CALIFORNIA ENERGY COMMISSION

California Energy Commission

COMMISSION REPORT

2011-2012 Investment Plan for Alternative Fuel and Vehicle Technology Program

Gavin Newsom, Governor

September 2011 | CEC-600-2011-006-CMF

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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, gasoline substitute fuels, and diesel substitute 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 must accomplish this, in part, by funding projects that provide for "a measurable transition from the nearly exclusive use of petroleum fuels to a diverse portfolio of alternative fuels that meet petroleum reduction goals and alternative fuel use goals." The Energy Commission has an annual program budget of roughly $100 million.

The statute also directs the Energy Commission to adopt an investment plan that describes how funding will complement existing public and private investments, including existing state and federal programs. The Energy Commission must establish and consult with an advisory committee during the development of the investment plan. 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. The *2011-2012 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 developing 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 *2011-2012 Investment Plan* provides proposed funding recommendations based on 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

Please use the following citation for this report:

Smith, Charles, Miles Roberts, Jim McKinney. 2011. *2011-2012 Investment Plan for the Alternative and Renewable Fuel and Vehicle Technology Program* Commission Report. California Energy Commission, Fuels and Transportation Division. Publication Number: CEC-600-2011-006-CMF.

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EXECUTIVE SUMMARY

Transportation fuel is one of the top three energy use sectors in the United States, accounting for two-thirds of the 20 million barrels of crude oil consumed daily. Of that, the United States imports about half from foreign sources. In California, the transportation sector represents roughly half of all energy consumed and is more than 90 percent dependent on petroleum. Despite the current economic turmoil, Californians still consume more than 50 million combined gallons of gasoline and diesel each day.

California's dependence on petroleum-derived fuels poses a number of significant challenges. The state's transportation sector contributes about 40 percent of the state's greenhouse gas emissions, the largest amount from any sector. Fuel prices are forecasted to increase from 35 to 50 percent by 2015, slowing California's economic recovery. Given our nation's dependence on foreign sources of crude oil, petroleum dependence also comes with national security risks.

California has and will continue to dramatically affect the direction of the nation's transportation sector as it leads 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 California Energy Commission and the California Air Resources Board, presented strategies to increase alternative and non-petroleum fuel use for transportation. The *State Alternative Fuels Plan* set goals to reduce petroleum dependence by 15 percent by 2020 and increase alternative fuels use to 26 percent of all fuel consumed by 2022. The alternative fuels proposed in the plan could achieve these goals and reduce greenhouse gases by 15 percent to 20 percent in the coming decade. Other California regulations include the Global Warming Solutions Act of 2006 (Assembly Bill 32, Núñez, Chapter 488, Statutes of 2006), the Low Carbon Fuel Standard, the Zero Emission Vehicle regulations, the *Bioenergy Action Plan*, the Renewables 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), is crucial in helping meet the state's climate change and energy policies. Through 2014, the Energy Commission is providing incentives up to $100 million annually, leveraging public and private investment to develop and deploy clean, efficient, and low-carbon alternative fuels and technologies. The program also provides a foundation for sustainable development and use of transportation energy and an economic stimulus creating California jobs and businesses by encouraging the invention and production of future transportation technologies and services. 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 program in providing alternative fuel vehicle incentives.

Each year the Energy Commission prepares an investment plan to determine the program funding priorities and opportunities and describe how this funding will be used to support other public and private investments. The Energy Commission adopted the first investment plan, combining a total of $176 million in funds from fiscal years 2008-2009 and 2009-2010 at

the April 22, 2009, Business Meeting. The second investment plan, for fiscal year 2010-2011 ($100 million), was adopted at the August 11, 2010, Business Meeting. The Committee *2011-2012 Investment Plan for the Alternative and Renewable Fuel and Vehicle Technology Program* is the proposed funding guide for fiscal year 2011-2012 ($100 million).

Summary of Program Funding

Since the first investment plan, the Energy Commission has invested $189 million in alternative and renewable vehicle technology, fuel and infrastructure. The first Investment Plan (a combination of fiscal years 2008-2009 and 2009-2010) allocated $175.5 million to projects. In response to public solicitations, the Energy Commission received requests for funds totaling more than $1.2 billion. To provide further funding for worthy projects, the Energy Commission also used $14.6 million of the second Investment Plan (fiscal year 2010-2011) to augment solicitations that had an oversubscription of passing proposals. (Table ES-1)

Among other solicitations, the Energy Commission used funds from the first Investment Plan to help California entities successfully compete for funding under the federal American Recovery and Reinvestment Act (ARRA) committing $36.5 million to California projects. These projects were awarded about $105.3 million in ARRA funds and also include $113.3 million in private funds. These funds are being used to:

- Install 2,860 new electric vehicle charging sites.
- Demonstrate and deploy more than 700 medium- and heavy-duty natural gas and hybrid-electric trucks.
- Develop high-energy-density lithium-ion batteries.
- Provide public outreach to promote deploying heavy-duty natural gas vehicles.
- Establish 75 new E85 fueling stations, capable of selling a blend of 85 percent ethanol and 15 percent gasoline.

The second Investment Plan projected $108 million for project and activity funding, based on estimated vehicle registrations, vessel registrations, identification plates, and smog abatement fees. Californians, however, registered fewer vehicles in 2009 than was originally estimated; as a result, only $86.4 million was available for fiscal year 2010-2011. As mentioned, $14.6 million was used to augment funding for oversubscribed solicitations. This leaves approximately $71.8 million remaining from the second Investment Plan for new projects. This funding, in conjunction with $100 million from this third Investment Plan, will be released for new solicitations and agreements (Table ES-2).

Table ES-1: Funding Awarded to Date (in Millions)

Category	Funded Activity	Initial Awards 2008-09 / 2009-10 (First Investment Plan)	Augmented Awards 2010-11 (Second Investment Plan)	Total Award
ARRA	Cost-Sharing for Federal Projects	$36.5	-	$36.5
Electric Drive	Charging Infrastructure	$3.2	$2.4	$5.6
	Convert State Vehicles to Plug-in Hybrid Vehicles	$0.6	-	$0.6
	Light-Duty Vehicle Rebates	$2.0	-	$2.0
	Medium- and Heavy-Duty Vehicle Rebates	$4.0	-	$4.0
	Medium- and Heavy-Duty Advance Vehicle Demonstrations	$10.0	$2.0	$12.0
	Manufacturing Facilities and Equipment	$19.0	$5.9	$24.9
Hydrogen	Public Fueling Stations	$15.7	-	$15.7
	Transit Project	$3.0	-	$3.0
	Fuel Standards Development	$4.0	-	$4.0
Natural Gas	Fueling Infrastructure	$5.1	-	$5.1
Propane	School Bus Incentives*	$2.0	-	$2.0
Biofuels	Biomethane Production	$35.1	$0.2	$35.3
	Diesel Substitutes Production	$2.8	$1.5	$4.3
	Advanced Ethanol and Gasoline Substitutes Production	$3.5	$1.9	$5.4

Category	Funded Activity	Initial Awards 2008-09 / 2009-10 (First Investment Plan)	Augmented Awards 2010-11 (Second Investment Plan)	Total Award
	California Ethanol Producers Incentive Program	$6.0	-	$6.0
	E85 Fueling Stations	$1.0	-	$1.0
	Upstream Biodiesel Infrastructure	$3.9	-	$3.9
Workforce Agreements	Workforce Training and Development	$15.0	$0.8	$15.8
Other Agreements	Sustainability Research	$1.5	-	$1.5
	Technical Assistance and Analysis	$1.6	-	$1.6
Total		$175.5	$14.6	$190.2

Source: California Energy Commission

Table ES-2: Future Funding Solicitations and Agreements (in Millions)

Category	Funded Activity	Funds Remaining from Second Investment Plan 2010-11	Proposed Allocations from Third Investment Plan 2011-12	Total Future Funding
Electric Drive	Plug-in Electric Vehicle Regional Readiness Plans*	$1.0	$1.0	$2.0
	Charging Infrastructure	-	$7.0	$7.0
	Medium- and Heavy-Duty Advance Vehicle Demonstrations**	$8.9	$8.0	$16.9
	Manufacturing Facilities and Equipment**	-	$10.0	$10.0
Hydrogen	Fueling Infrastructure	$10.2	$8.5	$18.7
Natural Gas	Fueling Infrastructure	$1.6	$8.0	$9.6
	Light-, Medium- and Heavy-Duty Vehicles*	$10.2	$12.0	$22.2

Category	Funded Activity	Funds Remaining from Second Investment Plan 2010-11	Proposed Allocations from Third Investment Plan 2011-12	Total Future Funding
Propane	Light- and Medium-Duty Vehicles*	$2.4	-	$2.4
	Light-Duty Vehicles	-	$1.0	$1.0
	Medium- and Heavy-Duty Vehicles	-	$3.0	$3.0
	Fueling Infrastructure	-	$0.5	$0.5
Biofuels	Biomethane Production	$5.3	$8.0	$13.3
	Diesel Substitutes Production	$3.9	$8.0	$11.9
	Advanced Ethanol and Gasoline Substitutes Production	$4.5	$8.0	$12.5
	E85 Fueling Stations	$5.1	$5.0	$10.1
	Upstream Biodiesel Infrastructure	$3.1	-	$3.1
Innovative Technologies	Innovative Technologies, Advanced Fuels and Federal Cost-Sharing	$6.3	$3.0	$9.3
Workforce Agreements	Workforce Training and Development	-	$6.5	$6.5
Other Agreements	Sustainability Studies	$2.0	$0.5	$2.5
	Marketing, Education and Outreach	$2.0	-	$2.0
	Technical Assistance and Analysis	$3.7	$2.0	$5.7
	Measurement, Verification and Evaluation	$1.7	-	$1.7
Total		$71.8	$100.0	$171.8

Source: California Energy Commission.

*Solicitation is currently underway using funds from the second Investment Plan. Funds from the third Investment Plan may be used to supplement this solicitation.

**Funding eligibility for these activities has been expanded beyond strictly electric drive technologies.

2011-2012 Investment Plan

To ensure a more comprehensive approach to the investment plan, the Energy Commission has restructured the analysis and reorganized the contents of the plan. More emphasis is given to the upstream fuel issues, such as feedstocks and fuel conversion processes. This is reflected in the biofuels section, which includes a detailed analysis of some of the more developed and promising feedstocks. The Energy Commission is also developing a similarly detailed analysis of biofuel conversion processes encouraging advanced pathways for biofuels (and other fuel types) that rely on lower carbon feedstocks and more efficient conversion processes.

The Energy Commission has also reshaped the investment plan's approach to medium- and heavy-duty vehicles. Previously, these vehicles were discussed in each fuel section. For the *2011-2012 Investment Plan*, the Energy Commission developed a separate medium- and heavy-duty section for a more detailed analysis of the opportunities and barriers for incorporating alternative fuels and advanced technologies for these types of vehicles.

2011-2012 Investment Plan **Funding Priorities**

The third investment plan has benefited from the Energy Commission's recent experience in reviewing and funding previous projects. This process has provided useful technical and market information and guidance for future solicitations and agreements. The program is currently oversubscribed in most funding areas, receiving more than 300 project proposals since the first investment plan. Potential greenhouse gas and petroleum use reductions are substantial, and the leveraged amount of public, stakeholder, and venture capital is unprecedented. The Energy Commission continues providing funding to accelerate developing and marketing clean, efficient low-carbon technologies that reduce greenhouse gas emissions and petroleum dependence and increase alternative and renewable fuel use and in-state biofuels production. Achieving these policy objectives requires a portfolio of fuels and vehicle technologies including electric drive and fuel cell vehicles, low-carbon biofuels, natural gas and propane vehicles, and improved vehicle efficiency.

The Energy Commission evaluated funding priorities based on an identified portfolio of fuels and technologies, to reflect a broad set of short-, medium- and long-term opportunities. To ensure the maximum value for the state's funding, the plan evaluates existing public and private funding that is already developing and deploying alternative fuels and vehicle technologies 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 is also considered.

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

The Energy Commission has relied on stakeholder input, contracted research, and other agreements to help develop the *2011-2012 Investment Plan. The 2011-2012 Investment Plan also relies on:*

- Program funds that have been awarded to date.
- American Recovery and Reinvestment Act of 2009 funds awarded to successful California project applicants.
- The effects of existing and anticipated regulations, including the Low-Carbon Fuel Standard, the *Bioenergy Action Plan*, the Zero Emission Vehicle regulation modifications, the Clean Fuels Outlets regulations, the Renewable Fuel Standard, the National Greenhouse Gas and Corporate Average Fuel Economy Standards for Vehicles, the Renewables Portfolio Standard, and the Clean Air Action Plan.

2011-2012 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 input from stakeholders. These allocations provide funding for demonstration and deployment opportunities in the short, mid- and long term to meet program goals (Table ES-3). For example, funding is being provided immediately to establish electric drive infrastructure for electric vehicles being deployed in 2011 to 2013—the near term. Funding for improved biofuel production methods will provide alternative vehicle fuels in subsequent years, and funding for hydrogen infrastructure will help to meet petroleum and greenhouse gas reduction goals as commercial fuel cell vehicles are introduced beginning in 2015. The *2011-2012 Investment Plan* also supports commercializing alternative fuels and vehicle technologies by funding market and program development activities.

Table ES-3: Funding Allocation Summary for FY 2011-2012

	Project/Activity	**Funding Allocation for FY (2011-2012)**
Plug-In Electric Vehicles	Plug-In Electric Vehicle Readiness	$1 Million
	Charging Infrastructure	$7 Million
	Subtotal	$8 Million
Hydrogen	Fueling Infrastructure	$8.5 Million
	Subtotal	$8.5 Million
Natural Gas	Fueling Infrastructure	$8 Million
	Subtotal	$8 Million
Propane	Light-Duty Vehicle Incentives	$1 Million
	Fueling Infrastructure	$.5 Million

	Project/Activity	Funding Allocation for FY (2011-2012)
	Subtotal	$1.5 Million
Gasoline Substitutes	Advanced Ethanol and Gasoline Substitute Production Plants	$8 Million
	E85 Fueling Infrastructure	$5 Million
	Subtotal	$13 Million
Diesel Substitutes	Advanced Diesel Substitute Production Plants	$8 Million
	Subtotal	$8 Million
Biomethane	Pre-Landfill Biomethane Production	$8 Million
	Subtotal	$8 Million
Medium- and Heavy-Duty Vehicles	Deployment Incentives for Natural Gas Vehicles	$12 Million
	Deployment Incentives for Propane Vehicles	$3 Million
	Develop and Demonstrate Advanced Technology Medium- and Heavy-Duty Vehicles	$8 Million
	Subtotal	$23 Million
Innovative Technologies, Advanced Fuels, and Federal Cost-Sharing	Innovative Technologies, Advanced Fuels, and Federal Cost-Sharing	$3 Million
	Subtotal	$3 Million
Manufacturing	Manufacturing Facilities and Equipment	$10 Million
	Subtotal	$10 Million
Workforce Training and Development	Workforce Training and Development Agreements	$6.5 Million
	Subtotal	$6.5 Million
Market and Program Development	Sustainability Studies	$.5 Million
	Technical Assistance and Analysis	$2 Million
	Subtotal	$2.5 Million
	Total	$100 Million

Source: California Energy Commission

Plug-In Electric Vehicles ($8 Million)

Sales of in-state plug-in electric vehicles are expected to increase rapidly over the next 2-3 years, as major automakers begin offering fully electric and plug-in hybrid electric vehicles. Based on automaker survey data, the combined number of these vehicles is expected to surpass 20,000 by 2012. To ensure the continued deployment of these vehicles, the Energy Commission is providing $1 million to support regional readiness planning of plug-in electric vehicles, and $7 million for charging infrastructure. This funding will potentially support a broad variety of charging installations and related activities, including residential chargers, workplace commercial and public chargers, and fast chargers that can fully charge a vehicle in minutes (rather than hours). These activities will be coordinated with the Air Resources Board, the California Public Utilities Commission, and the recently established California Plug-In Electric Vehicle Collaborative Council.

Hydrogen ($8.5 Million)

Hydrogen vehicles, predominantly fuel cell vehicles, are expected to expand rapidly in California during this decade, and the Energy Commission wants to ensure sufficient fueling infrastructure to support these vehicles. An updated survey of major automakers suggests that, despite a drop in anticipated vehicles before 2015, the number of vehicles expected after 2015 will be in the tens of thousands. Before 2015, anticipated hydrogen fueling stations should be able to provide significant coverage for the expected number of vehicles. For fiscal year 2011-2012, the Energy Commission will provide $8.5 million to address high-priority gaps in fueling infrastructure and funding for transit demonstration opportunities that use fuel cell vehicle technology. This funding may be combined with the funds from fiscal year 2010-2011 into a single solicitation.

Natural Gas ($8 Million)

Natural gas will play a growing role in the state's transportation sector, in response to greenhouse gas emission reduction targets, volatile oil prices, and air quality standards. Significant opportunities remain for expanding medium- and heavy-duty natural gas vehicles in a variety of applications and are discussed in greater detail in this section of the investment plan.

A modest network of fueling infrastructure already exists for natural gas vehicles. Many of these stations, however, require upgrades, and increases in natural gas vehicles will only happen when concerns about mileage range and fleet fueling operations are resolved. The Energy Commission is allocating $8 million to support installing new natural gas fueling infrastructure and upgrades to existing infrastructure. An expanded natural gas fueling infrastructure also creates additional opportunities to incorporate biomethane from anaerobically digested waste-based biomass feedstocks into California's transportation fueling infrastructure.

The Energy Commission will also continue to support the deployment and expanded offerings of light-duty natural gas vehicles through vehicle incentives. Funding for these

incentives will draw from the $12 million allocated to similar incentives for medium- and heavy-duty natural gas vehicles.

Propane ($1.5 Million)

Propane, like natural gas, offers the potential for immediately reducing greenhouse gas emissions, petroleum dependence, and fuel costs for light- and medium-duty vehicles. Propane produced by renewable methods will further reduce greenhouse gas emissions from propane-fueled vehicles. Propane has been the preferred alternative fuel for rural communities and school districts that do not have access to an alternative fuel, since propane fueling infrastructure is readily available and affordable. The Energy Commission is allocating $1 million specifically for light-duty propane vehicle deployment and $500,000 to expand the propane infrastructure in Northern California. Further allocations for medium- and heavy-duty propane vehicles are discussed in the Medium- and Heavy-Duty Vehicles section of the investment plan.

Biofuels ($29 Million)

There is a broad variety of feedstocks available for renewable biofuels. California possesses a significant volume of waste-based feedstocks, which offer a particularly excellent opportunity to expand low-carbon fuels production. The annual potential from California's waste-based feedstocks is estimated to be more than 2.6 billion diesel gallon-equivalents. The Energy Commission will invest in abundant, waste-based feedstocks and maximize the variety of fuel conversion processes that use these feedstocks. The investment plan focuses on three biofuel end uses: gasoline substitutes, diesel substitutes, and biomethane.

Gasoline Substitutes ($13 Million)

Ethanol and other drop-in gasoline substitutes offer a significant opportunity for reducing greenhouse gas emissions and petroleum use. The state's Low Carbon Fuel Standard and *Bioenergy Action Plan* and the federal Renewable Fuel Standard rely heavily on biofuels (including ethanol) to meet their targets. The Energy Commission is providing $8 million to expand in-state production of low-carbon ethanol and other gasoline substitutes from sustainable feedstocks. This funding is intended to develop new facilities that can produce a low-carbon fuel.

An additional $5 million will be provided to expand E85 (85 percent ethanol and 15 percent gasoline) dispensers and retail outlets. Given the relatively modest marginal cost of flex-fuel vehicles, the Energy Commission is not proposing vehicle funding for this fuel category.

Diesel Substitutes ($8 Million)

Diesel substitutes, such as biodiesel and renewable diesel, also offer an immediate opportunity to significantly reduce California's greenhouse gas emissions and petroleum dependence. The same policy drivers that will accelerate ethanol and gasoline substitutes will also accelerate diesel substitutes. To accelerate the in-state production of diesel substitutes, the Energy Commission will provide $8 million to expand and support California's diesel substitute production plants.

Biomethane ($8 Million)

Producing and using 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. Additionally, biomethane can reduce lifecycle greenhouse gas emissions in a broad variety of fuel pathways, from natural gas to hydrogen to ethanol. Anaerobic digestion from a variety of waste-based feedstocks, such as wastewater treatment plants and food-processing facilities, is proving to be a robust and cost-effective technology for creating very-low-carbon transportation fuels that can be readily incorporated into natural gas vehicles and fueling systems. For these reasons, the Energy Commission is allocating $8 million to develop pre-landfill biomethane production for the transportation sector.

Medium- and Heavy-Duty Vehicles ($23 Million)

Medium- and heavy-duty vehicles are a significant component of California's transportation sector, accounting for a combined 16 percent of the state's petroleum consumption and greenhouse gas emissions within the transportation sector. Yet, these vehicles represent fewer than 4 percent of the in-state vehicle population. Given the high amount of petroleum use per vehicle (compared to passenger vehicles), these vehicles offer an excellent opportunity to expand alternative fuel use, reduce petroleum dependence, and reduce greenhouse gas emissions. The Energy Commission is allocating $12 million in deployment incentives for on-road and off-road medium- and heavy-duty natural gas vehicles, and $3 million for propane vehicles.

Advanced technologies, such as battery electric applications, hybrid hydraulics, and fuel cell technology, can also be incorporated into medium- and heavy-duty vehicles. However, compared to passenger vehicles, medium- and heavy-duty vehicles serve a broader variety of purposes. The early use of advanced technologies may be limited to certain niche applications. Some vehicle suppliers have already begun incorporating a variety of advanced vehicle technologies. To expand the use of these technologies, the Energy Commission will provide $8 million to demonstrate advanced technologies in the medium- and heavy-duty sector.

Innovative Technologies and Advanced Fuels ($3 Million)

In addition to the previous fuel and technology categories, the Energy Commission is interested in providing funding for other types of projects that can help the state meet 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 create lightweight vehicle materials for multiple vehicle platforms. To ensure adequate funding for these opportunities, the Energy Commission is reserving $3 million for innovative technologies and advanced fuels. This funding will also be reserved for cost-sharing opportunities from highly leveraged federal solicitations.

Manufacturing ($10 Million)

Given the amount of venture capital invested in California's clean transportation sector, the state has the potential to develop and attract new opportunities for manufacturing alternative fuel vehicles and components. The Energy Commission has already made substantial investments in manufacturing. These successful projects will attract customers and production orders and will soon require greater manufacturing capacity. State support can help ensure that these commercial-scale manufacturing plants are located in California, benefitting California with jobs, environmental benefits, and tax revenue. The *2011-2012 Investment Plan* will allocate $10 million to fund projects that establish commercial-scale clean transportation manufacturing facilities in California.

Workforce Training and Development ($6.5 Million)

Workforce training and development is critical in California's efforts to develop a clean transportation energy market. Skilled workers are needed to manufacture low-emissions vehicles and components, produce alternative fuels, build fueling infrastructure, service and maintain fleets and equipment, and inform ongoing innovation and refinement to increase market acceptance. Training is required to respond to new technology, improve efficiencies, minimize waste, and reduce the cost of production. As the Energy Commission funds alternative fuel and low-emission vehicle projects, it is critical that funds are allocated to help develop a skilled workforce to implement and sustain those projects. The *2011-2012 Investment Plan* allocates $6.5 million for this purpose.

Market and Program Development ($2.5 Million)

The Energy Commission is also allocating funding for nonfuel categories to ensure the success of this program. The Energy Commission is providing $500,000 for sustainability studies to support commercializing renewable fuels and minimizing negative environmental impacts. Existing efforts in marketing and program outreach will continue using previous years' funds and do not require additional funding at this time. The Energy Commission will provide $2 million for technical assistance and environmental, market, and technology analysis. This work will help the program focus on funding priorities and identifying preferred opportunities for future funding. This category may also provide funding for a variety of analytical needs to support alternative fuels and advanced vehicle technologies. Finally, the Energy Commission will rely on previous years' allocations for the measurement, verification, and evaluation of the program's activities.

CHAPTER 1: Introduction

The transportation sector of California represents a critical element of the state's economy and society, with more than 26 million registered vehicles. This sector accounts for nearly half of all energy consumed within the state and produces roughly 40 percent of the state's greenhouse gas (GHG) emissions.[1] Petroleum-derived fuels account for 91 percent of all energy consumed within the transportation sector, and importing foreign-sourced petroleum is expected to increase, even under a "low-import" case.[2] Despite the climate and economic risks associated with petroleum dependence, California and the United States have yet to take full advantage of alternative and renewable fuels and advanced vehicle technologies.

During the past five years, however, California has begun aggressive measures to reduce GHG emissions across all sectors. In 2006, Assembly Bill 32 (AB 32) (Núñez, Chapter 488, Statutes of 2006), the Global Warming Solutions Act of 2006, was signed into law. AB 32 established a goal of reducing 2020 GHG emission reductions to 1990 levels. This followed the issuance of Executive Order S-3-05 in 2005, which set a target of reducing GHG emissions 80 percent further by 2050. Governor Jerry Brown has actively supported AB 32, and policies to specifically reduce GHG emissions in the transportation sector.[3]

Every day, Californians experience the economic consequences of an overdependence on petroleum fuels. While the current recession has resulted in a modest decrease in gasoline and diesel consumption, Californians still consume about 50 million combined gallons of gasoline and diesel each day. As the worldwide economy recovers, and the demand for petroleum-derived fuels increases, crude oil prices continue to be unstable. California fuel prices are forecasted to increase from 35 to 50 percent (adjusted for inflation) by 2015 with similar possible increases for diesel.[4] Some sectors of the economy are likely to respond to such price increases by reducing their transportation fuel demand; in other sectors, price increases will be met with greater commitments toward alternative fuel and advanced vehicle technologies.

Petroleum dependence also entails an energy security risk. In 2008, foreign supplies of crude oil provided nearly half of the supply for California's oil refineries.[5] The United States was similarly dependent on foreign imports for about half of its petroleum demand, while accounting for about 22 percent of worldwide petroleum consumption.

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[1] California Energy Commission, 2007 Integrated Energy Policy Report, CEC-100-2007-008-CMF.
[2] California Energy Commission, *2009 Integrated Energy Policy Report*, CEC-100-2009-003-CMF.
[3] Jerry Brown 2010, "Environment," (http://www.jerrybrown.org/environment), January 6, 2010.
[4] Gordon Schremp, Aniss Bahreinian, and Malachi Weng-Gutierrez, *2010 Transportation Energy Forecasts and Analyses for the 2009 Integrated Energy Policy Report*, California Energy Commission. CEC-600-2010-002-SF.
[5] Ibid.

At a forum on naval energy, Secretary of the Navy Ray Mabus summarized these concerns, stating, "We have ceded [a strategic resource] to other nations who are allowed to exert disproportionate influence as a result. This creates an obvious vulnerability to our energy security, and to our national security, and to our future on this planet." Taking these concerns seriously, the U.S. Navy plans to reduce its petroleum use by 50 percent in its commercial fleet by 2015, and to use alternative fuels for half of its total energy consumption for ships, aircrafts, tanks, vehicles, and shore installations by 2020.[6]

The growth of new fuels and technologies also poses a significant opportunity for economic development in California. While total state employment has grown by 18 percent since 1995, growth in the green jobs sector grew by 56 percent. Employment in clean transportation increased 6 percent from January 2008 to January 2009.[7] The potential for growth in these sectors is also visible in the venture capital market. From 2006 to 2009, California attracted more than $6.6 billion in clean technology funding, more than half of national funding.[8] In 2009, almost $400 million of venture capital was invested in clean transportation. In the first half of 2010, California attracted 40 percent of the global venture capital in the clean technology sector. These investments have helped California develop a competitive edge in intellectual property in green technology, with nearly 50 percent more green technology patents than the next state.[9]

Since 2003, California has implemented a number of key policies to reduce GHG emissions and 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 (Table 1). Transforming California's transportation sector to achieve these objectives requires the well-planned use of state and federal funds to encourage private investment in alternative and renewable fuels and technologies.

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[6] Honorable Ray Mabus, Secretary of the Navy, Remarks at the Naval Energy Forum on October 14, 2009, (http://www.navy.mil/navydata/people/secnav/Mabus/Speech/Energy_Forum_14Oct09.pdf).
[7] Next 10, *Many Shades of Green*, http://www.next10.org/next10/publications/pdf/2011_Many_Shades_of_Green_FINAL.pdf.
[8] Pew Charitable Trusts, *The Clean Energy Economy: Repowering Jobs, Businesses and Investments Across America*, (http://www.pewcenteronthestates.org/uploadedfiles/clean_economy_report_web.pdf).
[9] Next 10, 2010 *California Green Innovation Index*, (http://www.next10.org/pdf/GII/Next10_GII_2010.pdf).

Table 1: Summary of Key Policies

Objectives	Goals and Milestones
Petroleum Reduction[10]	Reduce petroleum fuel use to 15 percent below 2003 levels by 2020
GHG Reduction[11,12]	Reduce GHG emissions to 1990 levels by 2020 and 80 percent below 1990 levels by 2050
Alternative and Renewable Fuel Use[13]	Increase alternative and renewable fuel use to 9 percent of on-road and off-road fuel demand by 2012, 11 percent by 2017, and 26 percent by 2022
In-State Biofuels Production[14]	Produce in California 20 percent of biofuels used in state by 2010, 40 percent by 2020, and 75 percent by 2050

Source: California Energy Commission

To help achieve these policies, Assembly Bill 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 and energy security policies. The Energy Commission is providing incentives to accelerate the development and deployment of clean, efficient, low-carbon alternative fuels and technologies. The program has an annual program budget of about $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.
- Improve 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.

[10] *Reducing California's Petroleum Dependence*, California Energy Commission and California Air Resources Board joint agency report, August 2003, Publication #P600-03-005.
[11] Assembly Bill 32 (Núñez, Chapter 488, Statutes of 2006).
[12] Executive Order S-3-05.
[13] *State Alternative Fuels Plan*, Final Adopted Report, CEC-600-2007-011-CMF, December 2007.
[14] Executive Order S-6-06.

- Establish workforce training programs, conduct public education and promotion, and create alternative and renewable fuel and vehicle technology centers.

Each year the Energy Commission prepares an investment plan to determine funding priorities and opportunities and describe how program funding will 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 second investment plan, governing FY 2010-2011, was adopted at the August 11, 2010, Business Meeting. This *2011-2012 Investment Plan for the Alternative and Renewable Fuel and Vehicle Technology Program* (2011-2012 Investment Plan) guides funding for FY 2011-2012.

CHAPTER 2:
Determining Priorities and Opportunities

The Energy Commission's third investment plan continues to accelerate the development and deployment of clean, efficient low-carbon technologies that will achieve several key policy objectives: reducing GHG 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 opportunities were evaluated based on the identified needs of a portfolio of fuels and technologies, and reflects a broad set of short-, medium- and long-term opportunities. To ensure the maximum value for the state's funding, the plan evaluates existing public and private 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.

Summary of Program Funding

Since the first investment plan, the Energy Commission has invested $189 million in alternative and renewable vehicle technology, fuel and infrastructure. The first Investment Plan (a combination of fiscal years 2008-2009 and 2009-2010) allocated $175.5 million to projects. In response to public solicitations, the Energy Commission received more than 300 proposals requesting funds of more than $1.2 billion. To provide further funding for worthy projects, the Energy Commission also used $14.6 million of the second Investment Plan (fiscal year 2010-2011) to augment solicitations that had an oversubscription of passing proposals. These allocations are shown in Table 2.

Among other solicitations, the Energy Commission used funds from the first Investment Plan to help California entities successfully compete for funding under the federal American Recovery and Reinvestment Act (ARRA) committing $36.5 million to California projects. These projects were awarded about $105.3 million in ARRA funds and also include $113.3 million in private funds. These funds are being used to:

- Install 2,860 new electric vehicle charging sites.
- Demonstrate and deploy more than 700 medium- and heavy-duty natural gas and hybrid-electric trucks.
- Develop high-energy-density lithium-ion batteries.
- Provide public outreach to promote deploying heavy-duty natural gas vehicles.
- Establish 75 new E85 fueling stations, capable of selling a blend of 85 percent ethanol and 15 percent gasoline.

The second Investment Plan projected $108 million for project and activity funding, based on estimated vehicle registrations, vessel registrations, identification plates, and smog abatement fees. Californians, however, registered fewer vehicles in 2009 than was originally estimated; as a result, only $86.4 million was available for fiscal year 2010-2011. As mentioned, $14.6 million was used to augment funding for oversubscribed solicitations. This leaves approximately $71.8 million remaining from the second Investment Plan for new projects. This funding, in conjunction with $100 million from this third Investment Plan, will be released for new solicitations and agreements, as shown in Table 3.

Table 2: Funding Awarded to Date (in Millions)

Category	Funded Activity	Initial Awards 2008-09 / 2009-10 (First Investment Plan)	Augmented Awards 2010-11 (Second Investment Plan)	Total Award
ARRA	Cost-Sharing for Federal Projects	$36.5	-	$36.5
Electric Drive	Charging Infrastructure	$3.2	$2.4	$5.6
	Convert State Vehicles to Plug-in Hybrid Vehicles	$0.6	-	$0.6
	Light-Duty Vehicle Rebates	$2.0	-	$2.0
	Medium- and Heavy-Duty Vehicle Rebates	$4.0	-	$4.0
	Medium- and Heavy-Duty Advance Vehicle Demonstrations	$10.0	$2.0	$12.0
	Manufacturing Facilities and Equipment	$19.0	$5.9	$24.9
Hydrogen	Public Fueling Stations	$15.7	-	$15.7
	Transit Project	$3.0	-	$3.0
	Fuel Standards Development	$4.0	-	$4.0
Natural Gas	Fueling Infrastructure	$5.1	-	$5.1
Propane	School Bus Incentives*	$2.0	-	$2.0
Biofuels	Biomethane Production	$35.1	$0.2	$35.3
	Diesel Substitutes Production	$2.8	$1.5	$4.3
	Advanced Ethanol and Gasoline Substitutes Production	$3.5	$1.9	$5.4

Category	Funded Activity	Initial Awards 2008-09 / 2009-10 (First Investment Plan)	Augmented Awards 2010-11 (Second Investment Plan)	Total Award
	California Ethanol Producers Incentive Program	$6.0	-	$6.0
	E85 Fueling Stations	$1.0	-	$1.0
	Upstream Biodiesel Infrastructure	$3.9	-	$3.9
Workforce Agreements	Workforce Training and Development	$15.0	$0.8	$15.8
Other Agreements	Sustainability Research	$1.5	-	$1.5
	Technical Assistance and Analysis	$1.6	-	$1.6
Total		$175.5	$14.6	$190.2

Source: California Energy Commission

* Solicitation is currently underway.

Table 3: Future Funding Solicitations and Agreements (in Millions)

Category	Funded Activity	Funds Remaining from Second Investment Plan 2010-11	Proposed Allocations from Third Investment Plan 2011-12	Total Future Funding
Electric Drive	Plug-in Electric Vehicle Regional Readiness Plans*	$1.0	$1.0	$2.0
	Charging Infrastructure	-	$7.0	$7.0
	Medium- and Heavy-Duty Advance Vehicle Demonstrations**	$8.9	$8.0	$16.9

Category	Funded Activity	Funds Remaining from Second Investment Plan 2010-11	Proposed Allocations from Third Investment Plan 2011-12	Total Future Funding
	Manufacturing Facilities and Equipment**	-	$10.0	$10.0
Hydrogen	Fueling Infrastructure	$10.2	$8.5	$18.7
Natural Gas	Fueling Infrastructure	$1.6	$8.0	$9.6
	Light-, Medium- and Heavy-Duty Vehicles*	$10.2	$12.0	$22.2
Propane	Light- and Medium-Duty Vehicles*	$2.4	-	$2.4
	Light-Duty Vehicles	-	$1.0	$1.0
	Medium- and Heavy-Duty Vehicles	-	$3.0	$3.0
	Fueling Infrastructure	-	$0.5	$0.5
Biofuels	Biomethane Production	$5.3	$8.0	$13.3
	Diesel Substitutes Production	$3.9	$8.0	$11.9
	Advanced Ethanol and Gasoline Substitutes Production	$4.5	$8.0	$12.5
	E85 Fueling Stations	$5.1	$5.0	$10.1
	Upstream Biodiesel Infrastructure	$3.1	-	$3.1
Innovative Technologies	Innovative Technologies, Advanced Fuels and Federal Cost-Sharing	$6.3	$3.0	$9.3
Workforce Agreements	Workforce Training and Development	-	$6.5	$6.5
	Sustainability Studies	$2.0	$0.5	$2.5

Category	Funded Activity	Funds Remaining from Second Investment Plan 2010-11	Proposed Allocations from Third Investment Plan 2011-12	Total Future Funding
Other Agreements	Marketing, Education and Outreach	$2.0	-	$2.0
	Technical Assistance and Analysis	$3.7	$2.0	$5.7
	Measurement, Verification and Evaluation	$1.7	-	$1.7
Total		$71.8	$100.0	$171.8

Source: California Energy Commission.

*Solicitation is currently underway using funds from the second Investment Plan. Funds from the third Investment Plan may be used to supplement this solicitation.

**Funding eligibility for these activities has been expanded beyond strictly electric drive technologies.

American Recovery and Reinvestment Act of 2009

President Obama signed the ARRA into law February 17, 2009, to stimulate the economy, create jobs, and address a variety of critical areas of national concern.[15] 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 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[16] of program funds from the first investment plan as a 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 billions 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 Reduction and Advanced Research Projects Agency-Energy.

Table 4 shows ARRA funds awarded to date for California alternative and renewable transportation projects with and without program match funds.

[15] U.S. Department of Energy, "Recovery and Reinvestment," http://www.energy.gov/recovery.
[16] 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*.

Table 4: ARRA Awards with Program Match Funding in California (In Millions)

Program	**Federal Funds Available**	**ARRA Awards with Program Match**			**ARRA Awards w/o Program Match**
		ARRA Awards	**Program Match Funds**	**Private/ Other Match**	**ARRA Awards**
Transportation Electrification	$400	$75.025	$17.070	$53.182	$3[17]
Clean Cities	$300	$26.276	$18.450	$59.770	$6
Advanced Research Projects Agency-Energy	$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
Transit Investments for Greenhouse Gas & Energy Reduction	$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	*[18]
Algal/Adv Biofuels Consortia	$85	*[19]	$0	*[20]	$.4
Totals	$6,683-6,808	$105.301	$36.52	$113.281	$125.4

Source: California Energy Commission

[17] Funding is an estimate of California's share of multistate projects.
[18] 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.
[19] Total award of $44 million nationwide, but California portion is not yet available.
[20] California portion not yet available.

Air Quality Improvement Program

The California Air Resources Board (ARB) is responsible for administering the AB 118 Air Quality Improvement Program, which provides up to $40 million per year for grants to fund clean vehicles and equipment, air quality research, and workforce training.[21]

Both the Air Quality Improvement Program 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.[22] 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 zero-emission vehicles. The Energy Commission also provides vehicle deployment incentives but primarily for natural gas and propane vehicles.

As part of the FY 2008-2009 state budget, the Legislature directed FY 2008-2009 Air Quality Improvement Program 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 GHG 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 SmartWay technologies.[23] 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

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[21] ARB, "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.

[22] 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. 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).

[23] The 2009-2010 Air Quality Improvement Program 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.

out in the spring of 2010 with loan opportunities for truckers available in the following months.

For FY 2009-2010 total Air Quality Improvement Program funds of about $30 million[24] were 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). These amounts were supplemented in the 2010-2011 funding plan, which was adopted in June 2010. The Air Quality Improvement Program 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).[25]

The ARB has prepared a proposed funding plan for FY 2011-2012.[26] Assuming a $40 million funding level, the ARB has allocated $16 million for its hybrid truck and bus vouchers, $21 million for zero-emission and plug-in hybrid light-duty vehicle rebates, and $3 million for advanced technology demonstration and testing. If revenues limit the funding to $28 million, these allocations will be lowered to $15 million, $11 million and $2 million, respectively.

Low Carbon Fuel Standard

The Low Carbon Fuel Standard (LCFS) was established 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 standards (in grams of carbon dioxide per megajoule) 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 ARB will review the LCFS periodically to update advances in low-carbon fuels, production technologies, and full fuel cycle assessments.

Zero-Emission Vehicle Regulation

The Zero Emission Vehicle (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

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[24] 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 Air Quality Improvement Program projects based on revised revenue projections.
[25] 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).
[26] ARB, *Proposed AB 118 Air Quality Improvement Program Funding Plan for Fiscal Year 2011-12*, http://www.arb.ca.gov/msprog/aqip/fundplan/proposed_aqip_fy2011_funding_plan.pdf

"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, more than 1 million Californians are driving partial zero and advanced technology partial zero-emission vehicles.

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 partial ZEVs, advanced technology partial ZEVs, and enhanced advanced technology partial ZEVs. ARB is preparing regulatory changes that move the partial ZEV and advanced technology partial ZEV categories from the ZEV program to the Low Emission Vehicle and Pavley programs by 2020.[27]

Zero-Emission Bus Regulation

The ARB's Zero Emission Bus 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 Zero Emissions Bus 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 time frame for purchase requirement) and the alternative fuel path (2012-2026 time frame for purchase requirement), which includes fuel cell buses and battery-operated buses.

Bioenergy Action Plan

In 2006, Executive Order S-06-06 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 *Bioenergy Action Plan*[28] 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.[29]

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[27] Assembly Bill 1493 (Pavley, Chapter 200, Statutes of 2002), known as the Pavley Bill, requires 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.

[28] O'Neill, Garry, John Nuffer. 2011. *2011 Bioenergy Action Plan*. California Energy Commission, Efficiency and Renewables Division. Publication Number: CEC-300-2011-001-CTF.

[29] Staff workshops on the *2011 Bioenergy Action Plan* were held in June 2010 and December 2010. The *2011 Bioenergy Action Plan* was adopted at an Energy Commission Business Meeting on March 23, 2011.

Renewable Fuel Standard

The Energy Policy Act of 2005 established the federal Renewable Fuel Standard (RFS) Program. The United States Congress gave the United States Environmental Protection Agency the responsibility to coordinate with the United States Department of Energy, the United States Department of Agriculture, and stakeholders to design and implement the RFS program. With passage of the Energy Independence and Security Act 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).[30]

Certain parties (such as 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

On September 15, 2009, the United States Environmental Protection Agency and the United States Department of Transportation's National Highway Traffic Safety Administration 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 United States Environmental Protection Agency and National Highway Traffic Safety Administration 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.[31] 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).

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

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[30] 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."
[31] Air conditioning and tailpipe emissions represent an additional potential CO2 savings of 13.5 percent of fuel economy standards.

full range of vehicle choices.[32] 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 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.

On April 12, 2011, Governor Brown signed Senate Bill 1X 2 (Simitian, Chapter 1, Statutes of 2011-2012 First Extraordinary Session), which established requirements for utilities to meet goals of 25 percent renewable energy by 2016 and 33 percent by 2020.

Clean Air Action Plan

On November 20, 2006, the Port of Los Angeles and Port of Long Beach adopted the San Pedro Bay Ports Clean Air Action Plan.[33] The goal of the Clean Air Action Plan is to reduce port-related air pollution, including particulate matter, nitrogen oxide, and sulfur oxide, by at least 45 percent by 2012. As part of the Clean Air Action Plan, the ports are implementing a Clean Trucks Program,[34] which aims to reduce heavy-duty drayage truck-related air pollution by 80 percent by 2012. Part of the Clean Trucks Program 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 were 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.[35]

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, and ARB (with Proposition 1B funds), offers $50 million in incentives for the purchase of natural gas trucks for use within either of the ports.

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[32] United States Environmental Protection Agency, "Regulations and Standards," http://www.epa.gov/oms/climate/regulations.htm.
[33] Port of Los Angeles, "San Pedro Bay Ports Clean Air Action Plan," http://www.portoflosangeles.org/environment/caap.asp.
[34] Port of Los Angeles, "Clean Truck Program," http://www.portoflosangeles.org/ctp/idx_ctp.asp.
[35] Energy Commission staff conversation with Thomas Jelenic, March 24, 2010.

Chapter 3:
Alternative Fuels and Vehicle Technologies

Plug-In Electric Vehicles

The initial wave of new generation plug-in electric vehicles (PEVs) is entering the transportation sector of California, the nation, and the world. Automakers announce their plans almost daily for new electric vehicle models. President Obama recently unveiled new initiatives to make the United States the world's leader in manufacturing and deploying advanced technology vehicles with specific plans to support PEVs. California regions such as the Bay Area and Southern California have made giant strides in PEV readiness, with grass roots efforts to prepare the way for this new means of transportation. The California PEV Collaborative has organized a broad array of stakeholders to leverage existing efforts and help California lead in the global transition to PEVs.[36] The Energy Commission has made more than $18 million in awards to upgrade existing sites and install new charging infrastructure in California over the next two years. The Air Resources Board is funding the Clean Vehicle Rebate Program to provide incentives for consumers as they purchase qualified electric vehicles. The federal tax credit has significantly reduced the upfront cost of electric vehicles. Utilities are designing rates to encourage consumers to charge off-peak and are working with automakers and infrastructure providers to safeguard the grid. The California Public Utilities Commission has been conducting a rulemaking to consider alternative-fueled vehicle tariffs, infrastructure, and policies to support GHG reduction goals. Much is being done to address barriers to commercialization, but much more is needed.

The Energy Commission is proposing investments in PEV charging infrastructure to help achieve its goal of petroleum and GHG reduction. Battery electric vehicles (BEVs) are 65 percent to 70 percent lower in full fuel-cycle emissions than that of conventional vehicles based on California's present electricity grid.[37] As California shifts to an increasingly renewable electricity generation system, PEVs will account for fewer GHG emissions. Full fuel cycle emissions of plug-in hybrid electric vehicles (PHEVs) and extended range electric vehicles are estimated to be 50 percent lower than conventional gasoline vehicles. This depends on the proportion of miles driven in electric mode, which is a function of battery capacity and driver behavior.

As the Energy Commission considers the best use of funds to support commercialization of PEVs it must evaluate short-term, mid-term, and long-term PEV deployment in California. The Energy Commission's policy objectives regarding PEV deployment are to encourage off-peak charging, reduce on-peak charging and increase the renewable supply of electricity in California. In the short term (2011 through 2013), early PEV adopters will continue purchasing Nissan Leafs and Chevrolet Volts as well as newer

[36] California Plug-in Electric Vehicle Collaborative, "Members," http://www.evcollaborative.org/members
[37] ARB, "Low Carbon Fuel Standard Program, "http://www.arb.ca.gov/fuels/lcfs/lcfs.htm

models to be released in this time frame. Existing tax credits and state incentives available for PEVs and electric vehicle supply equipment (EVSE) purchase or lease present an attractive option to early adopters. These PEV pioneers are willing to purchase a PEV with the understanding that most of their charging will be done at home, with some availability of public or workplace charging. The short-term rollout of about 4,500 PEV chargers throughout the State and the upgrade of existing chargers provides some "range security" for this nascent PEV market.

In the mid-term, 2013-2015, the many unknowns make investment decisions more difficult. How many additional PEV early adopters are willing to pay a premium for new technology? Will PEV prices decline? Will gasoline prices continue upward? Will federal tax incentives continue to be available? Will sufficient funds be available for the ARB's Clean Vehicle Rebate Program? What will be the charging behavior of new PEV drivers? Will home and workplace charging satisfy the charging requirements of most drivers, or will additional public EVSE be needed? All these uncertainties increase the complexity of making investment decisions to support PEV commercialization. The scale of PEV deployment will soon outstrip government's ability to provide vehicle buydown incentives. As automakers scale up PEV production, strategies for this mid-term gap period will be addressed by the Statewide PEV Collaborative and a consortium of state agencies, academic institutions, and local and regional stakeholders.

The long term after 2015 is even less certain. By this time, PEV commercialization will likely have gained momentum, the price of PEVs will likely decline, EVSE availability will satisfy market demand, and government support may taper off. The investments proposed in this investment plan will remove some of the key barriers to successful PEV commercialization. A priority is charging infrastructure for homes, including multifamily dwellings, as well as workplace and fleet charging. Regional PEV readiness will smooth the way for local infrastructure plans and the streamlining of EVSE permitting and inspection processes. Consumers may desire the availability of additional public EVSE to supplement home and workplace EVSE. These investments should encourage off-peak charging or reduction of on-peak charging via renewables such as photovoltaic charging. The Energy Commission will continue to support the rollout of PEVs by investing in the strategic deployment of EVSE and related activities, especially during this initial phase.

Electricity Generation

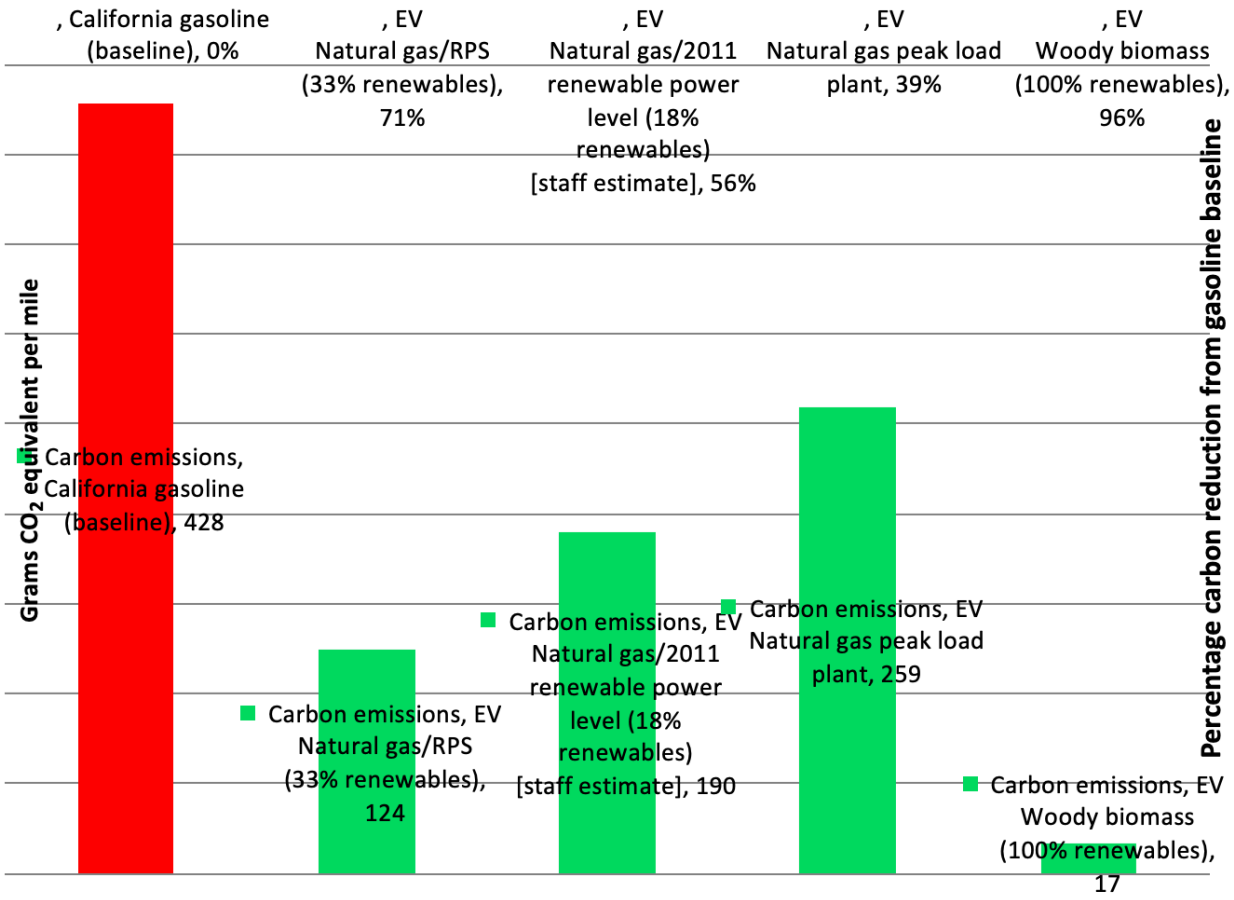
Although PEV charging will increase statewide demand for electricity, it is unlikely to require new power plant or transmission line capacity. By 2020, PEVs are expected to increase annual electricity demand on a statewide basis by roughly 4,400 gigawatt-hours (about 1.4 percent) and peak demand by roughly 190 megawatts (about 0.3 percent). The electricity demand forecast accounts for these minor increases.[38] Overall,

[38] Kavalec, Chris and Tom Gorin, *2009 California Energy Demand 2010-2020, Adopted Forecast*, California Energy Commission. CEC-200-2009-012-CMF

the introduction of PEVs will not seriously affect statewide electricity generation or transmission.

California's generation mix in 2020 is expected to have 40 percent lower carbon emissions than in 2008. California's 2008 electricity grid already has 35 percent lower carbon emissions than the national grid. The Renewable Portfolio Standard requires retail sellers to increase renewable energy as a percentage of their retail sales by 20 percent by 2010 and 33 percent by 2020. The reductions in GHG emissions over time resulting from electricity generation will directly benefit the carbon emission reduction calculations of PEVs, as shown in Figure 1.

Figure 1: GHG Emission Reductions of Electric Vehicles by Electricity Source



Source: ARB, California Energy Commission

Electricity Distribution

As more PEVs enter the market, grid impacts may become more apparent at the local distribution level. The "cul-de-sac" effect of additional electricity load added to neighborhood distribution lines due to the purchase of PEVs could cause reliability problems and could shorten equipment life. One or two PEVs could be the energy equivalent of adding an additional home to the neighborhood. Utilities can plan for and prepare local distribution infrastructure for PEVs if notified soon enough. Therefore,

utilities are working closely with automakers and other stakeholders to ensure timely notification of utilities regarding additions to load due to PEV deployment.

The development of the smart grid will promote high numbers of PEVs and allow them to operate effectively without causing major disruptions on the utility grid.[39] Communication between chargers, vehicles, and the utilities will allow customers to take advantage of lower off-peak charging rates. PEVs could also be used as grid assets and provide ancillary services for grid operators when parked in facilities where commercial energy service providers can aggregate their loads into a single energy response system.[40] The smart grid can also make PEV electricity use billing, wireless monitoring, and data gathering easier.

Electric Drive Charging Infrastructure

As automakers roll out PEVs over the next year, the widespread availability of charging infrastructure will reduce barriers to commercialization success. Residential chargers for single-family and multifamily dwellings will be the primary method of charging for most consumers, but workplace, commercial, and public charging will also address the needs of consumers as they adjust to this new technology. Charging sites will also be installed for fleet vehicles and medium-duty and heavy-duty electric trucks and transit buses. To promote the deployment of these chargers, California's regions will need to develop strategic charging infrastructure deployment plans and streamline the EVSE permitting and installation process. In the past several months, progress has been made toward addressing these challenges.

Over the 2011-2012 period there will be significant investment in California's charging infrastructure. The federal government's ARRA funds matched with Energy Commission program funds and other private and public funds are providing PEV charging infrastructure to support the deployment of PEVs in California. Table 5 below summarizes the planned deployment of PEV charging infrastructure in four strategic PEV regions: the nine-county Bay Area, the San Diego and Los Angeles Regions, and the Sacramento Region.

[39] The term "smart grid" refers to an electricity transmission and distribution system that is integrated with modern telecommunications.

[40] California Energy Commission, *2009 Integrated Energy Report*, Final Commission Report, December 2009, CEC-100-003-CMF

Table 5: PEV Public Charging Infrastructure Deployment by California Region[41]

Region	Existing	Planned		
	Public/Commercial Stations	Public/Commercial Points[42]	Direct Current Fast Charge Stations	Battery Switch
S.F. Bay Area	96	916	55	5
Los Angeles	237	972		
San Diego	16	1,452	60	
Sacramento	56	494		
Other	28	3	2	
Total	433	3,837	117	5

Source: California Energy Commission and Nissan

In the San Diego and Los Angeles regions, program funds of $8 million and ARRA cost-share funds of $39.35 million will be used to deploy 2,452 Level 2 chargers and 60 fast-charging stations in residential and commercial sites. This deployment will support the introduction of 1,000 Nissan Leafs in the near term, and eventually up to 5,000 Leafs. The Energy Commission also recently awarded funds to the SoCal Collaborative for $840,750 to upgrade and install at least 315 upgrades and new EVSE for fleets and public locations throughout the Los Angeles Metropolitan Region.

The program will also fund $3.4 million for Coulomb Technologies with $3.8 million in federal ARRA match share to install and upgrade up to 1,290 Level 2 public chargers in the Bay Area, Sacramento, and the Los Angeles areas. The Association of Bay Area Governments is awarded about $1.5 million with additional local match share to install about 423 charge points, of which 176 are Level 1, 228 are Level 2 chargers and 19 are fast chargers. This award will supplement the Bay Area Air Quality Management District two-phased infrastructure deployment. The first phase is for $1.3 million for 402 EVSE's, 6 fast chargers, and a battery switch station to be installed by the end of 2011. The second phase is a $3.9 million award for 2,750 Level 2 residential chargers (with a $700 incentive per charger) provided by Coulomb (500), AeroVironment (500), Clipper Creek (250) and Ecotality (1,500 as part of the "EV Project"). Also included are 30 corridor fast chargers by mid-2012.[43] Remaining funds will be used for additional

[41] Based on estimates of known deployments planned through 2013. This may not include all planned chargers.

[42] Some of these may be charging stations that have more than one charge point.

[43] Karen Schkolnick, Bay Area Air Quality Management District, February 2, 2011.

residential or commercial chargers, based on the results of a regional analysis of PEV infrastructure.

The Bay Area's Metropolitan Transportation Commission will provide additional PEV support with four battery switch stations for taxi cabs, $2.8 million for 90 PEVs and 90 charging stations and $1.7 million to "City Car Share" for the purchase of 29 PEVs, including 12 Nissan Leafs.

In the Sacramento region, 206 chargers will be funded by ARRA funds, Sacramento Municipal Utility District, and the EV Sacramento Coalition to demonstrate 34 Volts. Program funds of $0.553 million will be used for data collection and analysis. A similar Sacramento Municipal Utility District project will deploy 35 chargers to support the deployment of nine Chrysler PHEV vans and 11 Dodge PHEV pickups.

The Energy Commission is also updating up to 625 chargers to the Society of Automotive Engineers J1772 standard in California with an award of $2.3 million to Clipper Creek, including funds to update the chargers with new utility communication protocols.

In July 2010, the California Plug-In Vehicle Collaborative, an ad hoc group of high-level stakeholders, convened to work on a roadmap for the commercialization of PEVs in California. In December 2010, the collaborative, with the UC Davis Institute of Transportation Studies PHEV and BEV Research Center, produced a plan, "*Taking Charge—Establishing California Leadership in the Plug-In Electric Vehicle Marketplace.*"[44] The plan sets goals, recommendations, and suggested actions to guide the market launch, growth, and takeoff phases of PEV market development. Some of these suggested actions will be addressed in this section. In 2011-2012, the PEV Collaborative is implementing the recommendations and convening multi-stakeholder working groups.

To support the optimal deployment of PEV recharging infrastructure, the Energy Commission's Public Interest Energy Research Program is funding the development of an online Recharging Network Planning Toolbox. This toolbox will help regional and local planning agencies improve the placement of public, workplace, and direct current fast chargers relative to PEV market demand. In addition, this toolbox will also help assess the effect of future public and direct current fast chargers on encouraging PEV sales and use.

In October 2010, the Energy Commission, along with the collaborative, held a joint PEV Charging Infrastructure Workshop.[45] The public workshop provided a forum to discuss key PEV infrastructure issues important to the rollout of PEVs in California, including input to the collaborative's plan and the development of the Energy Commission's

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[44] California Plug-in Electric Vehicle Collaborative, *Taking Charge: Establishing California Leadership in the Plug-in Electric Vehicle Marketplace*, http://www.evcollaborative.org/evcpev123/wp-content/uploads/2010/07/Taking_Charge_final2.pdf.

[45] Meeting transcript and presentations are available at: http://www.energy.ca.gov/2010-ALT-1/documents/index.html.

infrastructure guidance document. The key findings from this workshop will be included in the next sections on PEV charging.

Regional PEV Readiness

Significant regional planning efforts for PEV infrastructure continue to develop in the key PEV rollout areas such as San Diego, Los Angeles, the San Francisco Bay Area, and the Sacramento region. The Energy Commission is encouraging regional coordination and planning with the release of a $1 million noncompetitive solicitation available to all California regions. This solicitation will allow regional government entities such as metropolitan planning organizations or councils of government to apply for funds to develop regional PEV strategic plans and best practices and guidelines for EVSE deployment, including PEV-friendly building and public works guidelines, PEV charger installation and permitting processes, consumer awareness programs, and locations for the number and type of EVSE to be deployed. Some regions may lead the way by sharing their guidelines and best practices with other regions that are just beginning to establish PEV strategic plans. A group called "Ready, Set, Charge California" drafted *Guidelines for Developing an EV Ready Community*.[46] This document will have two versions: one for policy makers and local government, and another suited for a technical audience including engineers, architects, and electricians. These guidelines could be adopted for statewide use and then revised by each California region to meet local needs. As another example, for the EV Project, Ecotality has developed a "Deployment Guidelines" document for EVSE in the San Diego region and has completed near-term and long-term plans to help that region identify optimal locations for future PEV infrastructure deployment.

The United States Department of Energy recently released the "Clean Cities Community Readiness and Planning Plug-In Electric Vehicles and Charging Infrastructure" funding opportunity.[47] This solicitation will serve as a pilot program to stimulate community-based electric vehicle infrastructure readiness planning and implementation activities in anticipation of larger electric vehicle deployment efforts in the future. This is in addition to President Obama's recently announced plans to reward communities that invest in PEV infrastructure through competitive grants. This new initiative would provide grants to up to 30 communities that are prioritizing advanced technology vehicle deployment. Statewide regional efforts toward getting communities ready for PEVs will potentially leverage up to $10 million in additional federal funds for each region on the "basis of their ability to demonstrate concrete reforms and use the funds to help catalyze electric vehicle deployment."[48]

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[46] Ready, Set, Charge California!, *Guidelines for Developing an EV Ready Community*, January 26, 2011.

[47] U.S. Department of Energy and National Energy Technology Laboratory, Funding Opportunity Number: DE-FOA-0000451, issued 4/19/11.

[48] White House, "Our Plan to Put One Million Advanced Technology Vehicles on America's Roads," http://www.whitehouse.gov/blog/2011/01/26/our-plan-put-one-million-advanced-technology-vehicles-america-s-roads.

The permitting, installation, and inspection of residential charging infrastructure need to be seamless. The process will vary for each community and for each installation, but on the whole, it is complex, costly, and protracted. The average residential installation time between ordering and installing charging equipment can be more than four weeks. Although the actual charging panels may take only 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. In a study conducted by the University of California, Los Angeles's Luskin Center for Innovation, it was estimated that nearly 25 percent of the entire Los Angeles market would not purchase a PEV due to the perceived difficulties with charger installation.[49] Regions are brainstorming to find ways to streamline the process and reduce installation time. It is also important to educate local government jurisdictions that often lack knowledge about the permitting process for PEV charging infrastructure and assist permit and inspection offices facing workforce reductions. The California PEV Collaborative has identified the following actions that can help to streamline the process: [50]

- Coordinate among auto dealers, electrical contractors, utilities, and local authorities to minimize red tape.
- Designate local contacts to respond to consumer questions about PEV charging.
- Develop automated inspection reporting executed at the time of inspection.
- Develop clear installation procedures and disseminate widely using the clearinghouse and other mechanisms.
- Develop online applications for local inspections and permitting.
- Establish 24-hour phone or Internet-based scheduling for inspections.
- Establish set fees and consolidate inspections.
- Prioritize applications for residential charging equipment in the permit review process.
- Provide customers information about installation incentives, costs, options, and trade-offs through an information clearinghouse or other mechanisms, such as PEV consultations.
- Seek compliance from nationally recognized testing laboratories (such as Underwriters Laboratory, Inc.) for dual-meter adapters.

For FY 2011-2012, the Energy Commission will allocate an additional $1 million for projects that will support the streamlining of permitting, installation, and inspection of residential charging infrastructure and preparation of infrastructure deployment plans. These funds could supplement the Energy Commission's recently released Statewide Regional PEV Readiness solicitation.

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[49] *Realizing the Potential of the Los Angeles Electric Vehicle Market*, page 72, University of California at Los Angeles Luskin Center for Innovation, May 2011

[50] California Plug-in Electric Vehicle Collaborative, "Taking Charge: Establishing California Leadership in the Plug-in Electric Vehicle Marketplace," http://www.evcollaborative.org/evcpev123/wp-content/uploads/2010/07/Taking_Charge_final2.pdf

Electrical Vehicles Supply Equipment

To recharge a PEV, EVSE is needed to safely deliver energy from the electric circuit to the vehicle. A charger converts electricity from alternating current (AC) from the electricity source to direct current required for the battery. It also converts the incoming 120- or 240-volt current to 300 or higher volts. PEVs carry an on-board charger capable of accepting alternating current from a Level 1 or 2 charging station. The Society of Automotive Engineers J1772 connection standard allows for delivery of up to roughly 19 kilowatts to an on-board vehicle charger. All known PEV on-board chargers are expected to provide at least 3.3 kilowatts charging when connected to a Level 2 charging station. For higher capacity charging, a charging station that delivers direct current to the vehicle is incorporated off-board in the wall or mounted pedestal.[51]

There are four options that provide various levels of service for recharging a PEV as shown in Table 6.[52] Level 1 is provided by a typical household outlet and is best for PEVs with relatively small battery packs, low daily mileage, or limited access to Level 2 charging. Level 1 charging allows PHEVs and small BEVs to charge fully overnight.

Level 2 can reduce the time it takes to recharge a PEV in half but may require the homeowner to upgrade his or her electrical panel to provide a dedicated circuit for PEV charging. A clothes dryer outlet is not recommended for recharging a PEV as it does not have sufficient amperage. The connectors for Level 1 and 2 charging are the same and most PEVs are compatible with both voltage levels.

Direct current charging (also commonly referred to as "fast charging") requires a permanent installed charging station that converts three-phase alternating current electricity to direct current. The North American standard for uniform direct current charging is being developed. Some demonstration programs and production PEVs incorporate fast charging at a rate sufficient to charge a 24 kilowatt-hour (kWh) battery to about 80 percent capacity in about 30 minutes.

Battery switch stations would accommodate the replacement of a discharged battery pack with a fully charged battery pack in within several minutes. Battery switch station deployment would enable third-party ownership, ease of battery replacement for servicing and use in secondary applications. These stations are being demonstrated by Better Place in various locations around the world, including a taxicab demonstration project in the Bay Area.

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[51] U.S. Environmental Protection Agency National Highway Traffic Safety Administration, and California Air Resources Board, *Interim Joint Technical Assessment Report: Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards for Model Years 2017-2025*, September 2010.

[52] Ibid.

Table 6: Charging Level Definitions

Level 1	120-volt AC, single phase, 12-16 amps continuous.
Level 2	240-volt AC, single phase, up to 80 amps continuous, typically 12-32 amps.
Direct Current Charging	Converts three-phase alternating current electricity to direct current off-board the PEV, delivering up to 250 kilowatts directly to the PEV battery.
Battery Switching	An automated process exchanges a depleted battery with a fully charged battery in less time than it takes to refuel at a gas station.

Source: California Energy Commission

Wireless charging, which enables PEVs to be charged seamlessly without operator interaction, is on the horizon. A Society of Automotive Engineers taskforce launched in October 2010 hopes to deliver the first J2954 Society of Automotive Engineers guideline by the end of 2011, to be published in 2012.[53]

Most chargers will come with smart components to 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 improve electricity transmission and distribution.

EVSE Costs

Significant potential exists for EVSE costs to decline over the next several years as competition among EVSE companies increase and as economies of scale result from increased EVSE production. Within the past year, there have been significant cost reductions for home charging stations by some providers, and the downward trend is likely to continue. Recently, for example, Ford announced a partnership with Best Buy to offer a Level 2 charging station for owners of the new Ford Focus BEV for roughly $1,500 for a standard installation—about one-third less than competitor's systems.[54]

Charging station costs vary depending on the level of service, location, type of station, and installation requirements, including electrical upgrading requirements. Estimated costs of charging stations are shown in Table 7.

[53] Green Car Congress, "SAE taskforce developing standards for wireless charging for plug-in vehicles; targeting first guideline by end of 2011," http://www.greencarcongress.com/2011/01/j2954-20110107.html.

[54] PR Newswire, "Ford Working with Best Buy to Offer Focus Electric Charging Station Sales, Installation and Support," 1/10/11.

Table 7: Estimated Costs for Charging Stations

Level	Location	Equipment	Installation
1	Single Residence	$30- $200 (charge cord only, included at no cost to consumer with BEV/PHEV) when an accessible household plug (e.g., in a garage or adjacent to a driveway) with a ground fault interrupter is already available	$400-$1000+ may be necessary depending on difficulty of installing a new circuit at the desired location, but in most cases, owners with sufficient panel capacity would opt for a more capable 220 Volts of alternating current Level 2 installation instead of a Level 1 dedicated circuit because the additional installation cost is only marginally higher.
2	Residential, Apartment Complex, or Fleet Depot	3.3 kilowatts EVSE (each): $300-$4,000 6.6 kilowatts EVSE (each): $400- $4,000	3.3- 6.6 kilowatts installation cost: $400-$2,300 without wiring/service panel upgrade, or $2,000-$5,000 with panel upgrade.
2	Public	$400-$3,800+ for each EVSE	$3,000- $7,000+ installation cost, varying significantly with distances from service entrance and number of EVSEs installed.
3	Public	$8,000-$50,000 for fast chargers	

Source: U.S. Environmental Protection Agency National Highway Traffic Safety Administration, and California Air Resources Board, September 2010

Residential Charging

One of the attractions of PEVs compared to internal combustion engine vehicles is the convenience of home charging instead of fueling at a gas station. In the early market, roughly 95 percent of charging will either be at home or at fleet facilities.[55] Forty percent of homes are likely to rely on Level 1 charging, and 60 percent will likely opt for Level 2 charging.[56] Surveys show that consumers strongly prefer home charging and rarely use public chargers.[57,58] Most PHEVs can charge from a typical 120 V household outlet (Level 1); however Level 1 charging for a typical BEV, such as a Nissan Leaf for

[55] ICF International Draft Report, "Technical Analysis for Alternative and Renewable Fuel and Vehicle Technology Program," September 2010.

[56] Summary of Southern California Edison Comments on the California Public Utilities Commission Order Instituting Rulemaking to Consider Alternative-Fueled Vehicle Tariffs, Infrastructure and Policies to Support California's Greenhouse Gas Emissions Reduction Goals, Morton Blatt, December 2009.

[57] Characterizing Consumers' Interest in and Infrastructure Expectations for Electric Vehicles: Research Design and Survey Results. Electric Power Research Institute, Palo Alto, CA, and Southern California Edison, Rosemead, CA: 2010.

[58] BMW, Presentation by Andreas Klugescheid given at the October 19, 2010, Joint Energy Commission and PEV Collaborative PEV Infrastructure Workshop.

example, would provide only 4 to 5 miles of range per hour of charging. Level 1, however, may be sufficient for consumers that drive relatively few miles each day and don't require faster charging daily. Many consumers would prefer Level 2 charging, which would provide 12 to 15 miles per hour of charging. [59] Charging at Level 2 will require an electrical panel upgrade, adequate wiring to the charging location, EVSE equipment, and city and county permits for any electrical or land use changes. A large percentage of homes will require the installation of a 220/240 V plug in their garages or parking shelters. This installation is an additional cost that will extend the payback period for PEVs.

Several automakers are teaming up with charging infrastructure companies as their PEVs roll-out. General Motors is partnering with SBX to provide Volt customers with Level 2 chargers and one-stop shopping, setting up permits, providing rebates, and sending out the electrical contractor. The charger cost is $490 (with installation costs about $1,500) and takes four to six hours to install. Nissan is partnering with ECOtality in the San Diego and Los Angeles regions to provide home installation of Level 2 chargers as part of its initial rollout. Mitsubishi will partner with Eaton and Best Buy to sell and install Level 2 home charging stations. The Best Buy "Geek Squad" will handle the consultation and installation for the charging units, including coordination with third-party licenses electrical contractors, if needed.

The broad consensus is that residential charging is the highest priority for deployment because consumers like the convenience and it encourages charging during periods of off-peak electrical demand. [60] The Energy Commission will consider providing PEV consumers with incentives to help defray the cost of home EVSE.

Many utilities are developing time-of-use rates for PEV consumers to encourage off-peak electricity usage. San Diego Gas & Electric is conducting a time-of-use rate demonstration project for the Volt in coordination with the Nissan-ECOtality project that will analyze the electricity price elasticity of demand for PEV charging. The three time-of-use rates offered will have a ratio of on-peak to off-peak rates of two, four, and six-to-one compared to the current two-to-one ratio. [61]

Electricity rates can encourage vehicle owners to charge their vehicles at times that best protect grid safety, reliability, and efficiency. Most California utilities already have some rate structures in place that encourage off-peak charging. The California Public Utilities Commission Alternative-Fueled Vehicle Rulemaking proposed decision of March

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[59] *Electrification Roadmap, Revolutionizing Transportation and Achieving Energy Security*, Electrification Coalition, November 2009.

[60] October 19, 2010, Joint Energy Commission Staff and Statewide PEV Collaborative PEV Infrastructure Joint Workshop, Residential Panel discussion.

[61] Joel Pointon, Presentation at the U.C. Davis Institute for Transportation Studies STEPS Conference, January 19, 2011.

15, 2011, has addressed many of the rate and tariff policies to encourage further off-peak charging and to manage the transmission and distribution impacts of PEV loads. Utilities, regulators, local governments, and consumer representatives are collaborating to develop and demonstrate pricing options, including time-of-use rate structures that convey the supply and demand balance of electricity. Sharing and clearly communicating pricing information with consumers can reward them with low-cost electricity for off-peak charging.[62] Many California utilities already have rate structures in place that are intended to encourage off-peak charging. These may be modified as data is collected and based on the California Public Utilities Commission rulemaking. They will vary depending on utility-specific factors including rate structure, type of charging in a service territory, measurement options, and consumer acceptance. Presently, many California utility customers have the option of selecting a "whole-house" time-of-use rate that bundles the vehicle charging with the home and offers a very low super off-peak rate (balanced by higher on-peak rates). Another common rate available to PEV customers measures vehicle usage separately from the home and, similarly, provides a favorable off-peak rate. Some specific examples for utilities include:

- Los Angeles Department of Water and Power has two options for PEV owners. The first would require a separate meter for the PEV, and the customer receives a discount on off-peak electricity of $0.025/kWh. The second allows the customer to sign up for a time-of-use rate for the entire home, and that home would receive a discount on off-peak electricity of $0.025. In both cases the discount saves PEV customers about 10 percent if they charge their PEV off-peak.
- Within Pacific Gas and Electric (PG&E), PEV owners can sign up for time-of-use rates that discount off-peak electricity $0.035-$0.05/kWh relative to partial peak and as much as $0.23/kWh relative to on-peak. This rate structure saves PEV customers from 35 percent to as much as 80 percent if they charge their PEV off-peak.

Work still needs to be done to determine how rates influence customer behavior and should be structured; different rate strategies may be preferred depending upon type of charging and location, the technologies available for measurement and load control, and consumer acceptance. Overall, the utilities' objective is that rates encourage customers to charge their vehicles during off-peak hours of the day.[63] The recent California Public Utilities Commission proposed rulemaking concluded that the existing PEV residential rate schedules are sufficient for the early PEV market, until about 2013. To encourage off-peak charging, however, the California Public Utilities Commission finds that PEV residential rates should be opt-in, non-tiered, and time-of-use for separately metered PEV customers.[64] The Public Interest Energy Research Program has tasked the Plug-in Hybrid and Electric Vehicle Research Center to study the

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[62] Eileen Tutt, California Electric Transportation Coalition, response to staff inquiry 1/17/11.

[63] Ibid.

[64] California Public Utilities Commission, Proposed Decision of Commissioner Peevey, Rulemaking 09-08-009 Phase 2, March 15, 2011.

effectiveness of a variety of special time-of-use rates, smart meters, vehicle interfaces, and other devices designed to encourage charging at off-peak hours.

Smart charging, which facilitates the timing of the vehicle's charging, is a critical component of home charging since it could actually occur on-peak during the early evening hours. A smart charger would ensure that charging occurs during the later off-peak hours.[65] To facilitate smart charging and encourage off-peak charging, the customer would need access to time-of-use rates and various metering options. Conclusions from the proposed California Public Utilities Commission Alternative Fuel Rulemaking Decision include: 1) PEV residential rates should be opt-in, non-tiered, and time-of-use for separately metered PEV customers, 2) utilities should continue to offer residential single-meter PEV rates because they are cost-effective and provide conservation signals, 3) a metering policy should promote customer choice, incorporate minimum communication technology, plan for future data needs, support standardization, and encourage off-peak charging, and 4) the submeter protocol developed by the utilities should address sub-metering issues at multiunit dwellings and workplaces.

In dense urban areas and population centers, not every household will have access to a dedicated parking space. This is particularly challenging in California because consumers in areas such as San Francisco and Los Angeles are likely to adopt PEVs faster than consumers in other areas. While in California up to half of residents do not own a home, in the San Francisco area, about 80 percent of the population does not have access to a garage.[66] In Los Angeles, renters and multifamily housing residents account for 62 percent of the population.[67] About half of new car buyers have a place to charge overnight within 25 feet of an outlet. In situations where dedicated parking is not available, consumers need a way to charge. The multiunit dwelling situation is complex, and therefore solutions must be diverse.

One consideration with multiunit dwellings is that the apartment or condominium owner must be involved in any siting decisions. While the PEV consumer will prefer a charging site close to the consumer's home, the multiunit dwelling owner may have other things to consider such as lighting and vandalism concerns, flooding or drainage conditions, and payment methods.[68] Homeowner associations must be consulted in some cases as

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[65] Ibid.

[66] October 19, 2010, Joint Energy Commission Staff and Statewide PEV Collaborative PEV Infrastructure Joint Workshop, Residential Panel discussion.

[67] University of California at Los Angeles, Luskin Center for Innovation, *Realizing the Potential of the Los Angeles Electric Vehicle Market*, page 79, May 2011.

[68] Electric Transportation Engineering Corporation, *Electric Vehicle Charging Infrastructure Deployment Guidelines for Greater San Diego Area*, May 2010.

well. San Diego Gas & Electric and Sacramento Municipal Utility District have developed a general process for addressing the multiunit dwelling charging situation that involves coordination with landowners, multiunit dwelling owners, homeowners' associations, and the consumers. The city of San Francisco is identifying multiunit dwellings and evaluating ways to provide EVSE, including possible nearby parking sites or car share companies.[69] Fast chargers are also being located at commercial sites in San Francisco and can be used by nearby multiunit dwelling tenants. Since all multiunit dwellings have 120-volt service, there is no need for separate service drops to the PEV charging station for this application, but new lines, conduit, and plugs will connect to the station from circuit breaker(s).[70]

To support multiunit dwelling charging, the Energy Commission will consider grants to provide multiunit dwelling charging infrastructure and demonstration projects to help solve this complex issue.

Workplace and Fleet Charging

After home charging, workplace charging, and fleet charging are the second highest funding priority for PEV infrastructure deployment. Consumers are likely to take advantage of the convenience of workplace charging, especially if they do not have access to home charging. Workplace charging can also offer off-peak and "shoulder" (between on-and off-peak) charging during the morning hours, thereby avoiding on-peak charging.[71] Employers will likely require some level of charging fee, since the Internal Revenue Service is likely to tax free charging as an employee benefit. Employers gain from having PEV charging available because it can contribute to their Leadership in Energy and Environmental Design certification, satisfy employee demand for "green" transportation options, and enhance the company's environmentally conscious (green) image.[72] Most companies view charging as a "facilities" decision and are willing to invest in them as employee parking lots are developed rather than retrofit at a higher cost later on. One example of workplace charging is at SAP's Palo Alto campus where the software company is installing 16 charging stations in its parking lot and purchasing 25 PEVs, of which 20 will be leased to employees.[73] Other companies

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[69] Conversation with Bob Hayden, Department of the Environment, San Francisco, January 7, 2011.
[70] Plug-In Electric Vehicle Infrastructure Installation Guidelines *Volume 1: Multi-Family Dwellings,* S Chhaya, S., and M Alexander, EPRI 1017682, September 2009.

[71] October 19, 2010 Joint Energy Commission Staff and Statewide PEV Collaborative PEV Infrastructure Joint Workshop, Workplace and Fleets Panel discussion. San Diego Gas & Electric Company has an off-peak electric vehicle time-of-use rate from 5:00 a.m. to noon.

[72] LEED certification for commercial building owners provides a competitive edge, mitigates risk and attracts tenants. Additional information is available at: http://www.usgbc.org/DisplayPage.aspx?CMSPageID=2331.

[73] *San Jose Mercury News*, "Workplace Charging Stations for Electric Vehicles are the Latest Silicon Valley Perk," December 9, 2010, http://www.mercurynews.com/business/ci_16809939?nclick_check=1.

such as Google and Dell offer charging for PEVs powered by solar arrays, an even more attractive zero-emissions option for employees. Workplace charging can be encouraged by education and outreach to companies and made easier by employee surveys on transportation needs and preferences. In the Bay Area, for example, the Business Council on Climate Change published *Electrify Your Business, a Bay Area Business Guide* to help Bay Area businesses create their own PEV programs.[74]

Fleets are an excellent fit for the purchase of PEVs, and many companies with fleets are investing in PEVs and providing charging infrastructure. Fleet vehicles typically charge in the off-peak hours and travel a regular route. Fleet managers also make purchasing decisions by evaluating total vehicle lifetime costs including maintenance, which is exceptionally low for PEVs. A recent study shows that light-duty PEVs, Class 2-3 trucks in particular such as parcel delivery vans and shuttle buses, will offer the best opportunity for near-term growth in the United States commercial fleet sector.[75] General Electric recently committed to purchasing 25,000 PEVs through 2015 for its Capital Fleet Services global sales force. It also has an agreement with Nissan and Better Place to develop smart grid electricity infrastructure for PEV charging and will deploy its Level 2 GE WattStation for commercial and home use.[76] Some car rental companies are actively pursuing the installation of charging infrastructure in locations such as airports for a portion of their fleets in California.

To encourage workplace and fleet charging, the Energy Commission will consider grants to support charging infrastructure (with emphasis on battery storage and renewable charging) and outreach to business and fleet owners.

Commercial, Public, and Fast Charging

The deployment of commercial and public charging stations over the next several years will provide a level of range assurance to new PEV drivers and could reduce barriers to PEV adoption. Public charging is more important for BEVs as opposed to PHEVs or extended range electric vehicles such as the Volt. Although most customers will charge at home, they must be assured of readily available chargers within their driving radius and near destinations that extend beyond their vehicle's driving range. As data on public charging infrastructure is collected over the next few years, consumers' behavior and charging requirements will become much better understood. The development of public charging stations should proceed under the guidance of a regional plan with regional partners developing network plans that are data driven.[77]

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[74] Business Council on Climate Change and the Bay Area Council, Michael Calise, April 6, 2011. http://www.bc3sfbay.org/uploads/5/3/3/9/5339154/electrify_your_business.pdf.

[75] Frost & Sullivan, *Strategic Analysis of the North American and European Electric Truck, Van and Bus Markets*, May 24, 2010. As reported in *Fleet Owner*, "Study Forecasts Electric Truck Growth by Weight Classes," January 4, 2011.

[76] *Fleets & Fuels*, December 20, 2010.

[77] Staff conversation with Tom Turrentine, U.C. Davis PHEV/BEV Research Center, April 2011.

The ratio of chargers per PEV (for home and public) needed varies from 0.6 to 3.5.[78] The California Public Utilities Commission estimates that one home charging and 0.2 public charging capacity is needed for each vehicle. Nissan, Ford, GM, and Chrysler similarly estimate that there is need for one home charger and 0.3 public chargers per vehicle. These ratios are highly speculative, and more analysis is needed to understand consumer behavior and charging patterns.

Government support of the initial rollout of PEV public charging infrastructure is necessary to support PEV commercialization until there are sufficient volumes of PEVs to provide a business case for infrastructure providers. Some studies, such as the Tokyo Electric Power Company study in Japan, showed that public or workplace opportunistic charging provided consumers with capacity (or the ability to charge) rather than actual electricity fuel usage. Consumers, therefore, used a greater portion of their battery storage capacity knowing that chargers were available if needed.[79]

It is generally agreed that charging levels should be matched to the purpose of the consumer's destination.[80] For example, airport parking garages may do well with Level 1 charging given the longer periods of parking at airports. Level 2 chargers are appropriate for destinations such as theaters, stores, and coffee shops where vehicles may park for several hours. It is important to maximize the public benefit by leveraging the location of chargers and considering the breadth of benefit.[81] In Sonoma County, charging sites are often multiuse with overlap between home, workplace, and fleet charging.[82]

Public charging will, however, increase the demand for "on-peak" electricity in most cases. Smart charging will help coordinate the vehicle's charging and user preferences with the needs of the power grid. Users may receive a lower rate for charging if the utility is allowed to control the timing of the charging to maximize grid benefits.[83] Grid

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[78] Based on input at the Joint Energy Commission Staff and Statewide PEV Collaborative PEV Infrastructure Joint Workshop, October 19, 2010. Estimates of this ratio included the following: Electrification Coalition indicates 1.5-3.5 per vehicles through 2015, and 0.5-1.5 after 2030; RMI indicates 0.6 per vehicle; Bay Area Corridor indicates 0.1-0.2 per vehicle; California Public Utilities Commission indicates 0.2 per vehicle.

[79] Tokyo Electric Power Company, "Desirable characteristics of public quick charger," http://www.emc-mec.ca/phev/Presentations_en/S12/PHEV09-S12-3_TakafumiAnegawa.pdf.

[80] Joint Energy Commission Staff and Statewide PEV Collaborative PEV Infrastructure Joint Workshop, Public Charging Panel, October 19, 2010.

[81] Ibid.

[82] Joint Energy Commission Staff and Statewide PEV Collaborative PEV Infrastructure Joint Workshop, Workplace Charging Panel, October 19, 2010.

[83] 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.

impacts can also be reduced by offsetting the increased demand for electricity by improving local efficiency and/or installing photovoltaic systems. The University California at San Diego's Zero Emission Vehicle Project is diverting a portion of its solar and biogas resources to charge a fleet of about 50 new PEVs.[84] This study will establish the technical feasibility of using renewable energy to electrify the transportation sector. The Electric Power Research Institute, Tennessee Valley Authority, and Oak Ridge National Laboratory are testing a solar assisted PEV charging station that uses a battery storage system to assess the effect on reliability, analyze EVSE, and test advance metering infrastructure. Envision Solar International, Inc., is installing PEV charging-enabled solar tracking trees at Axion Power International in Pennsylvania.[85] Envision will provide a solar array that incorporates solar tracking into the canopy structure of its parking array. Co-location of battery storage with public and workplace EVSE is also an effective way to reduce on-peak charging. All these developments can help solve the problem of "on-peak" PEV charging. The Energy Commission will consider how to encourage further development of renewable PEV charging infrastructure.

Business models for commercial charging have been evolving as PEVs roll out and the need for charging infrastructure develops. There are some concerns regarding the long-term economic viability of public charging, including the inclusion of maintenance and electricity costs. Various business models are emerging that could support future development of PEV infrastructure without government support. One company, NRG Energy Inc., will be creating a network of public charging stations in Houston, Texas. The company hopes to expand in the other 13 states that have deregulated electricity markets and will likely use a subscription model to cover the fixed costs of the network.[86] Another company, CCGI, plans to bill customers 50 cents per kWh for public charging, about four times what consumers pay at home for electricity.[87] Ecotality plans to generate revenue from hardware and equipment sales, monthly subscription fees from consumers and fleet owners, advertising at the charging stations, and grid services to utilities.[88] Subscription fees will likely be in the range of $5 to $10 per month and will ensure a revenue stream for infrastructure providers and charging availability

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[84] UC San Diego, *The Endgame: Charging of Electric Vehicles with Secure, Domestic, Renewable Energy Resources*.

[85] Envision Solar, "Envision Solar Commences EnvisionTrak™ and CleanCharge™ Solar Tree® Installations for Axiom Power International," September 30, 2010, http://www.marketwire.com/press-release/Envision-Solar-Commences-EnvisionTrak-CleanCharge-Solar-Tree-Installations-Axion-Power-1327606.htm.

[86] *The Wall Street Journal*, "Houston to Get Charging Stations", November 19, 2010.

[87] BNET, "Public EV Charging: Expect to Pay $3.50 an Hour for the Convenience", Jim Motavalli, December 8, 2010.

[88] *Greentech Media*, "Will EV Charging Stations be Free?" December 14, 2010, http://www.greentechmedia.com/articles/read/will-ev-charging-stations-be-free/.

"insurance" for consumers. Some retailers will offer free charging to draw consumers to their stores. Larger companies are entering the market, including General Electric, Schneider Electric, and Siemens, all of which have significant economies of scale regarding equipment sales.

Absent a business model, it is likely that public charging infrastructure will require substantial government investment. As viable business models emerge, the need for government support will diminish, and the expansion of the PEV charging network will be market driven.

In January 2011, the Energy Commission with the California Air Resources Board conducted an alternative fuels automaker survey. The survey was sent to 26 automakers, 20 of whom responded. Since the individual results are confidential, the data was collected for each year. Tables 8 and 9 provide the survey results for BEV and PHEV rollouts through 2015 in specified regions of California. The data provided is not sufficient for detecting trends, since automaker response rates were inconsistent for each year. For example, some provided data for only two years, and only one provided data for all five years. Only nine automakers provided vehicle production plans for BEVs and six for PHEVs, so the yearly results are underestimates. No single automaker showed a decline in production from one year to the next, despite the appearance of the data. These production numbers represent a minimum rollout.

Table 8: Battery Electric Vehicle Automaker Survey (Discrete Each Year)

	2011	**2012**	**2013**	**2014**	**2015**
Survey Responses	5	6	7	6	4
Bay Area	1,738	3,796	2,263	1,580	2,607
Northern Calif.	207	585	540	546	1,266
Central Valley	66	370	491	497	527
Central Coast	99	311	215	215	451
Los Angeles	1,575	3,702	3,288	2,555	2,882
San Diego	2,421	1,449	778	384	1,039
Not specified		3,000	3,450	3,600	3,000
Total	6,106	13,213	11,025	9,377	11,772

Source: ARB, California Energy Commission.

Table 9: Plug-In Hybrid Electric Vehicle Automaker Survey (Discrete Each Year)

	2011	2012	2013	2014	2015
Survey Responses	2	2	2	3	4
Bay Area					60
Northern Calif.					9
Central Valley					6
Central Coast					8
Los Angeles	5				198
San Diego					15
Not specified	1,200	9,583	12,013	6,241	6,879
Total	1,205	9,583	12,013	6,241	7,175

Source: ARB, California Energy Commission

As Tables 8 and 9 indicate, PEVs will continue to populate the San Francisco Bay Area, Los Angeles, and San Diego areas as expected, with some PEVs in new areas such as the Central Valley and Central Coast regions. The latter regions areas have fewer EVSE units available than the higher density areas such as San Diego, Los Angeles, and the San Francisco Bay Area but will still require adequate charging infrastructure.

To accommodate likely PEV sales in the Central Valley, Central Coast, and Northern California regions, the Energy Commission will consider funding a minimum level of public, workplace, and fleet EVSE in strategic locations to support the PEV rollout. The Energy Commission is evaluating direct current fast charging deployment in cities, metropolitan regions, and highway corridors. It is examining the potential to develop PEV public charging corridors on Interstate 5 and other California highways to expand the driving range of BEVs. PHEV and extended range electric vehicles drivers may also choose to maximize their electricity use on longer trips. The effectiveness of direct current fast charging will be studied as data from planned direct current fast chargers becomes available.

The availability of fast chargers will increase consumer convenience by reducing the recharge time. Fast chargers have an additional benefit in that widespread deployment would allow automakers the ability to design PEVs that have a lighter, lower cost battery pack designed for daily commute.[89] The ECOtality Blink 480 volt PEV charger is

[89] Presentation by David Patterson, Mistubishi Motors, at California Environmental Dialogue Meeting, November 30, 2010.

capable of fully recharging a BEV, such as the Nissan Leaf, in 15 to 28 minutes. ECOtality is partnering with Best Buy to install 12 Blink chargers in its parking lots, and with BP (and its subsidiary Arco) to install fast chargers at 45 gas stations.[90] ECOtality will install 60 fast chargers in the San Diego and Los Angeles regions with a grant from the United States Department of Energy and the California Energy Commission.

In the Bay Area, the Association of Bay Area Governments is partnering with 350Green (through its Energy Commission award) to install up to 19 fast chargers. They are using an Epyon fast charger Level 2 system that allows expansion for up to four charger bollards per one base power unit. Each bollard can accommodate twin fast-charge connectors or a dual Level 2 fast charge configuration.[91] The system can also allocate reduced voltage to vehicles and improve power flow, depending on the number of vehicles requiring recharging. The company 350Green is also partnering with the Bay Area Air Quality Management District to install six fast chargers at Safeway shopping centers. Bay Area Air Quality Management District is also deploying 30 fast chargers in the Bay Area corridor for extended range by local PEV drivers and destination charging for visitors or those passing through. Table 10 summarizes the known planned deployment of 115 fast chargers in California through 2012.

Table 10: Planned Deployment of Fast Chargers in California

Area	Installer	Partner	Number
San Diego and Los Angeles	ECOtality-Blink	DOE/Energy Commission	60
Bay Area	350Green-Epyon	ABAG	19
Bay Area	350Green	Bay Area Air Quality Management District	6
Bay Area	ECOtality/AeroVironment	Bay Area Air Quality Management District	30
Total			115

Source: California Energy Commission

Fast chargers are being deployed in California in the major PEV regions—in cities and near urban area connectors, as well as a few on highway corridors in Southern California and the San Francisco Bay Area. The first priority for fast charger location is

[90] *Los Angeles Times*, "BP, Arco, Best Buy to install fast chargers for electric cars", October 13, 2010.
[91] Richard Schorske, January 20, 2011.

at the city level, which can support consumers in multiunit dwellings.[92] From there, the priority extends to connecting urban corridors 100 miles apart or less.[93] The "West Coast Green Highway" is a three-state initiative involving Washington, Oregon, and California that could eventually result in a seamless recharging network along the 1,350 miles of Interstate 5 (I-5).[94] The majority of ECOtality's fast chargers in the EV Project will be installed along Interstate 5 connecting Vancouver, Canada, to the Mexican border. Washington and Oregon are planning to install fast chargers between major regional centers and recreational destinations partly funded by the EV Project. The Oregon Department of Transportation selected AeroVironment to build the first phase of the "West Coast Green Highway" along I-5 between the California state line and Willamette Valley. AeroVironment will analyze driving distances, common destinations, vehicle range, and other factors in its selection of the fast charging sites at eight interchanges identified by the Oregon Department of Transportation along the 150-mile span of I-5.[95]

A recent study by the Plug-In Hybrid and Electric Vehicle Research Center briefly examined establishing a string of Level 2 and direct current fast chargers along two corridors: Interstate 5 (I-5) and California Highway 99 (SR-99) between Sacramento and Bakersfield. Based on the performance of the Nissan Leaf, the findings showed that it takes about 6.5 hours for the BEV and 4 hours for the internal combustion engine driver to travel from Bakersfield to Sacramento at 70 miles per hour (mph). Charging time adds about 2.5 to 3 hours more for the BEV driver than the ICE driver at all speeds with between 4 to 8 stops depending on speed.[96] The study concludes that BEV drivers will not choose to drive this distance in a single day due to the number of stops required. Also, Nissan does not recommend direct current fast charging more than once per day due to wear and tear on the battery. Therefore, the use of such a corridor is not likely until BEVs have a much greater range. The study also concluded that SR-99 would have more local travel demand than I-5 based on travel distances and population and would be a more practical location for fast chargers than I-5. The routes from Sacramento to Stockton and Fresno to Bakersfield on those sections of SR-99 could be candidates for fast chargers. Further analysis and planning regarding fast charging on

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[92] October 19, 2010, Joint Energy Commission Staff and Statewide PEV Collaborative PEV Infrastructure Joint Workshop, Corridor Charging Panel discussion.

[93] Ibid.

[94] *Automotive News*, "Range Anxiety? Not on this Highway", December 6, 2010.

[95] BusinessWire, "Oregon Department of Transportation Selects AeroVironment to Build First Phase of West Coast 'Green Highway' Along Interstate 5," http://www.businesswire.com/news/home/20110601006267/en/Oregon-Department-Transportation-Selects-AeroVironment-Build-Phase

[96] "A Brief Analysis of Potential EV Corridors for the Energy Commission", Tom Turrentine, Gil Tal and Mike Nicholas, April 2011. Assumptions: A full charge of the Leaf offers 73 miles of range, a DC fast charge of the Leaf offers 80 percent of 73 miles in 25 minutes, and energy consumption per mile is 240W/h at 55 mph and up to 430 W/h at 80 mph.

these corridors are needed to take into consideration the numbers of vehicles and corridor use under various market growth scenarios.

The Energy Commission will consider funding a corridor planning initiative to provide an optimal framework to guide direct current fast charge deployment and future investment for these corridors. The Energy Commission may also fund fast chargers in strategic locations based on research and data gathered over the next several months.

Signs are important for alerting PEV drivers to recharge sites. Standards and best practices for signage need to be funded and developed for effective deployment of charging infrastructure. The Bay Area Ready, Set, Charge California! group is incorporating this into its local government PEV readiness plan. The Energy Commission supports signs within regions and along highway corridors and will work with the California Department of Transportation to explore possible solutions.

Americans with Disabilities Act compliance for PEV charging is an issue that needs further clarification. The State of California's Division of the State Architect has issued "Interim Disabled Access Guidelines for Electric Vehicle Charging Stations" (Policy #97-03). PEV charging stations are required to be accessible because they offer a public service. When PEV charging is coupled with regular parking, the PEV charging is considered the primary service. If there are up to 25 chargers at a site, then one accessible charger space is required. Accessible charging spaces are not reserved exclusively for people with disabilities. If there are only three parking spots, one of them must be Americans with Disabilities Act compliant, although in San Francisco, for example, chargers are allowed to adjoin an Americans with Disabilities Act -compliant parking site. Many communities are attempting to clarify the requirements for Americans with Disabilities Act-compliant PEV parking, and in many cases the requirements are unclear. To avoid litigation, communities are using more resources to ensure the highest possible standards. The Energy Commission supports further clarification of these Americans with Disabilities Act standards in the State Building Code Sections of Chapter 11 B and 11 C.

Table 11: PEV Infrastructure Funding Summary for FY 2011-2012

PEV Regional Readiness	$1 million
Charging Infrastructure and Related Activities	$7 million
Total	$ 8 million

Source: California Energy Commission

Light-Duty PEVs

In the past several months, a new generation of PEVs has entered the California light-duty vehicle market. The Nissan Leaf, a BEV with a 100-mile[97] range and a 24-kWh battery, is expected to be purchased by several thousand Californians over the next

[97] US EPA LA4 city cycle conducted in laboratory tests.

year or two. The General Motor Chevy Volt, an extended-range plug-in electric vehicle, with a 40-mile all-electric range and on-board gasoline generator, is starting to rollout in California. The Tesla Roadster, a BEV with a 245-mile range and 53 kWh battery, has sales of more than 1,500 worldwide, and over 160 in California.[98] In 2011, planned BEVs include the BMW ActiveE, Ford Focus, Mistubishi "I," BYD e6, and Coda Sedan. PHEVs planned for 2011 include the Toyota Prius Plug-in Hybrid, Fisker Karma, and BYD F3DM. Virtually all manufacturers are planning for greater electrification of their fleet.

There are many forecasts of PEV market penetration in California through 2020 ranging from less than 3 percent of sales to nearly 14 percent of California vehicle sales.[99] The California PEV Collaborative, in one scenario, estimates annual sales of 250,000 PEVs (representing 14.7 percent of projected total annual light-duty vehicle sales) during the "market launch" phase in 2020.[100] The collaborative also estimates a range of 2 percent to 4 percent PEV market share out of a total California light-duty vehicle market of 25 million vehicles. New PEV sales will depend on many variables including the success of the initial PEV rollout, future gasoline prices, reduction in battery costs and infrastructure availability. Replacing the existing vehicle fleet takes several decades. For example, conventional hybrid vehicles took 10 years to reach 5.9 percent of new vehicle sales and has reached 1.4 percent penetration into California's fleet.[101,102]

Automakers will continue to pursue the development of PEV technology due to adopted federal Corporate Average Fuel Economy standards and California Pavley-GHG regulations, securing the benefits of high efficiency, reduced GHG and other criteria emissions, attractive vehicle attributes, and fuel diversity. In addition, the ZEV mandate requires large automakers to produce certain percentages of "pure zero" emission and "near-zero" emission vehicles for sales in California to meet California's air quality goals. ARB staff is working on regulatory adjustments to focus on PHEVs and pure BEVs to incubate these technologies for large-scale market penetration. Traditionally, the ZEV regulation has been based on reducing criteria pollutant emissions. Based on a December 2009 hearing the ARB staff has begun regulatory development and will release proposed modifications to the ZEV regulation in fall 2011.[103]

These modifications may include the following:

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[98] California Energy Commission, DMV Analysis of 2009 File Pass.

[99] "Taking Charge: Establishing California Leadership in the Plug-in Electric Vehicle Marketplace," California PEV Collaborative, page 12.

[100] Ibid.

[101] Ibid.

[102] California Energy Commission, DMV Analysis of 2009 File Pass, with the Total Fuel Use Analysis.

[103] Air Resources Board staff, February 1, 2011.

- Closer alignment of the ZEV regulation requirements with the state's long-term air quality and GHG emission reduction goals, specifically for model years 2018 and beyond.
- A renewed and simplified focus on precommercial development vehicle technologies (ZEVs and Enhanced AT partial ZEVs), rather than technologies that already have demonstrated their market potential (partial ZEV and advanced technology partial ZEV).
- For model years 2018 and beyond, moving partial ZEV and advanced technology partial ZEV vehicle technologies out of the ZEV program and into the Low Emission Vehicle program for criteria pollutant and GHG reductions.
- Maintaining only elements of the ZEV regulation that promote the commercialization of ZEV and ZEV-enabling technologies.[104]

The main barrier to the penetration of light-duty PEVs is the high initial vehicle purchase price. Battery costs continue to be the most significant portion of PEV higher costs and are projected to decline with high-volume production and manufacturing efficiencies gained over time. Many forecasts report that the cost of a PEV battery pack will be reduced in half over the next 5 or 10 years.[105] To spur sales of PEVs, incentives may be required to offset the price differential between PEVs and gasoline-fueled vehicles.

Incentives

The Air Quality Improvement Program provides up to $50 million per year for program grants to fund clean vehicles and equipment, air quality research, and workforce training. The Clean Vehicle Rebate Project is funded by the Air Quality Improvement Program and administered statewide by the California Center for Sustainable Energy.[106] The ARB allocated up to $5 million from Air Quality Improvement Program in the 2010-2011 funding plan to promote the production and use of zero-emission vehicles, including BEVs, PHEVs, and fuel cell vehicles. Rebates up to $5,000 per light-duty vehicle are available for individuals and business owners on a "first come, first serve" basis who purchase or lease new eligible zero-emission vehicles or PHEVs. Certain zero-emission commercial vehicles are eligible for rebates up to $20,000. The rebate program is expected to be oversubscribed, so the Energy Commission has supplemented the Clean Vehicle Rebate Program with $2 million for 2011. The ARB is also proposing to increase the overall funding for the Clean Vehicle Rebate Program to

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[104] Ibid.

[105] California PEV Collaborative, *Taking Charge: Establishing California Leadership in the Plug-in Electric Vehicle Marketplace*, page 39.

[106] California Center for Sustainable Energy, "Clean Vehicle Rebate Project," https://energycenter.org/index.php/incentive-programs/clean-vehicle-rebate-project.

$15 million (or up to $21 million), and to reduce the per-vehicle incentives available for FY 2011-12 by approximately half.[107]

Federal tax incentives ranging from $2,500 to $7,500 are available as tax credits for full-function electric-drive vehicles. To qualify for a federal tax credit, an electric-drive vehicle must have a battery with a capacity of at least 4 kWh, making the vehicle eligible for the minimum $2,500 credit. Vehicles with a battery capacity of 5 kWh or greater are eligible for an additional $417 of credit for every kWh excess of 4 kWh. Vehicles such as the Nissan Leaf (24 kWh battery capacity) and the Chevrolet Volt (16 kWh battery capacity) will thus be eligible for the maximum $7,500 credit. President Obama recently announced a proposal to convert this tax credit to a rebate program.[108] Also available, although reduced from 2010, is a federal tax credit for 30 percent of the cost of home (up to $1,000) and commercial (up to $30,000) electric vehicle charging equipment and installations.

Additional PEV incentives include high occupancy vehicle lane access through 2015, free parking in many cities, reduced insurance rates by many providers, reserved parking spots with chargers, and the availability of reduced electricity rates. For example, San Francisco Bay Area residents may obtain a $700 charger rebate; San Joaquin Valley residents have a $3,000 PEV incentive; and Riverside residents have access to a $2,000 PEV rebate.[109]

If consumers considered the vehicle lifetime fuel savings rather than the upfront capital costs of the PEV, they would observe additional cost advantages compared to a conventional vehicle today. Table 12 compares the lifetime fuel cost savings of a typical BEV such as the Nissan Leaf with the PHEV Toyota Prius and the counterpart conventional vehicle given varying gasoline and electricity costs. Table 11 shows the fuel savings potential for a 5- or 10- year consumer vehicle ownership. Savings are quite sensitive to the price of gasoline with savings for BEVs almost doubling between $3 per gallon and $5 per gallon levels.

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[107] ARB, *Proposed AB 118 Air Quality Improvement Program Funding Plan for Fiscal Year 2011-12*, page 13.

[108] Department of Energy, "Vice President Biden Announces Plan to Put One Million Advanced Technology Vehicles on the Road by 2015," http://www.energy.gov/news/10034.htm.
[109] California Center for Sustainable Energy, "Plug-in Electric Vehicles," https://energycenter.org/index.php/technical-assistance/transportation/electric-vehicles.

Table 12: PEV Versus Conventional Vehicle Fuel Cost Savings Projections[110]

	$2 / gallon gasoline, 10¢/ kWh electricity	$3 / gallon gasoline, 10¢/ kWh electricity	$4 / gallon gasoline, 10¢/ kWh electricity	$5 / gallon gasoline, 15¢/ kWh electricity	$6 / gallon gasoline, 15¢/ kWh electricity
PHEV vs Conventional Savings at 5 years	$1,475	$2,212	$2,949	$3,686	$4,424
BEV vs Conventional Savings at 5 years	$1,497	$2,997	$4,497	$5,246	$6,746
PHEV vs Conventional Savings at 10 years	$2,949	$4,424	$5,898	$7,373	$8,847
BEV vs Conventional Savings at 10 years	$2,994	$5,994	$8,994	$10,491	$13,491

Source: California Energy Commission

A Nissan Leaf's manufacturer's suggested retail price is $32,780 (or $35,337 including sales tax). After deducting federal tax incentives and the state clean vehicle rebate, the final cost to the consumer is $22,837. This cost compares favorably to a similar conventional vehicle valued at $25,020. In some communities' additional incentives will apply. Charging infrastructure is not included in this analysis. A consumer would save $8,994 in fuel savings over 10 years of ownership (at $4 per gallon), resulting in a total cost of $13,753—almost half the price of the comparable conventional vehicle cost of $25,020.[111] Over five years of ownership a consumer would save $3,084 (at $4 per gallon) resulting in a total cost of $19,753, which is still less than the conventional vehicle. An important consideration in setting the appropriate level of incentives is understanding the consumer's approach to vehicle purchasing decisions. The UC Davis Plug-In Hybrid and Electric Vehicle Research Center indicates that consumers do not typically perform such an in-depth life-cycle cost analysis of vehicle costs; rather, they consider the upfront cost of the vehicle.[112] Consumer education regarding the life-cycle cost analysis will be essential to convey the true benefits and costs of PEV ownership.

Vehicle prices will decline as battery costs are reduced and PEV production volumes increase. Over time there will be less need for government subsidies. It is likely that, in the near term, incentives will still be needed to overcome barriers to the relatively high price of PEVs and PEV charging infrastructure. Creative financing strategies and vehicle leasing are other options for reducing the upfront cost of PEVs. As the price of gasoline

[110] Staff assumes 9,000 annual miles traveled, BEV at 33.4 kWh/100 miles combined fuel efficiency, PHEV at 59 combined mpg (a 20 percent increase to conventional hybrid) and the base conventional vehicle at 30 mpg.

[111] The Nissan Leaf cost is $35,337, including sales tax. The conventional vehicle is the Nissan Altima, costing $25,020 including sales tax. PEV drivers typically drive less than the average driver, at 9,000 miles annually.

[112] Tom Turrentine, staff meeting, November 2010.

rises and the costs of batteries continue to decline, PEVs will become increasingly attractive.

In 2010-2011, the Energy Commission provided $2 million in program funds to the ARB's Clean Vehicle Rebate Program for light-duty vehicles. The Energy Commission will consider providing funds once again for the rebate program if needed to continue support of the successful rollout of PEVs in California.

Batteries

Battery Technology

The key issue in PEV design is the selection of the battery. The cost of lithium batteries remains high ($500 - $1,000 per kWh) when purchased in relatively small quantities. For the 16-kWh battery pack in the Chevy Volt, this equates to around $8,000 - $16,000. Detailed cost modeling done at Argonne National Laboratory shows that – in high production volume (greater than 100,000 packs per year) – original equipment manufacturers should be able to produce batteries in the range of $250 - $400 per kWh for all chemistries.[113]

One key to improving the performance and reducing the costs of PEVs is increasing the amount of energy that can be stored in a battery given its size (energy density) and increasing the amount of power the battery can deliver (power density). A recent Energy Commission report presented test data on the performance of various battery chemistries for use in PHEVs. The data shows that for all lithium-ion chemistries tested, power density can be increased but not without sacrificing the battery's energy density and cycle life, and vice versa. As a result, battery pack sizes must either be increased or use more expensive materials to meet both the power and energy storage requirements of the vehicle.[114]

Researches recognize that combining batteries and ultracapacitors (capacitors with significant power densities) can offer advantages in hybrid electric vehicles. Ultracapacitors can deliver very high power and respond in fractions of a second but have limited storage capacity. Batteries have lower power capability but with high energy density can store relatively large amounts of energy. The combination of batteries and ultracapacitors can deliver high power and high energy and is ideal for PEVs in terms of extending the battery life and downsizing the battery pack. The Plug-In Hybrid and Electric Vehicle Research Center modeled various combinations of advanced lithium batteries and ultracapacitors in PHEVs and compared their performance with batteries alone. In all respects, vehicle performance was improved

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[113] Burke, Andrew, Miller, Marshall, Zhao, Hengbing, Institute of Transportation Studies, University of California, Davis. 2010. *PHEV System and Charging Technology Evaluation of Lithium Batteries of Various Chemistries: Battery Performance and Second Use and Vehicle Simulation.* California Energy Commission. Draft unpublished report.

[114] Ibid.

using ultracapacitors for all the batteries studied, including fuel economy improvements of 50-100 percent and 15-40 percent for charge depletion and charge sustaining modes. The simulation results also indicate that by using ultracapacitors, batteries with a wide range of power characteristics can be used in PEVs without sacrificing vehicle performance and subjecting the batteries to high stress that may shorten their life.[115]

As research and development continue to increase the energy density of lithium batteries, ultracapacitors will likely be needed to meet the power demands of PEVs. Currently the cost of ultracapacitors remains high, due mostly to high material and high manufacturing cost.

Battery Reuse

There are considerable interest and potential for the reuse of vehicle batteries for applications after they are no longer suitable for vehicle use. Vehicle batteries must provide a minimum level of power to the vehicle's electric motors. Although the batteries are no longer usable in the vehicle ("spent") when they drop to 70-80 percent of their power capabilities, such batteries could have significant life in other applications that have less demanding energy and power requirements. Repurposing vehicle batteries in second-use applications would increase their salvage value and extend their useful life. In particular, the utilities may find value for repurposed vehicle batteries as storage devices for intermittent renewables, particularly nighttime wind power, and delivery devices for peak needs, especially if such devices help to avoid building new power plants. Such devices could be distributed in household garages and basements or collected into power centers and be used to provide various services to the grid, the utility, and the electricity customers.

A recent Energy Commission report estimates that a repurposed 6 kWh battery pack, enough capacity to provide a PHEV with approximately 15 miles of all-electric range, could generate net revenue streams of more than $1,000 per year for grid ancillary services.[116] These revenue streams could significantly decrease the monthly lease payment for the vehicle battery pack. As vehicle battery production ramps, up and battery costs drop, revenues generated from second-use applications could fully cover and potentially exceed the monthly lease payments.

There are several ways in which the reuse of batteries could be used to reduce the cost of PEVs either initially or over time as the vehicle is used. In any case, the purchasers of PEVs would have to benefit from the value of second uses of batteries. This could be done by subtracting some fraction of the sale price of the reused batteries from the initial cost of the new plug-in vehicle batteries. This could be done easily if the same

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[115] Ibid.

[116] Williams, Brett D., and Timothy E. Lipman, 2010. *Strategies for Transportation Electric Fuel Implementation in California: Overcoming Battery First-Cost Hurdles*. California Energy Commission, Public Interest Energy Research Transportation Program. CEC-500-2009-091.

company owned the batteries over their complete life, including second use. Another approach is for the PEV owner to lease the batteries or pay for the batteries as they use electricity stored in the batteries. In either case, the cost of the batteries would be paid over their lifetime, significantly reducing the initial cost of the PEV.

To promote the development of the second-use vehicle battery market, the Energy Commission's Public Interest Energy Research Program is identifying and evaluating potential reuse strategies. In 2010, the Energy Commission, in coordination with the Plug-In Hybrid and Electric Vehicle Research Center, awarded funding to the California Center for Sustainable Energy to begin developing the home energy storage appliance. This device will use spent vehicle batteries, be suitable for placement in garages, and provide ancillary services to the electricity grid. The California Center for Sustainable is working with San Diego Gas & Electric to evaluate the effectiveness of the home energy storage appliance as a peak shaving application in homes and businesses. In addition, the California Center for Sustainable is working with AeroVironment to develop a protocol to determine if spent lithium-ion vehicle batteries are acceptable for second-use applications. Since the Energy Commission's initial award, the United States Department of Energy has awarded an additional $700,000 in funding over a longer period to the California Center for Sustainable and the Plug-In Hybrid and Electric Vehicle Research Center to conduct additional work on second-use applications for lithium-ion vehicle batteries.

The Energy Commission's Public Interest Energy Research Program has tasked the Plug-In Hybrid and Electric Vehicle Research Center to develop the home energy storage appliance further and evaluate new ways to use spent vehicle batteries in grid storage applications. This will include developing and testing energy storage devices, like the home energy storage appliance, in other smart-grid applications including industrial sites, shopping malls, large buildings, and public charging stations. In particular, the Plug-In Hybrid and Electric Vehicle Research Center will evaluate methods to integrate these storage devices in applications that have distributed generation resources such as solar photovoltaic systems.

Battery Recycling

The question of recycling the battery is something that must be addressed before significant quantities of vehicle batteries are produced. Large-scale recycling has the potential to not only reduce the environmental footprint of lithium vehicle batteries, but also reduce their high costs if battery materials are able to be reused. Currently, there is not yet the capacity (or the need) for recycling large lithium vehicle batteries. A recent Frost and Sullivan report estimates that the PEV lithium-ion battery recycling market will be worth more than $2 billion by 2022. In 2009, the U.S. Department of Energy awarded $9.5 million to a California company to build the nation's first lithium vehicle battery recycling facility in Ohio. As the PEV market grows, additional battery recycling centers will need to be built. In addition, some system of requiring that the batteries be recycled will need to be established. The Energy Commission's Public Interest Energy Research Program has tasked the Plug-In Hybrid and Electric Vehicle Research Center to discover the full cost of disposal, identify potential ways to reuse

battery materials, and assess the potential for large-scale recycling of lithium vehicle batteries.

Table 13: Plug-In Electric Vehicle Funding Allocation

PEV Readiness	$1 Million
Charging Infrastructure	$7 Million
Total	$8 million

Source: California Energy Commission

Hydrogen

Hydrogen can be derived from a number of sources, including natural gas, biomethane, electricity from fossil fuels, and electricity from renewable resources. Hydrogen produced through steam methane reformation and used in a fuel cell vehicle (FCV) can reduce GHG emissions by 56 percent[117] and petroleum consumption by 99.7 percent when compared to California's reformed gasoline used in a conventional vehicle. Like BEVs, FCVs produce no tailpipe emissions; however, unlike with BEVs, there are no energy storage issues with FCVs. They store the hydrogen fuel in on-board pressure tanks. Today's FCVs hold enough hydrogen in on-board tanks that driving ranges of 250 miles or more are possible in everyday use. Refueling is relatively quick with about 3-5 minutes per fill.

However, a major barrier for this fuel and the vehicle technologies using hydrogen remains the economy and high cost at numerous levels. Vehicle production and fueling infrastructure are still at a precommercial stage, where industry cannot take advantage of economies of scale benefits that come with commercial production volumes. However, there are indicators that cost is decreasing on both the vehicle and fuel infrastructure side. One original equipment manufacturer has mentioned that FCVs are now headed below the $100,000 mark, and several original equipment manufacturers are leasing vehicles to selected members of the public. The Energy Commission has also seen the cost per fueling station decrease, from a range of $3 million to $6 million to a range of $1 million to $2.5 million, over only a few years.[118] This was made possible due to modular designs and strategically designed fuel production and distribution models.

As interest and opportunities for hydrogen and FCVs have risen in California, there has been a continued reduction in financial support from the federal government. For FY 2012, United States Department of Energy has proposed reducing funding for hydrogen and fuel cell technologies by nearly 41 percent below the previous year's level, on the basis that the technologies will not be ready for mass markets until years from now.

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[117] Based on LCFS data, using a pathway of hydrogen produced 100 percent from natural gas steam methane reformation, used in an FCV.

[118] Based on information from proposals received by the Energy Commission under PON-09-608.

Fuel Conversion and Production

Steam Methane Reformation

The most common method for producing hydrogen is through large-scale steam methane reforming facilities, where methane from natural gas (or biomethane) is broken down in a reaction with high-temperature steam. The resulting products are hydrogen and CO_2, which is released into the atmosphere. The hydrogen is purified and compressed for storage and transport. Large-scale steam methane reformation units are relatively energy-intensive installations that allow for a comparably low-cost production per kilogram of hydrogen. The process energy is generated by the combustion of the same natural gas that serves as the feedstock and some electric power. The vast majority of hydrogen today is produced for various non-transportation purposes, such as in oil refineries, the chemical industry (methanol, ammonia, hydrochloric acid), in the food industry (oil/fat hydrogenation), or as a shielding gas for welding. Less than 1 percent of hydrogen produced today is used as a transportation fuel.

One major in-state provider, Air Products, produces its hydrogen in a large-scale industrial installation in Southern California, using natural gas derived from the pipeline. Although hydrogen is produced and traded in large quantities as an everyday industrial gas and can be produced at moderate cost today (at approximately $5-10 per kilogram), it has not yet reached cost-competitiveness with petroleum fuels on an energy-equivalent basis.[119]

Hydrogen as a transportation fuel furthermore requires higher purity levels than hydrogen for industrial uses because fuel cells stack membranes are sensitive to impurities. Purification, mostly from by-product gases, is typically performed by pressure swing adsorption, an effective but costly technology that adds to the capital and operation/maintenance cost for steam methane reformation facilities.[120]

Early hydrogen fueling station sites were equipped with on-site hydrogen production units, many using steam methane reformation technology, others using electrolysis. Energy Commission observations suggest that on-site production often comes with relatively high maintenance and capital cost and can produce only small amounts of hydrogen fuel. However, it can present significant potential for renewable hydrogen production if paired with a local source of biomethane or renewable power, for example, from photovoltaic systems.

Senate Bill 1505 (Lowenthal, Chapter 877, Statutes of 2006) requires that all hydrogen used for transportation fuel in the state must be at least 33.3 percent from renewable sources. The ARB, which administers this mandate, has not yet fully established the

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[119] One kilogram of hydrogen contains roughly the energy equivalent to one gallon of gasoline.

[120] Pressure swing adsorption is a process for separating distinct gases under pressure. In the production of hydrogen, refiners often use this process to separate hydrogen and CO2.

requirement and is working on establishing regulations to clarify details of the mandate. For example, the ARB is considering a temporary reduction of the 33.3 percent requirement to 20 percent to account for the lack of availability of renewable hydrogen or the feedstocks necessary for its renewable production during the early years of its implementation. In the case of steam methane reformation, these renewable resources are likely to depend significantly on the use of biomethane. Natural gas used in the steam methane reformation process can easily be substituted for biomethane to reach a renewable hydrogen product. Another aspect that ARB is investigating for the regulations is how credits for renewable power and renewable biomethane will be applicable to the mandate and what kind of tracking mechanisms can be used for these two compliance pathways. A July board meeting has been tentatively scheduled for the approval of the rulemaking.

Electrolysis

Electrolysis consists of water molecules being cracked with electric power into oxygen and hydrogen. The oxygen is released into the atmosphere and the hydrogen captured and compressed for storage. From 2002 to 2007, a few experimental and demonstration electrolysis fueling stations were built in California, funded by consortia of industry, federal government, state government, and local agencies. Some of these stations used electrolysis to produce hydrogen on-site. However, Energy Commission observations suggest that on-site electrolysis comes with relatively high maintenance and capital costs and can produce relatively small amounts of hydrogen fuel over time. This suggests that on-site may not be the most cost-effective option today. Electrolysis possesses significant potential for renewable hydrogen production, particularly when the electricity comes from renewable sources such as photovoltaic arrays. In recent years, California has seen a decline of on-site production fueling stations in favor distributed models with central production. Steam methane reformation is dominating centralized hydrogen production due to the high cost that large-scale central electrolyzers would entail while producing only moderate amounts of hydrogen. Today, central steam methane reformation seems to be favored over on-site production. The general trend moving away from electrolyzers can also be observed in the recent competitive solicitation issued by the Energy Commission in fall 2010, in which no on-site electrolyzers were proposed.

The same Senate Bill 1505 requirements for renewable hydrogen that were discussed under "Steam Methane Reformation" apply equally to electrolysis. Given that electrolysis does not use methane, renewable natural gas is unlikely to play a significant role in ensuring renewable hydrogen from electrolysis. Pairing electrolysis plants with distributed renewable electricity generation is a more likely avenue for compliance. Among the items the ARB is investigating before establishing its requirements is whether and how renewable electricity will be applied to this mandate as a feedstock.

Upstream Fuel Infrastructure

Today, centralized hydrogen production with truck-based delivery to the fueling stations is more cost-competitive than on-site production, particularly on a cost-per-kilogram basis. This approach allows large amounts of fuel to be produced at relatively low cost and allows for significantly reducing the cost for each fueling station because much equipment is only at a single central filling station, and not at each fueling station. On-site production has proven to be a relatively high-cost option, in part due to the high maintenance that on-site steam methane reformation units require and also given the relatively small amounts of fuel they produce.

There are multiple pathways for connecting centralized hydrogen production with fuel dispensing stations. Air Products, an in-state hydrogen provider, developed the first of these pathways. The hydrogen is produced in a centralized facility, purified by pressure swing adsorption, and then compressed and filled into tube trailers at a central filling terminal located at that same facility. The tube trailers serve as means of transportation and on-site storage at each fueling station. The trailer is connected to the on-site equipment, including compressors (for increasing the fuel transport pressure to the dispensing pressure) and the dispenser to allow fueling of FCVs. Once depleted of hydrogen, a trailer is replaced with a newly filled trailer.

Another in-state provider of hydrogen, Linde, has developed a different delivery system for its hydrogen. Its process produces liquefied hydrogen, which is filled into tanker trucks. These trucks deliver the hydrogen to fueling stations where the liquid hydrogen is pumped into a large on-site tank. Liquid hydrogen is super-cooled, and therefore, these tanks are built with thick, double-steel walls. The equipment at the fueling station includes vaporizers, which turn the liquid hydrogen fuel into its gaseous state on demand. Intermittent storage in tube stacks assures an immediately available supply of fuel at the necessary pressure. Compressors regulate the availability and correct pressures of fuel for dispensing.

Fueling stations with hydrogen production and fueling configurations located on-site have been demonstrated over the past decade. These stations required no upstream infrastructure, as the production of hydrogen is colocated with fuel dispensing. However, both electrolyzer and steam methane reformation on-site systems have significant downsides. They produce only small quantities of hydrogen and they are very cost-intensive and known to be relatively high-maintenance technologies. Given today's modern requirements for capacity and peak fueling, an on-site steam methane reformation unit would need to be very large, which may not necessarily be feasible at existing gasoline stations due to lack of space.[121] In recent years, California has seen a decline of on-site production fueling stations in favor of distributed models with central production. This can also be seen in the recent competitive solicitation issued by the

[121] Peak fueling is defined by Society of Automotive Engineers as three consecutive FCV fills totaling 20 kg within one hour.

Energy Commission in fall 2010, in which no proposals with on-site production were submitted.

Localized Fuel Retail Infrastructure

Private Fleet Fueling Infrastructure

Several original equipment manufacturers in California maintain and operate private hydrogen fueling stations to supply their own demonstration fleets of FCVs. These dispensing installations possess small capacities and are often located on the premises of original equipment manufacturer testing and development facilities; as such, they are typically inaccessible by FCVs from other original equipment manufacturer. Transit authorities' hydrogen stations are inaccessible in the same way; however, the first one that will be different is alternating current Transit's Emeryville station that will allow public access "outside the fence" to fuel FCVs in addition to fuel cell buses "inside the fence."

The Energy Commission has emphasized that these exclusionary, private stations do not contribute to the cooperation necessary to build a viable hydrogen station network that will address near-term consumer demand. Furthermore, the vehicle owners will soon be individual consumers, so fleet/private fueling generates a big fuel demand gap. Therefore, the Energy Commission, in its 2010 hydrogen infrastructure solicitation (PON-09-608), required that proposed stations be publicly accessible without prohibitive user agreements.

Some projects in the past and present use mobile fueling vehicles to supply location-independent demonstrations and fleets. This will likely continue to be an option, to bridge temporary gaps in fuel supply that may arise from lack of fueling stations in some areas of the state. However, as automakers begin deploying FCVs in the hundreds and thousands, they are not likely to be a significant part of hydrogen refueling strategy.

Public Hydrogen Fueling Infrastructure

As part of implementing the program, the California Energy Commission is funding projects that support hydrogen fueling infrastructure driven by the fuel demand of precommercial FCVs deployed by automakers in California. Following the *2008-2010 Investment Plan*, the Energy Commission provided $22 million to establish hydrogen infrastructure based on information available from public agencies, public and private organizations, and other stakeholders.

Based on this information, the Energy Commission released a competitive solicitation in June 2010. Out of the proposals for 16 stations received, 11 stations (totaling $15.6 million in Energy Commission funding) were proposed for award. Eight of the stations represent new installations, and three are upgrades. Once awards are finalized and grant agreements are developed, construction of the stations will begin. The stations are strategically located in areas where automakers have committed to significant numbers of fuel cell vehicle deployments over the next three years, with nine of the stations located in the greater Los Angeles area, one near San Francisco International Airport, and one in the Sacramento area.

One key requirement was that the proposed stations had to be backed with location-specific automaker endorsements for vehicle deployments, which allowed the Energy Commission to match supply to demand. All of the funded stations have a minimum of 100 kilogram/day capacity to ensure ample fuel supply for California's hydrogen FCV drivers.

To establish a baseline of existing publicly accessible hydrogen fueling stations in California, an agreement was successfully executed with the Energy Commission's technical support contractor to perform a comprehensive assessment of all publicly accessible stations in California. In 2010, the report found that of 12 fueling stations operating in California, 4 stations are publicly accessible, while the other 8 have limited operation and accessibility.

It is anticipated that five hydrogen fueling stations will be completed and come on-line in 2011. These stations, cofunded by the ARB during its 2008-2009 solicitations, are all located in Southern California. Another 11 stations are expected to be completed under Energy Commission funding by late 2012. The *2010-11 Investment Plan* included up to $13 million allocation for hydrogen fueling stations, which has been reduced to $10.2 million due to revenue shortfalls. Based on the 2010 solicitation, the Energy Commission anticipates that this amount should be able to fund five to seven additional stations.

There are two transit hubs in California that own and operate hydrogen-operated buses. SunLine in Thousand Palms and alternating current Transit in Oakland (together with a consortium of five transit agencies around the Bay Area) both also operate hydrogen fueling stations. SunLine has one bus fueling stations, and alternating current Transit's old station in Oakland is closed and will be replaced by a new station in the same location (cofunded by local, state, and federal sources). An additional station is being built by alternating current Transit in Emeryville.

Medium- and heavy-duty applications and other projects use mobile fueling vehicles to supply location-independent demonstrations and fleets. This will likely continue to be an option, also to bridge temporary gaps in fuel supply for such projects that may arise from lack of fueling stations in some state areas. Mobile fuelers are skid-mounted with a tube trailer. These can be easily moved for a greater level of flexibility of location.

Needs Analysis

The Energy Commission is committed to funding projects that support the fueling need for developing hydrogen fueling infrastructure driven by the fueling demand for precommercial FCVs deployed by automakers in California. In June 2010, the Energy Commission released a solicitation for hydrogen fueling stations, resulting in $15.7 million in proposed funding awards for a total of 11 stations: 8 new and 3 upgrades to existing facilities. The stations are strategically located in areas where automakers have committed to significant numbers of fuel cell vehicle deployments over the next three years, with nine of the stations in Southern California and two in Northern California.

This solicitation incorporated automotive and hydrogen producer industry input in its design to achieve the highest cost-efficiency. A key requirement was that the proposed stations had to be backed with location-specific automaker endorsements for vehicle deployments, which allowed the Energy Commission to match demand with supply.

The December 2010 original equipment manufacturer survey for FCV commitment numbers resulted in responses from seven original equipment manufacturers. Table 14 compares these numbers to the 2009 survey results. Although the new numbers are between 23 percent and 44 percent lower than the previous year's (and 11 percent higher for the long-term range 2015-17), the 2012 values are within range of the commitments presented by automakers in letters of commitment in proposals for the 2010 hydrogen fueling station solicitation.

Table 14: 2009 and 2010 Fuel Cell Vehicle Survey

	2011	2012	2013	2014	2015-17
2009 Survey	330	495	769	1,839	47,800
2010 Survey	253	312	430	1,389	53,000
Percent Change	-23%	-37%	-44%	-24%	+11%

Source: California Energy Commission

The geographical distribution of original equipment manufacturer vehicle commitment numbers shows that original equipment manufacturers are concentrating on more on the clusters where the Energy Commission is proposing awards for fueling stations (for example, Orange County, Torrance). Other locations identified in the survey, such as Burbank, are not currently considered key locations by original equipment manufacturers for their FCV deployments.

A thorough analysis and comparison with the 2009-10 gap analysis show that the 11 stations most recently proposed for funding by the Energy Commission will cover a significant amount of fueling demand through 2014. In combination with the five to seven stations that might be funded by the previous investment plan's $10.2 million allocation, this should provide adequate fueling supply the most significant regions identified in the original equipment manufacturer survey through 2014.

However, providing adequate fueling supply to the most significant regions will not, on its own, ensure the successful commercialization of FCVs in the 2015-2017-time frame. Additional state support is needed to build regional fueling networks, ensure a reliable supply of fuel, and establish fueling stations in regions with more modest FCV commitments through 2014.

For FY 2011-2012, the Energy Commission will allocate $8.5 million for hydrogen fueling infrastructure for light-duty vehicles and support of transit projects. Stations funded by this allocation should be on-line by 2014 to help establish a network of fueling stations before commercialization. In addition to the allocations provided through the Energy Commission's program, the state may need to consider broader incentives or regulations to encourage hydrogen fueling station deployment.

In December 2010, the Federal Transit Administration awarded CALSTART $10 million for two projects that will lead to the development of lower cost and more durable zero-emission fuel cell buses. Fuel cell buses improve urban air quality because they produce zero tailpipe emissions while also producing far fewer GHG pollutants. The funding will be used primarily to help leading fuel cell manufacturers improve the performance and lower the costs of their bus technology. The Energy Commission may support this program to help develop Southern California transit hydrogen fueling infrastructure to supply these buses with hydrogen transportation fuel. If so, this funding will come from the $8.5 million in funding for hydrogen fueling infrastructure for FY 2011-2012.

Studies to Support Strategic Infrastructure Planning

The Energy Commission is entering into an interagency agreement with the University of California that will enhance the Spatially and Temporally Resolved Energy and Environmental Tool. This multiyear project will expand an existing model to all of California (previously only the South Coast Air Basin) and to all alternative fuels. It represents UC Irvine's modeling approach for identifying, analyzing, and understanding the interplay among GHG emissions, criteria pollutant emissions, water usage, and other effects resulting from displacing existing transportation fuels and technologies. The work is used to predict environmental and resource usage impacts of current and proposed transportation infrastructure scenarios. Current and past funding sources include United States Department of Energy, Toyota, Air Products, Honda, Nissan, ARB, and the Energy Commission. The Energy Commission is also pursuing an agreement with the National Renewable Energy Laboratory'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 engaged in regarding scenario planning to achieve climate change, petroleum reduction, and state air quality goals.

Recent Improvements to Fueling Infrastructure

Earlier hydrogen fueling stations were built at costs ranging from $3 million to $6 million per station. This relatively high capital cost has been identified as a major hurdle in establishing a viable hydrogen fueling network in California. To address this and encourage equipment providers and project proposers to take steps in lowering the cost, the 2010 solicitation used a "sliding scale" performance incentive mechanism. This tool rewarded projects with a higher share of match funding the lower the overall price tag for each single fueling station was. The successful outcome of the incentive lowered the price range for the proposed stations to about $2 million to $3 million for each station. In general, there are signs of decreasing cost for stations as the industry develops innovative production, distribution, and retail supply strategies that are more cost efficient. For instance, more modular, "all-in one-container" designs as well as shifting some equipment to a central production/filling location instead of at each site can contribute to these decreases.

A similar performance incentive was included in that same solicitation that rewarded project proposals if their station could be built and brought on-line in 18 months or less. This time frame is considerably less than what has been observed in the past to build such stations. Shorter construction times reduce costs and allow the station to reach utility sooner. It also allows for better infrastructure planning in the long run. Much experience has been gained during recent years regarding the permitting processes for hydrogen fueling stations. Local government permitting agencies and fire officials in cities of prospective sites are slowly getting to know the technology better, and their understanding and familiarity have greatly helped accelerate and make these permitting processes easier. Automakers and station builders have done their share in working with local representatives to improve this. Permitting times as short as four to eight months have been reported in some cases.

The solicitation also included a set of minimum requirements. The Energy Commission included a requirement that called for projects to be public access and present a retail-like experience. This was done to improve the experimental character of many current stations to a more precommercial scenario where users had unrestricted drive-up access (including the absence of gates, fences, guards, key codes, or the like) to the fueling dispenser(s). In addition, the station design was supposed to offer most attributes that a typical conventional fueling station offers (such as good lighting, signs, and simple user interface).

Fuel Quality Standards

Through a contract with California Department of Food and Agriculture's Division of Measurement Standards, the Energy Commission is funding activities to develop and establish retail fuel quality standards for hydrogen. For hydrogen, a sound infrastructure is one of the biggest challenges before mass usage of hydrogen vehicles can take place. Offering high-quality fuel will be a key component in the successful deployment of commercial grade hydrogen fuel. Hydrogen fuel must be of the highest quality to provide the best possible vehicle performance, not damage fuel cells, and reward car manufacturers for their investment into new technology. Establishing testing procedures and quality standards for commercially available gaseous hydrogen as a transportation fuel is a critical first step in developing a fair and competitive marketplace in the California hydrogen infrastructure. This will enhance consumer protection, foster fair competition, and promote economic growth and trade. California Department of Food and Agriculture's Division of Measurement Standards will adopt regulations as necessary to incorporate any changes to its hydrogen standards or to clarify existing statute or code.

To further support hydrogen infrastructure development, the Energy Commission funded the California Department of Food and Agriculture's Division of Measurement Standards to develop retail fuel quality standards for hydrogen and a type approval for measuring and dispensing hydrogen for sale in California.[122] The same contract will

[122] A "type approval" is granted to a product that meets a minimum set of regulatory, technical, and safety requirements. Generally, type approval is required before a product is allowed to be sold.

allow California Department of Food and Agriculture's Division of Measurement Standards to prepare the groundwork to establish a standard for the commercial measurement of gaseous hydrogen for vehicles and other refueling applications. This type approval is strongly needed, as there is no regulatory standard established in California for equipment to measure hydrogen transportation fuel for sale on a per-kilogram basis. These efforts will help remove major obstacles to commercialization of hydrogen as a transportation fuel and help develop the fueling infrastructure.

Light-Duty Fuel Cell Vehicles

The benefits of high efficiency, reduced GHG and other criteria emissions, fuel source diversity, and attractive vehicle attributes are the primary motivations for original equipment manufacturers pursuing fuel cell and other electric drive vehicle technologies. In addition, state policy including the ZEV mandate is driving the timing of industry investments. While the current volumes are low, FCVs are expected to move from the current pre-commercial stage to early commercial volumes within the decade. The Energy Commission and the ARB surveyed eight original equipment manufacturers in 2009. The survey was conducted again in 2010, and the results can be seen in Appendix B.

Fuel cell vehicles are the most prevalent vehicle technology that uses hydrogen as a transportation fuel. FCVs produce electricity on board by forcing the hydrogen through a stack of membranes, where it reacts with the oxygen from the air and produces electric power. The vehicle is then powered by electric propulsion using this power. Temporary buffer storage of the electric power aids in increasing efficiency and drivability, thus some FCV are battery-assisted or a type of hybrid. Hydrogen is stored in on-board, pressurized tanks.

Several original equipment manufacturers have FCVs readily available and are planning to build these for lease to selected customers. Toyota announced on January 13, 2011, that it is on schedule to sell hydrogen cars by 2015 or sooner in California, Japan, and Germany. It also announced that it has cut the cost to make hydrogen vehicles to less than $100,000 and aims to cut that cost in half (to $50,000) by the time sales begin.[123]

The ZEV mandate is significantly driving the timing of industry investments. The ARB expects a number of vehicles could be rolled out under ZEV compliance path options and under the LCFS base case scenario. The ARB is evaluating a number of approaches to provide policy incentives to energy companies that 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.

Hydrogen internal combustion engine vehicles are vehicles that combust hydrogen as a gaseous fuel in an internal combustion reciprocating engine similar to a gasoline or natural gas-propelled vehicle. Unlike the FCV, this technology does not use electric

[123] Bloomberg, "Toyota Advances Hydrogen Fuel Cell Plans Amid Industry's Battery-Car Push," http://www.bloomberg.com/news/2011-01-13/toyota-advances-hydrogen-plans-amid-industry-s-battery-car-push.html.

power, but it does include on-board pressurized fuel storage of hydrogen. Hydrogen internal combustion engine vehicles have been tested in California for years, mostly in the five cities project in Southern California where originally 25 Toyota Priuses were converted to hydrogen internal combustion engine vehicle. While some of these cars are still used today and other original equipment manufacturers have experimented with hydrogen internal combustion engine vehicles as well, the technology has been observed as relatively high maintenance and low range. Accordingly, it does not seem likely that hydrogen internal combustion engine vehicle will become the prevalent hydrogen propulsion technology in the near future. There may also be a potential for blending up to 30 percent hydrogen with natural gas, which can reduce emissions and improve operations in trucks, buses and vans.

Stationary Applications

A recent report for the United States Department of Energy 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 includes certain classes of forklifts). 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 multishift 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 support such applications. The U.S. Department of Defense, through the Defense Logistics Agency, has a large fuel cell forklift 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 acknowledges the importance of non-road applications and their potential to further fuel cell technology. In its recent solicitation for hydrogen fueling infrastructure, the Energy Commission did not exclude non-road fueling stations. Such stations were eligible as long as a proposer could present a project that combined non-road fueling with FCV fueling dispenser installations in a multi-use project (and adhere to all other minimum requirements of the solicitation). However, no such project proposals were received.

Table 15: Hydrogen Funding Allocation

Fueling Infrastructure	$8.5 million
Total	$8.5 Million

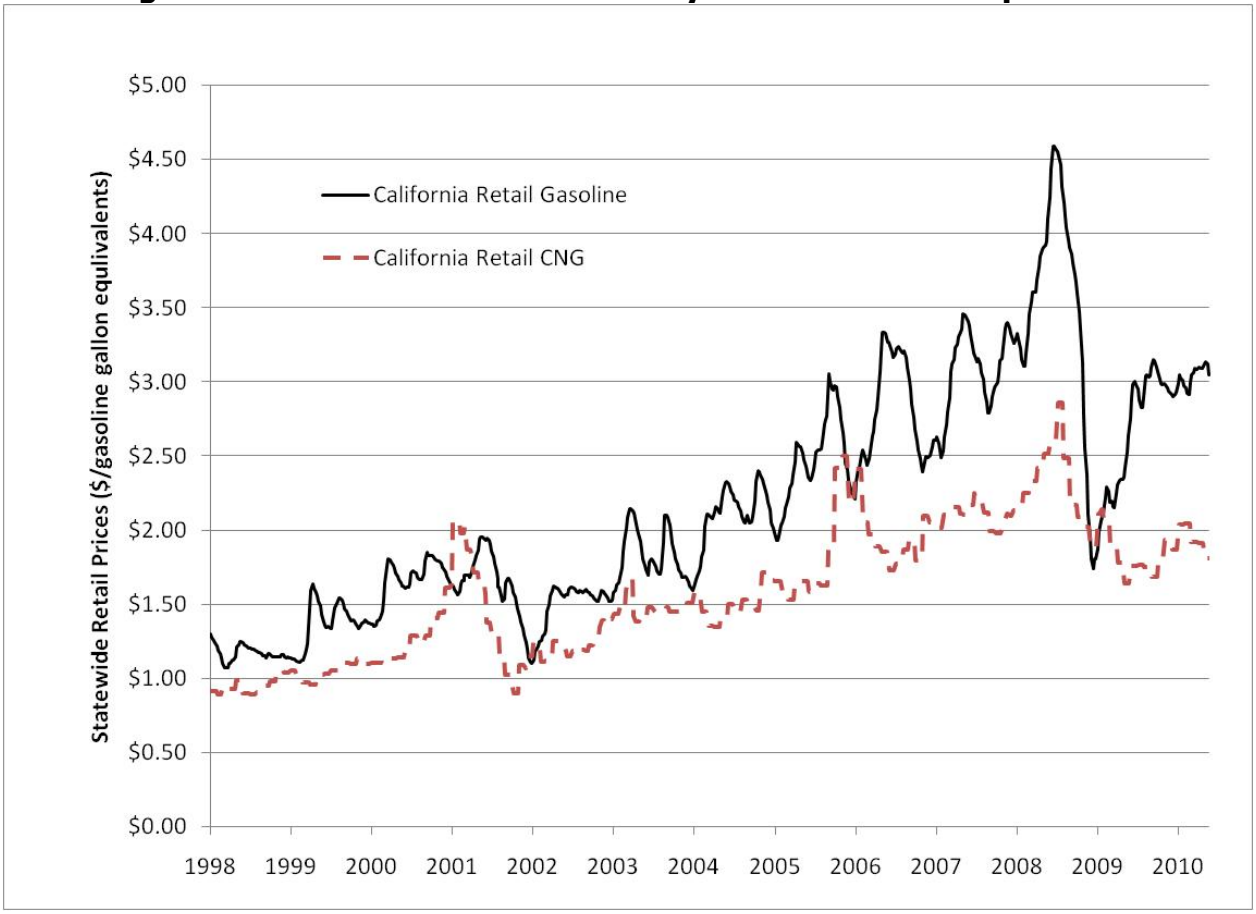
Source: California Energy Commission

Natural Gas

Given its abundant existing supply and distribution infrastructure, natural gas represents a strong opportunity to reduce petroleum dependence and GHG emissions within California. Vehicles operating on compressed natural gas (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 for new diesel vehicle counterparts).[124] Due to the clean-burning properties of natural gas, natural gas vehicles have also been historically favored as a means of reducing criteria air pollutants. Furthermore, because the high-pressure fuel system is sealed, there are little or no evaporative emissions during fueling and use (although there can be some gas release during refueling).

CNG is competitively priced with gasoline and has developed a significantly lower cost than gasoline since early in the previous decade, as shown in Figure 2. The energy efficiency of gasoline vehicles and natural gas vehicles result in comparable mileage per gasoline gallon equivalent.

Figure 2: Gasoline and CNG Prices by Gasoline Gallon Equivalent

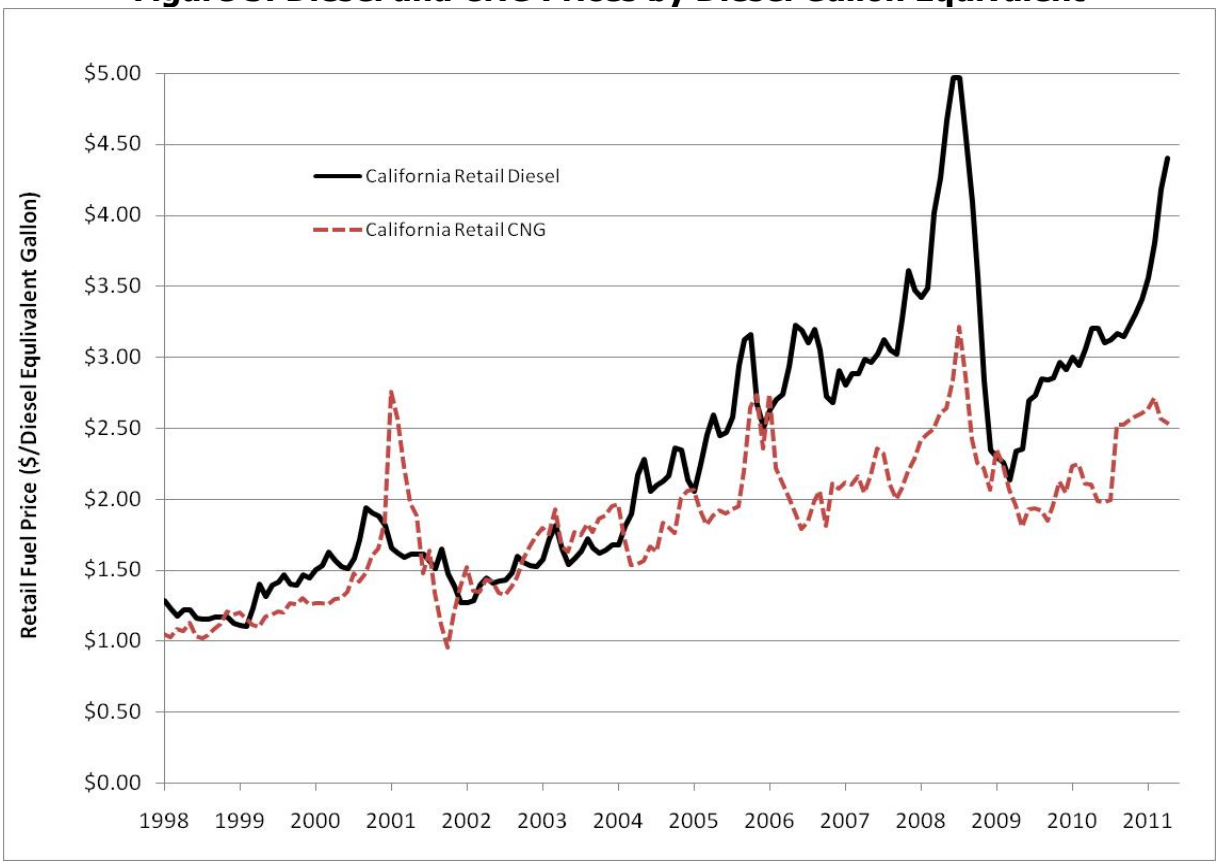


Source: Energy Information Administration, California Energy Commission

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

Figure 3 similarly shows the cost differential between CNG and diesel, on a diesel-gallon-equivalent basis. As shown, the price of a diesel equivalent gallon of CNG has become increasingly lower than the price of a gallon of diesel. However, unlike gasoline vehicles, diesel vehicles possess a slightly higher energy efficiency rate than CNG vehicles. Accordingly, the actual cost per mile traveled by a CNG vehicle might range from zero to 20 percent higher than depicted here.

Figure 3: Diesel and CNG Prices by Diesel Gallon Equivalent



Source: Energy Information Administration, California Energy Commission.

Natural gas has become an increasingly significant fuel in the medium- and heavy-duty vehicle markets. This is discussed in greater detail in the Medium- and Heavy-Duty Vehicle section of the investment plan.

Natural Gas Supply

Natural gas is primarily used as an energy source for space heating and water heating and is a significant resource in the state's electricity generation. The transportation sector accounts for less than 1 percent of natural gas consumption within the United States and California.[125] Estimates of natural gas reserves are expected to increase, as new technologies for extraction are developed and new reserves are located. The

[125] U.S. Energy Information Administration, *California Natural Gas Summary*, http://tonto.eia.doe.gov/dnav/ng/ng_sum_lsum_dcu_SCA_a.htm.

market price of natural gas, which was subject to significant periods of volatility in the previous decade, is expected to stabilize at a level that is significantly competitive with petroleum-derived fuels.[126] Historically, natural gas prices have been pegged to petroleum; this is increasingly no longer the case.

Roughly 87 percent of California's natural gas supply is delivered from outside the state, via five interstate gas pipelines.[127] Additionally, the liquefied natural gas (LNG) facility in Costa Azul, Mexico, is capable of processing up to 1 billion cubic feet per day and could provide additional supply to the California natural gas market. The source of this LNG is likely to be foreign, generally located in Southeast Asia, and transported via tanker ship. However, presently time none of the LNG imported into the United States is allotted for transportation fuel due to costs.[128]

The expansion of natural gas supply to include shale sources has the opportunity to provide an abundance of natural gas, keeping prices moderate. Estimates of shale gas reserves range from 842 trillion cubic feet to 2,240 trillion cubic feet[129,130]. The lower estimate gives a 37-year supply at the present consumption rates. By mid-2008, shale production represented almost 10 percent of production from the lower 48 states, and the Natural Gas Supply Association believes that production from the shales "…could double in the next 10 years and provide one-quarter of the nation's natural gas supply."[131]

A process known as hydraulic fracturing, used by gas producers, accesses natural gas from sources such as coalbeds and shale gas formations. This process involves creating fractures in underground formations to allow natural gas to flow. Water and sand are pumped into the rock formations under high pressure to create fractures. These newly created fractures are then "propped" open by the sand, which allows the natural gas to flow into the wellbore and be collected at the surface.[132] However, there are environmental risks associated with the use of hydraulic fracturing process in the recovery of shale gas. Hydraulic fracturing uses hundreds of thousands of gallons of

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[126] U.S. Energy Information Administration, *Forecasts and Analysis of Energy Data*, http://www.eia.gov/oiaf/forecasting.html.

[127] California Energy Commission, *2009 Integrated Energy Policy Report*, CEC–100–2009–003-CMF.
[128] Phone conservation with Michael L. Eaves, Clean Energy on January 6, 2011.

[129] January 9, 2009, PowerPoint presentation by Mitchell Pratt, Clean Energy.
[130] California Energy Commission, *2009 Integrated Energy Policy Report*, CEC–100–2009–003-CMF.
[131] Natural Gas Supply Association, News Release, October 8, 2008, "Natural Gas from Shale Could Double in Next Ten Years."
[132] Chesapeake Energy, Hydraulic Fracturing Fact Sheet, July 2010.

water treated with chemicals. The volume of chemicals in this water is a source of concern and debate.[133]

Natural Gas Processing

To be transported via pipeline, all-natural gas must conform to pipeline standards and be treated to remove solids, free liquids, and reduce water vapor content to acceptable levels. The treatment process also separates the heavier hydrocarbon components (ethane, propane, and butanes) that can derive higher economic value in the petrochemical feedstock market. Once the natural gas has been sufficiently purified, it enters interstate and intrastate commerce and becomes a fungible commodity.

In addition to its use in natural gas vehicles, natural gas can also be used as an input fuel for the production of other alternative fuels. In particular, natural gas can be converted directly into hydrogen via steam methane reforming. (For more details on this process, see the "Steam Methane Reforming" discussion.) Moreover, methane (whether natural gas or biomethane) can be blended with hydrogen. The advantages of combining natural gas and hydrogen include improved combustion efficiency and significantly smaller energy requirements for ignition.

Upstream Fuel Infrastructure

The most significant aspect in upstream infrastructure for natural gas is the network of interstate and intrastate pipelines. As mentioned, more than 87 percent of California's natural gas supply arrives from a combination of five interstate pipelines, with the remainder delivered strictly within the intrastate pipelines. Given the miniscule amount of natural gas used in California for transportation, increasing the amount of natural gas required within California for transportation is unlikely to have a significant effect on this network.[134] However, the Energy Commission will continue coordinate with other western state agencies on developing a natural gas transmission and storage system that can overcome any periodic disruptions in supply and reliability.[135]

Aside from supply and reliability issues, there are issues of natural gas purity standards that may affect natural gas for transportation. This has been a particularly sensitive issue for natural gas produced in California's coastal regions and the lower San Joaquin Valley. The ARB is responsible for adopting quality standards for natural gas used in vehicle engines, while the California Public Utilities Commission is responsible for quality standards in the natural gas pipeline. North American pipeline gas generally meets ARB specifications, but roughly 8 percent of in-state pipeline gas does not. To address these discrepancies, the ARB is evaluating potential changes to its CNG specifications,

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[133] As an example, see guidelines developed by New York for the use and disposal of water, the protection of groundwater, and the use of chemicals. Department of Environmental Conservation, New York State, *Final Scope for Draft Supplemental Generic Environmental Impact Statement on the Oil, Gas and Solution Mining Regulatory Program*, February 2009.
[134] Department of Energy, "California Natural Gas Summary," http://www.eia.doe.gov/dnav/ng/ng_sum_lsum_dcu_SCA_a.htm.
[135] California Energy Commission, *2009 Integrated Energy Policy Report*, CEC–100–2009–003-CMF.

including the use of new performance indicators, such as a methane number or Wobbe Index.[136]

Natural gas, when used for transportation purposes, may also require extra treating to remove solids and free liquids and reduce water vapor content to acceptable levels. Once sufficiently treated, the natural gas is can be compressed into CNG, which compresses pipeline natural gas to less than 1 percent of its standard volume. CNG is then used either by vehicles on-site or distributed to local fleet and retail fueling stations via delivery trucks. Alternatively, natural gas can be liquefied into LNG, which reduces the volume (but not the energy content) of CNG by half. This makes LNG more efficient to distribute over long distances to where pipelines may not exist (often by ship, rail, or truck). However, this liquefying process consumes additional energy, which results in higher well-to-wheel GHG emissions from LNG (83.1 grams of CO_2-equivalent per megajoule) when compared to CNG (68.0 grams of CO_2-equivalent per megajoule).

Biomethane

Methane derived from renewable resources, also known as biomethane, can be integrated into the upstream natural gas fuel infrastructure supply chain. The most direct application is to inject biomethane directly into the natural gas pipeline. However, there are a number of barriers to this approach. Expensive gas quality testing and interconnection fees, as well as different gas quality requirements among utilities, represent the first significant obstacle. Additionally, existing law effectively restricts biomethane derived from landfill gases to be injected into the natural gas pipeline.[137] Finally, a biomethane producer must be located close to the natural gas pipeline.

Alternatively, biomethane can be combined with gas from the pipeline for direct conversion into CNG or LNG. Biomethane can also be kept separate from natural gas and be compressed or liquefied for use as pure, low-carbon fuel. This is particularly applicable in situations where the supply of biomethane is colocated with the demand for natural gas as a transportation fuel, such as dairy farm vehicles or waste management fleets. For example, the Energy Commission is funding a grant for Northstate Rendering to produce biomethane from rendering waste, which will be compressed and supplied to an on-location fueling station, which serves a fleet of local trucks.

The use of biomethane as a low-carbon substitute for transportation natural gas is only one possible use for biomethane. Other opportunities include the use of biomethane for the production of renewable hydrogen, for reducing the lifecycle carbon intensity of other biofuels, or for use in generating renewable electricity (whether for use in the transportation sector or other sectors). All of these applications help reduce GHG emissions and fossil fuel dependence and would help the state meet a number of its

[136] California Air Resources Board, *Compressed Natural Gas (CNG) Motor Vehicle Fuel Specifications*, May 19, 2010.
[137] Assembly Bill 4037 (Hayden Chapter 932, Statutes of 1988).

climate and energy policies. Biomethane production is discussed in greater detail in the "Biofuels" section of the investment plan.

Retail and Fleet Fueling Infrastructure

One of the primary barriers to the penetration of natural gas vehicles is the lack of available fueling infrastructure. Until this problem is addressed, the use of natural gas vehicles will likely be confined to medium- and heavy-duty vehicles, which can use CNG/LNG stations on a regular route.

Fueling infrastructure for natural gas vehicles in California includes a combination of public and/or private access, CNG and/or LNG dispensing, and fast fill or time fill for CNG dispensing.[138] The number of stations is presented in Table 16.

Table 16: Natural Gas Fueling Stations

	Publicly Accessible Stations	**Private Access Stations**
CNG	140	424
LNG	13	19

Source: California Natural Gas Vehicle Coalition, United States Department of Energy Alternative Fuels and Advanced Vehicles Data Center

Home refueling options for natural gas also exist, primarily for the light-duty vehicle market. These homes refueling stations typically have a long refill time (up to 10 hours). An example of this technology used in the United States is the "PHILL" Fuelmaker, which compresses natural gas from a standard utility gas line for use in a CNG vehicle. The new PHILL unit is expected be ready for production and sale in North America within the next several months,[139] making home refueling more accessible for natural gas vehicle owners.

Table 17 presents Energy Commission estimates of current natural gas infrastructure costs, based on the station's size (measured in standard cubic feet per minute for CNG and gallon capacity for LNG). All of the prices for CNG stations are presumed to include fast fill dispensers, which may not be necessary for certain applications (such as those that return to a designated station overnight). To reduce these estimated station costs, the federal government offers a tax credit for up to 30 percent of the cost, not to exceed $30,000, if the station is installed in 2011.

[138] Fast fill and time fill refer to the speed at which a natural gas vehicle is refueled. Fast fill dispensers can perform a complete fill within several minutes. Time fill dispensers require several hours, often overnight. However, fast fill dispensers require more expensive equipment and maintenance. Fast fill dispensers are the only practical type of dispensers for public retail fueling stations, which necessarily serve multiple vehicles each day. However, time fill stations are expected to be more economical for dedicated fleet users.

[139] Phone conservation with Michael Eaves, Clean Energy, on January 6, 2011.

Table 17: Natural Gas Infrastructure Costs

Infrastructure Type	Estimated Cost Range[140]
Small CNG Station (≤ 500 standard cubic feet per minute)	$600,000 - $1,500,000
Medium CNG Station (500-2,000 standard cubic feet per minute)	$1,200,000 - $3,500,000
Large CNG Station (≥ 2,000 standard cubic feet per minute)	$3,000,000 - $5,000,000
Large LNG Station (≥ 15,000 gallons storage capacity) With Combined CNG dispensing	$1,000,000 - $2,200,000
Home Fueling	$3,600[141]

Source: Gladstein, Neandross & Associates, California Energy Commission

Self-contained dispensing systems, such as the Galileo Nanobox, also offer the option to provide small fuel dispensers at existing fuel stations. This significantly reduces the cost of new natural gas fueling infrastructure by using existing land, concrete infrastructure, and canopies.

The Energy Commission has invested $5,741,388 for the installation of 20 new stations or upgrades to existing stations across the state; 16 CNG stations, 3 LNG stations, and 1 combination station. Some of these stations include multiple dispensers at the same site. Each of these installations was targeted to match the fueling needs of particular fleets and natural gas customers.

Discussions with vehicle manufacturers, fuel providers, local air districts, and other program stakeholders revealed that additional investment in natural gas infrastructure is critical to the adoption of natural gas vehicles and market transformation for this alternative fuel.[142] Seed money for regional planning for natural gas fueling infrastructure may also be needed.[143] Fuel accessibility is one of the key considerations for fleet managers for the purchase of natural gas vehicles. Increased demand for clean fuel alternatives to gasoline and diesel along with regulatory requirements, such as the South Coast Air Quality Management District Fleet Rule, has driven an increase in natural gas infrastructure by private investors.

The combination of CNG and LNG dispensing at a single station is particularly attractive because LNG can be vaporized and pressurized into CNG with conventional pumps using less energy than it takes to compress pipeline gas into CNG. These stations also allow the station owner to serve different markets using much of the same support equipment, such as canopy and pavement, without a significant difference in the cost of

[140] Estimates based on submitted proposals as well as discussions with industry representatives.
[141] *Consumers Reports*, March 2008, "Review of the 2008 Honda GX."
[142] Industry meetings with Freightliner, Kenworth, Navistar, Westport, December 2010 – January 2011.

[143] Comments submitted by the California Center for Sustainable Energy, Energy Commission Docket Number 10-ALT-1, June 3, 2011.

the station. These combination stations also support the corridor approach to refueling, making CNG and LNG available along major goods movement corridors to support regional and interstate trucking operations. These corridors typically run through areas with the worst air pollution, making a stronger case for fueling infrastructure to support cleaner vehicle technologies.

Industry and government strongly support the corridor refueling concept. The Interstate Clean Transportation Corridor project, supported by the United States Department of Energy, employs public and private partnerships to expand alternative fuel vehicle use and refueling station access throughout the Western United States.[144] The Interstate Clean Transportation Corridor project has successfully developed 23 natural gas refueling stations in California and Nevada. The Interstate Clean Transportation Corridor project continues to work to build a sustainable corridor of LNG refueling stations along the I-15, I-80, and I-5 corridors connecting Southern California, Salt Lake City, and Northern California to support the movement of goods by alternative fuel heavy-duty trucks throughout the Western United States. Several of the stations proposed for funding by the Energy Commission will directly support corridor refueling along I-10, I-5, SR-99, and other in-state goods movement corridors.

Recent federal funding further demonstrates government and industry support to expand refueling infrastructure along goods movement corridors. One example of many is the United States Department of Energy's award of nearly $5.6 million for an LNG station in Las Vegas, Nevada, that will provide a 700-mile LNG fueling corridor along one of the nation's most heavily traveled truck routes for the movement of various goods.[145]

The aging stations and equipment in California do not meet today's fleet refueling needs. Many fleets involved in goods movement are concerned with the bottom line, which, in part, depends on the reliability of fueling equipment and time it takes to refuel their fleets. In the *2010-11 Investment Plan*, the Energy Commission dedicated $2 million to natural gas station upgrades for public fleets, particularly school districts and local governments. While the Energy Commission has not yet issued a solicitation for this allocation, this funding will likely be substantially oversubscribed based on conversations with managers of existing stations, especially those serving school district bus fleets and growing transit fleets.

Recognizing that market transformation for natural gas will occur only when range anxiety and fleet fueling operations are addressed, the Energy Commission proposes an allocation of $8 million to support the installation of new natural gas fueling infrastructure and upgrades to existing infrastructure. This funding will be closely tied toward identifiable needs in LNG and CNG fueling infrastructure, focusing primarily on

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[144] Interstate Clean Transportation Corridor, "About the Interstate Clean Transportation Corridor," http://ictc.gladstein.org/aboutictc.html.
[145] Department of Energy, "Secretary Chu Announces Nearly $300 Million in Clean Cities Grants to Support Clean Fuels, Vehicles, and Infrastructure Development," http://www.energy.gov/7843.htm.

long-haul LNG goods movement corridors and pairing new CNG stations with high-volume fleets that make a concerted effort to convert from diesel to CNG. Based the Energy Commission's cost share for the 20 natural gas station projects funded from the infrastructure solicitation, this funding will support roughly 30 new stations and/or existing station upgrades.

Light-Duty Vehicles

In 2009, there were 36,100 natural gas vehicles of all sizes registered in California. Of these, light-duty vehicles represent 69 percent of the total natural gas vehicle population but consume only 12 percent of the natural gas fuel used as vehicle fuel. At present, Honda is the only original equipment manufacturer that offers a light-duty passenger natural gas sedan. The Honda Civic GX is comparable to the conventionally fueled Honda Civic LX but possesses a maximum vehicle range of 225-250 miles on a full tank, with a fuel tank capacity of about eight GGEs. Interest in the Civic GX has increased notably in recent months. In 2011, the number of these vehicles sold through April was triple the number sold during that period in the previous year.[146] A redesigned version of the vehicle, renamed the Civic Natural Gas, will launch in Fall 2011. In 2010, General Motors announced that it would begin offering natural gas versions of cargo and shuttle van models (Chevrolet Express and General Motors Savanna), intended for commercial fleets. Chrysler and Fiat jointly plan to develop natural gas vehicles for the U.S. market, beginning in 2017.[147] Worldwide, the market for natural gas vehicles is much wider. General Motors alone, mainly through its Opel subsidiary, offers 18 natural gas vehicle models for the world market, and may soon offer these models for California fleets and individuals.[148]

In addition to original equipment manufacturer models, some companies offer conversions to natural gas. 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 converted vehicles and engines have been evaluated and certified by the ARB. Two firms (Baytech and BAF) have ARB certification to convert light-duty conventional vehicles to light-duty-dedicated natural gas vehicles. Baytech offers various General Motors light- and medium-duty vehicles on an aftermarket basis (including pickups, vans, and cutaways). BAF offers natural gas versions of the Ford Crown Victoria and Ford Connect Transit, as well as E-series passenger cargo vans and

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[146] Los Angeles Times, "Rising Gasoline Prices Fuel the Growing Appeal of Compressed Natural Gas Vehicles," http://articles.latimes.com/2011/may/04/business/la-fi-autos-natural-gas-20110505.
[147] Bloomberg, "Chrysler Will Start Selling Natural-Gas Vehicles in U.S. Market by 2017," http://www.bloomberg.com/news/2011-04-12/chrysler-plans-to-introduce-natural-gas-powered-vehicles-in-u-s-by-2017.html.

[148] Comments submitted by the California Natural Gas Vehicle Coalition, Energy Commission Docket Number 08-ALT-1, January 23, 2009.

F-series pickup trucks.[149] Among these, the Ford Connect Transit is rapidly expanding into the taxi fleet market, with nearly 120 natural gas vehicles entering Los Angeles taxi fleets alone by the end of 2011.[150] Additional firms, such as Natural Drive and Altech-Eco, have obtained emissions certification from the U.S. Environmental Protection Agency for certain dedicated and bi-fuel vehicle conversions, but have not obtained full certification from the ARB.[151] In 2007, California-based IMPCO sold about 13,000 natural gas and propane conversion kits per month to the world market, but none in California, primarily due to the expense required to comply with current ARB certification.[152]

Initial vehicle costs remain a significant issue for the light-duty natural gas vehicle market. The incremental cost for original equipment manufacturers' natural gas vehicle offerings ranges from roughly $6,900 for the Civic GX[153] to $15,910 for the Chevrolet Express and GMC Savanna. These incremental costs are roughly in line with the cost of converting a conventional pick-up truck to natural gas, about $15,500.[154] A federal tax credit for the purchase of light-duty original equipment manufacturer natural gas vehicles and for the conversion of light-duty vehicles to natural gas expired at the end of 2010, leaving customers with a high initial vehicle cost. As natural gas prices are lower than gasoline, owners of these vehicles can expect to recoup some of this initial cost difference. The federal fuel excise tax credit, currently extended through 2011, offers consumers an additional $0.50 per GGE.[155] Additionally, most dedicated natural gas vehicles will be permitted single-occupant access into California's high occupancy vehicle lanes through January 1, 2015, while access for many hybrid electric vehicles ended in July 2011.[156] This change will encourage additional commuters to consider natural gas vehicles as an attractive alternative to conventional gasoline and diesel vehicles.

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[149] Natural Gas Vehicle America, *Guide to Available Natural Gas Vehicles and Engines*, http://www.ngvamerica.org/pdfs/marketplace/MP.Analyses.NGVs-a.pdf

[150] Ford Motor Company, "A Taxi Trend: Ford Transit Connect Compressed Natural Gas Taxis Heading to Los Angeles and Chicago," http://corporate.ford.com/news-center/news/press-releases/press-releases-detail/pr-a-taxi-trend2658-ford-transit-34802

[151] Natural Gas Vehicle Global News, January 29, 2010. Confirmed by Seong Kim of ARB.

[152] Presentation by Tim Standke, IMPCO, on September 18, 2009.

[153] E-mail from Tim Carmichael, California Natural Gas Vehicle Coalition, dated June 6, 2011.

[154] E-mail from Matt Weiss, Natural Gas Vehicle America, dated December 14, 2010. E-mail from Tom Sheehan, Natural Gas Vehicle America, dated December 14, 2010.

[155] U.S. Department of Energy, "Federal Incentives and Laws for Natural Gas," http://www.afdc.energy.gov/afdc/laws/laws/US/tech/3253.

[156] CalEPA, "Eligible Vehicles - Single Occupant Carpool Lane Use Stickers," http://www.arb.ca.gov/msprog/carpool/carpool.htm.

In April 2011, the Energy Commission offered vehicle buydown incentives for natural gas vehicles and propane vehicles. This included $3,000 in incentives for light-duty natural gas vehicles. The program is intended to accelerate the deployment of currently offered natural gas vehicles, and to encourage original equipment manufacturers to expand their natural gas vehicle offerings. As of June 1, 2011, the Energy Commission made 142 incentive reservations for light-duty natural gas vehicles, at a total cost of $426,000. None of these reservations, however, were from Honda or General Motors dealers. This suggests that higher numbers of reservations may be yet to come with the change to a new model year. In order to further support the expanded availability and deployment of light-duty natural gas vehicles, the Energy Commission will continue to provide vehicle incentives. Funding for these vehicles' incentives will draw from the $12 million allocated for medium- and heavy-duty natural gas vehicle deployment (see the Medium- and Heavy-Duty Vehicles section).

Table 18: Natural Gas Funding Allocation

Fueling Infrastructure	$8 Million
Total	$8 Million

Source: California Energy Commission

Propane

Propane can offer significant and immediate petroleum use reductions and moderate GHG emission reductions. Currently, propane can be produced as a by-product of either natural gas processing or petroleum refining; however, current research is showing promise in the production of propane from renewable resources. According to the Western Propane Gas Association, California consumed about 620 million gallons of odorized propane in 2008, and 70 million to 80 million gallons of this consumption was used specifically for on- and off-road vehicles.

Propane is very attractive in terms of pricing compared to both diesel and petroleum, and if federal excise tax credits for propane use continue to be made available in the future, propane will be a viable option for fleets. According to the United States Department of Energy, the average cost for propane is $2.69 per gallon.[157] The federal government also offers a fuel use tax credit of $0.50 per gallon-gallon equivalent, which acts as an incentive to propane users to offset the energy loss with the use of propane in vehicles. Propane's energy content is about 25 percent less than gasoline. Even with the energy loss, propane's price remains attractive to fleets as an alternative fuel option.

Upstream Fuel Infrastructure

About 570 million gallons of propane are produced annually in California. Of this, about 430 million gallons of this propane come from refinery production, and the remainder comes from natural gas plant production. The refinery propane production numbers

[157] As of July 2009, according to U.S. DOE ERRE Price report. Does not include excise tax credit.

have varied slightly in recent years, but not significantly. This is a result of the refinery runs of crude oil. Propane sourced from natural gas plants continues a modest decline, although new natural gas fields in the San Joaquin Valley have yet to come into production. The supply source is typically a function of price, rail car transportation costs, rail car availability, and contract provisions. Gradual demand increases in the propane autogas market can be easily accommodated by increased imports or shifting indigenous supply from declining markets to growing ones.[158]

From the refinery or processing plant, propane is shipped in two stages—first, to an intermediate terminal and from there to the local propane supplier for delivery to the end user. All propane is transported under pressure in its more compact liquid form. Propane is mainly transported via a pipeline and truck combination but can also be transported via rail in steel cylinders. Because there are no pipelines into or out of California that carry propane as a finished product, the area relies on imports mostly by rail car.

Two types of trucks are used for propane transportation: a highway transport (which typically carries 7,000 to 12,000 gallons) and a smaller bulk delivery truck, called a "bobtail" (which carries 1,000 to 5,000+ gallons). Both types of trucks are constructed of high-strength steel.[159]

About 60 percent of propane used in California is produced in California refineries, while the rest of the propane imported typically comes from Texas, the Midwest, Utah, Washington, and Canada. While a majority of the propane used in California is domestically produced, this number can vary depending on seasons. California tends to be a net exporter in the summer, while the amount of propane it imports in the winter can increase significantly if California has an especially cold winter.

The Energy Commission is also following the development of biopropane for vehicles. Renewable propane can be derived from feedstocks such as sugarcane and corn. The derivation of renewable propane requires little additional energy use and results in a product that contains the same energy content as propane derived from petroleum. As indicated in a report by the Gas Technology Institute's report, prepared for the Propane Education and Research Council, significant quantities of bio-LPG could be ready for use in the next 5 to 10 years.[160] Additionally, bio-DME is being used as a blendstock for propane and is being tested in various demonstration projects in California, including the Port of Long Beach. This could provide a further emission reduction benefit while effectively using the existing propane supply.

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[158] E-mail from Lesley Garland, Western Propane Gas Association, April 25, 2011.
[159] National Propane Gas Association Propane, "Facts About Propane," http://www.npga.org/files/public/Facts_About_Propane.pdf.
[160] Gas Technology Institute, *Expert Analysis of the Concept of Synthetic and/or Bio-LPG*, February 19, 2010, http://staging.propanecouncil.org/WorkArea/DownloadAsset.aspx?id=3955.

Local Fuel Infrastructure

Propane retail infrastructure is already widely available and can easily be expanded as demand for propane as a transportation fuel increases. There are about 228 propane fueling stations already in place for vehicles in California, according to the United States Department of Energy's Alternative Fuel and Advanced Vehicle Data Center. California has the second largest number of accessible propane fueling stations for vehicles in the nation, which can already support an expanded vehicle market with funding for light- and medium-duty vehicles.[161] 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 California can be retrofitted to meet a propane vehicle's needs. Additionally, many fuel suppliers have indicated that they are willing to enter into a contract to install fueling equipment and stations for propane fleets at no charge, given the fleet has a minimum monthly throughput. This will promote the increasing demand for propane as a transportation fuel in the years ahead.

Due to its low cost and ease of installation, a minimal amount of funding is needed to support propane infrastructure. Based on information contained in applications for the DOE's Clean Cities program, coupled with propane working group information, the Energy Commission estimates that the cost of a fueling station is $35,000 to $50,000 for a 2,000-gallon storage tank, and $75,000 to $150,000 for a 30,000-gallon tank, including four dispensers. Additionally, federal incentives already offer a sufficient support for propane infrastructure, as indicated in Table 19.

Table 19: Propane Infrastructure Summary

Current Stations in California	**228**
Station Costs	2,000-gallon storage tank: $35,000-$50,000 30,000-gallon storage tank: $75,000-$150,000 Station equipment upgrades: $2,000
Federal Incentives	Up to 30 percent or $30,000 of infrastructure installation costs for stations installed after January 1, 2011

Source: California Energy Commission.

The Energy Commission intends to support the Northern California sector pilot project for regional use of propane autogas. This funding would cover the cost of about 10 stations along the I-5 corridor in Northern California. This funding supports a larger effort to launch a pilot project in Northern California that integrates vehicle deployment, infrastructure development, and workforce development for the alternative fuel

[161] Department of Energy, "Alternative Fueling Station Total Counts by State and Fuel Type," http://www.afdc.energy.gov/afdc/fuels/stations_counts.html.

industry. Propane is considered the most viable option for alternative fuel market development in Northern California, where propane is easily accessible. This pilot project will also serve as a model for the benefits propane as autogas can have in rural communities with limited access to other alternative fuels. For this purpose, the Energy Commission allocates $500,000 for propane fueling infrastructure.

Light-Duty Vehicles

Currently, there are four light-duty vehicles certified by the United States Environmental Protection Agency and ARB. Roush has certification for the propane F-150 and F-250 trucks, as well as the E-150, and 250 cutaway vans, which have been attracting interest from several fleet owners including Time Warner, PrimeTime, ThyssenKrupp, and Direct TV.[162]

The incremental cost for purchasing a light-duty propane vehicle ranges from $7,500 to $10,400. Roush anticipates that a $3,500-per-vehicle incentive is needed to generate sales and stimulate the growth of the light-duty propane market.[163] Nonetheless, fleet owners have expressed interest in using propane as an alternative to gasoline due to its cost and availability.

With the emergence of new propane vehicles in 2010 and 2011, there is an increased interest in using light-duty vehicles as part of delivery, airport, and utility fleets. Given the new models, current propane fuel pricing, and reasonable buydown costs for these vehicles, funding availability for these vehicles 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. 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 reducing GHG emissions in the transportation sector.

Manufacturers indicate that funding in the form of vehicle incentives in the first few years is critical to the growth of the propane vehicle market in California. Propane can play an especially significant role in rural communities, which may not have the option of using other alternative fuel vehicles due to the lack of infrastructure. Propane is readily available in most rural communities in California already, and the cost of installing either an entire station or the appropriate fueling equipment for autogas use is very affordable. As the market grows in California, manufacturers anticipate that the need for funding support will decrease by about 20 percent each year.

Roush estimates that covering about 30-35 percent of the incremental vehicles cost is sufficient to stimulate propane vehicle sales. Considering the funding available for propane vehicles through the Energy Commission's anticipated gaseous fuel incentive

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[162] Meeting with Todd Mouw, Roush, January 5, 2011.
[163] E-mail from Todd Mouw, Roush, September 8, 2009.

program for $3 million in 2011, along with incentives for vehicles being offered through the Western Propane Gas Association through August 2011, it is anticipated that these funds will be sufficient to cover expected vehicles through 2011. For expected vehicles sales through June 2012, the Energy Commission intends to allocate $1 million to support the growth of the light-duty propane vehicle market in California.

Table 20: Propane Funding Allocation

Fueling Infrastructure	$0.5 Million
Light-Duty Vehicle Incentives	$1 Million
Total	$1.5 Million

Source: California Energy Commission

Biofuels

Feedstocks

There is a broad variety in the feedstocks available for alternative and renewable fuels. For this investment plan, these feedstocks are divided into two categories: waste-based and purpose-grown. For each feedstock, common characteristics are addressed, such as volume, sustainability, carbon intensity, market potential, and likely fuel pathway. By identifying and contrasting these characteristics, the Energy Commission can weigh the relative advantages and disadvantages of each feedstock.

Most biofuels used in California continue to be derived from purpose-grown feedstocks such as corn and soy. Internationally, oil palm and sugarcane predominate as biofuel feedstocks. All four of these major feedstocks can be grown economically at industrial scales, yet all create serious sustainability concerns. The Energy Commission seeks to identify and promote alternative biomass-based feedstocks that can serve as the basis for liquid and gaseous fuels for California's transportation sector. Most waste-based and alternative feedstocks face substantial challenges and barriers to market entry; high costs, uncertain supplies, and not yet commercially viable process technologies prevent waste-based feedstocks and alternative feedstocks from forming a larger basis in California's alternative fuels markets. This year's investment plan investigates waste-based and alternative feedstocks in more detail than in previous years to understand their potential and market barriers and identify specific opportunities to advance their development through program funding. This enhanced investigation also complements Energy Commission work to review and update the *Bioenergy Action Plan*.

Waste-Based Feedstocks

This category includes feedstocks that can be used as a source of transportation fuel but would otherwise need to be landfilled or disposed of in some other way. California's robust agricultural and food processing sectors generate large volumes of biomass-based waste material that is potentially suitable for low-carbon alternative fuel production. Landfills, urban transfer stations, and wastewater treatment plants also generate high volumes of waste materials with similar potential. These waste-based feedstocks avoid difficult issues, such as the use of high productivity arable lands for

fuel production, sustainability, or indirect land use effects. These feedstocks also foster some of the highest GHG emission reductions. For these reasons, the Energy Commission is particularly interested in expanding the use of waste-based feedstocks, such as those identified below, in the creation of alternative and renewable transportation fuel. The volumes in millions of bone-dry tons and fuel potential for these feedstocks are summarized in Table 21.

Table 21: Waste-Based Feedstock Volumes and Fuel Potential

Feedstock	**Volume Technically Available**[164]	**Biomethane Potential (billion cubic feet)**	**Biofuel Potential**[165] **(million gge)**	**Diesel Gallon Equivalent Potential (million)**
Agricultural Residue	4.3 M bone-dry tonnes	9.3[166]	302	261
Animal Manure	3.8 M bone-dry tonnes	14.6	127	110[167]
Fats, Oils and Greases	14.4 M lbs	Unknown	63.6	55
Food Wastes	0.8 M bone-dry tonnes	1.9[168]	56	48
Forest Biomass Waste (via cellulosic ethanol)	14.2 M bone-dry tonnes	N/A	784[169]	678
Forest Biomass Waste (via gasification)	14.2 M bone-dry tonnes	30.7[170]	1,000	864

[164] Technical potential accounts for residues needed to maintain soil fertility and tilth or for erosion control purposes. There are a number of technical and social constraints that can limit the amount of biomass that can be sustainably collected.
[165] California Biomass Collaborative, *California Biomass and Biofuels Production Potential*, December 2007. Assumes thermochemical process of gasification followed by Fischer-Tropsch synthesis. Does not assume any constraint for moisture content. Unless otherwise noted, 27 million bone-dry tonnes yields 1.9 billion gge.
[166] Ken Krich, *Biomethane from Dairy Waste: A Sourcebook for the Production and Use of Renewable Natural Gas in California*, July 2005. Assumes 2.4 million bone-dry tonnes of agricultural residues yields 5.2 billion cubic feet of methane.
[167] California Biomass Collaborative, 2008.
[168] Ken Krich, July 2005. Includes meat processing waste, cheese whey, and food processing waste.
[169] Brian Hunt, "Woodwaste to Ethanol: A Second-Generation of Ethanol Process." Presented at Ethanol Policy Forum, October 24, 2008. Current technology has proven 1 BDT of wood waste to yield 45 gallons of ethanol, but a yield of 80 gallons of ethanol may be possible.
[170] Assumes same conversion ratio used for agricultural residues.

Feedstock	Volume Technically Available[164]	Biomethane Potential (billion cubic feet)	Biofuel Potential[165] (million gge)	Diesel Gallon Equivalent Potential (million)
Landfill Gas	79 billion cubic feet	39.5[171]	368	318
Municipal Solid Waste	16 M bone-dry tonnes [172]	41.4	1,126	972
Wastewater Treatment Plants	9.6 billion cubic feet	4.8	45	39
Total[173]		142.2	3,088	2,667

Source: Multiple sources, see footnotes

Agricultural Residue

A large source of available biomass in California will come from agricultural residues. Agricultural residues can be processed using a variety of technologies, producing process heat, electricity, and/or transportation fuel as an end product. When looking at the transportation sector, agricultural residues are often processed using technologies including, but not limited to, gasification, anaerobic digestion, fermentation, and hydrolysis to produce either liquid or gaseous transportation fuels such as hydrogen, biogas, and cellulosic ethanol.

Primarily composed of orchard and vine, field and seed, and vegetable residues, agricultural residues will most likely be sourced from the Central Valley as well as the coastal and southern valleys.[174] With California having 9.15 million acres of crops planted in 2007, there is a gross potential of 8.7 million bone-dry tonnes per year and a technical potential of 4.3 million bone-dry tonnes per year of agricultural residues available for conversion to energy.[175] Based on the technical potential, this is enough to produce 220 million gasoline gas equivalents annually through 2020.[176] The GHG reduction when using agricultural wastes as a feedstock can vary significantly

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[171] Assumes 50 percent methane content.
[172] Comments submitted by CalRecycle, Energy Commission Docket Number 10-ALT-1, May 20, 2011.

[173] Assumes forest biomass converted using gasification process.
[174] California Biomass Collaborative, *Biomass Resource Assessment for California*, 2007.

[175] Ibid. Technical potential accounts for residues needed to maintain soil fertility and tilth or for erosion control purposes. There are a number of technical and social constraints that can limit the amount of biomass that can be sustainably used.
[176] *Draft Bioenergy Action Plan*, 2010. Number found in *Bioenergy Action Plan* reduced to exclude animal manure and food processing.

depending on the feedstock characteristics, conversion technology, and fuel produced; however, reductions can potentially be significant – around 80 percent for cellulosic technologies and in the mid 80s for some anaerobic digestion processes.[177] Also, because agricultural residues are classified as a waste stream, they could be considered highly sustainable when collected and processed sustainably.

The Energy Commission proposed nearly $1.5 million in funding for the Advanced Bioenergy Center Mendota. This project integrates four technologies in one facility to produce advanced ethanol, renewable biomethane, compost and fertilizer, and green e-electricity, using sugar beets and almond prunings as feedstocks. Once this project is complete, it will convert an estimated 80,000 tons of almond prunings to produce 6.3 megawatts of renewable electricity.

Some of the most difficult components to navigate when considering using agricultural residues as a feedstock are collection, transport, and storage. Collecting and transporting waste residues can be costly and could jeopardize the economic feasibility of a project. A key to reducing transport costs is to locate production facilities as close to feedstock sources as possible, preferably within 50 to 100 miles.[178] Although transporting feedstock using rail or barge are options, often these residues are transported by truck as it allows for the greatest amount of flexibility. The cost of transporting via truck can range from $0.12 to $0.23 per ton-mile and depends heavily on the price of diesel.[179] Another factor to consider is the seasonality of agricultural production. Crops are seasonal, and production facilities will have to adjust to feedstock supplies through either a variety of crop residues or expanded storage capabilities.[180]

Animal Manure

Animal manure is an optimal feedstock for producing energy or biofuels because it is a waste stream available in California. California's agricultural animal population is close to 70 million, the majority being poultry and cattle.[181] The manure these animals generate has a gross potential of more than 11 million bone-dry tonnes per year and a technical potential of 3.8 million bone-dry tonnes per year.[182] Anaerobic digestion of animal manure creates biogas, which has a potential of 14.6 billion cubic feet billion cubic feet or 110 million diesel gas equivalents.[183] The biogas can be cleaned and used as biomethane, or burned to generate heat or electricity.

If the manure is kept on the farm, it can be collected by flushing the barn with water or by scraping. Once collected, the feedstock is anaerobically digested onsite, or special transport companies collect the manure and take it to centralized anaerobic digesters.

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[177] GHG Reductions based on staff estimates.
[178] *Draft Bioenergy Action Plan*, 2010.
[179] Ibid.
[180] California Biomass Collaborative, *Biomass Resource Assessment for California*, 2007.
[181] California Biomass Collaborative, *An Assessment of Biomass Resources in California*, December 2006.
[182] Ibid.
[183] California Biomass Collaborative, 2008.

The quantity of biogas produced depends on how the manure is collected and stored. Generally, the fresher the manure, the greater the biogas generation potential.[184] Manure has an estimated 80 percent to 85 percent GHG emission reduction from the diesel baseline.

A number of dairies in California use manure as a feedstock for producing energy; however, most of those facilities are producing electricity. Only the Hilarides Dairy in Lindsay, California, is producing a transportation fuel. The Hilarides Dairy originally collected biogas for electricity generation but has since expanded to producing biomethane that is used onsite in milk trucks. This is a small-scale demonstration project; currently, no commercial projects are using animal manure to produce transportation fuel in California.

One of the greatest challenges of using manure as a feedstock is the limited number of large dairies and farms. Scale of production is an important factor in determining economic feasibility. An alternative to large dairies or farms is clusters of smaller ones that could transport their feedstock to a central anaerobic digestion site. Another challenge is access to an end use market. Once biomethane is produced, it needs to be distributed to the transportation market or used onsite in agricultural vehicles such as tractors, combines, threshers, pickup trucks, and milk trucks. If the volume produced exceeded what could be used onsite, the excess would have to be either trucked or piped to a location where it could be sold into the market.

Fats, Oils, and Greases

When waste fat, oil, and grease (FOG) from restaurants is dumped down drains, it solidifies and clogs sewers. To prevent clogs, some wastewater service areas require restaurants to collect FOG in grease traps. The FOG can then be picked up, delivered to a wastewater treatment facility, and converted to biodiesel or added to anaerobic digesters to produce gas for electricity.

Before conversion to biodiesel, brown grease needs to be separated from FOG by screening, settling, heating, and filtering. Wastewater high in organics is left over; water is recovered from it, and the remaining material can be added to an anaerobic digester. The brown grease is then converted to biodiesel. Because it is high in free fatty acids, it requires an acid-catalyzed process before transesterification—the traditional process used to produce biodiesel.[185] Glycerin, methanol, and water are the remaining coproducts.[186]

Studies suggest that the best use of FOG is conversion to biodiesel. In one study, the net energy comparison showed 1,120 kilojoules per liter-FOG for biodiesel and 1,010 for

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[184] Ibid.

[185] Transesterification is a chemical process in which the ester groups of a FOG material are exchanged with alcohol groups, to produce a mix of glycerin and biodiesel.

[186] URS Corporation, "FOG Control & Beneficial Reuse: A Case Study in San Francisco," http://www.pprc.org/BrownGreaseSymposium/docs/Presentations/URS_Presentation_15APR09.pdf.

anaerobic digestion; the GHG comparison showed a reduction of 0.48 kilogram CO_2 per liter-FOG for biodiesel and 0.23 for anaerobic digestion.[187] Challenges to using FOG for biodiesel production include foul odor, content of up to 98 percent free fatty acids, contamination with food and trash, need to remove sulfur, heavy emulsification, cold flow (FOG is solid at room temperature), and water contamination.

Wiltsee calculated the gross amount of available FOG for the United States.[188] Using Wiltsee's results for Sacramento, about 414 million pounds of FOG are available per year in California (11.2 pounds per person * 36,961,664 people[189]). Because it takes about 7.5 pounds of FOG to make one gallon of biodiesel, potential production of biodiesel is about 55 million gallons per year. According to a 2011 report from RAND Corporation, fuels derived from animal fats and waste oils will never have a significant role in the larger domestic commercial marketplace due to limited production potential.[190]

Despite an upward cap on market growth, producing fuel from FOG in wastewater service areas with a large quantity of readily available feedstock will stop 75 percent of sanitary sewer overflows, keep FOG out of landfills, help meet California's *Bioenergy Action Plan* goals, reduce reliance on fossil fuels, and reduce GHG emissions.[191] FOG-based biofuel has the potential to make a modest contribution to meeting California's goals for low-carbon biofuel use. Current fuel production demonstrations and conversion technology research efforts include:

- East Bay Municipal Utility District is using program funds to build a FOG receiving station and small-scale biodiesel production facility.
- San Francisco Public Utility Commission is using the Energy Commission's Public Interest Energy Research Program funds to test removal of brown grease from FOG and produce biodiesel. The San Francisco Public Utility Commission is using licensed technology from BlackGold Biofuels.
- BlackGold Biofuels, a Pennsylvania-based company, has developed technology to produce high-quality biodiesel from FOG.
- BioFuelBox minirefinery, a San Jose-based company, developed a process to separate wastewater into proteins and carbohydrates for anaerobic digestion, and lipids for biodiesel.[192]

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[187] Chakrabarti, Alicia R., John M. Hake, Idit Zarchi, Donald M.D. Gray. 2008. *Waste Grease Biodiesel Production at a Wastewater Treatment Plant*. Water Environment Federation.
[188] Wiltsee, G., Appel Consultants, Inc., *Urban Waste Grease Resource Assessment*, November 1998, NREL/SR-570-26141.
[189] U.S. Census Bureau, "California QuickFacts," http://quickfacts.census.gov/qfd/states/06000.html.
[190] Bartis, James T. and Lawrence Van Bibber, RAND Corporation, 2011, *Alternative Fuels for Military Applications,* http://www.rand.org/pubs/monographs/MG969.html.
[191] San Francisco Public Utilities Commission, "San Francisco's Future Bioenergy Park Phase I: FOG-to-Biodiesel," http://www.energy.ca.gov/proceedings/2008-ALT-1/documents/2009-02-11_workshop/presentations/Lewis_Harrison.PDF.
[192] *Treatment Plant Operator*, "Mini-Refinery Converts Fats, Oils and Grease into Biodiesel," http://www.tpomag.com/editorial/view/2161/Mini-Refinery-Converts-Fats-Oils-and-Grease-into-Biodiesel.

- Piedmont Biofuels, a North Carolina-based company, opened a plant in 2010 to produce biodiesel from waste grease.[193]

Restaurants pay third-party companies to clean out grease traps and dispose of FOG. For wastewater treatment districts such as East Bay Municipal District and the San Francisco Public Utility Commission, the third-party companies deliver FOG to the district's receiving station, where they pay a tipping fee. East Bay Municipal District's receiving station, which will be built with program funds, will have truck unloading bays, below-grade concrete tanks to receive the FOG, screens to remove large solids, grinders, pumps, blend tanks, and an odor treatment system. East Bay Municipal District's FOG receiving station is expected to cost $1.5 million. The small-scale equipment used to separate brown grease from FOG is expected to cost about $350,000.

Preconsumer Food Waste

Food waste includes waste products from fruits and vegetables processed by canners, freezers, dryers, and dehydrators, as well as nut shells, fruit pits, rice hulls, cotton gin trash, and whey resulting from producing cheese. The League of California Food Processors estimates that 14 tons to 16 million tons of fruits and vegetables are processed every year in California.[194] The gross food waste potential is 1 million bone-dry tonnes per year, and the technical food waste potential is 0.8 million bone-dry tonnes per year.[195] However, when using food waste as a feedstock, one of the biggest challenges is seasonal availability.

Food waste would most likely be anaerobically digested to produce biomethane, but it can also be fermented to produce a gasoline alternative. Parallel Products, a company that runs a number of recycling facilities nationwide, uses beverage waste to produce ethanol at its Ontario, California, facility. Through the fermentation of sugar-laden liquids and the distillation of alcohol from beverage and industrial waste streams, Parallel Products produces more than 5 million gallons of waste-derived ethanol annually.[196]

The best "use" of food waste is to reduce the amount of waste. The United States Environmental Protection Agency has developed a food waste recovery hierarchy that recommends food waste be reduced first, then used to feed hungry people, feed animals, or processed for fuel.[197] Assuming that United States Environmental Protection

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[193] *Herald Sun*, "Biofuel plant to turn waste grease into top-quality fuel," http://www.heraldsun.com/view/full_story/8794804/article-Biofuel-plant-to-turn-waste-grease-into-top-quality-fuel.
[194] Ken Krich, Biomethane from Dairy Waste: A Sourcebook for the Production and Use of Renewable Natural Gas in California, July 2005.
[195] California Biomass Collaborative, *Biomass Resource Assessment for California, Draft Report*, April 2005
[196] Parallel Products, "Ethanol Recovery and Production," http://www.parallelproducts.com/ethanol.html.
[197] United States Environmental Protection Agency, "Generators of Food Waste," http://www.epa.gov/wastes/conserve/materials/organics/food/fd-gener.htm.

Agency's campaign is successful, the market potential for fuel made from food waste will be decreasing.

Forest Residue

California's 40 million acres of forests face increasing risks from severe wildland fires, due to unhealthy accumulation of forest growth from historic fire suppression policies and climate change. State and federal forest agencies recommend active thinning to reduce the risk of high-severity fires, potentially creating large volumes of woody biomass waste materials. This situation presents an opportunity to reduce these unstable fuels by using woody biomass from forest restoration as carbon-neutral feedstocks for biofuels. Preliminary estimates indicate that about 40 percent of California's total biomass resources are contained within the 40 million acres of forests in California.

Estimates of potential forest biomass waste streams available for energy production depend on assumptions and method. A recent study by the California Department of Forestry and Fire Protection, funded by the Energy Commission, estimated that gross nonmerchantable standing forest and shrub biomass is 1.32 billion bone-dry tonnes.[198] The proportion of this total that is technically available (not limited by legal or engineering constraints) is 699 million bone-dry tonnes. This study also estimated that potential annual biomass that is technically available from forest management activities would total 14.2 million bone-dry tonnes per year. Assuming a conversion factor of 80 gallons per bone-dry tonnes, this annual volume equates to almost 1 billion gallons per year of ethanol, which would offset about 660 million gallons per year of gasoline. A new cold pyrolysis conversion technology being evaluated by the G4 company through a $1.2 million program grant in Placer County may produce higher yields of more than 100 gasoline gallon equivalents per bone-dry tonnes and produce a transportation grade biogas. More investment is needed to continue the development and evaluation of technologies with the potential to convert woody biomass waste streams to low-carbon transportation fuels.

Cellulosic ethanol production from conifer waste streams is not yet commercially viable due to the technical challenges associated with breaking down the lignens and tannins found in conifer softwoods. Transport costs can also be prohibitively high when material must be trucked from remote forest locations to potential processing sites. To date, woody biomass feedstocks are used to generate electricity. California has 26 active power plants that consume about 3.2 million bone-dry tonnes annually.

Numerous environmental organizations have raised concerns about sustainability in harvest and use of forest biomass as an energy source. The Energy Commission

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[198] California Energy Commission and California Department of Forestry and Fire Protection, *Biomass Potentials from California Forest and Shrublands Including Fuel Reduction Potentials to Lessen Wildfire Threat,* Consultant Report, Contract 500-04-004, October 2005.

addressed these issues during the 2008 AB 118 Rulemaking proceeding and adopted the following sustainability language into its regulations:

> Section 3101.5(b)(2)(F) Projects that use forest biomass resources as part of their feedstock, and that demonstrate the advancement of natural resource protection goals, are those that use forest biomass collection or harvesting practices that do not diminish the ecological values of forest stands, and that are consistent with forest restoration, fire risk management and ecosystem management goals.

The Energy Commission has worked actively with the California Department of Forestry and Fire Protection, the U.S. Forest Service, and ARB through the Interagency Working Group to further define and establish sustainability standards for forest management and thinning. The Energy Commission is using sustainability funding to enter into a $1.5 million research agreement with the U.S. Forest Service and UC Davis to research forest management, thinning, fire risk reduction, and other issues associated with forest management and sustainable energy production. The Air Resources Board's LCFS program is also investigating appropriate sustainability standards for woody biomass-based fuels seeking eligibility in the LCFS credit program.

Landfill Gas

Landfill gas (LFG) is methane-rich biogas naturally created as microbes chemically break down the waste in landfills through a complex series of reactions. Landfill gas is generally composed of 40 percent to 60 percent methane, CO_2, and small amounts of other chemicals, such as volatile organic compounds and sulfur-containing compounds.

Due to stringent air quality regulations, LFG may not be released into the atmosphere. The LFG must be captured, and—due to difficulties obtaining air permits in some California air districts—combusted on site or flared. An alternative to flaring LFG is to build LFG-to-energy projects. Once captured, LFG can be cleaned and used as biomethane for transportation fuel or used to generate electricity.

LFG has a gross potential of 118 billion cubic feet per year and a technical potential of 79 billion cubic feet per year or about 600 million diesel gas equivalent.[199] For every 1 million tons of municipal solid waste landfilled, 432,000 cubic feet per day of LFG is created.[200] The United States Environmental Protection Agency has identified 37 candidate landfills in California that could accommodate LFG-to-energy projects.[201]

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[199] Waste Management, "Opportunities for Landfill Gas to Energy and Fuel in California," http://www.biomethanesummit.com/pdfs/presentations/105_SOLID_WASTE_LANDFILL/ChuckWhite.pdf.
[200] Ted Barnes, CPR Meeting – Task 2.0 Altamont Landfill Gas Purification, Testing and Monitoring Agreement #500-09-004 Presentation, August 31, 2010.
[201] United States Environmental Protection Agency, "Energy Projects and Candidate Landfills," http://www.epa.gov/lmop/projects-candidates/index.html#map-area.

LFG is a sustainable feedstock because it is derived from waste. On a well-to-wheels basis, it reduces GHGs by 82 percent to 87 percent from the diesel baseline.[202]

Two LFG-to-energy projects in California are producing biomethane for use in the transportation sector. The Altamont Pass Landfill, located in Livermore, California, is the larger of the two, with a capacity to produce 13,000 gallons of LNG per day, fueling 300 local refuse trucks. The second project, located at the Frank R. Bowerman landfill in Orange County, has a production capacity of 4,000 gallons of LNG per day and also uses the biomethane produced to fuel refuse trucks.[203] Waste Management Inc. is developing a third landfill gas to energy project using $11 million in AB 118 program funds at the Simi Valley landfill in Ventura County. This high-volume project will produce 750 million cubic feet of biomethane annually, equivalent to 6 million gallons of LNG, or 3.4 million diesel gas equivalents. Waste Management will use the LNG biogas to power 500 heavy-duty refuse hauling trucks.[204]

One of the greatest challenges faced by LFG-to-energy projects is lack of accessibility to the natural gas pipeline. Pipeline injection of biomethane from landfills is prohibited even if the gas is treated to meet health and safety standards.[205] Without access to the natural gas pipeline, LFG-to-energy producers need to find alternative methods for moving their product into the market. Some landfills are using the LFG for onsite electricity generation, and others such as the Altamont and Bowerman Landfills are fueling local refuse trucks, but large quantities of biomethane—estimated as high as 50 percent of the total methane captured at California landfills—continue to be flared.[206] Creating uniform gas quality standards among utilities would help bring LFG-to-energy projects to fruition.

Municipal Solid Waste

Municipal solid waste (MSW) is the waste collected, both urban and commercial, before it enters a landfill. The waste stream is composed of 57 percent biomass, which can be separated using various methods, with the remainder being plastics, textiles, and nonorganics.[207] Once separated, recycling and composting employ most of the resource, but a substantial fraction remains that could be used for energy conversion.[208] The primary use of post-recycled MSW is feedstock for biogas, but it has also been considered as a feedstock for producing ethanol and synthetic diesel.

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[202] California Air Resources Board Low Carbon Fuel Standard fuel pathway documents.
[203] Private Communication with Jesus Perez of Orange County Waste & Recycling, December 9, 2010.
[204] High Mountain Fuels received funding under PON-09-003.
[205] Chuck White, Waste Management. June 3 Stakeholder Workshop transcript.
[206] Ibid.
[207] Rob Williams, "Biofuels from Municipal Wastes Background Discussion Paper" March 28, 2007.
[208] Ibid.

MSW could be a significant source of feedstock—it has a technical potential of 16 million bone-dry tonnes per year.[209] The biogas potential of landfilled materials is 79 billion cubic feet or about 300 million diesel gas equivalents.[210]

Using MSW as a feedstock for producing energy can significantly reduce the waste stream in California's landfills, thus extending the life of landfills. Currently, no Low Carbon Fuel Standard pathway exists for the conversion of MSW to biomethane, but a GHG reduction of up to 75 percent from the diesel baseline is possible, depending on the energy consumption of any necessary pretreatment processes.[211] California projects should be encouraged to use MSW as a feedstock because it has 10 times greater energy production potential on a per-ton basis than landfilled waste.[212]

Currently, East Bay Municipal Utility District is the only facility anaerobically digesting MSW. CalRecycle staff strongly supports the use of the organic fraction of solid waste as well as post-recycled MSW as a transportation fuel or energy source.[213] However, a number of project developers are proposing facilities that will use postrecycled MSW as a feedstock. The Energy Commission will provide $4.5 million in program funding to CR&R, which operates the Perris Transfer Station in Riverside County. CR&R will construct a 50,000-ton facility that will separate MSW from Los Angeles County. The CR&R project will sort the MSW, anaerobically digest the organic material to produce biomethane, clean it to pipeline standards, and produce a transportation-grade biomethane that will be used to fuel 60 to 80 vehicles in CR&R's heavy-duty truck fleet. Total output will be equal to 865,000 diesel gas equivalents.

As a feedstock, the cost of obtaining MSW would be low or negative because it would otherwise be land filled. It would be easily accessible because it is already collected. Unlike large landfill projects, MSW projects should be smaller and decentralized to reduce the need to transport feedstock over long distances.[214] MSW projects could also be colocated with existing facilities such as recycling centers to minimize storage and transport issues. One of the biggest challenges to using MSW for producing biofuel is the perception that these processes will infringe on recycling and composting efforts. In fact, biofuels projects funded through the AB 118 program, such as CR&R, will use only postrecycled MSW as a feedstock.

Wastewater Treatment Plants

Waste from wastewater treatment plants generally includes municipal wastewater, sewage, and biosolids. These facilities often deploy anaerobic digesters to stabilize a

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[209] Letter from Howard Levenson, CalRecycle, dated May 20, 2011.
[210] California Biomass Collaborative. Assumes approximately 50 percent methane content of landfill gas.
[211] Energy Commission staff.
[212] One ton of organic waste landfilled has a 65-kWh potential while 1 ton of MSW has a 550-kWh potential. Energy Commission staff meeting with CalRecycle, October 28, 2010.
[213] Letter from Howard Levenson, Cal Recycle, dated May 20, 2011.

[214] CalRecycle, verbal communication, October 28, 2010.

portion of the waste and to produce biogas.[215] The biogas can be used to generate electricity or produce biomethane. Waste from treatment plants has a gross potential of 16 billion cubic feet per year and a technical potential of 9.6 billion cubic feet per year.[216] Biogas potential is about 40 million DGE.

Using waste as a feedstock for producing energy can significantly reduce the waste stream in California's landfills, thus extending the life of landfills. California has more than 240 wastewater treatment plants that treat sewage and other waste prior to discharge. A number of them already have anaerobic digesters installed onsite and are using the biogas produced to generate electricity.[217]

In November 2009, the Energy Commission awarded a $1 million grant to UC Riverside's College of Engineering-Center for Environmental Research and Technology to build a process demonstration unit to convert biosolids to clean synthetic diesel fuel. The unit uses a steam hydrogasification process to convert biosolids from Riverside's wastewater treatment facility comingled with green waste.[218]

Yellow Grease

The Energy Commission is further investigating this feedstock.

Purpose-Grown Feedstocks

This section reviews a series of purpose-grown feedstocks used for ethanol and biodiesel production. Some, like algae and switchgrass, have high volumetric potential for renewable diesel or cellulosic ethanol but face ongoing cost and technology challenges. Others, like corn, soy, oil palm, and sugarcane, can be grown efficiently at industrial scales but engender strong sustainability concerns. For example, recent work by Holly Gibbs of Stanford University indicates that global agricultural land acreage increased by 629 million hectares between 1980 and 2000; 100 million hectares of this new agricultural land was created in tropical zones, and 55 percent of the tropical zone agricultural land came from newly cleared tropical forests. Palm oil, soy oil, and sugarcane account for much of this new agricultural production.[219]

Algae

Algae are organisms that grow in water. They include microalgae and cyanobacteria (both microscopic), and macroalgae (seaweed). They can be grown and processed to produce biodiesel, renewable diesel, biomethane, ethanol, and other fuels. Different types of algae are grown depending on the type of fuel to be produced. Algae can be grown with light in open mixed or unmixed ponds or in enclosed plastic bags or tubes

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[215] Rob Williams, "Biofuels from Municipal Wastes Background Discussion Paper" March 28, 2007.
[216] California Biomass Collaborative, *Biomass Resource Assessment for California, Draft Report*, April 2005.
[217] Ibid.
[218] U.C. Riverside, "Converting Biosolids into Clean Synthetic Diesel Fuel," http://www.waterandwastewater.com/www_services/news_center/publish/article_001916.shtml.
[219] Gibbs, Holly, *Proceedings of the National Academy of Sciences*, Vol. 107, No. 37 August 31, 2010.

(known as photobioreactors). They can also be grown without light and fed a carbon source, such as sugars, to generate new biomass (heterotrophic cultivation). [220]

The best locations for growing algae are in the Southwest and Florida, near fossil fuel plants with waste CO_2. The number of annual average cumulative sun hours should be at least 2800, the annual average daily temperature should be at least 55°F, and the number of annual average freeze-free days should be at least 200.[221] Algae can grow in water of all types, including wastewater and saline groundwater. When grown to produce oil, the yield is from 1000 to 6500 gallons per acre per year.

Compared to other purpose-grown fuels, algae possess the potential to produce a significant amount of fuel from a relatively small area. Yusuf Chisti estimates that growing algae on 1 percent to 3 percent of the total United States cropping area would be enough to produce 50 percent of transportation fuel needs.[222]

The carbon intensity of algae-based fuels depends on the type of fuel produced. In September 2010, the National Academy of Sciences began a study of sustainable development of algal biofuels. The resulting report will include information about centralized and distributed production, land use, water use, nutrients, human health and safety, and potential toxicity. It will also recommend indicators and metrics to help assess sustainability. The report will not include an economic analysis because production has not yet reached commercial scale. The report is expected to be issued in early 2012.[223]

In 2010, the United States Department of Energy's Office of Biomass Program published a *National Algal Biofuels Technology Roadmap*, which summarizes the state of technology for algae-based fuels and the research and development needed to produce them at a commercial scale. The Office of Biomass Program also released an Algae Biomass Supply Request for Information (DE–FOA–0000466) to gather information about supply systems and services for the production, handling, storage, transport, and delivery of algae biomass.

DOE contributed about $20 million for research and demonstration projects to develop algae feedstock, demonstrate technology to capture CO_2 for growing algae, and open a fully integrated algal biorefinery. In California, the San Diego Center for Algae Biotechnology, led by the University of California at San Diego, was one of the recipients ($9 million). The center's research into biofuel development includes growing algae in more than 40 open ponds at its test facility in the Imperial Valley.

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[220] U.S. DOE 2010. *National Algal Biofuels Technology Roadmap*. U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Biomass Program. Visit http://biomass.energy.gov for more information.
[221] Ibid, pages 76-81.
[222] Chisti, Yusuf. 2007. "Biodiesel From Microalgae," *Biotechnology Advances,* volume 25, page 296.
[223] National Academies, "Project: Sustainable Development of Algal Biofuels," http://www8.nationalacademies.org/cp/projectview.aspx?key=49316.

ARRA contributed more than $150 million for projects that experiment with growing algae in open ponds, develop an alga harvesting system, develop metabolic engineering and synthetic biology approaches to increase lipid production, produce a diesel substitute, and develop a systems approach for sustainable commercialization of algal biofuel. California companies receiving funding from ARRA are Sapphire Energy, based in San Diego ($50 million), and Solazyme Inc., based in South San Francisco ($22 million). United States Department of Transportation contributed a $54 million loan guarantee to construct a pilot algal biorefinery in New Mexico.

Venture capital and private equity firms contributed the most funding (more than $1 billion), mostly for projects that will experiment with commercial-scale production. California companies receiving funding from venture capital and private equity firms are Sapphire Energy ($100 million), Solazyme Inc. ($57 million), Aurora Biofuels, based in Alameda ($35 million), ExxonMobil and Synthetic Genomics, Inc., based in La Jolla ($600 million), and Green Pacific Biologicals, based in San Francisco ($225,000). The program contributed almost $1.5 million to design and configure a pilot-scale production plant that uses algae to produce oils in standard fermentation tanks, and $250,000 for a project that will experiment with growing algae at a wastewater treatment plant.

The *National Algal Biofuels Technology Roadmap* describes a literature review of production costs, which reveals that many estimates are dated and use widely different basic assumptions. It notes, however, that "a combination of improved biological productivity and fully integrated production systems can bring the cost down to a point where algal biofuels can be competitive with petroleum at approximately $100 per barrel."[224]

T. J. Lundquist et al. estimated costs for five production scenarios.[225] Depending on type and size of the plant, capital costs range from about $21 million to more than $100 million. Land and pond construction are the most expensive capital costs and staffing and maintenance are the most expensive operating costs.

Before converting algae to biofuel, the algae must be harvested, dewatered, and the oil or carbohydrates extracted. These processes are energy-intensive and expensive. Research is needed to develop cost-effective ways to prepare algae for conversion.

Phillip Pienkos lists 28 hurdles to algae cultivation, oil recovery, and biofuel production that include temperature control, CO_2 availability and transport, resistance to invasion in

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[224] U.S. Department of Energy 2010. *National Algal Biofuels Technology Roadmap*. U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Biomass Program, page 104.
[225] Lundquist, T.J., I.C. Woertz, N.W.T. Quinn, and J.R. Benemann, 2010. *A Realistic Technology and Engineering Assessment of Algae Biofuel Production,* page vii. http://works.bepress.com/tlundqui/5/. Accessed 11/9/2010.

open ponds, and dewatering methods.[226] Additionally, Rene Wijffels and Maria Barbosa write that research is needed in biology, algae strain development, scale-up, biorefineries, and whole system design. They believe that production will be economically feasible only if combined with production of bulk chemicals, food, and feed ingredients. They estimate that sustainable, commercial production of algae-based biofuels will require another 10 to 15 years of development.[227]

The Energy Commission's Public Interest Energy Research Program is also supporting research into renewable algae as a drop-in transportation fuel, requiring no additional processing. The identified research solutions will develop alternative fuels designed for compatibility. In this respect Public Interest Energy Research Program is investigating large molecule alternative fuels (fuels that mimic gasoline, jet fuel, and diesel), such as algae-derived fuels, but also including others derived from single-cell organisms such as bacteria. Four research gaps affecting algae-derived fuels have been identified:

- Strain selection, including finding, breeding, or genetically engineering the best oil producers.
- Growth media and containment, such as ponds and bioreactors.
- Oil separation technologies to separate algal lipids from water and biomass.
- Improved life cycle analysis tools and method to better assess carbon emissions and land use impacts.

Public Interest Energy Research Program has funded two competitively bid projects that address one or more of the research gaps. The first project is a $794,000 contract with NASA Ames to research, develop, and demonstrate the Offshore Membrane Enclosures for Growing Algae system, primarily to address growth media and containment. This system consists of lightweight, flexible, closed photo-bioreactors constructed of inexpensive plastic, with small sections of semipermeable membranes for gas exchange and dewatering. They will be filled with nutrient-rich primary or secondary treated wastewater from municipal sewage treatment facilities, and the sealed enclosures will be inoculated with lipid-producing freshwater algae (mono-cultures or communities). Strains of algae will be cultivated that are able to thrive under local conditions and outcompete weed species in the wastewater. This project is addressing the growth media and containment research gap.

The second project is for the production of Soladiesel RD, a renewable diesel, from cellulosic feedstocks. As a part of this project, the Energy Commission awarded $790,000 to Solazyme, Inc., to carry out the research to enable development of a commercial lipid biomanufacturing process using cellulosic feedstocks and heterotrophic algal fermentation. While Soladiesel RD could ultimately leverage existing industrial

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[226] Pienkos, Philip T, National Renewable Energy Lab, 2007. "The Potential of Biofuels from Algae." Presentation given at the Algae Biomass Summit. www.nrel.gov/docs/fy08osti/42414.pdf, slide 16. Accessed 10/20/2010.

[227] Wijffels, Rene H. and Maria J. Barbosa. 2010. "An Outlook on Microalgal Biofuels," *Science*, August 13, 2010, Vol. 329, pages 796-799.

bioproduction facilities and commercial oil refineries to prove commercial viability quickly, this project's aim is to research and develop the use of cellulosic biomass in Solazyme's algal biofuel technology. This project also addresses the strain selection and growth media and containment research gaps.

Future large molecule research will continue to develop the economic and environmental potential of algae-derived fuels. The Public Interest Energy Research Program will work with UC Merced to improve LCA tools and methods for algae-derived fuels. The Public Interest Energy Research Program will also establish a California Initiative for Large Molecule Sustainable Fuels to perform research essential to developing the next generations of large molecule biofuel technologies and related materials. Research results should provide information for future investment recommendations.

Camelina

Camelina, also known as false flax or gold-of-pleasure, is a member of the mustard family and a distant relative to canola. It grows as an annual from one to three feet tall producing seed pods containing many small seeds (400,000 seeds per pound) with high oil content (35-38 percent and high in omega-3- fatty acid). As a comparison, the oil content of soybeans is 20 percent.

Camelina is a short-seasoned, fast-growing crop planted in March and harvested in late July most years, even in northern climates. Camelina can grow in crop rotation with wheat. The plant can grow on marginal conditions with low inputs surviving on low moisture (10-17 inches of rainfall annually) with fewer nutrients than many other crops. However, the plant still requires management including herbicide application to help ensure successful establishment. Field trials in Oregon, Montana, and Idaho indicate that camelina seed oil production is more cold-resistant that average biodiesel feedstock.

Camelina yields are roughly double that of soy and provide more than 100 gallons of oil per acre. Early trial results have shown an increase in 15 percent production to wheat when rotated with camelina. According to Washington State University, Camelina provides 1,400 pounds of seed per acre at 16 cents per pound or provides up to $224 per acre (compared to 28 bushels of wheat at $8.23 per bushel, which produces $230 per acre).

Camelina has the potential for use as cattle feed supplement, feedstock for biofuel and bio-lubricant, and soil nutrient enhancer. Primary energy market potential exists as a feedstock for aviation biofuel as it can reduce emissions nearly 85 percent over conventional fuel.

Great Plains and Sustainable Oils have been identified as early commercial ventures in the development of camelina as an aviation biofuel. AltAir has a contract with 14 airlines to produce 100 million gallons per year of diesel and renewable jet fuel at Tesoro facility in Washington. Sustainable Oils has a partnership with BioJet to produce

up to 200 million gallons per year plus 65 million gallons per year of coproducts, and 2.3 million tons per year camelina meal for animal feed.

There are key issues to address in expanding the commercialization of camelina as a feedstock, including educating growers to new commodity markets, providing incentives for aviation alternative fuels in California, and focusing camelina development in cooler climates of the state.

Corn

The most rapidly increasing use of corn in the United States has been as a feedstock to produce fuel ethanol, rising from 12.8 percent of total supply in 2005 to nearly 36 percent today.[228] Over the same period, corn for animal feed and residual use has declined from 57.6 percent during 2005 to 39.3 percent today.

Corn kernels are used in biorefinery fermentation facilities to produce conventional ethanol from the starches in the kernel. Oil from the kernel can now be removed and used as a biodiesel feedstock with a very low carbon intensity value. Corn stover (consisting of the stalks, leaves, husks, and cobs remaining after harvesting) can be used in a cellulosic conversion process to produce ethanol with lower lifecycle carbon emissions. The United States corn ethanol industry is becoming increasingly sophisticated in its ability to use all parts of the corn plant for fuel and feed production.

After starches are removed during ethanol fermentation, high protein distillers' grains in wet or dry form are separated and sold as animal feed. Roughly one-third of every bushel of grain processed into ethanol is returned to the animal feed market in more concentrated forms as distillers' grains, corn gluten feed, or corn gluten meal. Corn by-products are also used for fertilizer and soil amendment.

U.S. corn grain production is estimated at 12.4 billion bushels in 2010, down from the record 13.1 billion bushels for 2009, while it was 13.0 billion bushels in 2007. U.S. corn yield was 158.2 bushels per acre in 2010, down from a record 164.7 bushels per acre in 2009. Per-acre productivity for corn production has increased from about 90 bushels per acre in the early 1980s to 158 bushel per acre in 2010. Total U.S. acreage to corn was about 88 million acres in 2010, with most production occurring in Midwest states. California has about 625,000 acres allocated to corn, which serves the sweet corn market and local silage demand. Nationally, per-acre productivity is projected to increase steadily at a rate of two bushels per acre per year. Productivity gains are a result of continuing improvements in plant genetics, machinery, and tillage practices.[229] The consumption of corn for U.S. ethanol production was 41.6 percent during 2010.[230]

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[228] United States Department of Agriculture Economic Research Service statistics. Total supply includes production, imports, and changes of inventory levels.

[229] United States Department of Agriculture Economic Research Service, "Corn Market Outlook," http://www.ers.usda.gov/Briefing/Corn/2010baseline.htm.

[230] During 2010, 4.724 million bushels of corn were converted to fuel ethanol out of a total of 11.346 million bushels of total use. Energy Commission analysis of U.S. Department of Agriculture statistics.

The carbon intensity for Midwestern biorefineries using conventional ethanol processing of Midwest corn is 98 g CO_2e/MJ, with 30 g CO2e/MJ attributed to indirect land use change. California-produced corn ethanol using Midwestern corn feedstocks has a CI of 81 g CO_2e/MJ with 30 g CO_2e/MJ attributed to indirect land use change. This 18 percent lower carbon intensity value for California-produced ethanol using Midwestern corn feedstocks is a result of modern biorefineries using state-of-the-art process efficiencies and the use of natural gas and California's relatively green electricity mix as process energy sources. Midwestern biorefineries rely on coal for process energy.

Sustainability concerns for first generation corn ethanol tend to be expressed in terms of indirect land use change,[231] effects of demand for corn ethanol on global corn commodity prices, and water use for corn cultivation and ethanol refining. The Energy Commission actively investigates sustainability issues associated with alternative fuel production. Professor Wally Tyner of Purdue University is an original author of the Global Trade Analysis Project model used by the Air Resources Board to estimate indirect land use change numbers for the LCFS. His 2010 revision to the model produced a range of results one-third to one-half lower than the current figure of 30 g CO_2e/MJ. The Indirect Land Use Expert Workgroup convened by the Air Resources Board during 2010 reviewed Professor Tyner's revisions and recommended that ARB staff consider some of the model's updates in revising the Global Trade Analysis Project model. Portions of the model's updates may result in reduced indirect land use change numbers, while other aspects may further increase or decrease these numbers.[232] Energy Commission staff participated in this Expert Workgroup.

Some stakeholders have voiced concern regarding increased water use and higher fertilizer application rates associated with corn. Based on the most recent agriculture census by the United States Department of Agriculture (in 2007), the majority of corn is grown without the use of any irrigated water, solely dependent on rainfall during the growing season. In 2007, only 15.3 percent of corn acres were irrigated, with the balance (84.7 percent) receiving no irrigated water.[233] It is not known if expanded

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[231] The concept of indirect land use change is that for each acre of food or forage replaced by a bioenergy crop, somewhere in the world, a landowner will indirectly make an economic decision to clear virgin land to produce more food and release additional carbon from the surface vegetation and soil. Some portion of this carbon should then be attributed to biofuels production in a carbon accounting system. This phenomenon is sometimes called "market mediated effects." ARB added indirect land use change carbon intensity estimates to direct emissions fuel pathways for purposes of the LCFS regulation to conform with results of the Searchinger paper in *Science* from 2008, which found that corn ethanol had nearly twice the carbon intensity of petroleum when indirect land use change was factored in (~200g CO2e/MJ total carbon). Current indirect land use change estimates for corn ethanol production are much lower. A copy of the Serchinger paper may be viewed at the following link: http://www.princeton.edu/~tsearchi/writings/SupportingMaterials.pdf.

[232] ARB Staff, Cover Report on the Results of the Indirect Land Use Expert Workgroup to the Air Resources Board, January 2011.

[233] Corn using irrigated water totaled 13.16 million acres in 2007, while non-irrigated corn amounted to 73.09 million acres. Since irrigated corn has a higher yield, the percentage of corn produced from

production of corn will occur as a result of an even higher ratio of irrigated acres over the forecast period. Assuming the ratio remains fairly constant, increasing corn production due to higher mandated ethanol demand should primarily occur through expansion of dry cropping, rather than through increased irrigation. Regarding fertilizer use, Energy Commission staff examined United States Department of Agriculture statistics and noted that the application rate per acre of corn for nitrogen has increased 6.2 percent between 1980 and 2005, while the average corn yield has increased 62.5 percent over the same period.[234] The continued improvement of corn yields is primarily a consequence of other improvements unrelated to increased use of nitrogen per acre.

Corn ethanol is imported from major ethanol production facilities in the Midwest via rail cars to major California ethanol distribution terminals in Carson and Albany. This ethanol is used as an oxygenate for California reformulated gasoline and is blended at the E10 (10 percent ethanol) level. During 2009, 95 percent of California's 962 million gallons of ethanol use was imported from outside the state via rail cars, 4 percent produced from California facilities, and the remaining 1 percent imported from foreign sources via marine vessel. During 2009, the emerging E85 retail fueling market in California dispensed about 1,173,025 gallons.

There are five corn-based ethanol plants in California, with a combined production capacity of 250 million gallons per year. Estimated capital cost to construct these plants is about $500 million in private capital. Direct employment when the five plants are operating at full capacity is estimated to be 175. Most of these plants have been idled since January 2009 due to poor operating economics and high debt loads. Until the LCFS begins in earnest, there is no market mechanism to value and remunerate California producers for their lower carbon ethanol products. In early 2011, the Energy Commission allocated $6 million from the California Ethanol Producer Incentive Program to provide operators of existing corn ethanol production plants in California with temporary financial assistance, as funding is available, during periods of difficult economic operating conditions that would be repayable under specifically identified favorable market conditions. This program also will stimulate operational improvements at existing ethanol facilities and the use of advanced process technology to convert cellulose and other low-carbon feedstocks. Two of these facilities are operating using Midwestern corn.

The federal RFS2 and California's LCFS will affect the demand of and distribution infrastructure facilities for ethanol. The federal program of mandated renewable fuel

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irrigated acres is slightly higher, approximately 16.9 percent for the same year. *2007 Census of Agriculture*, United States Department of Agriculture, Table 32, page 26, updated September 2009. http://www.agcensus.usda.gov/Publications/2007/Full_Report/Volume_1,_Chapter_1_US/usv1.pdf.

[234] Most recent complete year of fertilizer data for U.S. corn acres is 2005. Nitrogen application for fertilized corn was 130 pounds per acre in 1980 and 138 pounds per acre in 2005. U.S. Fertilizer Use and Price, United States Department of Agriculture Economic Research Service, Table 10, updated November 20, 2008. The data is available at: http://www.ers.usda.gov/Data/FertilizerUse/Tables/FertilizerUse.xls.

use is expected to increase ethanol use in California significantly such that gasoline demand will be decreased to a greater extent than demand reductions forecast as a result of higher Corporate Average Fuel Economy standards. In addition, due to the current state ethanol blending limit of 10 volume percent in gasoline, the RFS2 will likely result in significantly greater use of E85 so that obligated parties achieve their "fair share" compliance levels. The 2009 transportation fuels forecast by the California Energy Commission estimated that E85 demand levels would increase from 1.1 million gallons in 2010 to 1,725 million gallons in 2020 and 2,262 million gallons by 2030 under the Low Demand Case for gasoline.[235]

The state LCFS may not appreciably alter the demand forecast for ethanol; rather, it will necessitate the use of specific types of ethanol with lower carbon intensity relative to Midwestern corn-based ethanol supplies. Although commercial production levels of cellulosic ethanol have yet to be achieved by the market, low-carbon intensity ethanol of this kind will eventually be needed to help refiners and marketers to achieve LCFS compliance in the latter years of the regulation.

Farmed Tree Products

The Energy Commission is further investigating this feedstock.

Grasses

Grasses have been grown in the United States for various purposes including turf, cattle feed, and in cofiring power plants. Predominant grasses for energy, in particular as a biofuel, include switchgrass, miscanthus, and bermudagrass. All three of these grasses are perennials that have different characteristics related to planting practice (seed, stolons, rhizomes), nutrient requirement (varying macronutrient levels), harvesting (single or multiple), and yield (length of growing season, water availability).

Most of the grasses are native to Texas, require several years to reach maximum maturity, and have an optimum daytime temperature requirement above 75 degrees. Grasses can also suffer from insect damage if proper management practices are not implemented.

Early switchgrass field trials suggest a technical yield of 20 tons per acre and an actual yield of 10-12 dry tons per acre in the Imperial Valley of California. Bermudagrass production in California is largely harvested as sod for turf purposes as genetically modified strains typically produce sterile seed.

The California Biomass Collaborative has identified Bermudagrass and other grasses as strong candidates for cultivation in fallowed agricultural lands that are no longer arable due to selenium and boron concentrations, or due to reductions in available irrigation

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[235] *Transportation Energy Forecasts and Analyses for the 2009 Integrated Energy Policy Report*, Final Staff Report, California Energy Commission, Publication Number CEC-600-2010-002-SF, May 2010, page 72.

water. The grasses could remediate soil conditions in areas like the western San Joaquin Valley and provide a feedstock resource for cellulosic ethanol.[236]

The costs of switchgrass production approach $225 per acre in total costs. Grass is baled at a cost of $30 per ton or $300 per acre.

According to a United States Department of Agriculture report, grasses have been identified as a carbon-neutral plant. As a biofuel, grasses can be a source for ethanol production via cellulosic conversion technology.

Issues identified with grasses as a feedstock include the need to establish itself effectively as a bioenergy crop, high biochemical conversion costs, and thermochemical conversion technology requiring more development.

Palm Oil

Palm oil, one of the world's largest agricultural commodities, is widely used for a number of food and cosmetic purposes, including as a renewable diesel substitute. Palm oil is projected to make up 34-46 percent vegetable supply in 2010 to 2020.[237] A palm plantation typically produces 435 -630 gallons of oil per acre, compared to soybean oil's 74 gallons/acre.[238] Palm oil yields are the second most productive fuel volume crop. (Sugarcane produces roughly 800 gallons/acre.[239]) In 2009 more than 50.5 million metric tons of palm oil were produced; 20 percent of this volume was estimated to be used in nonfood purposes (such as renewable fuel).[240] This potential renewable fuel volume represents 2.9 billion gallons. For comparison, California uses 3 billion gallons of diesel fuel per year.

Malaysia and Indonesia account for 83 percent of palm oil production and 89 percent of global exports. In 2009, Indonesia became the largest producer of palm oil, producing more than 20.9 million metric tonnes,[241] while Malaysia produced 19.8 million metric tonnes.[242] (One ton is approximately equivalent to 5.6 billion gallons.) Extremely high palm oil production growth rates have been sustained over the past 10 years in Malaysia and Indonesia. These historic growth rates are a result of strong global vegetable oil demand and significant political and economic reforms established by the government following the Asian Financial Crisis in the late 1990s. Continued palm oil production growth rates are expected for at least two more decades due to improved

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[236] Professor Steven Kaffka, UC Davis and California Biomass Collaborative, Presentation to Energy Commission during AB 118 Regulatory Proceedings for Sustainability, 2009.
[237] Sime Darby Plantation, "Palm Oil Industry in Malaysia," Skills & Knowledge for Sustained Development in Africa, June 24, 2009.
[238] Biofuels: Production, Use and Its Implications on GHG emission, Dato' Dr. Mohd. Basri Wahid, Malaysian Palm Oil Board. Cites 3.8 tonnes per hectare per year.
[239] Energy Commission staff analysis of published production yields.
[240] Sime Darby Plantation, 2009.
[241] United States Department of Agriculture Foreign Agricultural Service, "Indonesia: Palm Oil Production Prospects Continue to Grow," December 31, 2007, http://www.pecad.fas.usda.gov/highlights/2007/12/Indonesia_palmoil/.
[242] Economics and Industry Division Statistics, & Oil World Annual (2000-2009).

crop yields from existing fields, new maturing plants starting production, and new crop plantations being built.

Palm oil costs vary over time and can be affected by commodity prices for other bio-oils, international tariffs, and international events (including natural disasters). A refiner's interest in palm oil is also directly related to the price of petroleum crude oil and is affected by the costs and savings associated with any GHG regulations. From 2008 to 2010, palm crude oil commodity prices raised from $438-$1,200 per metric tonne.[243] These palm prices represent $1.50 to $4.25 per gallon of feedstock to a potential fuel producer. Additional costs to receive, transport, and process the feedstock would raise the cost 30-45 percent.

Worldwide, an increasing number of refineries are demonstrating interest in palm oil as a feedstock. In the summer of 2010, Bloomberg reported Europe's first new palm oil plant in Liverpool. This palm oil refinery supplies 40 million tons of palm oil per year, or theoretically 11.3 billion biofuel gallons.[244] Additionally, two new renewable diesel plants using Neste oils' biomass-to-liquid process are coming on-line in 2011, one each in Rotterdam and Singapore. Each will consume 800,000 metric tons of palm oil and produce 226 million renewable diesel gallons per plant. These two plants combined demand represent one year's production capacity growth from Indonesia.

Oil palm cultivation and processing, like other agricultural and industrial activities, raises environmental issues and sustainability concerns. Forest clearing, land degradation and loss of fertility caused by soil erosion are a major problem in many parts of the world and are especially rampant in the tropics. A recent paper by Stanford researcher Holly Gibbs documents forest clearing and land conversions in Asian and Southeast Asian countries where oil palm plantations expanded rapidly to meet growing global demand for palm oil. Indonesian palm oil plantations expanded from 2 million hectares to 5 million hectares between 2000 and 2008. For Southeast Asia as a whole, plantations increased from 11 million hectares to 17.4 million hectares between 1980 and 2000, with oil palm plantations accounting for 80 percent of the increase.[245] Koh and Wilcove found that half of the land cleared for plantations between 1990 and 2005 in this region came from tropical forests.[246]

In response to the urgent and pressing global call for sustainably produced palm oil, the Roundtable on Sustainable Palm Oil (RSPO) was formed in 2004 with the objective of developing and implementing global standards for sustainable palm oil through credible

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[243] Index Mundi, "Palm Oil Monthly Price," http://www.indexmundi.com/commodities/?commodity=palm-oil&months=60.
[244] New Britain Palm Oil Limited, "Latest News," http://www.nbpol.com.pg/n_latest_news.php.
[245] Gibbs, 2010.
[246] Koh and Wilcove, Conservation Letters, 2008.

global standards and engagement with stakeholders.[247] In 2008 the first Malaysian palm oil plantation was certified by the RSPO's Certificate of Conformance. By the end of 2010, there were 22 growers, 81 palm mills RSPO-certified, representing 3.5 metric tons, or 17 percent of the Malaysian palm crude oil.[248]

Additionally, New Britain Palm Oil Limited has developed an Environmental Management System to help the company to minimize its effects on the environment. The company is using the international standard for environmental management, known as ISO 14001 (1996), as the vehicle to deliver this system, and in May 2004 New Britain Palm Oil Limited achieved accreditation. This standard is universally employed and recognized as a measure of quality in establishing a systematic approach to environmental management. This recognition will foster environmental confidence and demonstrate environmental responsibility to the people who buy palm oil.

An initial estimate for the carbon intensity of palm oil used for biodiesel or renewable diesel determined an 88 percent GHG reduction, but this did not account for indirect land use emissions estimates.[249] The Air Resources Board has not yet adopted a Life Cycle Analysis value for palm oil for the LCFS. Current indirect land use change estimates for soy (62 gCO_2e/MJ) and Brazilian sugarcane (46 gCO2e/MJ)[250] indicate that the indirect land use change value for Southeast Asian oil palm may be comparably high. Worst case examples include peat forest land use at 45 tonnes CO_2e per hectare year and rubber plantation-based palm oil plants at 7 tonnes CO_2e per hectare year. Better case examples include natural forest, oil palm (food), and tropical fallow sources, at 2, 6, and 8 tonnes CO_2e per hectare year, respectively.[251] These figures indicate that multiple fuel pathway estimates may be warranted for Southeast Asian oil palm to create positive market incentives for oil palm from older, converted cacao plantations, and negative incentives for palm oil from new plantations from recently cleared tropical forests.

In addition to palm oil, about 60 million metric tons of palm plant waste is created annually in the production of palm oil. This biomass could theoretically be converted via second-generation biofuel processes to yield 1.0 billion biofuel gallons.[252] The additional

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[247] RSPO stakeholders include oil palm producers, palm oil processors or traders, consumer goods manufacturers, retailers, banks and investors, environmental or nature conservation organizations, and social or developmental organizations.
[248] RSPO Certified, "Growers Certification," http://www.rspo.org/?q=page/508.
[249] Energy Commission, Consultant Report, *Full Fuel Cycle Assessment: Wells-To-Wheel Energy Inputs, Emissions, and Water Impacts,* August 1, 2007.
[250] ARB, "Proposed LCFS Look Up Tables for the February 24, 2011, Board Hearing," http://www.arb.ca.gov/fuels/lcfs/010611lcfs_lutables.pdf.
[251] Reinhardt, Guido, "LCA of Biofuel Oil Crops: State of the Art Balancing Scientific Accuracy with the Demands of Policy Makers," International Palm Oil Life Cycle Assessment Conference Kuala Lumpur, Malaysia, October 19-20, 2009.
[252] Global Business Leaders, Forum 2010, Plenary 6: Creating a Sustainable Energy Mix, M.R. Chandran Advisor to EB, RSPO, KL Convention Centre, Kuala Lumpur, November 22-23, 2010.

biofuel or bioenergy would be counted in future life cycle analyses to yield greater GHG benefits over time.

Soybean

For 20 years soybean oil has been the feedstock of choice to produce biodiesel in the United States. In the past, soybean oil has been used for 30-60 percent of California's biodiesel supply. Soybeans are the predominant row crop grown in the United States for biodiesel fuel production; canola, palm, and rapeseed are similar alternatives grown worldwide for the biodiesel fuel. All are generally interchangeable in practice and share some market price linkages.

California does not grow soybeans, and for the last three years no soybean acres are evident by the Agriculture Statics Board January 2010 report.[253] Soybean oil used in California for biofuel is brought in by trains at a cost of 15-45 cents per gallon. Soybeans are predominantly grown for the meal and protein. The by-product of soybeans is used to make biodiesel. Most (85 percent) of the soybean is used as meal, and the other 15 percent is used for ink, plastics, and fuel. Historically, soybeans were grown and genetically engineered to maximize meal, not plant oil. Now, genetic research is seeking to maximize the oil production aspects to expand this crop for fuel markets.

Of all the food crops considered for biofuels, soybeans have the lowest fuel yield per acre. Soybeans yield roughly 75 biodiesel gallons per acre, as compared to 450 gallons per acre for corn-to-ethanol or 635 gallons per acre from palm oil.[254] As a consequence of the low oil yield per acre, soybean oil is not envisioned to be a major domestic transportation fuel source beyond a 5 percent level.[255]

The production volume of soybean oil has been steadily growing and accelerating since a federal $1.00 per gallon subsidy was enacted in 2004. Soybean oils provide a steady oil quality, desired by biodiesel producers, major oil companies, and marketers for its consistent qualities and good cold weather flow properties. Soybean oils produce a better cold weather fuel than palm oil feedstocks.

America is a significant world soybean producer. Planted acres for soybean increased from 24,440,000 acres in 1960 to 77,451,000 acres in 2009, while production of soybean oil grew to nearly 700 million gallons by 2008.

In 2010, the United States Environmental Protection Agency adopted a GHG emission reduction 57 percent for soybean oil converted to biodiesel or renewable diesel, including indirect land use effects. For California, ARB adopted a 12 percent GHG benefit; direct carbon emissions from soy are 21 g CO_2e/MJ, while the indirect land use

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[253] U.S. Department of Agriculture, National Agriculture Statistics Service, "Crop Production 2009 Summary," January 2010.

[254] Staff assumes soybean values of 51 bushels per acre, 11.28 pounds of soybean oil per bushel, and 7.8 pounds of oil per gallon.

[255] National Biodiesel Board has a 5 percent biodiesel displacement goal by 2015.

emissions estimate is 62 g CO_2e/MJ. This high indirect land use change estimate reflects large-scale forest clearing in countries like Brazil for new soy plantations, where soy plantings increased from 13 million hectares to 21 million hectares in just 10 years.[256]

There are no known projects in California pursuing soybean or canola farming. The closest plant that is grown in California that produces an oil is sunflower, of which 34,000 acres were planted in 2009, and none were reported in 2007 and 2008.[257] More critically, California lacks soybean crushing facilities, and the crushing process uses hexane, a volatile petrochemical with which California air quality districts have raised issues.

International commodity prices for soybean oils, canola, rapeseed, and palm oils are somewhat linked in the market. During 1996-2006, soybean prices ranged from $50 to $110 per barrel, during the same time crude oil was $20-$40 per barrel lower. Absent governmental intervention, soybean oil does not compete well with petroleum prices. Historically, soybean market prices are more volatile and higher than crude oil prices. The federal $1.00 per gallon incentive is powerful but not as powerful as the food markets' strength. Worldwide interest and policies pursuing renewable and GHG reduction have spurred the supply and the cost to secure most all plant oils and are likely to continue this trend.

[256] Gibbs, 2010.
[257] U.S. Department of Agriculture, National Agriculture Statistics Service, "Crop Production 2009 Summary," January 2010.

Sugar Beets

Sugar beets have been grown in California from the 1950s to present times, primarily in the San Joaquin and Imperial Valleys, as a feedstock for sugar mills and as a supplemental cattle feed.[258] California-grown sugar beets have very high per acre yields and sugar content and is highly regarded as a potential ethanol feedstock. Sugar beet production in California peaked in 1964 and 1971 with about 350,000 acres of production, but current production is about 40,000 acres. Average yields can be as high as 35 tons per acre (California corn yields are 4.8 tons per acre), with an ethanol conversion factor of about 25 gallons per ton. Production on 200,000 acres could yield about 170 million gallons per year of ethanol. As a coproduct, sugar beets yield 18 to 25 tons of beet pulp per acre, which can be used as an animal feed supplement.

No sugar beets are in use as a biofuels feedstock in California. Several large and modern ethanol biorefineries totaling roughly 90 MGPY have recently been built in Germany using sugar beets as the feedstock. In California, UC Davis has evaluated their potential as a feedstock and has conducted crop trials. Professor Steven Kaffka of the Department of Agronomy has led much of this research.[259] The California Department of Food and Agricultural is further evaluating sugar beet potential through a $1 million research agreement for energy crop assessment with the Public Interest Energy Research Program.

The Energy Commission is funding the Mendota Beet Cooperative's feasibility study of an integrated biorefinery through a $1.5 million program grant. The Mendota project would use 840,000 tons of sugar beets per year to produce about 33.5 million gallons per year of low carbon ethanol (45 percent below the petroleum baseline). The Mendota Beet Cooperative estimates cultivation on 11,000 to 22,000 acres of farmland that has either been used historically for sugar beet production or that is currently fallow.

Sugarcane

While primarily considered a tropical crop, a variety of sugarcane known as energy cane may be well-suited for cultivation in the Imperial Valley. Initial field trials through UC Davis indicate extremely high yield potential of 1,200 to 1,400 gallons per acre (as compared to 870 gallons per acre for sugar beets or 459 gallons per acre for corn).[260] Energy cane could be grown on nonprime agricultural soils in the Imperial Valley that are currently fallow or that are used for forage grasses such as Bermuda grass, which is used for dairy production. While the potential for high productivity is evident, energy cane requires high volumes of irrigation water of about 8 to 9 acre-feet per year. This is comparable to current Imperial Valley alfalfa cultivation but higher than the 2 acre-feet

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[258] Robert Williams and the California Biomass Collaborative, "California Biofuels Potential," Draft Consultant's Report, unpublished, 2007.
[259] Steven Kaffka, Presentation at the Energy Commission's Staff Workshop for the 2010-2011 Investment Plan (Biofuels Waste-Stream, Purpose Grown, and Bioengineered Feedstocks, and Production Technology and Economics), September 14-15, 2009.
[260] *California Biofuels Potential*, Draft Consultant's Report.

per year required for sweet sorghum cultivation. A UC Davis Biomass Collaborative draft report estimates potential ethanol production of up to 200 MGPY if energy cane were produced on 100,000 acres – 20 percent of the irrigated 500,000 acres of farmland – currently in production in the Imperial Valley.[261] Such production would not affect primary food crop production on prime soils.

Proposals for ethanol production from energy cane in California are modeled after state-of-the-art practices developed for Brazilian production. All parts of the plant would be used; juice for primary fermentation, with the plant remainder (bagasse) being used for process energy for combined heat and power, green energy production, or building products. The carbon intensity value for ethanol from energy cane could be as low as 4 gCO_2e/MJ, or 95 percent below the gasoline baseline.[262]

The Energy Commission received several proposals for energy cane to ethanol production in response to the Energy Commission's PON-09-604 solicitation, released in April 2010. This solicitation was extremely competitive, and the Commission was able to fund only 12 of the 44 proposals received.

Sweet Sorghum

Sweet sorghum is a variety of grain sorghum with very high sugar concentrations in its stalk. It has not been grown commercially in California, although numerous field trials have been conducted in Colusa and San Joaquin Counties.[263] It has lower water requirements than California-grown corn (2 acre feet per year as opposed to 3 acre feet per year for corn). Sweet sorghum will grow on soils with salinity and boron contamination that are unsuitable for food crops, which makes it promising for cultivation in the San Joaquin Valley, which suffers from selenium contamination from long-term irrigation.

Sweet sorghum plants can be pressed to extract the sugar juice, which is then fermented to form ethanol. Initial yield estimates are 70 gallons per acre to as high as several hundred gallons per acre. As with sugarcane, the plant remainder can be used as an energy resource (bagasse), as a cellulosic fuel feedstock, or further broken down to form a variety of feed materials, pharmaceuticals, or building materials.

The Energy Commission is funding the Great Valley Energy Center sweet sorghum feasibility project through a $1.9 million program grant. This project will assess multiple sweet sorghum varieties through field trials in Kern County. Great Valley's approach is to produce ethanol from the sorghum juice and assess the feasibility of producing building products from the plant remainder using the Tilby Press, which was developed in Australia to break down sugarcane stalks into beneficial coproducts.

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[261] Ibid.

[262] California Ethanol and Power, "California-Produced Sugarcane Ethanol to Be Responsible for Less Greenhouse Gas Emissions Than Gasoline and Brazilian Ethanol," http://www.californiaethanolpower.com/pdfs/CEP-Press-Release-Feb20-2009_Final.pdf.

[263] Phillip Trainer, Presentation at Energy Commission Biofuels Workshop, September 14-15, 2009.

Fuel Conversion Processes

The Energy Commission continues to research and assess major biofuel conversion processes. These assessments are summarized in Appendix C.

Gasoline Substitutes

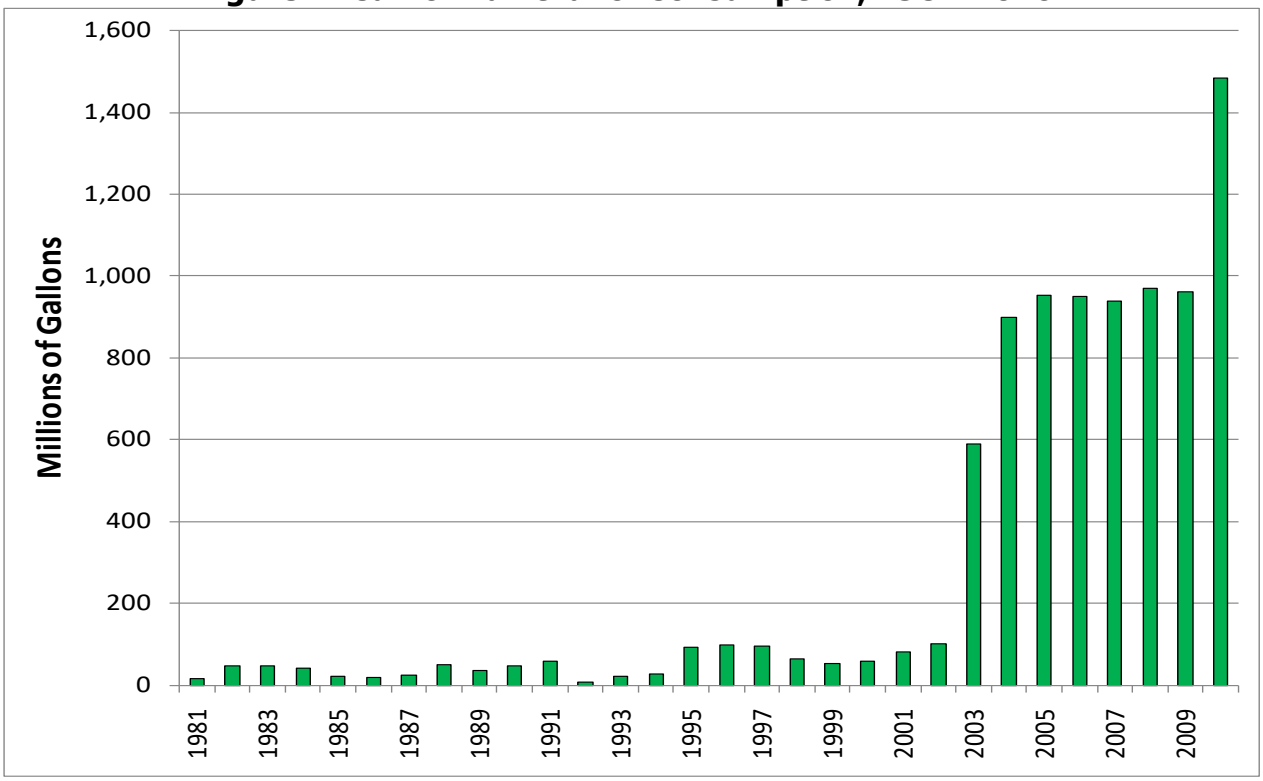
Gasoline substitutes, including ethanol, represent a significant opportunity to use existing technologies to expand low-carbon alternative fuel use. Gasoline substitutes refer to any liquid fuel that can significantly displace gasoline in internal combustion engines. This section also refers to renewable drop-in gasoline substitutes, which are physically identical to gasoline but are produced through alternative technologies. These drop-in gasoline substitutes have energy densities similar to conventional gasoline and can use existing infrastructure.

Ethanol is the most prominent alternative fuel produced and consumed in the United States and California. Between 1997 and 2010, nationwide production has increased more than 19.5 percent per year, with about 13.1 billion gallons of ethanol produced in 2010. Similar increases in ethanol production were seen within California throughout the previous decade. Between 2004 and 2008, California ethanol production capacity grew at an average annual rate of more than 55 percent to its current capacity of 240 million gallons per year. However, this capacity has been significantly underused in recent years, with just 21 million gasoline gallon equivalent produced in 2009.[264]

Despite its relatively small production of ethanol, California consumes a significant amount of the fuel each year. In 2003, California ethanol consumption jumped from a little more than 100 million gallons to a little less than 600 million gallons, due to its replacement of methyl tertiary butyl ether as a prominent gasoline additive. Consumption jumped another 44 percent in 2004 and almost 10 percent in 2005, and remained fairly steady until 2010, when the ethanol blend in California reformulated gasoline increased to 10 percent, and total ethanol use grew to nearly 1.5 billion gallons. However, California ethanol facilities contributed less than 4 percent of the state's needs during 2010. Figure 4 shows California ethanol consumption.

[264] O'Neill, Garry, John Nuffer. 2011. *2011 Bioenergy Action Plan.* California Energy Commission, Efficiency and Renewables Division. Publication Number: CEC-300-2011-001-CTF.

Figure 4: California Ethanol Consumption, 1981-2010



Source: California Energy Commission and Energy Information Administration

A variety of federal and state policy mandates will necessitate an increase in the consumption of renewable fuels through this decade. Given that California is about 11.5 percent of the U.S. population, California's "fair share" consumption of biofuels under the federal RFS2 is expected to be roughly 3 billion gallons.[265] At the state level, the ARB's LCFS outlines four scenarios for achieving GHG emission reductions from gasoline, each of which prominently includes contributions from ethanol. These scenarios include a broad range, from 2.2 billion gallons to 3.1 billion gallons per year by 2020.[266] The state's *Bioenergy Action Plan* establishes a 2 billion gasoline gallon equivalents target for biofuel consumption by 2020, in which ethanol is likely to feature prominently. The *Bioenergy Action Plan* also calls for 20 percent of the state's biofuel consumption to be met by in-state resources. For ethanol, this will entail about 500 million gallons per year in additional production (in addition to the full resumption of production at existing plants).[267]

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[265] Orta, Jason, Zhiqin Zhang, and et. al. 2010. *2009 Progress to Plan – Bioenergy Action Plan for California*. California Energy Commission. CEC-500-2010-007.
[266] Air Resources Board, *Proposed Regulation to Implement the Low Carbon Fuel Standard: Volume II, Appendices*, March 5, 2009, http://www.arb.ca.gov/fuels/lcfs/030409lcfs_isor_vol2.pdf.
[267] California Energy Commission, *2009 Progress to Plan – Bioenergy Action Plan for California*, http://www.energy.ca.gov/2010publications/CEC-500-2010-007/CEC-500-2010-007.PDF

Currently, California's ethanol is a mixture of ethanol produced in-state, in the Midwest, and from foreign sources. California is uniquely positioned, however, to use vast low-carbon feedstocks and to produce ethanol from feedstocks other than corn. For example, 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.[268] Specialty bioenergy crops such as cane, sweet sorghum, and perennial grasses can also be grown on marginal soils to produce very low-carbon biofuels (with 75 percent and higher GHG reductions from the petroleum baseline).

However, at this time, these types of renewable fuel technologies have not been demonstrated to be commercially successful. The United States Environmental Protection Agency issues renewable volume obligations each December to provide guidance on the mandated minimum volumes of renewable fuels by various categories for the upcoming calendar year. Over the last two years, the Environmental Protection Agency has significantly reduced the cellulosic renewable fuel requirement due to the lack of production capacity in the United States, most recently reducing the RFS cellulosic requirement for 2011 down from 250 million gallons to 6 million gallons.

To encourage further development of low-carbon liquid fuel options, the Energy Commission intends to allocate $8 million for the development of new production facilities that can convert sustainably derived, low-carbon feedstocks into ethanol. This funding will also be open to projects that produce drop-in gasoline substitutes, rather than ethanol.

Additionally, process energy efficiency measures and alternative fuels used for process energy can further reduce the GHG emissions from California ethanol. At the Energy Commission's *2010-2011 Investment Plan* Biofuels Workshop, several project developers described strategies to produce very low-carbon intensity biofuels (with more than 80 percent reductions from the CaRFG baseline) at competitive prices in California. These strategies include:

- Separation of feedstocks into multiple value-added products including ethanol, renewable diesel, green electricity, and other coproducts.
- Development of specialty bioenergy feedstocks such as energy cane, sweet sorghum, and perennial grasses that can be grown on marginal, nonfood crop soils.

[268] *An Assessment of Biomass Resources in California, 2007* Draft Report, Public Interest Energy Research Collaborative Report, March 2008. Using a California Biomass Collaborative average 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.

- Capital investments to increase biorefinery production outputs to meet shifting and new market demands, similar to the production strategy used by petroleum refiners.[269]

However, a lack of capital and debt financing is impeding biofuel plant development and upgrades at existing plants. If capital and debt financing were readily available, California's existing and planned plants could initiate use of California's biomass wastes and other alternative low-carbon feedstocks. Many instate developers of advanced biofuels projects are positioned to provide technology specifically designed to convert agricultural, forest, and municipal waste streams to transportation fuel. However, the present poor operating economics associated with these potential projects is the primary reason that financing has not been forthcoming.

The profitability of the U.S. ethanol industry has fluctuated with gasoline price and demand as well as corn prices. Consequently, in recent years the industry has had very narrow margins, as the impact of the global economic slowdown and decline in oil demand and prices, as well as upward pressure on corn price, have made survival more difficult. This poor performance has occurred despite a number of policy actions that support the ethanol industry, including:

- The Volumetric Ethanol Excise Tax Credit: a $0.45 per gallon excise tax credit for refiners and blenders. It is set to expire in 2011.
- The Secondary Tariff on Ethanol: a $0.54 per gallon ethanol import tariff intended to support domestic production. It is set to expire in 2011.
- The Small Ethanol Producer Tax Credit: a $0.10 per gallon tax credit for ethanol production up to 15 million gallons. The credit is available only to small-scale ethanol producers with an annual production capacity of no more than 60 million gallons. It is set to expire in 2011.
- The Cellulosic Biofuel Producer Tax Credit: a $1.01 per gallon tax credit for producers of cellulosic biofuel, intended to spur cellulosic production. It is set to expire in 2012.

California Ethanol Producer Incentive Program

The California Ethanol Producer Incentive Program provides operators of existing corn ethanol production plants with a minimum capacity of 10 million gallons per year with temporary financial assistance during periods of difficult economic operating conditions; funding was to be reimbursed under specifically identified favorable market conditions. The Energy Commission developed the California Ethanol Producer Incentive Program to increase statewide biofuel production by stimulating operational improvements and the use of advanced process technology to convert cellulose and other low carbon

[269] 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.

feedstocks, reduce GHG emissions, and retain and create California jobs. Originally, five plants were eligible for assistance, and four submitted applications for assistance. The Energy Commission does not currently have plans to provide additional funds to the California Ethanol Producer Incentive Program beyond the initial $6 million investment.

The California Ethanol Producer Incentive Program requires participants to comply with "biorefinery operational enhancement goals" in one of two ways. The first biorefinery operational enhancement goals is based on the participants' reducing the carbon intensity value of their produced fuel by at least 10 percent, relative to the default value adopted under the LCFS for their particular process application and type of feedstock. The second biorefinery operational enhancement goals requires the biorefiner to displace at least 20 percent of their existing feedstock with waste-based feedstocks. Participants in the California Ethanol Producer Incentive Program must achieve either of these goals according to a set timeline of milestones. The first milestone requires the biorefiner to submit a draft plan for compliance with either of the biorefinery operational enhancement goals within six months of participation. In the first quarter of 2011, three of the four eligible California Ethanol Producer Incentive Program facilities are producing ethanol. It is expected that one more facility may start operations in 2011.

The objectives of the California Ethanol Producer Incentive Program reflect the state's broader objectives for alternative fuels. These include the production of an in-state alternative fuel that is widely used to meet state gasoline oxygenate content requirements. California consumed more than 1.4 billion gallons of ethanol in 2010. before the California Ethanol Producer Incentive Program, more than 95 percent of this volume was imported from outside the state. The reopening of instate biorefiners also has important job benefits at this critical juncture in California's economic recovery, as each facility has been able to rehire dozens of workers who had been laid-off. In-state biorefiners also ensure a technology and facility base for California to expand into next-generation biofuels. Finally, the continued operation of these plants protects millions of dollars in existing private investment into California alternative fuels production and gives participants an opportunity to leverage additional private investment in their facilities.

During the administration of the California Ethanol Producer Incentive Program, market conditions have become increasingly unfavorable for ethanol production. This is due in part to near-record commodity costs for corn. Given uncertain market conditions and future price projections, it is unclear whether a modest state price support program can sufficiently offset the effects of this unprecedented change in the ethanol fuel market.

The Energy Commission and the California Department of Food and Agriculture are planning a forum for fall 2011 to explore the nexus between agriculture and energy. The forum will investigate connections among alternative fuels, agriculture markets, and food commodities. This forum will incorporate input from ethanol producers, federal and state agriculture agencies, livestock and poultry farmers, and other interested

stakeholders in order to ascertain whether continued financial support for California ethanol producers is necessary and, if so, in what form.

Upstream Fuel Infrastructure

More than 80 percent of the nation's ethanol production is in six Midwestern states and must be shipped to distribution terminals in other regions via truck, barge, or rail, transport modes that are more expensive than pipelines. California produces less than 5 percent of the ethanol it consumes and will continue to rely heavily on imports even if this percentage increases. Ethanol is imported into California by unit train volumes moving from the Midwest to terminals in Southern and Northern California before being redistributed by truck.

In the near term, most of the projected increase in shipments of ethanol to terminals will be handled by tanker truck and rail tank car as opposed to pipelines. Except for a few proprietary pipelines, the common carriers generally do not ship ethanol in their systems. The increased risk of corrosion and potential for water contamination associated with ethanol are key factors limiting its transport via pipeline. Investment funding for distribution improvements is small. An existing infrastructure moves ethanol from production sites to service stations, and that process is not expected to change materially over the next 10-20 years. However, as ethanol demand grows due to RFS2 and LCFS requirements, the scope of the distribution system will need to expand. For the United States overall, new sources of ethanol from cellulosic plants will be producing ethanol from sites outside the traditional Midwest, requiring more truck, rail, and barge movements to markets.

Local Fuel Infrastructure

California sales of E85 have risen significantly over the past five years, surpassing 3 million gallons in 2010. However, the Energy Commission expects that the retail presence and sales of E85 will need to expand if the state is to meet its fair share of RFS2 compliance. [270] Depending on the average quantity of fuel sold by a typical E85 dispenser, California could require between 4,400 and 30,900 E85 dispensers by 2022. To put that estimated number of new dispensers into perspective, there were about 42,050 retail dispensers in California during summer of 2008 for all fuel types.[271] Figure 5 shows the recent trends of E85 stations and E85 sales volume.

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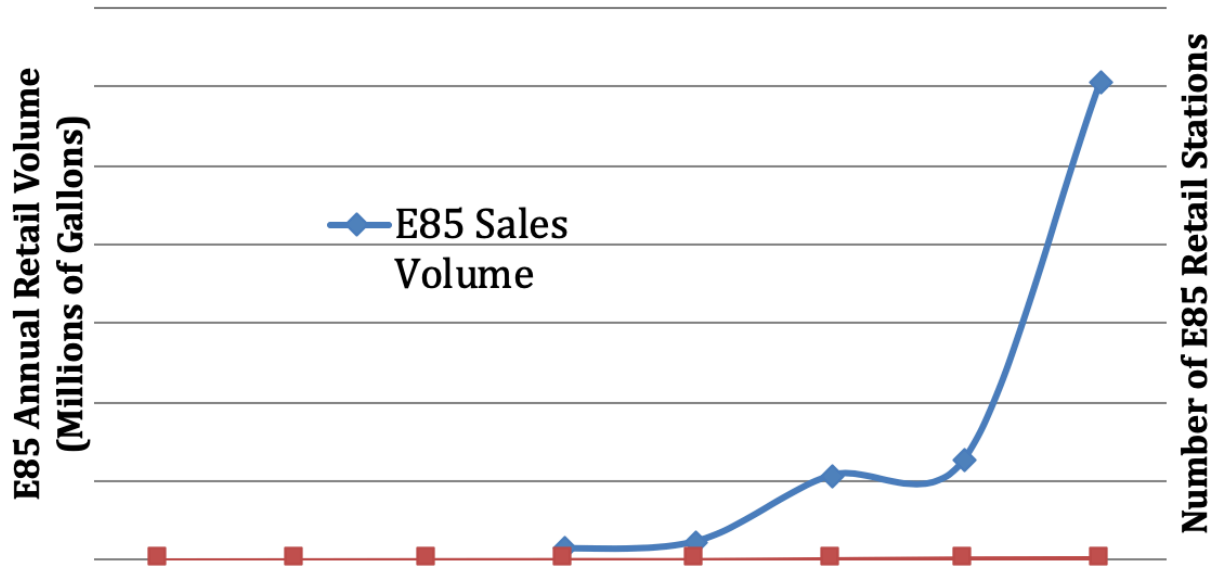
[270] *Transportation Energy Forecasts and Analyses for the 2009 Integrated Energy Policy Report*, California Energy Commission, Final Staff Report, Publication Number CEC-600-2010-002-SF, May 2010.
[271] Gordon Schremp and Nicholas Janusch, 2009. *Fuel Delivery Temperature Study*, California Energy Commission. CEC-600-2009-002-CMF.

Figure 5: Historical E85 Stations and E85 Sales Volume



Source: Energy Commission, Board of Equalization

As of February 2011, 57 retail stations in California offered E85.[272] To date, the Energy Commission has funded two projects for 85 new E85 fueling stations using $5 million of funds from the program. The project partners will provide $14.1 million, and the DOE will contribute an additional $6.9 million.

A review of the National Renewable Energy Laboratory's flexible fuel vehicle (FFV) density map indicates that the highest density of FFVs is observed in major population centers including San Francisco, Los Angeles, San Diego, and Sacramento. However, there are only a handful of E85 fueling stations in the Los Angeles basin.

The primary barrier to establishing new E85 dispensers is the upfront cost. E85 retail infrastructure is expensive. Costs for installing a new underground storage tank, dispenser, and appurtenances range between $50,000 and $200,000.[273] Statewide, the E85 retail infrastructure investment costs could be as low as $192 million to upwards of $4.7 billion between 2009 and 2020. Between 2009 and 2030 the E85 dispenser infrastructure costs could range from $251 million to $6.1 billion. Most conventional service stations are no longer owned by oil companies, and the investment needed to

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[272] U.S. DOE, "E85 Fueling Stations in California," http://www.afdc.energy.gov/afdc/progs/ind_state.php/CA/E85.

[273] National Association of Convenience Stores (NACS) and the Society of Independent Gasoline Marketers of America (SIGMA), Letter to Congress, March 27, 2006, http://www.sigma.org/pdf/E85-Mandates.pdf. According to the National Commission on Energy Policy's (NCEP) recent report, replacing an entire system can be expected to cost substantially more than $150,000 per facility depending upon the market. *Task Force on Biofuels Infrastructure*, NCEP, May 2009, Appendix B, page 53; available from http://www.energycommission.org/ht/a/GetDocumentAction/i/10232. Additional cost estimates for both new and retrofit scenarios are provided in the following brief paper: *Cost of Adding E85 Fueling Capability to Existing Gasoline Stations: NREL Survey and Literature Search*, National Renewable Energy Laboratory, Publication NREL/FS-540-42390, March 2008, http://www.afdc.energy.gov/afdc/pdfs/42390.pdf.

accomplish the conversion to E85 must be borne by the independent dealer. Moreover, most conventional service stations generate profits from convenience store sales and service or repair business, while usually breaking even on fuel sales. Investors have the challenge of recovering significant investment cost while marketing an initially lower volume product.

The most significant factors in fuel sales are location and price. Locating E85 stations at high-volume stations on busy commuter routes will be an important factor in achieving the required volumes. Another factor in siting E85 stations is the size of many existing service stations, which occupy small parcels that cannot readily accommodate an additional tank. The service station owner may be reluctant to dedicate an existing tank to E85 due to initial low penetration and volume sales of E85. Without external funding sources, retail availability of E85 would solely rely on retail site owners voluntarily choosing to invest in E85 dispensing equipment.

Permitting for the development of stations must be done through the local authority having jurisdiction – usually the local fire marshal. According to the State of California Supervising Deputy State Fire Marshal, there are local fire marshals who do not allow the permitting of the construction of E85 distribution stations within their jurisdiction.[274] Other authorities having jurisdiction consider E85 as a fuel equivalent to gasoline and are determining E85 distribution equipment as having natural equivalency.

In June 2010, Underwriters Laboratory certified two fuel dispensing systems for E85, including dispenser, hose, nozzle, swivel, breakaway, and shear valves. Because Underwriters Laboratory policy stipulates its listings apply only to those particular units that were manufactured after the date of certification, current retailers who sell E85 may need to purchase all new equipment. In addition, those retailers may need to ensure that their underground equipment is also listed as compatible or replace the entire system, an expensive undertaking.

Given the anticipated demand growth for E85 and the associated retail station infrastructure needs discussed above, the Energy Commission intends to allocate $5 million for the further expansion of E85 fueling infrastructure. This amount of funding could provide 60-90 stations, depending on capital cost. This funding will be guided in part by the numbers and locations of FFV deployments, as well as the locations of existing E85 fueling infrastructure.

Vehicles

Engine modifications are needed to accommodate E85, while retaining capability to operate on gasoline or any blend containing up to 85 percent ethanol. Modification costs, however, are sufficiently low that U.S. automakers have produced FFVs since 1993, primarily to take advantage of the credit allowed toward meeting Corporate Average Fuel Economy standards, as provided by the Alternative Motor Fuels Act of

[274] ICF interviewed the State of California Supervising Deputy State Fire Marshal to develop a clearer understanding of the safety and permitting issues associated with E85 stations.

1988. According to the Office of Energy Efficiency and Renewable Energy, there were about 8.4 million E85 FFVs on the road in the United States in 2009, with more than 400,000 of these in California. Due to the limited availability of E85 and the cost relative to gasoline, most FFVs never use this fuel.

All gasoline vehicles can now use E10 blends safely, and EPA has determined that newer (post-2000) vehicles can use E15 safely.[275] As older vehicles are retired, most of the fleet will be E15-capable by 2015. However, several barriers would need to be overcome if E15 use were to become a reality in California. California has its own reformulated gasoline regulations that are based on vehicle testing of gasoline with ethanol no greater than 10 percent. New testing of vehicles, assuming no deleterious emission impacts, would take time – at least three years to complete. In addition, no vehicle manufacturer allows ethanol concentrations in excess of 10 percent to be used without violating the vehicle warranty. Finally, service station owners have no liability protections against misfuelling damage claims for people that use E15 in vehicles older than model year 2001.

In contrast, E85 can be used only in vehicles designated as an FFV. Future emission standards for California will make certification of FFV models more difficult in California. At the federal level, new fuel economy regulations phase out the fuel economy credits available to manufacturers for producing FFV models by 2020.[276]

FFVs account for 1.5 percent of California light duty vehicles, or more than 400,000 vehicles.[277] All E85 use is in the light duty vehicle category. By 2020, projections based on DMV vehicle registration data indicate upwards of 800,000 FFVs for both light- and medium- duty applications.[278]

To make a gasoline vehicle ethanol-capable, manufacturers install a computerized optical sensor or other technology that detects how much ethanol is in the fuel mixture. Because ethanol is more corrosive than gasoline and has less energy content, manufacturers need to use modified materials and larger sizes for the gas line, gas tank, pumps, and injectors.

E85 has about 30 percent less energy per gallon so the fuel efficiency of an FFV running on E85 will be about 30 percent lower on a volumetric basis. As a result, the vehicle range will be proportionally reduced since original equipment manufacturers do not typically specify larger fuel tanks for FFVs. This means that E85 prices should be

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[275] United States Environmental Protection Agency, "EPA Announces E15 Partial Waiver Decision," http://www.epa.gov/otaq/regs/fuels/additive/e15/420f11003.pdf.
[276] ICF International, "Technical Analysis for the Alternative & Renewable Fuel & Vehicle Technology Program - Task 2 –Evaluate Alternative and Renewable Fuel Infrastructure and Distribution Development for E85," draft unpublished report, November 22, 2010.
[277] DMV data.
[278] Energy Commission staff estimate, based on DMV data.

reduced a comparable percentage to be fairly priced at gasoline gallon equivalent prices.

In 2006, Ford, DaimlerChrysler, and General Motors indicated they would produce 2 million FFVs by 2010. In May 2010, Ford announced it would fulfill its projection by the end of the year. Ford has also announced that FFV-certified engines would be available on 50 percent of nameplates by model year 2013, including new small engines such as in the Focus. General Motors made a commitment that more than 50 percent of its production by model year 2013 will be FFVs. DaimlerChrysler made this same pledge.[279]

The high-octane rating of E85 is a significant driver for research into vehicle technologies that improve engine technologies that capitalize on this physical property of the fuel. Most researchers focus on increased compression ratio engines operating with natural, or more frequently, boosted aspiration. For example, Ricardo Motors has demonstrated an ethanol-boosted direct injection engine with extreme downsizing and estimated that a fuel economy improvement of up to 30 percent is possible on an equal performance basis.[280]

Ford is supporting the development of a similar technological approach using ethanol-boosting systems.[281] The proposed technology uses conventional gasoline fuel in higher compression ratio engines as long as a small quantity of E85 is available on board for high load conditions when engine knock is most likely to occur. Their research determined that a small, turbocharged, high-compression-ratio spark ignition engine can provide the same peak power as a naturally aspirated gasoline spark ignition engine but will be 20 to 30 percent more fuel-efficient. As a reference, that level of fuel economy increase is provided by some of today's hybrid vehicles but at a substantial cost disadvantage.

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[279] ICF International, "Technical Analysis for the Alternative & Renewable Fuel & Vehicle Technology Program - Task 2 –Evaluate Alternative and Renewable Fuel Infrastructure and Distribution Development for E85," draft unpublished report, November 22, 2010.

[280] Ricardo Motors, "The Impact of Federal Requirements on Future Vehicle Technologies," Presentation at AVT Conference, October 30, 2009.

281 Ethanol Boosting Systems, LLC, "Ethanol Turbo Boost for Gasoline Engines," http://www.ethanolboost.com/EBS_Overview.pdf.

Table 22: Gasoline Substitutes Funding Allocation

Advanced Ethanol and Gasoline Substitute Production Plants	$8 Million
E85 Fueling Infrastructure	$5 Million
Total	$13 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.[282] Of these fuels, only biodiesel is commercially available in California, and renewable diesel is now produced in Louisiana and abroad in Rotterdam, Singapore, and Finland.

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 2009, California used 6.9 million gallons of biodiesel.[283] 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 retail infrastructure. Wholesale modifications, however, are necessary to store and blend segregated biodiesel into diesel fuel.

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. Segregated wholesale rack infrastructure modifications may be needed for renewable diesel as well.

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 Amyris, Solazyme, Jiangsu Yuehong Chemical Co., Ltd.). Biochemical processes vary considerably, and the final fuel product specifications are as varied as the

[282] Thermal depolymerization is a process in which pressure and heat reduce complex organic materials into short-chain hydrocarbons (such as light crude oil).

[283] Energy Commission staff based on data from the California Board of Equalization.

processes and are in the beginning stages of development. Energy Commission staff will continue to monitor these promising technologies.

Algae-derived diesel is a 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.[284] Additionally, algae-derived diesel may have 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.[285]

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 12 percent to 93.8 percent compared to conventional diesel fuel.[286] Additionally, the 6.9 million gallons of biodiesel used in California in 2009 had the estimated emissions reductions (with the exception of nitrogen oxide, which increases) shown in Table 23.[287]

Table 23: Estimated Emission Reductions From 6.9 Million Gallons of Biodiesel in 2009

	Particulate Matter	**Hydrocarbons**	**Carbon Monoxide**	**Nitrogen Oxide**	**SO_2**
Percentage Reductions	47	67	48	-15	100
Emission Reductions (lbs)	34,775	38,880	383,685	-160,425	30,430

Source: National Biodiesel Board, ARB

The ARB's Research Division is investigating biodiesel nitrogen oxide impacts, and its staff released a draft biodiesel nitrogen oxide mitigation plan. Preliminary research findings suggest that nitrogen oxide emissions increase 10-35 percent depending on engine, feedstock, and test cycle. The staff draft biodiesel nitrogen oxide mitigation plan relies on blending renewable diesel or a common cetane improver to render biodiesel's nitrogen oxide emissions neutral, requiring no further mitigation. An ARB hearing and regulation on this are anticipated in October 2011.

Biodiesel is today's option, but it requires bulk storage and rack modifications to significantly expand beyond its current volume. Ultimately, biodiesel is expected to

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[284] (S&T)2 Consultants, Inc., *The Addition of Algae and Jatropha Biodiesel to GHGenius*, September 30, 2009.
[285] National Renewable Energy Laboratory, *Aquatic Species Project Report FY 1989-90*. January 1992.
[286] California Air Resources Board, Low Carbon Fuel Standard Table 6 Carbon Intensity Lookup Table for Diesel and Fuels that Substitute for Diesel, at http://www.arb.ca.gov/fuels/lcfs/121409lcfs_lutables.pdf.
[287] Original data derived from the National Biodiesel Board's online calculator, available at http://www.biodiesel.org/tools/calculator/default.aspx?AspxAutoDetectCookieSupport=1. Nitrogen oxide emission data weighted by Energy Commission staff to reflect ARB's research on California-specific diesel.

supply less than 10 percent of California's diesel demand due to domestic feedstock supply limitations. In the near-term, renewable diesel is envisioned to become a commercial product, will be comingled with petroleum diesel, flow through the existing pipelines, and be dispensed from petroleum storage and rack terminals. Renewable diesel is also envisioned to use separate and dedicated storage and blending facilities similar to today's regular and premium grade gasoline.

Most renewable diesel is likely to be produced at refineries on California's coast, and the fuel transported via pipeline throughout the state. Concurrently, most biodiesel is envisioned to 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 diesel substitutes 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 diesel substitutes 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. The federal subsidy of $1 per gallon will spur diesel substitutes' economic viability in the short term, and the federal RFS and the California LCFS will spur economic viability 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 Energy Independence and Security Act of 2007.
- 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.[288] Up to 30 new biorefineries could be needed in California to meet the LCFS carbon intensity reduction requirements for diesel fuel.[289]
- 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,

[288] California Air Resources Board, *Proposed Regulation to Implement the Low Carbon Fuel Standard: Initial Statement of Reasons*, March 5, 2009, http://www.arb.ca.gov/regact/2009/lcfs09/lcfs09.htm.
[289] About 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 Energy Commission staff analysis done in support of the *2009 IEPR*.

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 million gallons per year. In-state production increases California jobs and economic benefits and reduces GHG emissions by minimizing imported fuel transport costs and impacts. California needs to add 4-8 new facilities for a total of 115 million gallons of new capacity to meet the 2020 BAP goal.[290]

Biodiesel/Renewable Diesel Fuel Use and Vehicles

In 2010, 1.0 million on-road diesel vehicles were registered in California, consuming 2.6 billion gallons of diesel. Off-road diesel demand adds an additional 1 billion gallons. Heavy-duty and off-road vehicle applications use more than 92 percent of all diesel fuels and therefore represent the key market for biomass-based diesel fuels.[291] Biodiesel has unique fuel properties that require a unique American Society for Testing and Materials 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 American Society for Testing and Materials D975 (petroleum diesel fuel) or American Society for Testing and Materials D396 (home heating oil).[292] Engine manufacturers favor these characteristics. Based on current American Society for Testing and Materials specifications, renewable diesel fuels are not anticipated to require any vehicle modifications or preventative maintenance.

Today, the main barrier to expanded B20 or renewable diesel R20 use is the 20-cent to 40-cent per-gallon higher price for blend 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.[293] 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.[294] 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

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[290] This assumes 15-30 million gallons per year plant size.
[291] Energy Commission staff analysis.
[292] National Biodiesel Board. *Biodiesel, Renewable Diesel & Co-Processed Diesel.* http://www.biodiesel.org/pdf_files/fuelfactsheets/Co-Processing%20One%20Pager.pdf.
[293] The Energy Policy Act of 1992 regulations require that federal, state, and alternative fuel provider fleets build an inventory of alternative fuel vehicles.

[294] National Biodiesel Board, "Original Equipment Manufacturer Information / Standards and Warranties," http://www.biodiesel.org/resources/oems/default.shtm.

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 or R5 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 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.[295]

In November 2008, American Society for Testing and Materials International adopted new biodiesel standards for B5, B20, and B100 blends to address the fuel quality problems identified in the last decade. 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.[296] Compliance with the recently established American Society for Testing and Materials 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.[297] 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 diesel substitute fuels are requesting vehicle demonstration funds. These demonstrations will allow for precommercial 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 12 biodiesel plants with a combined annual production capacity of 76 million gallons. Due to the industry's inability to compete with petroleum-based diesel

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[295] Renewable diesel engine testing finds that blends up to nearly 90 percent have the ability to meet American Society for Testing and Materials 975 Standards, Preliminary Results from Neste and Conoco Phillips Testing, 2003-2007.

[296] This task part of a $4 million agreement with Department of Food and Agriculture.

[297] Energy Commission, Petroleum Industry Information Reporting Act data.

prices, these plants likely produced fewer than 5.5 million gallons in 2010.[298] Six plants, representing one-third of the state's biodiesel production capacity, are idle due to their price disparity.[299] 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 gallons. The ARB LCFS program's 2020 goal is projected to require 0.7 billion-1.0 billion gallons of diesel substitutes assuming 50-75 percent carbon reduction respectively – assuming 5.25 billion gallons of diesel demand in 2020.

Biodiesel plants use recycled cooking oil (yellow grease) as their lowest-cost and lowest GHG feedstock as well as more expensive (and typically higher GHG) feedstocks such as soybean, palm, and a variety of plant and animal oils. To reach higher diesel substitute volumes, 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 precommercial-scale plant sizes. Expansion of both first- and second-generation biofuel plants 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 *Bioenergy Action Plan* and directly supports California's jobs and economy.

A federal $1 per gallon incentive for biodiesel production began in 2002 and expired on December 31, 2009 but was resumed in December 2010. The federal subsidy expiration significantly reduced biodiesel production nationwide and in California. The ARB's LCFS program has a gradual phase-in and will not significantly affect the market demand for biodiesel for another year. Accordingly, fuel producers will have little motivation to invest in ensuring these plants' continued operation in the short term. 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, United States Department of Energy and the United States Department of Agriculture 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 awarded $2,845,744 for five diesel substitute projects using funds from the first investment plan. An additional $3.9 million solicitation is planned for FY 2010-2011 funds.

For FY 2011-2012 the Energy Commission is allocating $8 million to support new diesel substitute plants or plant expansions. California needs to expand current production to

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[298] Based on Board of Equalization data up to September 2010, staff assumed three months of 500,000 gallons per month in subsequent months for a total of 5.398 million biodiesel gallons.

[299] Comments submitted by the California Biodiesel Alliance, Energy Commission Docket Number 09-ALT-1, February 16, 2009.

at least 700 million gallons to reach 2020 *Bioenergy Action Plan* goals and to support ARB LCFS objectives.

Fuel Terminal Storage and Blending

For California to reach the 2050 GHG emission reduction goals and other near-term goals, all diesel substitutes sources must have access to California's market. Diesel substitutes 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 diesel substitutes produced and used in California depends on establishing bulk storage and terminal blending facilities for distributing biofuels and feedstocks. California imports about 62 percent of its transportation fuels from domestic and foreign sources, and this amount continues to grow for petroleum and biofuels alike.[300] Biodiesel and renewable diesel will require bulk terminals to receive and store the large volumes of bio-oils required to competitively produce diesel substitutes. 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 mainstream diesel market. Adding biofuel capacity and modifying existing bulk terminals to accept biofuels are critical to diesel substitute's 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 diesel substitute fuels. Diesel substitute 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.[301] These higher transportation costs should be eliminated with the establishment of appropriate rack terminal modifications to accept the biofuel.

Retail sales of low-level B5 and R5–R20 diesel substitute blends through existing retail facilities that require no modifications (referred to as drop-in fuels) are hampered by a lack of wholesale storage and distribution diesel substitute facilities. Regionally located distribution terminals with diesel substitute storage tanks are needed so that B5 and R5-R20 blends can be loaded for distribution to local retail diesel stations.

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[300] 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.

[301] Tellurium's comments made at the Energy Commission workshop, November 2009.

The relatively poor or marginal blending economics for diesel substitutes means that the payback for the investment in a storage tank at a distribution terminal can be questionable for the facility operator. In addition, the independent jobbers who want to sell B5 of R5-R20 to retail normally do not own and operate distribution terminals, which means they have little control or say on whether or where a B99 or R100 storage tank is constructed. Strategically allocated funding from the Energy Commission can provide an opportunity to increase substantially the distribution and end use of low-level diesel substitute blends in retail markets that are price sensitive.

Currently, financial institutions are not funding diesel substitute infrastructure projects. Funds from sources such as the federal government, ARB, or local air quality districts have not been made available for diesel substitute 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.

California has more than 100 rack-terminals and several plants, some of which may require modifications to dispense diesel substitutes. Based on FY 2008-2010 funded projects, infrastructure modification costs are estimated to be $500,000 to $3.0 million per site. Making these modifications would reduce costs and retail prices of diesel substitutes and increase diesel substitutes' sales volumes.

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, about $3.86 million has been awarded as identified in Table 23. Additional funds from FY 2010-2011 of roughly $3.1 million will also be available for blending and storage terminal projects in a future solicitation, culminating in a total of nearly $7 million in funding for diesel substitute infrastructure.

Table 24: FY 2008-2010 Funded Diesel Substitute Infrastructure Projects

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

Source: California Energy Commission

The Energy Commission is awaiting the results of the previous fiscal years' projects before allocating additional funds to diesel substitutes infrastructure. The Energy Commission will also assess the relative need of renewable diesel for upstream fueling infrastructure.

Table 25: Diesel Substitutes Funding Allocation

Advanced Diesel Substitute Production Plants	$8 Million
Total	$8 Million

Source: California Energy Commission

Biomethane

Biomethane, or renewable natural gas, is most commonly sourced from the anaerobic digestion or gasification of organic matter. These processes result in a biogas, which can then be cleaned up to biomethane with the removal of impurities such as CO_2, hydrogen, sulfide, and water. Biomethane can be used as an energy source for a variety of purposes, 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.
- Powering natural gas electricity generating stations.
- Blended or enhanced with hydrogen, further extending its GHG benefits.
- 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.

In the transportation sector, biomethane is a highly desirable alternative to fossil fuels as it has low carbon intensity values as determined by ARB on a well-to-wheels basis. Compared to traditional fuels such as gasoline, diesel, and fossil-based natural gas, biomethane can reduce emissions by up to as much as 87 percent.[302] These reductions can be even higher if additional technologies, such as a carbon sequestration process, are used. As determined by the LCFS, biomethane is the lowest carbon intensity alternative fuel readily available in California.

Biomethane can be generated from a variety of biomass sources. However, the Energy Commission favors the use of waste stream feedstocks for the transportation sector due to the high emission reduction potential and other environmental and health benefits realized on a wells-to-wheels basis with these feedstocks. California's waste streams have a gross production potential of 124 billion cubic feet per year and a technical potential of 23 billion cubic feet per year, equivalent to 2.6 billion diesel gas

[302] Detailed California-Modified Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation Pathway for Compressed Natural Gas (CNG) from Landfill Gas, February 2009. Detailed California-Modified Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation Pathway for Ultra Low Sulfur Diesel from Average Crude Refined in California, February 2009. 87 percent reduction based on landfill gas to CNG pathway compared to diesel baseline.

equivalents,[303] more than 70 percent of the state's annual on-road diesel fuel usage. Some of the most likely feedstock sources include diverted organic material from post-recycled municipal solid waste streams, animal manure, woody biomass from forest fuels management activities, agricultural residues, food waste, and wastewater treatment waste.

MSW one of the largest waste streams available in California and is a prime feedstock for conversion to biomethane as it will not only be using a waste product for energy production, but will also be diverting waste from entering landfills, thus extending the life of landfills. Roughly 39 million tons of MSW are landfilled annually, and about 22 percent of that is suitable for anaerobic digestion. Two of CalRecycle's Strategic Directives further support the diversion of organic matter from the landfills, setting a goal of 50 percent reduction of organics in the waste stream by 2020 and encouraging the development of alternative energy and biofuels.[304] MSW is composed of 57 percent biomass, which can be separated using various methods, with the remainder being plastics, textiles, and nonorganics.[305] When diverted from landfills, the organic fraction of MSW has 10 times greater energy production potential on a per-ton basis compared to landfilled waste.[306] Another benefit to MSW as a feedstock source is that an established collection system is already in place, and the waste is already transported to centralized locations.

Although production potential for biomethane is significant, currently there are a limited number of biomethane or biogas projects operational in California. To date, the program has funded nine biomethane projects with more than $33 million; one-third of this funding has gone toward landfill gas projects. These projects, spread throughout the state, are in various phases ranging from feasibility to commercialization and use a variety of feedstocks including waste-water treatment sludge, food waste, animal manures, landfill gas, woody biomass residues, and post-sorted MSW. Once fully commercialized, these projects are expected to displace more than 6.5 million DGE.

As more biomethane projects come on-line, it will be important that there is access to natural gas pipelines. When connecting to the natural gas pipelines, interconnection can be a financial burden. Gas quality testing and certification are expensive processes with

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[303] Ken Krich, *Biomethane from Dairy Waste: A Sourcebook for the Production and Use of Renewable Natural Gas in California.* Technical potential is based on physical system constraints including but not limited to agronomic and ecological requirements, terrain limitation, and inefficiencies in collection and handling. DGE calculated based on technical potential using conversion of 106 billion cubic feet = 800 million DGE.

[304] CalRecycle's "Strategic Directive 6.1" identifies a reduction of the number of organics in the waste stream by 50 percent by 2020, and "Strategic Directive 9.2" encourages the development of alternative energy and biofuels. More information is available at: http://www.calrecycle.ca.gov/AboutUs/StrategicPlan/.

[305] Rob Williams, *Biofuels from Municipal Wastes Background Discussion Paper*, March 28, 2007.

[306] Energy Commission meeting with CalRecycle, October 28, 2010.

no certainty over who should pay for them, such as 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.[307] Without access to the natural gas pipeline, a number of producers will have to determine other methods for moving their product into the market.

For the biomethane for transportation industry to develop successfully, California will have to ensure supportive government policies and additional financial incentives. Because this is a relatively new industry, additional financial incentives are needed to help offset high capital costs. In light of the $33 million already allocated to biomethane projects, funding is still a substantial need. Consequently, the Energy Commission is allocating $8 million for FY 2011-2012 to help further establish the biomethane for transportation industry. The allocation will focus on projects that use a variety of prelandfill waste materials as a feedstock and will provide financial assistance to projects that require gas quality testing on new feedstocks entering the natural gas pipeline.

Table 26: Biomethane Funding Allocation

Prelandfill Biomethane Production	$8 Million
Total	$8 Million

Source: California Energy Commission

Medium- and Heavy-Duty Vehicles

Medium- and heavy-duty vehicles represent a significant component of California's transportation sector. These vehicles account for about 16 percent of the state's petroleum consumption and 16 percent of GHG emissions within the transportation sector yet represent fewer than 4 percent of the state's vehicle population. Table 27 below summarizes the number of vehicles and petroleum demand in each gross vehicle weight rating class.

Table 27: Medium- and Heavy-Duty Vehicles and Petroleum Use

Truck Classification	Vehicles	Petroleum Use (Gallons/Year)	Average Petroleum Use per Vehicle (Gallons/Year)
Gross Vehicle Weight Rating 4 TRUCK	154,235	230,804,674	1,496

[307] E-mail to Energy Commission staff from Ken Brennan, November 18, 2009. 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.

Truck Classification	Vehicles	Petroleum Use (Gallons/Year)	Average Petroleum Use per Vehicle (Gallons/Year)
Gross Vehicle Weight Rating 5 TRUCK	65,034	123,506,209	1,899
Gross Vehicle Weight Rating 6 TRUCK	182,872	410,903,496	2,247
Gross Vehicle Weight Rating 7 TRUCK	83,210	496,086,082	5,962
Gross Vehicle Weight Rating 8 TRUCK	147,186	986,248,158	6,701
Total	632,537	2,247,548,619	

Source: California Energy Commission, DMV

As shown, each of these vehicles uses a significant amount of petroleum fuel, particularly when compared to a light-duty vehicle. For comparison, a light-duty truck that averages 20 MPG and 12,000 miles per year uses 600 gallons per year, while a passenger sedan that averages 30 MPG and 12,000 miles per year uses 400 gallons per year. On a per-vehicle basis, then, medium- and heavy-duty vehicles represent an excellent opportunity to expand alternative fuel use, reduce petroleum consumption, and lower GHG emissions, as outlined in Table 28.

Table 28: Petroleum and GHG Reductions

Vehicle Type	Incremental Cost of an Alternative Fuel Vehicle	Petroleum Reduction (Gallons per Year)	GHG Emission Reduction (metric tons $CO2_e$/year)[308]
Gross Vehicle Weight Rating 8 Diesel Truck	$40,000 (for CNG)	6,701 (based on historic average)	12.0
Light-Duty Sedan (30 MPG; 12,000 miles per year)	$10,000 (for BEV)	400	3.2

Source: California Energy Commission staff estimates; Total Fuel Use Analysis for 2009

Medium- and heavy-duty vehicles serve a variety of purposes in California's economy, from student and public transportation to urban delivery to long-haul goods movement. This means that any attempt to encourage petroleum and GHG emission reductions

[308] Assumes heavy-duty natural gas vehicles have a 15 percent GHG benefit, and light-duty BEVs have 72 percent GHG benefit per the Energy Commission *Full Fuel Cycle Assessment: Wells-to-Wheels Energy Inputs, Emissions, and Water Impacts Analysis*, Consultant Report, August 1, 2007.

must consider the unique applications of a particular vehicle. Using registration data from the Department of Motor Vehicles, the Energy Commission tracks the populations of nearly 40 medium- and heavy-duty vehicle vocations. Using this data, as well as fuel sales data from the Board of Equalization, the Energy Commission can estimate the annual petroleum demand for various vocations. This historical fuel use information, when combined with interviews from fleet managers, alternative fuel vehicle suppliers, and infrastructure providers, begins to form a foundation for the Energy Commission to identify and implement approaches for reducing petroleum and GHG emissions.

Natural Gas and Propane Vehicles

Natural gas and propane are again becoming popular alternative fuels for medium- and heavy-duty vehicles in California. In particular, the number of natural gas vehicles increased from fewer than 2,000 vehicles in 2000 to more than 12,500 vehicles in 2009, an increase of 10,500 vehicles over nine years. The number of CNG and propane vehicles as of 2009, as well as their estimated petroleum displacement, is shown in Table 29. These numbers will further increase as a result of the Energy Commission's funding of two natural gas deployment projects (discussed below). Anticipated vehicle buydown incentives for natural gas and propane, also funded by the Energy Commission, will further drive this market by providing incentives for the purchase of roughly 400 medium- and heavy-duty gaseous fuel vehicles.[309]

Table 29: Propane and Natural Gas Vehicles and Petroleum Displacement

Truck Classification	**CNG**		**Propane**	
	Vehicles	Petroleum Displaced (Gallons/Year)	Vehicles	Petroleum Displaced (Gallons/Year)
Gross Vehicle Weight Rating 4 TRUCK	567	896,664	232	458,611
Gross Vehicle Weight Rating 5 TRUCK	89	151,436	64	136,122
Gross Vehicle Weight Rating 6 TRUCK	7,617	35,925,646	1,142	3,366,408
Gross Vehicle Weight Rating 7 TRUCK	267	1,121,571	325	1,706,510

[309] Energy Commission staff analysis, June 2011. Final vehicle counts will depend on the types of incentives requested.

Truck Classification	CNG		Propane	
	Vehicles	Petroleum Displaced (Gallons/Year)	Vehicles	Petroleum Displaced (Gallons/Year)
Gross Vehicle Weight Rating 8 TRUCK	2,436	11,489,415	39	229,930
Total	10,976	49,584,732	1,802	5,897,581

Source: Department of Motor Vehicles, Board of Equalization

While these vehicle numbers are low compared to the overall market, they may not wholly reflect the direction of the transportation industry in recent or future years. Recent conversations with manufacturers of medium- and heavy-duty vehicles and engines have shown a renewed interest in both natural gas and propane. Major vehicle manufacturers are or will be offering natural gas and propane options in their class 1 through 8 (<6,000 through >60,000 GVW) vehicles. While product offerings are small, they are finding acceptance in many niche markets such as refuse haulers, drayage trucks, and transit buses. United States corporations and fleets see alternative fuels as a way to reduce GHG emissions and encourage wider use and production of efficient vehicles and domestic petroleum alternatives.

School bus and other transit bus vehicles represent a significant opportunity for natural gas and propane, and school districts have already shown an interest in these fuels. In particular, school buses may be more cost-effectively served with propane's lower incremental cost given school buses' significantly lower annual fuel demand. Sales of the Bluebird school bus continue to increase, and school districts across California are expressing increased interest in propane school buses.

Since the 1990s, transit buses within the South Coast Air Basin have favored the use of natural gas to meet air quality standards, and, statewide, all transit buses receive significant Federal Transit Agency support to cover a high percentage of the upfront vehicle cost. Public transit also encourages reduction of vehicle miles traveled, which in turn reduces GHG emissions and petroleum use. Today, transit bus purchases represent nearly 600 vehicles per year, which is roughly half of all heavy-duty natural gas vehicle sales. Given existing funding commitments, alternative fuel requirements for transit vehicles, and comparatively low petroleum demand by buses, the Energy Commission does not intend to supplement existing funding for transit vehicles. However, the Energy Commission plans to support workforce training and development for transit to ensure that well-trained service and maintenance employees are available to support the deployment of these vehicles and keep them in service.

While light-duty passenger vehicles can be retrofitted to use propane, retrofits and upfits are more common for medium-duty vehicles used in fleets. Propane is viewed as an economical upfit option for delivery trucks, shuttle buses, and school buses. Propane vehicles are an especially viable option for more rural communities looking to use an

alternative fuel for their vehicles or for an entire fleet because of its availability. The incremental cost for medium-duty and heavy-duty propane vehicle upfits depends on the application for which the system is being used. Systems in the $7,500 price range are typically for applications that include lighter trucks, while the incremental costs for shuttle and school buses are around $20,000. Companies and government fleets have already begun to express interest in and place orders for various medium- and heavy-duty propane vehicles, including: Time Warner, Primetime, Supershuttle, Santa Monica, Riverside, and Marquez.

To support the development and deployment of advanced medium- and heavy-duty natural gas vehicles and infrastructure, the Energy Commission has already committed funding for the following projects using funding from the first investment plan:

- Gas Technology Institute and Cummins Westport was awarded $1,777,364 to develop an advanced ISX11.9 G natural gas engine which will be a low-emission, high-efficiency engine designed for the Class 8 market. Swift Transportation will demonstrate one engine in a highway tractor for 12 months to accumulate about 2,000 miles per month while hauling loads up to 80,000 pounds gross vehicle weight. This engine will fill an important market gap where there is not a natural gas engine option available.
- South Coast Air Quality Management District was awarded $5,142,000 to offset the incremental cost of 120 commercially available new 2009 or 2010 model Class 8 Freightliner M2-112, Peterbilt, Kenworth, or other liquefied natural gas (LNG) drayage trucks. South Coast Air Quality Management District is partnering with the Ports of Long Beach and Los Angeles, which together are America's largest port complex. These ports together are the single largest fixed source of air pollution in the South Coast Air Basin. Each LNG drayage truck displaces about 10,000 gallons of diesel fuels each year.
- The San Bernardino Association of Governments was awarded $9,308,000 to purchase and deploy 202 heavy-duty natural gas trucks. San Bernardino Association of Governments has partnered on this project with Ryder Truck Transport Services, Inc., to purchase and deploy these trucks. The U.S. DOE's American Recovery and Reinvestment Act funds will provide $9,950,708 for the construction of two liquefied natural gas refueling stations and truck purchases.

With funds from the second investment plan, the Energy Commission has released a program opportunity notice for buydown incentives for specific classes of natural gas and propane fueled vehicles. Incentives will be provided at varying levels depending on the class of vehicle. The incentives will reduce the high initial capital cost of natural gas and propane vehicles to assist public and private fleets and individual consumers in making the decision to purchase and use vehicles powered by non-petroleum, lower-carbon, alternative and renewable fuels. The funding available for this solicitation is $14.54 million and is estimated to cover incentives for more than 1,000 natural gas and propane vehicles, with roughly 400 being medium- or heavy-duty vehicles.

Based on historical vehicle and fuel data available to the Energy Commission, as well as the current market descriptions provided by vehicle suppliers and customers, the Energy Commission is well-positioned to identify effective opportunities for promoting petroleum and GHG emission reductions in medium- and heavy-duty vehicles. Toward

this end, the Energy Commission will allocate $15 million in FY 2011-2012 for further purchase incentives to support the deployment of new, medium-duty or heavy-duty gaseous fuel vehicles: $3 million for propane vehicles and $12 million for natural gas vehicles. This funding will be available for both on-road and off-road vehicles. Using ratios derived from the previously discussed incentives, this level of funding should leverage roughly 700 to 1,000 additional medium-duty and heavy-duty natural gas and propane vehicles. A portion of the funding for natural gas vehicles may also be used to provide smaller incentives for light-duty natural gas vehicles, as discussed in the Natural Gas section.

Advanced Vehicle Technologies

In addition to gaseous alternative fuels, several medium- and heavy-duty vehicle suppliers have begun incorporating a variety of advanced vehicle technologies and other alternative fuels into their offerings, ranging from natural gas hybrid-electric vehicles to hydrogen fuel cell buses. In each case the qualities of the alternative fuel or advanced technology are being carefully matched to the duty cycles of the customer's vehicle. For this reason, the use of alternative fuels or advanced technology may be limited to certain niche market applications where the payback period is most attractive. As the technologies evolve and if associated costs fall, the opportunity for broader deployment of these technologies will arrive, allowing them to expand into new applications.

The Energy Commission, through the Public Interest Energy Research Program, funded the CALSTART Hybrid, Efficient, Advanced Technologies project for $3 million, establishing a center for research, development, demonstration, and commercialization of advanced, efficient truck technologies and systems. Through this project, a roadmap will be developed, with industry input, to commercialize advanced technologies for medium- and heavy-duty vehicles by 2020. The project also includes vehicle demonstrations for parcel delivery trucks and Class 8 trucks.

Hybrid-electric and hydraulic technologies on medium- and heavy-duty vehicles can potentially reduce GHG emissions 60 percent on a full fuel-cycle basis compared to conventional diesel 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 for this technology, due to their unique duty cycles.

The Energy Commission has funded a number of hydraulic hybrid demonstration projects to advance the state of the technology and match fleets and key niche markets with the appropriate vehicles. Examples of program awards made for hydraulic hybrid vehicle demonstrations include:

- Parker-Hannafin Corp. was awarded $750,000 to design, develop, and deploy four hydraulic hybrid Class 6 Coca Cola delivery trucks. These trucks may provide 40 percent better fuel economy over the conventional delivery trucks. Coca Cola Enterprises has the largest fleet of hybrid trucks currently

deployed with 335 units in fleet operations as of January 1, 2010. Coca Cola Enterprise and the South Coast Air Quality Management District are providing matching funding totaling $1.25 million.

- Kenworth Truck Company and its partners were awarded $1,458,735 and will demonstrate one truck with an advanced Class 8 hybrid electric system and an intercooled recuperated 350 kilowatts microturbine. The ICR microturbine will be run on natural gas for this demonstration due to its low GHG potential, low cost, and available distribution infrastructure. However, the microturbine will be capable of using any fuel including ethanol, LNG, hydrogen, and biodiesel. The system will initially be designed for Class 8 but can be readily scaled to fit all Class 6, 7, and 8 vehicles over a wide range of operation.

Additionally, the ARB funds the Hybrid Voucher Incentive Program, which provides vouchers up to $30,000 for the purchase of eligible new hybrid trucks and buses. The ARB has selected CALSTART to administer the Hybrid Voucher Incentive Program; however, the ARB maintains responsibility for designing and guiding the program. Unlike the Energy Commission's advanced vehicle technology demonstration projects, the Hybrid Voucher Incentive Program provides incremental funding for deployment of commercially available vehicles. Funding is provided on a first-come basis. The ARB's Air Quality Improvement Program Funding Plan for FY 2010-11 allocated $11 million for this program. Due to higher costs associated with purely electric medium- and heavy-duty vehicles, the Energy Commission has supplemented the Hybrid Voucher Incentive Program with $4 million to provide a higher incentive for these vehicles. As of mid-June 2011, this amount has provided funding for 165 vouchers. The ARB has proposed $11 million for the Hybrid Voucher Incentive Program in FY 2011-12 based on anticipated program revenues, or up to $16 million if revenues are higher than expected.[310]

Battery-electric and battery-electric hybrid vehicles have also shown promise for certain applications. The following projects were funded under the same solicitation:

- ISE was awarded $888,595 to produce a battery-electric 45-foot transit bus for the Los Angeles Metropolitan Transportation Authority Battery Electric Bus Program. ISE will install its electric drive system and lithium ion batteries in place of the engine and fuel storage tank. This is the first battery-based technology to meet the "40 feet and greater" transit bus requirements. This size class represents two-thirds of the transit bus market. If this demonstration is successful, the Los Angeles Metropolitan Transportation Authority is expected to purchase 30 to 40 buses per year on average.
- Motiv Power Systems, Inc. (Motiv), Bauer Worldwide Transportation, Inc. (Bauer), and Seeo, Inc. (Seeo) were awarded $1,345,552 to integrate Motiv's customizable electric-drive Power Control System into a prototype Class 4 vehicle to demonstrate the viability and benefits of the system's 100-mile all-electric range. Motiv will install its system on a new shuttle bus chassis as a test platform to illustrate the large-scale applicability of the technology. This shuttle will operate along routes at campuses of Bauer's client companies, including Google, Cisco, Facebook, and Yahoo. Upon successful completion of the proposed project, Bauer will employ the vehicle technology in a large-scale roll-out of Motiv's electric-drive vehicle platform, which can be configured with different battery packs and

[310] ARB, *Proposed AB 118 Air Quality Improvement Program Funding Plan for Fiscal Year 2011-12,* page 15.

with or without generators on board to meet the specific needs of medium- and heavy-duty vehicle fleets.

- Terex, in collaboration with PG&E and CALSTART, was awarded $494,678 to demonstrate the economic and environmental viability of its innovative new Hypower Hybrid system retrofitting 12 medium- and heavy-duty PG&E utility service vehicles. The Hypower Hybrid uses stored energy from the system's rechargeable batteries to provide power for aerial boom operation, cabin heating and air conditioning, and worksite lighting. This will virtually eliminate the need for chassis engine idling during these types of operation which typically exceed more than 4 hours per day for the average utility service vehicle.
- Electric Vehicles International was awarded $1,153,053 to design, develop, and deploy a range-extended electric vehicle powertrain for medium-duty truck applications. Electric Vehicles International will build 10 range-extended LNG medium-duty pickup trucks, which will use Valence Technology lithium-phosphate batteries for a 100-115-mile range. Electric Vehicles International will integrate the new powertrain into an industry standard pickup truck and will deploy prototypes for onsite testing with partners.

Opportunities for hydrogen and fuel cell use in medium- and heavy-duty applications are also on the horizon. California has pursued development and deployment of alternative-fueled and hydrogen fuel cell transit buses through regulations and incentives for more than 10 years. 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.[311,312] Fuel cell transit buses also almost double the fuel mileage (on a diesel gas equivalents basis compared to a conventional diesel transit bus) and reduce particulate matter and air toxics associated with diesel.

Since 2004, the ARB has directed its staff to develop fuel cell bus demonstration programs in the Bay Area and in Southern California. The HyRoad Program, led by alternating current Transit in Oakland/Emeryville, will roll out 12 hydrogen fuel cell buses by April 2011 (five buses have been delivered). In addition, the ARB cofunded two fuel cell buses with SunLine Transit in Twentynine Palms. Proterra, a Colorado-based vehicle manufacturer, has produced a battery-assisted hydrogen hybrid transit bus. One such bus is located at the Burbank city yard in Southern California, but it has not entered regular transit service due to the lack of sufficient fuel supply at the Burbank hydrogen fueling station.

Hydrogen fuel cell technology is not strictly limited to bus applications. Vision Motor Corporation of 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

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[311] California Air Resources Board, *Detailed California Modified GREET Pathway for Compressed Gaseous Hydrogen from North American Natural Gas Version 2.1*. https://www.arb.ca.gov/fuels/lcfs/lcfs.htm

[312] *Full Fuel Cycle Assessment: Well-to-Wheels Energy Inputs, Emissions, and Water Impacts.* Consultant Report. 2007. California Energy Commission, CEC-600-2007-004-REV.

deployment. To test the technology for its potential for commercialization, Vision put two trucks to work at the ports of Los Angeles in early 2011 for an 18-month project. One "terminal tractor" will be an in-port goods-mover and the other one a big-rig vehicle for moving cargo from the port to short-haul destinations. Both will operate under real-life scenario conditions. Funding for this battery-dominated hydrogen fuel cell truck commercialization project comes from the port's authorities (as well as some United States Environmental Protection Agency funding from the 2010 Clean Air Technologies Award) under the ports' Technology Advancement Program and is being supported by local trucking companies.[313]

A federal tax credit of $10,000 to $40,000 is available for heavy-duty fuel cell vehicles, depending on the vehicle weight. The credit may be claimed for vehicles placed in service after December 31, 2005 and purchased on or before December 31, 2014. The South Coast Air Quality Management District also serves as an important funding partner, reserving about 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. Cofunding demonstration and test fleet projects through the AQMDs are already in progress as explained in the Zero Emissions Bus section above. Additionally, ARB is reviewing, monitoring, and reassessing components of the Air Quality Improvement Program to potentially fund and support hydrogen fuel cell buses in future funding plans.

To build on these opportunities, the Energy Commission intends to offer $8 million for the further development and demonstration of new technologies for the medium- and heavy-duty vehicle sector. Additional funding for advanced technology commercial deployment projects may also be warranted. This funding will extend to a broad variety of advanced technology projects, including hybrid hydraulics, battery electric, and fuel cells, but will also consider improvements together alternative fuel engines and systems.

Table 30: Medium- and Heavy-Duty Vehicles Funding Allocation

Deployment Incentives for Natural Gas Vehicles	$12 Million
Deployment Incentives for Propane Vehicles	$3 Million
Develop and Demonstrate Advanced Technology Medium- and Heavy-Duty Vehicles	$8 Million
Total	$23 Million

Source: California Energy Commission

[313] *Fuel Cell Industry Report*, "Vision Motors Testing Fuel Cell Trucks," Volume 12, No. 2, February 2011.

Innovative Technologies, Advanced Fuels, and Federal Cost-Sharing

The previous sections of the investment plan identified high-priority investments related to specific fuels and vehicles as well as analytical and outreach strategies. The statutes establishing the program also give the Energy Commission authority to make public investments in opportunities not specifically identified in the annual investment plan including projects that improve 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 cofund 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,[314] research consortiums such as "Centers of Excellence," recruitment of financial investors, or a combination of such activities.

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, United States Environmental Protection Agency, United States Department of Transportation, and the United States Department of Agriculture. 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.[315]

The Energy Commission allocated a combined $8 million for these activities in the previous fiscal year. This funding will support a variety of projects, including the possibility of a "small grants" program akin to the Energy Innovations Small Grants administered by the Energy Commission's Public Interest Energy Research Program. For FY 2011-2012, the Energy Commission will allocate $3 million for innovative technologies, advanced fuels, and federal cost-sharing opportunities.

Table 31: Innovative Fuels, Advanced Fuels, and Federal Cost-Sharing

Innovative Fuels, Advanced Fuels, and Federal Cost-Sharing	$3 Million
Total	$3 Million

Source: California Energy Commission

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

[315] The Energy Commission will also consider funding for highly leveraged proposals with local governments.

Chapter 4: Manufacturing

Encouraging manufacturers of alternative fuel and vehicle technologies to locate or expand their operations in California has the potential to create thousands of green jobs and substantial benefits to the state's economy. For example, at its peak production before it closed in early 2010, the New United Motor Manufacturing, Inc., plant in Fremont, California, employed 4,500 high-skilled laborers and up to 35,000 supply chain workers in a joint venture between General Motors and Toyota. California-based Tesla Motors, Inc., bought the Fremont plant to expand its in-state manufacturing capacity.

Several California manufacturers produce batteries and component parts for automakers, components for the electronics industry, electric vehicle charging stations, and stationary power storage systems for military and industrial customers. In addition, several startup vehicle manufacturers have emerged in California and begun developing prototype and early market PEVs. However, difficulties in raising upfront capital can impede these manufacturers from developing and expanding the plants and assembly lines to make advanced PEV components and produce electric and alternative fuel vehicles for commercial sales.[316]

Large vehicle manufacturers have made many capital-intensive investments in alternative fuel vehicle and component production capacity in recent years. These corporate investments have been bolstered by large-scale financial support from the federal government in the form of grants, loans, and loan guarantees. Under the DOE's Advanced Technology Vehicle Manufacturing program, $8.5 billion was loaned to companies such as Fisker Automotive, Ford Motor Company, Nissan, and Tesla Motors.[317]

Most manufacturers in California, however, do not have the funds required to invest tens or hundreds of millions in facility improvements, or the size to attract federal support. They rely on a combination of venture capital, commercial credit, and state and local incentives to fuel their growth. The availability of state and local incentives, therefore, can play a large role in determining where companies locate their manufacturing facilities. By offering program funds in support of manufacturing, the Energy Commission can ensure California attracts and retains vibrant, job-producing, and sustainable manufacturing facilities.

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[316] 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. 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 affect California's market for electric drive vehicles.

[317] ICF Report, draft consultant report, Analysis of Alternative Fuel and Vehicle Investments.

Using FY 2008-2010 program funding, the Energy Commission awarded $19 million for a combination of grants for predevelopment 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 encouraged investment in California-based manufacturing and assembly plants that produce alternative fuel and vehicle technologies that help the state meet its GHG emissions and petroleum fuel demand reduction targets. In addition to awarding grants and loans, the Energy Commission will support California manufacturing by collaborating with the California Alternative Energy and Advanced Transportation Financing Authority to establish loan mechanisms and promote sales tax exemptions for the purchase of equipment to manufacture ZEVs.

The Energy Commission reviewed a number of worthy responses to PON-09-605, which was designed 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 and alternative fuel vehicles.[318] Below is a list of the successful applicants and a brief description of their proposed projects:

- Boulder Electric Vehicles will produce medium- and heavy-duty electric vehicles from its 20,000-square-foot manufacturing facility in Los Angeles.
- Coulomb Technologies will design and manufacture its Charge Point Communications Processor, which allows existing electric vehicle chargers to be retrofitted with smart grid connectivity.
- Electric Vehicles International will develop, test, and improve an automated, pilot, electric vehicle production process that realizes cost savings by bringing many parts of a diverse supply chain under one roof.
- Leyden Energy will develop and test a new lithium-ion battery technology and build a pilot production line that is capable of assembling electric vehicle battery packs.
- Mission Motor Company will develop its battery module and motor control systems and install a manufacturing line capable of producing 30,000 battery packs and control systems per year by 2015.
- Quallion is developing a pilot-scale automated production line that will allow for the large-scale manufacturing of lithium-ion battery modules.
- Quantum Fuel Systems Technologies Worldwide, Inc., will retool one of its Lake Forest, California, facilities to develop, test, and produce a combination inverter/charger for hybrid-electric vehicle applications.
- Transpower is studying the feasibility of constructing a manufacturing facility for Class 8 electric trucks in California by 2013.
- Wrightspeed will validate a new electric drive retrofit kit for Class 3 through Class 6 trucks, which includes a range-extending microturbine generator.

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

- Zero Motorcycles will design and bring to pilot production a new advanced electric motor and integrated controller for use in next-generation electric vehicles.

Through PON-09-605, the Energy Commission has made substantial investments in California alternative fuel vehicle and component manufacturers. These investments support manufacturers as they develop products and install pilot-scale assembly lines in preparation for full commercial-scale production. Successful projects will attract customers and receive production orders and will soon need greater manufacturing capacity. State support can help ensure that these commercial-scale manufacturing plants are located in California with their attendant jobs, environmental benefits, and tax revenue. Therefore, in FY 2011-2012, the Energy Commission will allocate $10 million to fund projects that establish commercial-scale alternative fuel vehicle and component manufacturing facilities in California.

Table 32: Manufacturing Funding Allocation

Manufacturing Facilities and Equipment	$10 Million
Total	$10 Million

Source: California Energy Commission

Chapter 5:
Workforce Training and Development

Workforce training and development are critical in the Energy Commission's efforts to develop California's clean transportation market. Training is required to respond to new technology, improve efficiencies, minimize waste, and reduce production costs. Skilled workers are needed to manufacture low-emissions vehicles and components, produce alternative fuels, build fueling infrastructure, service and maintain fleets and equipment, and inform ongoing innovation and refinement to increase market acceptance. As the Energy Commission funds alternative fuel and low-emission vehicle projects, it is critical that funds are allocated to help develop a skilled workforce to implement and sustain those projects.

Workforce Training and Development Implementation

A combined $15.78 million was allocated to support workforce training and development in the first two investment plans. The funds were used to establish interagency agreements with Employment Development Department, the California Community Colleges Chancellor's Office, and the Employment Training Panel (ETP). The interagency agreements have been structured to fund alternative fuel and low-emission vehicle training as a portion of the partner agency's broader workforce projects. This approach ensures that program funds supplement workforce training programs to include training consistent with the program investment plan.

This funding structure has required a concerted effort by Energy Commission staff and partners to identify those elements within each training project that best suit the mission and goals of each funding source. Partner agencies provide traditional workforce training services as well as basic fuel and vehicle training, and program funds are used to support advanced training in alternative fuels and vehicle technologies. While this approach is not a common model in the workforce training system, the strategic alignment of multiple agencies' goals and resources has served to leverage limited funds and better serves the multifaceted workforce training needs of the alternative transportation industry and individuals alike.

Workforce training and development grantees have developed programs that establish or expand regional partnerships with local workforce investment boards, community colleges, local training organizations, public/private employers, community and business development organizations, labor organizations, and other key stakeholders to address the workforce training needs of the industry within their region, based on the fuels and vehicle technologies adopted.

To date, partner agencies have awarded more than $7.9 million in program funding, which includes four regional industry cluster assessment and planning grants, eight regional training grants, and eight employer training contracts to train more than 3,500 individuals.

These grants and contracts have secured more than $8.7 million in non-state matching funds. Partner agencies have also conducted an industry assessment and developed the *Green Transportation Jobs Report*, which provides a transportation-focused analysis of the *Green Jobs Survey*.

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 evolving workforce training needs of California's developing clean transportation industry.

Workforce Training Activities

California Employment Training Panel

The ETP provides financial assistance to California businesses to support customized worker training. The ETP plays an important role in California's workforce system by helping businesses provide lifelong learning opportunities to their incumbent and new hire workers.

The ETP was allocated $5.78 million to fund performance-based training contracts that provide workforce training related to alternative fuels and vehicle technologies that are consistent with the priorities established in this investment plan.

The ETP interagency agreement was finalized in June 2010. ETP immediately funded five training contracts before the close of FY 2009-2010. Due to delays resulting from the extended period without a state budget, it was unable to fund additional projects until January 2011. Three program-related contracts were awarded during its January 2011 Panel Meeting for eight training contracts totaling $4,172,830 to train more than 2,400 individuals and secured more than $4.5 million in non-state match (Table 33).

Table 33: ETP-Funded Training Contracts

Contractor	Program-Related Training Focus	Number of Trainees	Program Funding	Non-State Match
Terex Utilities%	Installation, service and maintenance training related to HyPower aerial device.	44	$158,400	$242,644
ISE Corp%	Hybrid drive vehicles; lean manufacturing; quality control ISO 9001	126	$453,600	$546,084
Electric Vehicles, Inc%	MD and HD electric drive vehicles	100	$494,000	$315,000
Fillner Construction%	Alternative fuels fueling Storage	28	$149,240	122,500
*California Manufacturers & Tech Assoc (CMTA)	Hydrogen fuel cell; Alt fuels; hybrid electric lean manufacturing; production solutions; quality controls	305	$559,060	$900,000
**California Labor Federation (CLF)				
Blue Sky Bio-Fuels	San Francisco	19	$59,280	$56,883
MV Public Transportation	Alameda, Los Angeles, Tulare	100	$180,000	$200,000
California Labor Federation	Sacramento, Santa Clara Valley, Los Angeles Regional Transits	1,750	$2,119,250	$ 2,200,000
Totals		2,472	$4,172,830	$4,583,111

Source: California Energy Commission

*CMTA is a multiemployer training contractor that supports training for multiple companies, which may include: Altergy Systems, Pacific Ethanol, Peterson Power, and Cummins West

**CLF is a multiemployer training contract that will provide training for multiple companies, which may include Sacramento Regional Transit District, and Santa Clara Valley Transportation Authority % Program development or deployment project grantees

California Employment Development Department and California Workforce Investment Board

The Employment Development Department operates one of the largest public employment services operations in the world. The Job Service program offers resources at hundreds of locations throughout the state and connects 1 million job seekers with employers each year through its comprehensive One-Stop Career Centers. These regional centers provide access to a full range of programs pertaining to educational activities, local employer services, and referrals to other appropriate social services.

Employment Development Department delivers prepaid training and employment services to unemployed, underemployed, and incumbent workers and helps employers connect with skilled workers.

Employment Development Department and California Workforce Investment Board have awarded eight local workforce training programs and four regional industry cluster planning and implementation program grants related to alternative fuels and vehicle technologies consistent with the investment plan. These 12 grants totaled more than $3.9 million in program funds and attracted more than $6.3 million in non-state match.

Table 34: Employment Development Department 2009 Local Workforce Subgrants

Grantee	Partner	Sample of Industry Participants	Training Sample	Number of Trainees	Program Award/ Match
Los Angeles Co. Workforce Investment Board	Los Angeles Community College District	GM, Miles Electric Vehicles	Alt Fuel and Electric Vehicles	64	$400,000/ $975,000
Pacific Gateway Workforce Investment Board - Long Beach	Long Beach City College	Port of Long Beach, City of Long Beach Fleet Services Bureau	Hybrid / Electric Natural Gas Heavy-Duty Vehicles	150	$400,000/ $813,059
City of Richmond; Richmond Works	Peralta College District & Contra Costa College	Alternating current Transit, Toyota	CNG and Electric Drive Vehicles	100	$400,000/ $834,000
Sacramento Employment and Training Agency	American River College	Sacramento Municipal Utilities Department PG&E	Biodiesel, Natural Gas/Hybrid /Electric Vehicles	120	$400,000/ $641,610
Imperial County Workforce Development	On-Site Multiple Employers	SunEco Energy, Carbon Capture Corp, Biolight	Bio-Fuel Production	60	$400,000/ $709,593
Orange County Workforce Investment Board	Cypress Community College and Society of Automotive	Society of Automotive Engineers International and Orange County Business Council	Heavy-duty CNG, fuel cell, hybrid, and electric drive vehicle technologies	150	$500,000/ $550,000

Grantee	Partner	Sample of Industry Participants	Training Sample	Number of Trainees	Program Award/ Match
	Engineers International				
Solano Community College (multiple locations)	Solano Workforce Investment Board (multiple locations)	Green Employer Council Bay Area EV Corridor Network	Hybrid and electric drive vehicle technologies	400	$500,000/ $503,692
Northern Rural Training and Employment Consortium	Regional Community Colleges – CSU Chico	PERC; National Propane Gas Association Roush CleanTech	Hybrid and propane vehicles	136	$500,000/ $525,000
Totals				594	$3,500,000 /$5,52,929

Source: California Energy Commission

The Energy Commission partnered with the California Workforce Investment Board to fund four regional industry cluster of opportunity planning and development projects related to alternative fuels or low-emission vehicle technology. The California Workforce Investment Board Regional Industry Cluster of Opportunity initiative is a structured economic and workforce development planning process that brings regional economic and workforce development practitioners and industry together to develop data-based regional strategies to support and advance the competitive position of targeted industry clusters (Table 35).

The Regional Industry Cluster of Opportunity process consists of four phases, which include:[319]

- Clusters of Opportunity Diagnosis: Research and analyses to identify regional industry clusters.
- Collaborative Priority-Setting: Design and implementation of a collaborative cluster engagement plan based on results of the research and analyses.
- Cluster of Opportunity Investment Strategy**:** Identify and connect specific investments and other commitments to advance the competitive position of regionally targeted clusters.
- Sustainable Implementation: Support the long-term sustainability and growth of regional clusters.

[319] California Workforce Investment Board, "Fact Sheet: Regional Industry Clusters Opportunity Grant," http://www.cwib.ca.gov/page/library/RICOG_Fact_Sheet.pdf.

Table 35: California Workforce Investment Board Clean Transportation Regional Industry Cluster Opportunity Subgrants

Grantee	Counties	Program Funding	ARRA Match
Pacific Gateway – Long Beach	Los Angeles, Orange, and Ventura	$49,987	$200,000
San Bernardino County	Riverside & San Bernardino	$49,000	$200,000
Santa Barbara County	San Luis Obispo, Santa Barbara, and Ventura	$50,000	$200,000
Northern Rural Training and Employment Consortium	Butte, Del Oro, Lassen, Modoc, Nevada, Plumas, Shasta, Sierra, Siskiyou, Tehama, and Trinity	$49,000	$200,000
Total		$197,987	$800,000

Source: California Energy Commission

As an example of a Regional Industry Cluster of Opportunity grant, the Northern Rural Training and Employment Consortium is developing a regional action plan to support propane auto gas market development within its 11-county region. Propane has been selected as one of Northern Rural Training and Employment Consortium's industry clusters due to regional familiarity and comfort with the fuel, widespread use of propane in other applications, and the industry's interest in developing the propane auto gas market. Northern Rural Training and Employment Consortium's propane auto gas regional action plan is being developed in partnership with vehicle manufacturers/suppliers, fleets, municipalities, service and maintenance providers, fuel and infrastructure suppliers, community colleges, universities, and economic, business, and workforce training agencies. The full market approach, including both the supply and demand side of this market, being adopted by Northern Rural Training and Employment Consortium should serve as an example of successful implementation of the Regional Industry Cluster of Opportunity sector strategy approach to economic and workforce development.

California Community College

California's community college system is the largest higher education system in the nation. It consists of 72 districts and 112 colleges and enrolls more than 2.9 million students.

The California's Community Colleges Chancellor's Office has been allocated $4.5 million to assess industry workforce training need, alternative fuel and vehicle courses currently available, the need for training course development, the development of needed courses, and development of instructor training and course materials. To date,

California's Community Colleges Chancellor's Office has completed only the industry assessment in 2010. Findings are represented under Workforce Demand below.

Workforce Demand

These partnership and outreach efforts have provided access to regional training service providers, transit agencies, original equipment manufacturers, and fleets providing on-the-ground information to inform workforce planning for the coming year.

Industry and workforce training partners alike are reporting a mounting skilled workforce gap resulting from the combined impact of the economic downturn, reduced training resources, and the aging workforce; these challenges are compounded further with the current need for a workforce trained in advanced transportation technologies. An example of industry and partner input on the need for workforce training assistance for transit is provided below:

- The transit sector is experiencing significant technological change along with the retirement of existing workers. New technology designs in bus systems relating to alternative-fueled engines, hybrid buses, multiplex systems, and onboard diagnostic panels created the need to improve technician's diagnostic skills to maintain new bus fleets.[320]
- Today's technicians use computers in their daily work on public transit vehicles. Operators and mechanics use laptops, scanners, programmers, and electronic communication devices to diagnose these new subsystems in transit buses and rail vehicles. These trends are resulting in skill shortages, particularly in vehicle maintenance occupations.[321]
- The Southern California Regional Transit Training Consortium Workforce Needs Assessments report transit technician skill gaps in basic electrical, basic electronics, basic computer skills, troubleshooting skills, diagnostics and software analysis, specific vendor supplied training, computerized engine controls, plus the ability to read schematics and locate and interpret technical manuals and specifications.[322]

A sampling of program-related training needs includes:

- Electronics systems for transit; include troubleshooting and schematics.
- Network electronics diagnosis and repair, including multiplexing.
- CNG computerized engine controls.
- Hybrid electric transit training.
- Hybrid transit safety training.
- CNG transit safety training.[323]

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[320] Santa Clara Valley Transportation Authority, submitted to docket 10-ALT-1, March 3, 2011.

[321] Based on discussions with regional transit agencies and statewide and regional workforce training partners

[322] Based on excerpts from the Southern California Regional Transit Training Consortium Transit Workforce Needs Assessment Update 2009

[323] Ibid.

Electric Vehicle Manufacturers

The recent *Taking Charge* report published by the California Plug-in Electric Vehicle Collaborative states that while the state has a skilled workforce and currently faces high unemployment, additional workforce training is needed to prepare employees for the burgeoning "green" economy and to attract PEV-related manufacturing to the state. The report goes on to suggest that workforce training to support growing PEV markets should be incorporated into current training programs using existing partnerships.[324]

Tesla recently communicated that its most pressing need was to find assistance to fund workforce training for 500 immediate hires and 1,000 near-term workers it plans to hire to begin production on the Model S. In 2010, Tesla purchased a part of the New United Motor Manufacturing, Inc., plant in Fremont to expand its instate production capacity to produce electric vehicles and components. Tesla products include the Roadster and the Model S, which is expected to rollout in 2012. Tesla's Model S sedan will be the first vehicle produced at the plant with future vehicles to follow in the coming years.[325]

Medium and Heavy-Duty Vehicle Manufacturers

Energy Commission staff recently conducted outreach meetings with medium- and heavy-duty vehicle manufacturers to obtain information on current and planned alternative-fueled vehicle rollouts. The industry is facing a workforce shortage due to the loss of 70 to 80 percent of its journey-level technicians. If they should chose to exit in large numbers, this has the potential to create a skills gap. The situation is compounded by the industry's adoption of alternative fuel and vehicle technologies. Workforce training development is needed to address this pending skilled workforce shortage. Training must focus on the following:

- CNG-certified training for vehicle technicians at 29 California dealerships
- Training for customer vehicle technicians who perform their own maintenance (California Department of Transportation, Ryder, Sysco, and so forth)
- Training related to propane vehicle retrofit, service and maintenance
- Hybrid vehicle training for vehicle technicians
- Electric light-rail
- Dedicated electric drive[326]

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[324] California Plug-in Electric Vehicle Collaborative, *Taking Charge: Establishing California's Leadership in the Plug-in Electric Vehicle Marketplace,* December 2010, http://phev.ucdavis.edu/Taking_Charge_final2.pdf.

[325] Energy Commission staff meeting with Tesla Motors, Inc.

[326] Based on Energy Commission staff meetings with industry, including International/Navistar, Roush, Kenworth, and Freightliner.

Workforce Training Partners

Employers must be able to train workers effectively in response to changing business and industry needs. While the need for workforce training is critical, businesses generally reserve capacity building dollars for highly technical and professional occupations – limiting investment in training for frontline workers who produce goods and deliver services.[327]

Regional training providers report an increased demand in training related to new vehicle rollouts and specifically note an overwhelming need for troubleshooting and diagnostics training for transit vehicle technicians and hybrid and electric-drive vehicles.[328]

Clean Transportation Workforce Research

Clean transportation is a fledgling entrant in California's Green Jobs assessment efforts, which results in a lack of industry-focused data to measure the current and near-term workforce needs and inform development of the program's workforce training efforts. Current efforts rely on informal survey, stakeholder input, anecdotal information, and bits of data pieced together from studies of the larger green economy, which primarily focus on energy efficiency, clean energy, and the building and construction industry.

Three such research efforts focused on California's Green Economy and Jobs are the Next 10 *Shades of Green*, the California Community Colleges' Chancellor's Office Fleet Training Needs Assessment, and the Employment Development Department's *Labor Market Information Division Green Jobs Survey*. The fleet assessment, developed in collaboration with Energy Commission staff, provides alternative fuel- and vehicle-dedicated information, while the Next 10 and Labor Market Information Division reports were mined for data related to the clean transportation industry and jobs. The results will be used to guide continued development of the workforce training program. A summary of program applicable information is provided below.

Alternative Fuels and Alternative Fuel Vehicles Training Needs Assessment

In spring 2010, the California's Community Colleges Chancellor's Office conducted an informal training needs survey with public and private employers throughout California that currently own or otherwise work with alternative fuels and alternative fuel vehicles. The survey questioned employers about their vehicle use, now and in the future; their current occupational employment; and their need for or interest in training topics.

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[327] Employment Training Panel, *2010-2011 Strategic Plan*, http://www.etp.ca.gov/packet/Strategic%20Plan%202010-2011.pdf.

[328] Based on Energy Commission staff discussions with regional training providers.

The report provides information on survey efforts and responses from employers in five geographic regions:

- Los Angeles Region – includes the counties of Los Angeles, Riverside and San Bernardino
- Sacramento Region – includes the counties of Sacramento, Solano, and Yolo
- San Joaquin Valley – includes the counties of Fresno, Kings, Madera, Merced, and Tulare
- Imperial County
- Modoc County

The 65 survey respondents working with fleets statewide are responsible for close to 68,416 vehicles. Of these, almost 21 percent or 14,351 are alternative fuel vehicles. Transit agencies reported the highest concentration of alternative fuel fleet ownership (92 percent of vehicles are alternative fuel), followed by private fleets (48 percent), state government (19 percent), and city/county government (14 percent).

Fleet Alternative Fuel and Vehicles

Employers were asked to provide more detail on the alternative fuel vehicles in their fleets, including fuel types, type of usage, makes, and models. CNG vehicles seem to be the most prevalent choice among these respondents. Fifty-two of the 65 fleet employers operate CNG vehicles. Eleven employers use all three light-, medium- and heavy-duty vehicles fueled by CNG; 12 indicated they own a combination of two types of CNG vehicles, while 29 operate a single type.

Hybrid and electric vehicles received the next highest amount of responses among employers (42 and 30, respectively); in both cases, the majority of responses were for light-duty usage.

Looking forward, employers indicated the types of alternative fuel vehicles they plan on purchasing in the short-term future (next two years) or long-term future (within three to six years). As in current ownership, the most popular fuel choice for future purchases is CNG, with 38 respondents expecting to add this fuel type in the next two years and 12 respondents anticipating a purchase in the next three to six years.

Repair and Maintenance

Given the large numbers of vehicles these employers need to maintain and repair, it is not surprising that 88 percent reported they support at least some of these services in-house (57 employers). Of these, 71 percent perform all maintenance and repairs needed, while 15 percent limit their on-site shop to maintenance and light repair work.

The majority of fleet employers support general repairs, such as brake repair, lube and oil changes as well as vehicle tune-up and diagnostics (54 and 49 employers, respectively). Another 38 employers conduct major repairs on-site, such as engine rebuilds, replacements, and transmission repair. Other comments confirmed that general repairs, preventive maintenance inspections, and select major repairs are subcontracted to vendors.

Only 3 of the 65 employers responded that they outsource or are still under warranty for some or all maintenance and repair work.

Current Employment

To better understand training needs, the survey queried respondents about their current staffing levels and specific occupations in their organizations. Within the sample, 82 employers responded to this question – accounting for 25,197 workers; of these, 41 percent, or 10,271, are estimated to work directly with or around alternative fuels and/or vehicles.

To assess training needs, the survey first asked employers to indicate their immediate need (next six months) and their future need (next two years) for training across seven broad categories: engine diagnosis and repair, emission systems inspection, high-pressure fuel system analysis, fuel properties, electrical drive systems and battery technologies, first responder safety training, and fuel station maintenance. A majority of employers indicated a need for all seven training areas (a combined need of 53 percent for fuel station maintenance to 87 percent for engine diagnosis and repair and repair, electrical drive systems and battery technologies is most in demand by transit agencies and city/county government, although other groups showed interest as well.)

Overall, the surveyed employers have a preference for, or an already established inventory, of three types of alternative fuels and/or vehicles: CNG/LNG, hybrid, and electric. In addition to current ownership, these types of alternative fuel vehicles are consistent with employer plans to increase fleets in the short- and long-term future as well as respondent support for training topics and subject areas that focus on maintaining, repairing, or otherwise working with these fuels and vehicles. These responses are also consistent with the majority of employers who support onsite fueling and onsite repair and maintenance functions.

Green Transportation Jobs Report

As part of the Employment Development Department interagency agreement, the Energy Commission tasked EDD's Labor Market Information Division to analyze relevant data from the *California Green Economy Survey* (*Green Survey*) that relate to the program.

The Energy Commission asked for a special focus on the following industrial activities:

- Production, storage, and transportation of renewable fuels
- Green transportation manufacturing, distribution, installation, and maintenance
- Sustainable fuel feedstock production and extraction

The Labor Market Information Division used data collected from the *Green Survey* to support analyses of employment in green jobs and businesses, and green occupations. In addition to analyzing the *Green Survey*, further research on program-related occupations helps increase understanding of knowledge, skills, and other variables associated with workforce development for related occupations.

Green business practices reported by firms related to the program, findings consistent across industry groups include:

- On-the-job training was the most prevalent method for preparing current workers.
- Economic conditions and costs of implementation were the greatest barriers to implementing green practices.

Program Industry Groups

To analyze the survey data on green industries and green business practices relevant to the program, Labor Market Information Division needed to relate the Energy Commission's focus areas above to industries, as defined according to the North American Industry Classification System. To do this, Labor Market Information Division coordinated with the California Community Colleges' Centers of Excellence and the Energy Commission to develop the following three groups:

- Alternative Advanced Vehicles – 11 North American Industry Classification System codes
- Alternative Fuels – 13 North American Industry Classification System codes
- Transportation Systems – 20 North American Industry Classification System codes

Analysis based on employees working 50 percent or more of their time in a green transportation job reveals an estimated 15,208 jobs in Alternative Advanced Vehicles, 35,546 jobs in Alternative Fuels, and 21,466 jobs in Transportation Systems. This analysis depicts the extent to which green employment exists in each of the program industry groups.

Program-Related Occupations

Research focused on 14 occupations relevant to the program's goals with potential for re-skilling programs. Findings include estimated green employment for the six program-related occupations included in the *Green Survey*. The data from the *Green Survey* also support comparisons of estimated green employment to estimated total employment in California for three established program-related occupations. In addition to analyzing the survey, employment demand and occupational profiles were developed for each of the 14 program-related occupations.

The *Green Survey* results provide employment data on six green transportation occupations. The largest estimated green employment was reported for Industrial Production Managers involved in green activities (more than 20,000 employees), with Alternative Fuel Vehicle Technicians coming in second (more than 19,000 employees). Further, data from the *Green Survey* show a substantial portion of estimated employment (approximately 30-50 percent) being involved in green activities at least some of the time for the three established occupations of Electrical Engineers, Mechanical Engineers, and Automotive Service Technicians.

In addition to reporting the *Green Survey* findings, the Labor Market Information Division conducted demand analyses for program-related occupations by using a proprietary software tool, WANTED Analytics 2.0. While job listings declined for almost every occupation from May 2009 through April 2010, job ads for automotive service technicians grew 4 percent in California during this period. While 4 percent may appear

low, the occupation is growing, and the need for these workers to service and repair the growing number of alternative fuel vehicles is expected to rise as current vehicles age and need servicing.

As a final deliverable to the Energy Commission, and as part of the standard agreement, follow-up focus groups are planned for some of the roughly 5,000 employers who responded to the *Green Survey* who expressed a willingness to provide additional information about green jobs, associated training requirements, and desirable skill sets. This information will be delivered as an addendum to this report by the end of 2012.

Next 10 Many Shades of Green Report

The second edition of Next 10's "Many Shades of Green" reports, *Many Shades of Green: Regional Distribution and Trends in California Green Economy,* tracks employment and business growth related to products and service that improve efficiencies in the consumption of all-natural resources and reduce negative environmental impacts.[329]

Clean transportation, including alternative fuels and vehicle and equipment, is identified as one of 15 segments of California's Core Green Economy. Clean transportation hubs are emerging in Orange County, the Bay Area, San Diego, and the Inland Empire, but activities associated specifically with fuels and vehicles are showing up in different places.

Regional Trends

Los Angeles Area: The Los Angeles Area is one of the state's hot spots for clean transportation, increasing 33 percent since 1995 and 9 percent between January 2008 and 2009. In particular, the region has a high concentration of employment in motor vehicles and equipment, which witnessed a leap of 11 percent in jobs in the recent single-year period.

Orange County: Orange County is a leader in the clean transportation in the vehicle sector as well as the alternative fuels sector. With employment shares 2.1 times higher that the state average, the region reflects a mounting strength in clean transportation, building from expertise in its conventional auto industry. Motor vehicles and equipment are driving much of this growth, increasing employment by 116 percent (450 jobs) from 1995 to 2009.

San Diego Region: Clean transportation employment growth accelerated by a factor of six between January 1995 and 2009. Establishments grew at a similar rate during that time. More than half of the employment in this segment is in alternative fuels. Employment in particular segments soared from fewer than 50 to more than 350

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[329] Next 10, *Many Shades of Green: Diversity and Distribution of California's Green Jobs*, December 2009, (http://www.next10.org/next10/publications/green_jobs/2011.html).

between 1995 and 2009. Primarily in Imperial County, alternative fuels are taking off: Employment expanded more than 700 percent between 1995 and 2009.

Inland Empire: In clean transportation, the Inland Empire has become a leader in alternative fuels with employment shares nearly triple the statewide average. Overall clean transportation employment increased 42 percent over the 15 years. The merger of two locally based electric vehicle companies resulted in employment losses in the nineties. The employment jump in 2002 was the result of a cheap producer leveraging its wastewater for the production of biofuels. New jobs created in 2008 following formation of a new electric vehicle company.

San Joaquin Valley: Clean transportation employment more than tripled from 1995 to 2005. With an employment concentration 50 percent above the state average, this segment represents an important regional strength. Growth has been driven mostly by alternative fuels, which accounts for 85 percent of employment in clean transportation. Alternative fuel employment is three times more concentrated in the San Joaquin Valley than in the state as a whole and grew 364 percent from 1995 to 2009.[330]

2011-2012 Workforce Training and Development Plan

The Energy Commission intends to provide $6,500,000 for additional implementation of workforce training and development. The Energy Commission staff will continue to work with partner agencies, California business, labor, local economic development, and other stakeholders to provide access to workforce training resources, to obtain timely information on current and evolving workforce training needs, and to develop and refine training delivery systems that provide a well-trained workforce to support the development and deployment of alternative fuels, infrastructure, and vehicles.

This effort will use existing partnerships and funding to complete the projects and goals formalized in the last investment plans, and allocate funds to support additional partnerships, workforce training contracts, and workforce training program development.

California Community College Office of the Chancellor

With the remaining funds from previous years (about $3 million), the California's Community Colleges Chancellor's Office will focus on curriculum development, train-the-trainer instruction, training equipment, and development of training materials to meet the immediate program-related training needs of program community college grantees (funded through Employment Development Department). In addition, the California's Community Colleges Chancellor's Office will develop training modules. Training modules are intended to target those areas identified through the industry assessment for community colleges (non-program grantees) that have identified demand for program-related training. The training modules developed will be made available to community

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[330] Next 10, *Many Shadse of Green: Regional Distribution and Trends in California's Green Economy*, January 2011, (http://www.next10.org/next10/publications/pdf/2011_Many_Shades_of_Green_FINAL.pdf).

colleges throughout the state with similar programs and/or regional workforce training needs.

The California's Community Colleges Chancellor's Office will use remaining available grant funds ($575,000) to provide occupational and industry information to identify training needs by region. The California's Community Colleges Chancellor's Office will prepare environmental scan reports to provide regional workforce information for use by community colleges in program planning and resource development. In addition, California's Community Colleges Chancellor's Office will also prepare a draft community colleges assessment report that will itemize the training and instructional needs of each college in need of a program, along with training and instructional resources in existence within the community college network/system.

These reports will guide development and refinement of the program's workforce training efforts and provide information for future investment planning.

Employment Training Panel

The ETP will use remaining grant funds ($1,182,170) to fund workforce training contracts to support training related to alternative fuels and vehicle technologies.

The Green Transportation Jobs Report indicates that 79 percent of employers prefer on-the-job training, where the curriculum can be tailored to meet specific production process needs while minimizing production disruption. The partnership with ETP supports training identified by business and industry that can be delivered at the employer's worksite.

ETP has received inquiries from companies interested in funding to support alternative fuel and vehicle technology training. With the level of interest expressed by the employer community, combined with ETP's marketing efforts, it is anticipated that the initial $5,780,000 allocation will be obligated in contracts before the close of FY 2010-2011. The Energy Commission will allocate $3.5 million to the ETP to meet the workforce training needs of businesses developing and/or deploying alternative fuels and vehicle technologies.[331]

Employment Development Department

EDD will continue to help regional and community college grantees achieve their workforce training goals, as established in their program-funded workforce training grants, to ensure that regional workforce training needs related to the program are being addressed.

Using the remaining available grant funds ($300,000) in the Employment Development Department's Energy Commission interagency agreement, Employment Development Department will work with Energy Commission staff and workforce training partners to

[331] Letter from Brian McMahon, Employment Training Panel, dated June 27, 2010.

develop a plan to deliver workforce training related to 2011 vehicle rollouts through existing workforce training grantees. To be eligible for additional funds grantees must:

- Demonstrate a new or unmet training need, which was not addressed in the original grant.
- Have demonstrated successful performance under the original grant.
- Establish partnerships with at least one training provider; with the capacity to provide training in clean alternative fuels and/or vehicles and with one employer; who employs workers in the development and/or deployment of clean alternative fuels and/or vehicles.

California Workforce Investment Board

California Workforce Investment Board will continue to work with the Energy Commission's funded Regional Industry Cluster of Opportunity grantees to finalize development of regional sector strategies related to alternative fuels and vehicles. Working with Energy Commission staff will use funds remaining available ($300,000) to support Regional Industry Cluster of Opportunity grantees in implementing regional action plans that support long-term sustainability and growth of an alternative fuel and/or vehicle regional cluster.

Only those grantees that develop a regional action plan, which addresses all aspects of the market chain, will be eligible for additional funding. Fundable action plans would include partnerships and commitments in the following market elements:

- Vehicle manufacturers/suppliers
- Vehicle market demand/purchase commitments
- Fuel producer/supplier
- Fueling infrastructure
- Economic development
- Business development
- Workforce training and development agencies
- Each region awarded implementation funds will provide sector strategy-related data, which at a minimum will quantify and include:
- Vehicles deployed.
- Increase in alternative fuel consumption.
- Decrease in traditional fuel consumption.
- GHG reductions.
- Number of jobs created or retained.
- Number of instructors trained.
- Businesses served (vehicles purchased, infrastructure installed, workforce trained).

In addition, the Energy Commission will allocate $2.0 million to fund three to five regional industry cluster of opportunity planning and development projects, which are related to alternative fuels or low-emission vehicle technology. This year's effort will focus primarily on those regions not addressed in the first round of the Regional Industry Cluster of Opportunity project, which may include the San Diego, Central

Valley, Sacramento, and the three Bay Area regions. The effort also will provide support to first-round Regional Industry Cluster of Opportunity projects with demonstrated success in applying the Regional Industry Cluster of Opportunity process principles and connecting alternative fuel and vehicle industries to the regional effort and resources. As described above, only those grantees that have developed a regional action plan that addresses all aspects of the market chain will be eligible for additional funding. As noted above, fundable projects would also be required to demonstrate how program funding would be used to expand their Regional Industry Cluster of Opportunity effort to reach broader segments of the market chain, provide additional support services, and/or fund resources to their cluster industries.

New Entrant Career Path Development Future Planning

Energy Commission staff will work with education departments, workforce training agencies, and stakeholder groups to identify possible programs geared to develop career paths for new industry entrants and address white-collar workers training needs related to alternative fuel and vehicle technologies. The Energy Commission will allocate $500,000 to develop partnerships and fund a pilot project.

Table 36: Funding for Workforce Training and Development Delivery

ETP Workforce Training Contracts	$3.5 Million
California Workforce Investment Board Regional Industry Cluster Opportunities	$2 Million
New Entrant Career Path Partnerships and Pilot Program Development	$.5 Million
Total	$6 Million

Source: California Energy Commission

Workforce Training and Development Outreach

A primary workforce training goal for the coming year will be to increase the level of connectivity between existing program fuel and technology projects and industry requests for training with the training resources available through Energy Commission's partner agencies and training delivery grantees. Toward this end, the Energy Commission intends to allocate $250,000 for outreach in expanding workforce training and development.

Agency Partners

ETP has developed a marketing plan to get the word out to the clean transportation industry on the availability of program workforce training funds. ETP officials also work closely with Energy Commission staff to respond to requests for workforce training assistance received by the Energy Commission. ETP, with more than 20 years of reputation building performance, is well-positioned to get program training funds out into the clean transportation industry. Even greater Energy Commission staff resources will be rededicated to working with ETP partners to ensure that funding is accessible to the alternative fuel and vehicle industry.

The Employment Development Department and Energy Commission-funded community college grantees and local workforce investment boards provide the opportunity for outreach on a statewide, regional, and local basis. Workforce training opportunities and information on industry workforce needs flow in both directions with these leading workforce and training agencies. Local and regional needs are often communicated at the local level and communicated up to the state level for funding consideration or strategic planning, while statewide initiative and funding opportunities are communicated to local workforce boards and one-stops who inform local businesses. The Energy Commission staff will work with Employment Development Department and community college partners to develop an outreach and marketing plan to increase awareness of training resources available to support clean transportation industry workforce needs.

Industry Partners

The Energy Commission engages with industry and stakeholders to obtain real time and projected workforce training needs, to identify specific skill set needs, guide curriculum and training program development, to improve access to training resources, and to inform future workforce investment.

In addition, based the recommendation provided by the California Workforce Investment Board during the development of the previous *Investment Plan*, Energy Commission staff will collaborate with the California Workforce Investment Board's Regional One-Stop Business Services, Small Business Development Centers, and the Governor's Office of Economic Development to increase small and medium-sized businesses awareness of workforce training and other program resources available to help them transition to clean transportation.[332]

Workforce Training and Development Demand Research

To develop effective workforce programs, to address immediate workforce needs, and to provide information on long-term planning, information must be compiled on types of alternative fuel and/or vehicle technology being adopted by each region, where clean energy jobs will be located, and what skills are needed to meet the needs of those industries.

The Energy Commission will allocate $250,000 to solicit for research services dedicated to quantifying workforce training needs of the alternative fuel and vehicle industry. The information obtained through a clean transportation research effort will shape the program's workforce training efforts and provide information for future funding allocation assessments.

[332] California Workforce Investment Board, submitted to docket 09-ALT-1, April 1, 2010.

Table 37: Workforce Training and Development Funding Allocation

Workforce Training and Development Delivery	$6 Million
Workforce Training and Development Outreach	$0.25 Million
Dedicated Clean Transportation Workforce Needs Study	$0.25 Million
Total	$6.5 Million

Source: California Energy Commission.

Chapter 6:
Market and Program Development

Outreach and Marketing

An essential component for achieving the program goals is getting information out to the various enterprises as incentives and financing options become available. Businesses discouraged by the sluggish economy and wanting to leverage their costs of development and commercialization plans toward cleaner transportation systems need to be aware of funding opportunities that can benefit them. The developers of the AB 118 legislation had the foresight to include critical activities like outreach and marketing into the program to ensure its success in advancing California's transportation.

So far, the most visible method of public marketing and outreach has been a series of workshops held by the Energy Commission during the development of the investment plans and those describing guidelines for the various funding opportunities and solicitations. As the number and types of funding mechanisms increase and funded projects progress into self-sustaining marketing concerns, the need for up-to-date program information and news is intensified.

Communication Plan

In 2009, when Energy Commission staff refined the communications plan, the stage was set for the 2010-12 launch of the Alternative and Renewable Fuel and Vehicle Technology Program's media and marketing campaign. Working within the Energy Commission's internal Media and Public Communications Office and collaborating with key agency partners, marketing materials such as fact sheets, brochures, and press kits are being developed to offer simple, straightforward details about the program, and highlight the funding priorities identified in the investment plan, and provide links to more detailed information via the program's website and partner/stakeholder sites. The Media and Public Communications Office also coordinates press releases to announce program opportunities and events and to feature up-to-date program milestones and success stories.

Website Redevelopment

In 2010, Energy Commission staff, recognizing the importance of providing the public up-to-date information on program activities and opportunities and providing the most current information on the fuels and vehicle technologies the program supports, began redesigning the program website to promote easier access to program and technology information. The first phase of this undertaking, launched in early 2011, enables interested people to quickly find basic information about the program, the types of projects that are being funded, and opportunities for financing or other incentives. The program site offers users easy access to agencies and programs such as ARB's Drive Clean Campaign and the Bureau of Automotive Repair's Drive Healthy information site and others promoting related projects or events. Additionally, in compliance with Senate

Bill 1455 (Kehoe, Chapter 337, Statutes of 2010), the site also includes links to local publicly owned electric utility companies to provide consumer information about charging infrastructure for PEVs. The Energy Commission anticipates that the website redesign will be completed by July 2011, and content will be updated monthly thereafter.

Marketing and Media Solicitation

A multimedia campaign is required to reach the wide range of businesses, fleet managers, universities, elected officials, air districts, environmental organizations, and early adopters targeted in the investment plan. The services of an outside public awareness and marketing firm will be secured to develop audience- and region-specific print, radio, television, and cable ads and to negotiate media buys that maximize exposure to these targeted audiences. The selected firm will also work with the Energy Commission's staffed to develop metrics and tools to measure the campaign's effectiveness.

Alternative Clean Transportation Expo 2011

In May 2011, the Energy Commission sponsored the Alternative Clean Transportation Expo 2011. This nationally publicized event targets advanced transportation industry officials, government and policy professionals, legislators, public and private fleet administrators, and consumers. The expo brings together a wide range of national and state businesses and other groups influencing the growth of the advanced transportation industry sharing the latest information on funding opportunities, regulatory policies, and inside details on new and emerging technologies. This conference and others like it offer the Energy Commission an opportunity to showcase the program and potentially bring projects in under future funding opportunities.

The *FY 2010-11 Investment Plan* allocated $2.5 million to support program marketing and public outreach. The goals and activities described in this investment plan will be supported using remaining funds from the 2010-2011 allocation. While no additional allocation for program marketing and public outreach is required in this round of investment planning, it is expected that additional funds will be allocated in future investment plans for this area.

Standards and Certification

As new fuels and technologies are developed, standards and certifications will need to be researched and adopted for the fuels, vehicles, and fueling infrastructure. The Energy Commission continues to assess possible needs for funding in this area. Previous funding for these activities is going toward developing "type-approved" retail fuel dispensers for hydrogen and fuel quality standards for hydrogen and biodiesel blends. This will be accomplished via a $4 million agreement with the California Department of Food and Agriculture's Division of Measurement Standards. Unless further needs for this category are identified, the Energy Commission will not likely allocate further funding.

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[333] 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 lifecycle 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 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. 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.

The potential for indirect land use change effects from biofuels production has emerged as a proxy for sustainability concerns about biofuels produced at industrial scales from purpose-grown energy crops such as corn, soy, oil palm, and sugarcane. As described in the previously referenced paper from Holly Gibbs of Stanford, about 100 million hectares of land have been cleared and developed for plantations, much of which has occurred in tropical zones. Brazil, Indonesia, and Malaysia now account for 40 percent of global soy, oil palm, and sugarcane production.

Estimating indirect land use change values from energy crop production is a legally and methodologically complex endeavor, as evidenced by the work of the ARB's Expert Workgroup during 2010. Indirect land use change values do not directly address primary issues of concern, such as tropical deforestation, loss of high-quality ecosystems and their dependent species of fauna and flora, water pollution, or air pollution. The Energy Commission staff encourages ongoing support and investigation into alternative systems for conservation of sensitive, high-carbon, and high-habitat-

[333] The implementing regulations for the program include 13 sustainability evaluation criteria that are used by staff during review and evaluation of funding proposals.

quality lands at risk of loss from bioenergy crop production.[334] For example, the United Nation's Reducing Emissions from Deforestation and Forest Degradation program needs ongoing development. The United Kingdom and European Union are also evaluating alternative approaches that would identify and preserve high-carbon and high-habitat-quality lands and disqualify any biofuels produced from such land types from receiving advanced biofuels credits in Europe.[335]

When AB 118 was being drafted in the State Legislature, there was strong concern that in-state energy crop production could displace prime farmlands used for primary human food production or could result in large acreages of grasslands or forestlands being converted to energy crop production. The program sustainability goals and evaluation criteria were crafted to ensure that no program money was allocated to projects with such potential. Neither phenomena have occurred, and several project proposals with nonsustainable features were not funded.

The Energy Commission supports the development of an environmentally sustainable in-state bioenergy industry so that California can benefit economically from instate biofuels production from the waste-based feedstocks and alternative purpose-grown energy crops described earlier.

For internationally produced biofuel feedstocks, Energy Commission 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. To this end, the Energy Commission has joined the Roundtable on Sustainable Biofuels.

Previous year's sustainability funding has been spent on forest biomass sustainability research to implement the sustainability work plan developed by the Energy Commission for the Interagency Forestry Working Group,[336] which aims to develop consistent definitions and standards for sustainable woody biomass from California's 40 million acres of private and public forests. Substantial technical and scientific field work are needed to establish sustainability definitions and standards for the emerging woody biomass fuels industry.

For FY 2011-2012, the Energy Commission is allocating $500,000 for sustainability research and technical support in the areas of biofuel feedstocks, water use concerns, potential of third-party sustainability certification programs to ensure sustainability, and

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[334] Jim McKinney, Energy Commission Staff Representative to the Expert Workgroup, oral comments at November 5, 2010, Expert Workgroup Meeting.

[335] Paul Hodson, European Commission, Presentation to the ARB Expert Workgroup, February 26, 2010.

[336] 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.

manufacturing sustainability. At this time, sustainability research funding is not available through any other California regulatory programs such as Air Quality Improvement Program or the federal ARRA program. Energy Commission staff has a standing offer to the LCFS Sustainability Working Group to fund for research issues identified in their working group meetings.

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 assess 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 measure 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.

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 help determine which sustainability certification programs are most relevant to California's regulations and transportation needs.

Finally, California has the potential to attract many firms vying to capture market share in California's green technology and alternative transportation sector and potentially locate manufacturing facilities in California. Manufacturing facilities – even for green technologies – have the potential to consume natural resources at nonsustainable levels (such as water) or to release toxic wastes into the air, water, or land. The current sustainability goals and evaluation criteria for AB 118 were crafted to ensure sustainable use of natural resources associated with potential biofuels production. Different

sustainability goals and evaluation criteria are needed to ensure a sustainable manufacturing sector for technologies associated with electric drive or other alternative powertrains.

Technical Assistance and Analysis

The Energy Commission will need continuous updates of the status of vehicle technology and fuels, market analyses, financing trends, and other factors that attract 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 $2 million in grants or contracts to fund this technical assistance and analytical work, which is likely to include:

- Ongoing technical support necessary 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 program will need additional technical and training support with the California Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation 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 help small companies develop and demonstrate the carbon intensity of their alternative and renewable fuels.
- Studies on the effect of alternative fuels on engines and vehicles, including recreational boats and other marine vehicles.
- Regional planning initiatives for alternative fuels to address the regional infrastructure needs for medium- and heavy-duty vehicle needs. To the extent these initiatives focus on particular alternative fuels, funding may be drawn from those fuels' allocations.
- Technical assistance with evaluation of new technologies, and verification of claims made by program applicants.
- An expansion of the California Biomass Collaborative's work to identify and quantify all California biomass feedstocks available for fuel production.

The Energy Commission is also responsible for program measurement, verification, and evaluation 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 measurement, verification, and evaluation efforts 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, GHG emissions reduction, technology advancement, and progress toward 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. In

the early years, these activities will be funded through a $1.7 million allocation for MV&E from FY 2010-2011.

Table 38: Technical Assistance and Analysis Funding Allocation

Sustainability Studies	$.5 Million
Technical Assistance and Analysis	$2 Million
Total	$2.5 Million

Source: California Energy Commission

Chapter 7:
Funding Allocations

Table 39: Funding Allocation Summary for FY 2011-2012

	Project/Activity	Funding Allocation for FY (2011-2012)
Plug-In Electric Vehicles	Plug-In Electric Vehicle Readiness	$1 Million
	Charging Infrastructure	$7 Million
	Subtotal	$8 Million
Hydrogen	Fueling Infrastructure	$8.5 Million
	Subtotal	$8.5 Million
Natural Gas	Fueling Infrastructure	$8 Million
	Subtotal	$8 Million
Propane	Light-Duty Vehicle Incentives	$1 Million
	Fueling Infrastructure	$.5 Million
	Subtotal	$1.5 Million
Gasoline Substitutes	Advanced Ethanol and Gasoline Substitute Production Plants	$8 Million
	E85 Fueling Infrastructure	$5 Million
	Subtotal	$13 Million
Diesel Substitutes	Advanced Diesel Substitute Production Plants	$8 Million
	Subtotal	$8 Million
Biomethane	Pre-Landfill Biomethane Production	$8 Million
	Subtotal	$8 Million
Medium- and Heavy-Duty Vehicles	Deployment Incentives for Natural Gas Vehicles	$12 Million
	Deployment Incentives for Propane Vehicles	$3 Million
	Develop and Demonstrate Advanced Technology Medium- and Heavy-Duty Vehicles	$8 Million
	Subtotal	$23 Million

	Project/Activity	Funding Allocation for FY (2011-2012)
Innovative Technologies, Advanced Fuels, and Federal Cost-Sharing	Innovative Technologies, Advanced Fuels, and Federal Cost-Sharing	$3 Million
	Subtotal	$3 Million
Manufacturing	Manufacturing Facilities and Equipment	$10 Million
	Subtotal	$10 Million
Workforce Training and Development	Workforce Training and Development Agreements	$6.5 Million
	Subtotal	$6.5 Million
Market and Program Development	Sustainability Studies	$.5 Million
	Technical Assistance and Analysis	$2 Million
	Subtotal	$2.5 Million
	Total	$100 Million

Source: California Energy Commission

GLOSSARY

CALIFORNIA AIR RESOURCES BOARD (ARB)— The "clean air agency" in the government of California, whose main goals include attaining and maintaining healthy air quality; protecting the public from exposure to toxic air contaminants; and providing innovative approaches for complying with air pollution rules and regulations.

AMERICAN RECOVERY AND REINVESTMENT ACT (ARRA)— U.S. Congress passed the American Recovery and Reinvestment Act of 2009 on February 13, 2009, at the urging of President Obama, who signed it into law four days later. A direct response to the economic crisis, the Recovery Act strives to create new jobs and save existing ones, spur economic activity and invest in long-term grown, and foster unprecedented levels of accountability and transparency in government spending. Among its objectives, the act makes $275 billion available for federal contracts, grants, and loans.

BATTERY ELECTRIC VEHICLE (BEV)— Also known as an "All-electric" vehicle (AEV), BEVs utilize energy that is stored in rechargeable battery packs. BEVs sustain their power through the batteries and therefore must be plugged into an external electricity source in order to recharge.

COMPRESSED NATURAL GAS (CNG)—Natural gas that has been compressed under high pressure, typically between 2,000 and 3,600 pounds per square inch, held in a container. The gas expands when released for use as a fuel.

CARBON DIOXIDE (CO_2)— A colorless, odorless, non-poisonous gas that is a normal part of the air. Carbon dioxide is exhaled by humans and animals and is absorbed by green growing things and by the sea. CO2 is the greenhouse gas whose concentration is being most affected directly by human activities. CO2 also serves as the reference to compare all other greenhouse gases (see carbon dioxide equivalent). The major source of CO2 emissions is fossil fuel combustion. CO2 emissions are also a product of forest clearing, biomass burning, and non-energy production processes such as cement production. Atmospheric concentrations of CO2 have been increasing at a rate of about 0.5% per year and are now about 30% above preindustrial levels. (EPA)

EMPLOYMENT TRAINING PANEL (ETP)— Provides funding to employers to assist in upgrading the skills of their workers through training that leads to good paying, long-term jobs. The ETP was created in 1982 by the California State Legislature and is funded by California employers through a special payroll tax.

FUEL CELL VEHICLE (FCV)— A zero-emission vehicle that runs on compressed hydrogen fed into a fuel cell "stack" that produces electricity to power the vehicle.

KILOWATT HOURS (kWh)— The most commonly-used unit of measure telling the amount of electricity consumed over time. It means one kilowatt of electricity supplied for one hour. In 1989, a typical California household consumes 534 kWh in an average month.

LOW CARBON FUEL STANDARD (LCFS)— A set of standards designed to encourage the use of cleaner low-carbon fuels in California, encourage the production of those fuels, and therefore, reduce greenhouse gas (GHG) emissions. The LCFS standards are expressed in terms of the "carbon intensity" (CI) of gasoline and diesel fuel and their respective substitutes. The LCFS is a key part of a comprehensive set of programs in California to cut greenhouse gas emission and other smog-forming and toxic air pollutants by improving vehicle technology, reducing fuel consumption, and increasing transportation mobility options.

LANDFILL GAS (LFG)— Gas generated by the natural degrading and decomposition of municipal solid waste by anaerobic microorganisms in sanitary landfills. The gases produced, carbon dioxide and methane, can be collected by a series of low-level pressure wells and can be processed into a medium Btu gas that can be burned to generate steam or electricity.

LIQUEFIED NATURAL GAS (LNG)— Natural gas that has been condensed to a liquid, typically by cryogenically cooling the gas to minus 260 degrees Fahrenheit (below zero).

PLUG-IN ELECTRIC VEHICLE (PEV)— is a general term for any car that runs at least partially on battery power and is recharged from the electricity grid. There are two different types of PEVs to choose from -- pure battery electric and plug-in hybrid vehicles.

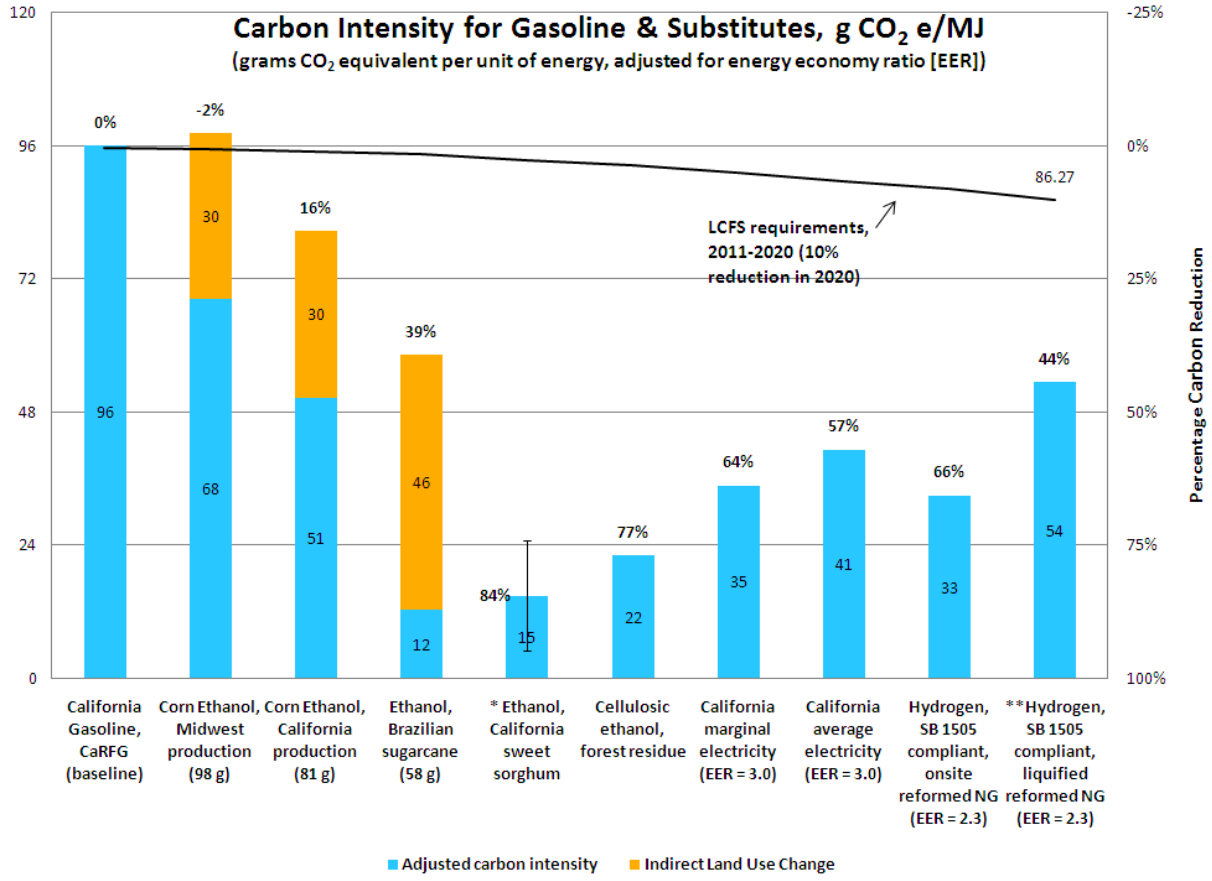
PLUG-IN HYBRID ELECTRIC VEHICLE (PHEV)— PHEVs are powered by an internal combustion engine and an electric motor that uses energy stored in a battery. The vehicle can be plugged in to an electric power source to charge the battery. Some can travel nearly 100 miles on electricity alone, and all can operate solely on gasoline (similar to a conventional hybrid).

RENEWABLE FUEL STANDARD (RFS)— A federal program to increase the volume of renewable fuels used in transportation fuels. Created under the Energy Policy Act of 2005, and revised by the Energy Independence and Security Act of 2007, the RFS program requires increasing annual volumes of renewable fuel, starting from 9 billion gallons in 2008 to 36 billion gallons by 2022. Within those total volumes, the RFS also requires certain volumes of specific fuels, such as cellulosic and advanced biofuels.

ZERO EMISSION VEHICLE (ZEV)— Vehicles which produce no emissions from the on-board source of power (e.g., an electric vehicle).

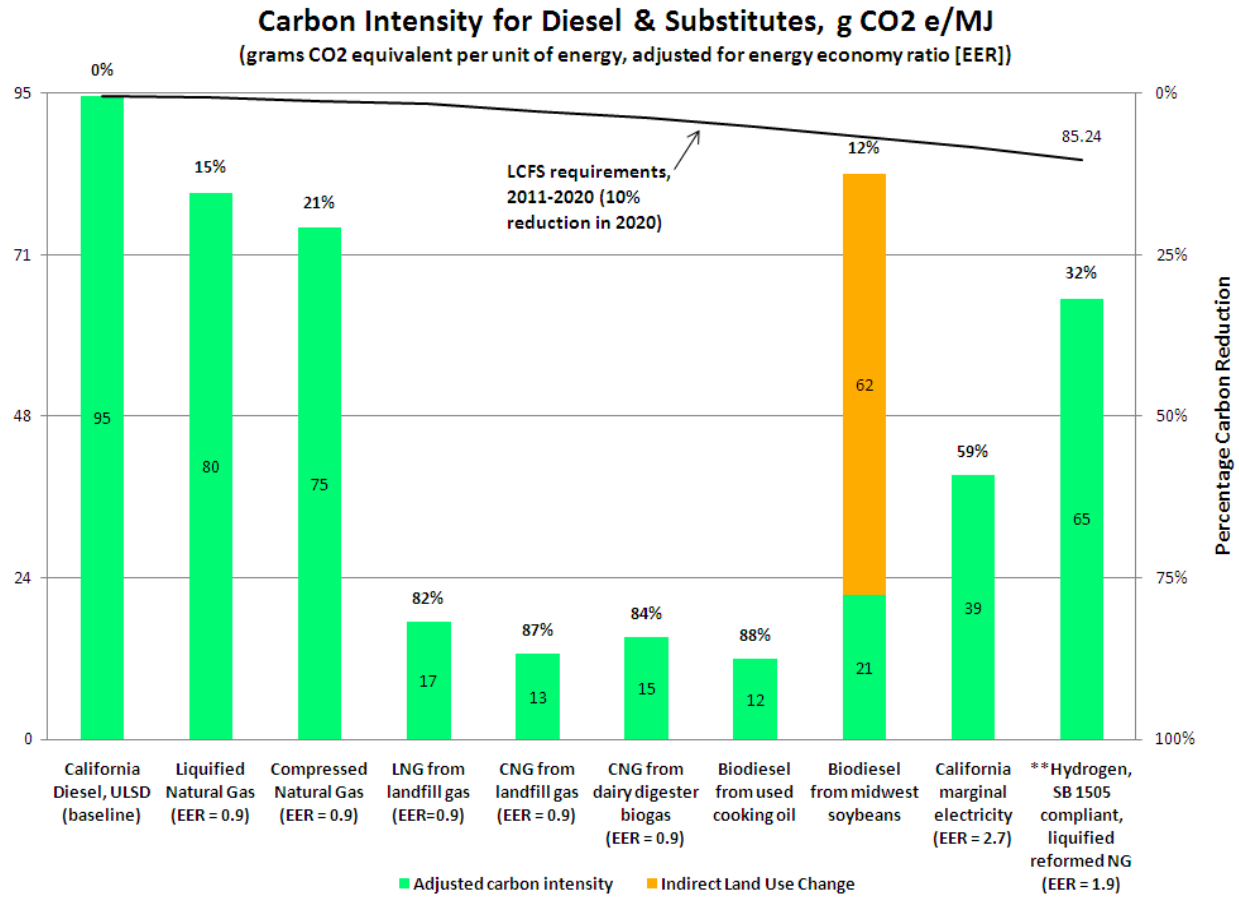
APPENDIX A:
Carbon Intensities for Fuel Pathways

Figure A-1: Carbon Intensity for Gasoline and Substitutes



Source: ARB LCFS. *California sweet sorghum is an Energy Commission staff estimate; error bars indicate range of estimates; Indirect land use change unknown. **Liquefied hydrogen is derived from ARB LCFS pathway document.

Figure A-2: Carbon Intensity for Diesel and Substitutes



Source: ARB LCFS. **Liquefied hydrogen is derived from ARB LCFS pathway document.

APPENDIX B:
Hydrogen Fuel Demand and Supply

Table B-1: Hydrogen Fuel Demand and Supply Gaps (2011-2012)

	2011			
Basin/Co.	**Supply**	**Demand**	*Gap*	**# of Stations**
Sacramento/Yolo	100	22	*78*	1
San Diego	0	5	*(5)*	0
Alameda	60	7	*53*	1
San Francisco	0	6	*(6)*	0
San Mateo	0	2	*(2)*	0
Santa Clara	0	13	*(13)*	0
Santa Barbara	0	0	*0*	0
Northwest LA County, Coastal	170	55	*115*	2
Southwest LA County, Coastal	150	45	*105*	2
Southern LA County, Coastal	0	0	*0*	0
Western San Fernando Valley	0	0	*0*	0
Pomona/Walnut Valley	12	4	*8*	1
Northern Orange County	0	0	*0*	0
Central Orange County[337]	0	2	*(2)*	0
Northern Orange County, Coastal	200	14	*186*	2
Saddleback Valley	0	27	*(27)*	0
Central Orange County, Coastal	25	37	*(12)*	1
Capistrano Valley	0	13	*(13)*	0

[337] Regions in green may have some overlapping supply and demand.

	2012			
Basin/Co.	**Supply**	**Demand**	***Gap***	**# of Stations**
Sacramento/Yolo	240	22	*218*	1
San Diego	0	7	*(7)*	0
Alameda	60	10	*50*	1
San Francisco	0	6	*(6)*	0
San Mateo	240	10	*230*	1
Santa Clara	0	13	*(13)*	0
Santa Barbara	0	3	*(3)*	0
Northwest LA County, Coastal	710	67	*643*	5
Southwest LA County, Coastal	510	54	*456*	4
Southern LA County, Coastal	0	0	*0*	0
Western San Fernando Valley	0	0	*0*	0
Pomona/Walnut Valley	180	4	*176*	1
Northern Orange County	0	0	*0*	0
Central Orange County	0	5	*(5)*	0
Northern Orange County, Coastal	200	18	*182*	2
Saddleback Valley	180	35	*145*	1
Central Orange County, Coastal	420	40	*380*	2
Capistrano Valley	0	17	*(17)*	0

Source: California Energy Commission

Table B-1 (cont.): Hydrogen Fuel Demand and Supply (2013-2014)

	2013			
Basin/Co.	Supply	Demand	*Gap*	# of Stations
Sacramento/Yolo	240	25	*215*	1
San Diego	0	3	*(3)*	0
Alameda	60	10	*50*	1
San Francisco	0	6	*(6)*	0
San Mateo	240	18	*222*	1
Santa Clara	0	16	*(16)*	0
Santa Barbara	0	4	*(4)*	0
Northwest LA County, Coastal	710	80	*630*	5
Southwest LA County, Coastal	510	65	*445*	4
Southern LA County, Coastal	0	0	*0*	0
Western San Fernando Valley	0	0	*0*	0
Pomona/Walnut Valley	180	4	*176*	1
Northern Orange County	0	6	*(6)*	0
Central Orange County	0	20	*(20)*	0
Northern Orange County, Coastal	200	30	*170*	2
Saddleback Valley	180	48	*132*	1
Central Orange County, Coastal	420	63	*357*	2
Capistrano Valley	0	31	*(31)*	0

	2014			
Basin/Co.	Supply	Demand	*Gap*	# of stations
Sacramento/Yolo	240	48	*192*	1
San Diego	0	29	*(29)*	0
Alameda	60	37	*23*	1
San Francisco	0	28	*(28)*	0
San Mateo	240	41	*199*	1
Santa Clara	0	38	*(38)*	0
Santa Barbara	0	6	*(6)*	0
Northwest LA County, Coastal	710	277	*433*	5
Southwest LA County, Coastal	510	183	*327*	4
Southern LA County, Coastal	0	10	*(10)*	0
Western San Fernando Valley	0	10	*(10)*	0
Pomona/Walnut Valley	180	4	*176*	1
Northern Orange County	0	10	*(10)*	0
Central Orange County	0	52	*(52)*	0
Northern Orange County, Coastal	200	167	*33*	2
Saddleback Valley	180	143	*37*	1
Central Orange County, Coastal	420	148	*272*	2
Capistrano Valley	0	157	*(157)*	0

Source: California Energy Commission

Table B-2: FCVs by Air Basin in 2015-2017

Air Basin	2015-2017 FCV Population
Sacramento Valley	1,730
Salton Sea	100
San Diego	1,725
San Francisco Bay Area	14,500
San Joaquin Valley	310
South Central Coast	405
South Coast	34,230
TOTAL	53,000

Source: California Energy Commission

APPENDIX C:
Fuel Conversion Processes

Table C-1: Fuel Conversion Processes for Non-Cellulosic Feedstocks

	Non-cellulosic Feedstocks				
	Fermentation[338]	Anaerobic Digestion	Transesterification	Thermochemical Processes	Algae
Description	Fermentation is the simplest process of producing ethanol. Yeast anaerobically converts sugar to alcohol and CO_2.	In the absence of oxygen, "acid formers" convert volatile solids to fatty acids. "Methane formers" convert the acids to methane-rich biogas. The process occurs naturally in landfill cells, wastewater treatment plants, and manure lagoons, or can occur	Oils are processed with methanol, a catalyst, and heat to produce trademarked Biodiesel, glycerin, and alcohol. Biodiesel must meet American Society for Testing and Materials [339] D6751 specifications.	Gasification, pyrolysis, and depolymerization are applicable processes for non-cellulosic feedstocks. The descriptions of the processes are listed under the Cellulosic Feedstocks table.	Three primary stages: cultivation includes open, closed, and offshore[340]; harvesting/processing includes dewatering, fractionation, and extraction; conversion includes processing algae-produced carbohydrates and lipids[341]; direct synthesis of fuels[342];

[338] "The definition of cellulosic biomass ethanol . . . made at any facility – regardless of whether cellulosic feedstock is used or not – may be defined as cellulosic if at such facility 'animal wastes or waste materials are digested or otherwise used to displace 90 percent or more of the fossil fuel normally used in the production of ethanol", Federal Register, 40 CFR Part 80, Environmental Protection Agency, Regulation of Fuels and Fuel Additives: Renewable Fuel Standard Program; Final Rule, May 1, 2007.
[339] American Society for Testing and Materials.
[340] Open systems are typically open ponds. Closed systems include clear vessels known as photobioreactors or dark tanks. Offshore is growing contained algae in the ocean.
[341] Carbohydrates to fermentation and lipids to transesterification or refinery process for gasoline, diesel, and/or jet fuel.
[342] Alcohols (ethanol) and hydrocarbons.

	Non-cellulosic Feedstocks				
	Fermentation[338]	Anaerobic Digestion	Transesterification	Thermochemical Processes	Algae
		in specially constructed containers.			or putting the algae directly into a conversion process[343].
Potential Feedstocks	Sugar cane, sugar beets, corn, wheat, barley and other grains.	Almost all organic material, including agricultural residues and woody materials (with size processing to speed up decomposition and, with some cellulosic material, hydrolysis).	Plant, animal, and algae derived oils. Plant derived oils include vegetable, soybean[344], rape seed, and canola. Used oils from cooking are also used.	Almost all non-cellulosic feedstocks. Some processing such as dewatering may be required, depending on the thermochemical process used.	Depending on algae and cultivation method, growth can be in solutions of sugar, municipal green waste, municipal wastewater, switchgrass, and/or cellulosic material.
Sustainability and Emissions	Well-to-Wheels (WTW) Mid-west corn ethanol – 65.66 gCO_2e/MJ.[345] WTW Brazilian	WTW Compressed landfill gas – 11.26 gCO_2e/MJ.[347] WTW Compressed dairy	WTW Cooking oil Biodiesel – 15.84 gCO_2e/MJ.[349] WTW Midwest soybeans	Varies with process and feedstock (see Cellulosic Feedstocks)	Reduced direct and indirect land impacts, fresh water not needed, non-competitive with food/feed production.

[343] Biochemical, thermochemical, and/or anaerobic digestion.
[344] According to the American Soybean Association, for every 1.5 gallons of soybean oil derived Biodiesel, more than 6 pounds of protein-rich soybean meal is available for animal and human consumption.
[345] California Air Resources Board, Detailed California-Modified Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation Pathway for Corn Ethanol, February 27, 2009.
[347] California Air Resources Board, Detailed California-Modified Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation Pathway for Compressed Natural Gas (CNG) from Landfill Gas, February 28, 2009.
[349] California Air Resources Board, Detailed California-Modified Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation Pathway for Biodiesel Produced in California from Used Cooking Oil, September 23, 2009.

	Non-cellulosic Feedstocks				
	Fermentation[338]	Anaerobic Digestion	Transesterification	Thermochemical Processes	Algae
	cane ethanol – 27.40 gCO_2e/MJ.[346]	digester gas – 13.45 gCO_2e/MJ.[348]	Biodiesel – 21.25 gCO_2e/MJ.[350]		CO_2 can be used to enhance cultivation.[351]
Summary of Existing Projects	195 facilities nationwide producing 13,508 million gallons/year.[352] In California, 3 plants produce 120 million gallons/year.[353]	Altamont Pass Landfill – up to 13,000 gallons LNG/day.[354] Bowerman Landfill – 4,000 gallons LNG/day capacity. Hilarides Dairy	550 million gallons were produced in 2009 nationwide.[355]	Depolymerization: palm and vegetable oil – Neste Oil/Finland, Holland, and Singapore; chicken processing waste – Dynamic Fuels/LA	Sapphire/NM – open pond demonstration; Algenol/TX – photobioreactor pilot plant; Solazyme/PA – heterotrophic[356] pilot plant.

[346] California Air Resources Board, Detailed California-Modified Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation Pathways for Brazilian Sugarcane Ethanol: Average Brazilian Ethanol, With Mechanized Harvesting and Electricity Co-product Credit, With Electricity Co-product Credit; September 23, 2009.
[348] California Air Resources Board, Detailed California-Modified Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation Pathway for Compressed Natural Gas (CNG) from Dairy Digester Biogas, July 20, 2009.
[350] California Air Resources Board, Detailed California-Modified Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation Pathway for Conversion of Midwest Soybeans to Biodiesel (Fatty Acid Methyl Esters-FAME), December 14, 2009.
[351] Morello, Joanne and Ron Pate, "The Promise and Challenge of Algae as Renewable Sources of Biofuels, DOE-EERE-Office of Biomass Program," September 8, 2010.
[352] Renewable Fuels Association, "Biorefinery Locations," http://www.ethanolrfa.org/bio-refinery-locations/, February 3, 2011.
[353] Pacific Ethanol, Calgren, Parallel Products.
[354] Ted Barnes, *Altamont Landfill Gas Purification Testing and Monitoring – Critical project Review Draft Report*, August 30, 2010.
[355] National Biodiesel Board.
[356] ". . . heterotrophic methods (where algae are grown without light and are fed a carbon source, such as sugars, to generate new biomass)", from National Algal Biofuels Technology Roadmap, DOE-EERE-Office of Biomass Program, May 2010, p. 8.

	Non-cellulosic Feedstocks				
	Fermentation[338]	Anaerobic Digestion	Transesterification	Thermochemical Processes	Algae
Technology maturity and Companies working on technology	Corn/grain fermentation is mature. Three companies produce 1/3 of the ethanol: Archer Daniels Midland, Valero, and POET.[357]	Technology well established. Various landfills and wastewater treatment facilities pursuing capture of gas.	Commercial plants range from 1 - 40 million gallons/year. There is a 100 million gallons/year plant in Washington.		Four major R&D Consortia:[358]
Process cost	Corn ethanol production cost - $1.26 to $1.32 per gallon in 2012 (2004 dollars)[359]	Cost varies with digester technology and scale of production.[360]	Feedstock costs are 80 percent of the final fuel cost. Larger plants are more profitable.	Varies with process and feedstock. Depolymerization economically competitive at $80-$120/bbl crude oil prices.	Not yet known and will vary on the process used.

[357] Renewable Fuels Association, "Biorefinery Locations," http://www.ethanolrfa.org/bio-refinery-locations/
[358] National Alliance for Advanced Biofuels and Bioproducts, Cellana Consortium, Consortium for Algal Biofuels Commercialization, Sustainable Algal Biofuels Consortium; from Morello, Joanne and Ron Pate, "The Promise and Challenge of Algae as Renewable Sources of Biofuels," DOE-EERE-Office of Biomass Program, September 8, 2010
[359] *Federal Register*, 40 CFR Part 80, Environmental Protection Agency, Regulation of Fuels and Fuel Additives: Renewable Fuel Standard Program; Final Rule, May 1, 2007
[360] Patrick Chen, et. al., "Economic Assessment of Biogas and Biomethane Production from Manure," March 20, 2010

	Non-cellulosic Feedstocks				
	Fermentation[338]	Anaerobic Digestion	Transesterification	Thermochemical Processes	Algae
Market potenial	Ethanol is not new to transportation sector and market already has necessary production and distribution mechanisms in place.[361]	Current low price of natural gas is making biogas harder to compete on production cost basis.	Existing plants are underutilized.	Considered as having market potential based on the type of fuel produced. Fuels are compatible with petroleum infrastructure, pipelines, and engines (including jets).	Potential yields of at least 700 gallons of oil/acre/year.[362]
Gap analysis		Support with capital investments for equipment, interconnection fees to natural gas pipeline.	2010 estimates are 70 percent less than 2008[363] due in part to issues with underground storage tanks[364] and 12/31/09 expiration of fuel subsidy.	Support with improved feedstock processing and transport.[365]	RFS is a policy driver for algae fuel R&D. Algae derived biofuels show potential.

[361] *Federal Register*, 40 CFR Part 80, Environmental Protection Agency, Regulation of Fuels and Fuel Additives: Renewable Fuel Standard Program; Final Rule, May 1, 2007.
[362] Comparable gallons of oil/acre/year: corn – 18, soybeans – 48, sunflower – 102, rapeseed – 127, palm – 635.
[363] California Board of Equalization, Clear and Dyed Biodiesel Transition Reported by Diesel Fuel Suppliers Jan-05 to Dec-08.
[364] California governmental policies have had a chilling effect on Biodiesel production. The 2008-2009 State Water Resources Control Board's actions that prohibited Biodiesel blends greater than 5 percent in underground storage tanks has identified as a key impediment by producers.
[365] *Federal Register*, 40 CFR Part 80, Environmental Protection Agency, Regulation of Fuels and Fuel Additives: 2011 Renewable Fuel Standards/Final Rule, December 9, 2010.

	Non-cellulosic Feedstocks				
	Fermentation[338]	Anaerobic Digestion	Transesterification	Thermochemical Processes	Algae
	California Energy Commission solicitations for biofuels to include above processes. Responses to previous solicitation included applications in all the technologies and feedstocks discussed in this table. Application requests were greater than amount available.				
Primary transportation fuel product	Ethanol	Biogas, compressed and/or liquefied	Biodiesel	Syngas, diesel, gasoline, ethanol, methanol, jet fuel, and dimethyl ether	Ethanol, Biodiesel, gasoline, diesel, jet fuel

Source: California Energy Commission

Table C-2: Fuel Conversion Processes for Cellulosic Feedstocks

Cellulosic Feedstocks					
	Thermochemical Conversion[366]			Biochemical Conversion[367]	Other[368]
	Gasification	Pyrolysis	Depolymerization	Hydrolysis	
Description	There are two general classes of gasifiers: partial oxidation and indirect. Indirect gasifiers use steam as the gasifying agent.	Pyrolysis thermally breaks down biomass into pyrolysis oils at lower temperatures than gasification. The primary product is a	Depolymerization includes two stages. The hydrothermal upgrading stage is water slurry pulping and heating under	The full process begins with size reduction and pretreatment with heat, pressure, acid, or base to break up lignin and hemicelluloses.	Other processes include hybrids of thermochemical and biochemical processes, hybrids of thermochemical

[366] Thermochemical conversion involves biomass being broken down using heat and upgraded to fuels using a combination of heat and pressure in the presence of catalysts.
[367] The general process of most biochemical cellulosic biofuel process consists of feedstock handling, pretreatment, hydrolysis, fermentation or fuel conversion, and a final distillation/separation step.
[368] *Federal Register*, 40 CFR Part 80, Environmental Protection Agency, Regulation of Fuels and Fuel Additives: 2011 Renewable Fuel Standards/Final Rule, December 9, 2010.

Cellulosic Feedstocks					
	Thermochemical Conversion[366]			Biochemical Conversion[367]	Other[368]
	Gasification	Pyrolysis	Depolymerization	Hydrolysis	
	The primary product of gasification is a synthesis gas or syngas that may be cleaned and used as a fuel gas or as the feedstock for other fuel production processes[369].	liquid instead of a synthesis gas. Pyrolysis oil requires further treatment be used to produce gasoline and diesel fuel.	pressure, flashing, and cracking the produced oil. The hydrotreating stage uses hydrogen, heat, and pressure to break the light hydrocarbons into fuels for vehicles and jets.	Cellulose and hemicellulose are converted to sugars via enzymatic or acid hydrolysis. Sugars are fermented or used in some other fuel conversion step.	or biochemical conversion processes with new processes, and all-new technology processes.
Potential Feedstocks	Any cellulosic biomass material including agricultural residues such as corn stover, rice straw, wheat stalks, sugarcane and sorghum bagasse, perennial grasses such as switchgrass and *Miscanthus*, woody crops such as poplar and willow, and forestry residues.				

[369] Syngas to Fischer-Tropsch is the leading method for producing diesel substitute fuel. Fischer-Tropsch produces a paraffin wax that can be refined into diesel, jet fuel, and naptha.

Cellulosic Feedstocks					
	Thermochemical Conversion[366]			Biochemical Conversion[367]	Other[368]
	Gasification	Pyrolysis	Depolymerization	Hydrolysis	
Sustainability and Emissions	Well-to-wheels GHG for cellulosic ethanol from forest waste via gasification is 22.20 gCO_2e/MJ.[370] Biomass derived Fischer-Tropsch diesel: approx. 88 percent GHG reduction.[371]	California Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation well-to-wheels GHG analysis not conducted. For forestry waste: collection is 8.61 g/MJ, transport is 3.67 g/MJ, and CO_2 credit from not burning is -130.15 g/MJ.		Well-to-wheels GHG for cellulosic ethanol from farmed trees by fermentation is 2.4 gCO_2e/MJ.[372]	Information not found for cellulosic feedstock.

[370] California Air Resources Board, Detailed California-Modified Greenhouse Gases, Regulated Emissions, and Energy Use Pathway for Cellulosic Ethanol from Forest Waste, February 27, 2009.
[371] Well-to-Wheel assessments by California Energy Commission, ConocoPhillips, Sasol Chevron, Shell International.
[372] California Air Resources Board, Detailed California-Modified Greenhouse Gases, Regulated Emissions, and Energy Use Pathway for Cellulosic Ethanol from Farmed Trees by Fermentation, February 27, 2009.

Cellulosic Feedstocks					
	Thermochemical Conversion[366]			Biochemical Conversion[367]	Other[368]
	Gasification	Pyrolysis	Depolymerization	Hydrolysis	
Summary of Existing Projects	There are more than 50 fully commercial thermochemical facilities in Japan, Germany, and the United Kingdom.[373]		Existing projects currently use palm oils. See Non-Cellulosic table.	Enzymatic hydrolysis to ethanol: AE Biofuels (California), DuPont Danisco Cellulosic Ethanol (Tennessee), KL Energy (Wyoming).[374]	Primarily in R&D.
Technology maturity[375] and Companies working on technology[376]	With Fischer-Tropsch: Choren, Flambeau River Biofuels, Baard, Clearfuels, Gulf Coast Energy, Rentech, TRI, Nature's Fuel, Chemrec, New Page.	National Renewable Energy Laboratory investigating stabilized higher quality oil. Dynamotive Energy Systems.	Hydrothermal upgrading is 8 years old and requires R&D. Hydrotreating is a 3-year-old commercial technology.[377] Green Power Inc., Cello Energy.	EPA is tracking progress of more than 70 facilities. Several companies (e.g. Abengoa, BlueFire Ethanol, Coskata, Fulcrum, POET, and Vercipia) intend to	Processes are considered second generation or new. Coskata, INEOS Bio, Lanzatech, Zeachem, Virent.

[373] *Federal Register*, 40 CFR Part 80, Environmental Protection Agency, Regulation of Fuels and Fuel Additives: 2011 Renewable Fuel Standards/Final Rule, December 9, 2010.
[374] *Federal Register*, "Regulation of Fuels and Fuel Additives: 2011 Renewable Fuel Standards," http://www.federalregister.gov/articles/2010/07/20/2010-17281/regulation-of-fuels-and-fuel-additives-2011-renewable-fuel-standards#p-127.
[375] The technology process components (gasification, pyrolysis, Fischer-Tropsch, etc.) are in commercial use. Advancements are being made in making the process more efficient, providing higher quality products, new catalysts, and hybridizations.
[376] *Federal Register*, 40 CFR Part 80, Environmental Protection Agency, Regulation of Fuels and Fuel Additives: 2011 Renewable Fuel Standards/Final Rule, December 9, 2010.
[377] Status of Neste Oil's Biobased NExBTL Diesel Production for 2007, Neste Oil, Synbios, Stockholm, May 19, 2005.

Cellulosic Feedstocks					
	Thermochemical Conversion[366]			Biochemical Conversion[367]	Other[368]
	Gasification	Pyrolysis	Depolymerization	Hydrolysis	
	With catalytic conversion to ethanol: Range fuels, Pearson Technologies, Fulcrum Bioenergy, Enerkem, Gulf Coast Energy.	Pyrolysis with Depolymerization: Dynamotive, Envergent, Petrobras[379]		have commercial sale of cellulosic ethanol in 2012.[378]	
Process cost	Varies with technology and feedstock.	Varies with technology and feedstock.	Process cost varies based on efficiencies at converting feedstock energy content (50 percent to 80 percent).	Production cost of gallon of cellulosic ethanol: $1.65 in 2012 (2004 dollars) or 31 percent higher than corn ethanol using same parameters.[380]	Not yet quantified. Environmental Protection Agency is tracking processes for RFS.
Market potential	The Environmental Protection Agency acknowledges that the cellulosic biofuel industry is progressing at a rapid pace and is tracking the progress of more than 100 cellulosic biofuel projects. The technologies also have application for municipal solid wastes processing.[381]				

[379] Ibid.
[378] *Federal Register*, 40 CFR Part 80, Environmental Protection Agency, Regulation of Fuels and Fuel Additives: 2011 Renewable Fuel Standards/Final Rule, December 9, 2010.
[380] Ibid.
[381] Conversion Technologies Status Update Survey, Publication #IWMB-2009-008, Integrated Waste Management Board, April 2009

Cellulosic Feedstocks					
	Thermochemical Conversion[366]			Biochemical Conversion[367]	Other[368]
	Gasification	Pyrolysis	Depolymerization	Hydrolysis	
Gap analysis	Improved pre-processing of feedstock material and methods to use lignin in biochemical processes.[382] Fuel incentives for cellulosic biomass-based fuels. California Energy Commission solicitations for biofuels to include above processes.				
Primary transportation fuel products	Syngas, diesel, gasoline, ethanol, methanol, dimethyl ether.[383]	Diesel, gasoline, jet fuel.	Diesel and gasoline.	Ethanol	Varies.

Source: California Energy Commission

[382] Federal Register, 40 CFR Part 80, Environmental Protection Agency, Regulation of Fuels and Fuel Additives: 2011 Renewable Fuel Standards/Final Rule, December 9, 2010

[383] Requires syngas to Fischer-Tropsch, biochemical, or some other process to convert to liquid transportation fuel product.