LNG	liquefied natural gas
MGPY	million gallons per year
$MMTCO_2e$	million metric ton carbon dioxide equivalent
MPCO	Media and Public Communications Office
MPG	miles per gallon
MV&E	measurement, verification and evaluation
NAFTA	North American Free Trade Agreement
NEV	neighborhood electric vehicle
NG	natural gas (mainly methane)
NGV	natural gas vehicle
NHTSA	National Highway Traffic Safety Administration
NOx	nitrogen oxide
NREL	National Renewable Energy Laboratory, U.S. DOE

NUMMI	New United Motor Manufacturing Inc.
OEM	original equipment manufacturers
PERC	Propane and Education Research Council
PHEV	plug-in hybrid-electric vehicles
PIER	Public Interest Energy Research Transportation Program Area
PON	program opportunity notice
PZEV	partial zero- emission vehicle
R&D	research and development
RFP	request for proposal
RFS	renewable fuel standard
RIN	renewable identification number
RPS	Renewables Portfolio Standard
SCAQMD	South Coast Air Quality Management District
SEP	State Energy Program
SMUD	Sacramento Municipal Utility District
STEP	Sustainable Transportation Energy Pathways (UCD)
STREET	Spatially and Temporally Resolved Energy and Environmental Tool
SULEV	super ultra low emissions
SWRCB	California State Water Resources Control Board
TIGGER	Transit Investments for Greenhouse Gas and Energy Production
TSE	truck-stop electrification
UC	University of California
USDA	United States Department of Agriculture
U.S. DOE	United States Department of Energy
U.S. EPA	United States Environmental Protection Agency
UL	Underwriters Laboratories
UST	underground storage tank
ZEB	zero-emission bus
ZEV	zero-emission vehicle