California Fuel Cell Partnership
DRIVING FOR THE FUTURE

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February 27, 2009

Karen Douglas, Chair
James D. Boyd, Vice Chair
California Energy Commission
Dockets Office, MS-4
Re: Docket # 08-ALT-1
1516 Ninth Street
Sacramento, CA 95814-5512

Dear Commissioners Boyd and Douglas:

The California Fuel Cell Partnership is pleased to submit the enclosed document, "Hydrogen Fuel Cell Vehicle and Station Deployment Plan: A Strategy for Meeting the Challenge Ahead," to support AB118 funding for hydrogen fuel stations in California. This Action Plan was recently approved by consensus among our industry and government members.

Fuel cell vehicles and hydrogen stations are at the cusp of transition into the early commercial market. Automakers plan to place more than 700 high-performance, zero-emission electric fuel cell vehicles in California by 2011, 4,300 by 2014 and 50,000 by 2017. To fully use and enjoy their FCVs, customers need convenient hydrogen stations and ample fuel in the communities where they live, work and play. By preparing early market communities, California will stimulate new jobs and lead the world with transportation solutions that can meet 2050 goals for reducing petroleum use and greenhouse gas emissions. California has everything to gain by starting now to support a hydrogen fuel cell market transition.

The Action Plan calls for a total government and industry investment of $179 million through 2012 to build hydrogen stations and an additional $3 million for regulatory development and outreach. This investment will provide hydrogen stations to meet early customer fuel needs through 2014, and set California on a path to meet the needs of tens of thousands of fuel cell vehicle drivers coming in 2017.

CaFCP's Action Plan recommends that government invest a total of $120 million through 2012, starting with $52 million in 2009 and 2010, as shown in the table below. Government support is essential to stimulate a nascent industry that, according to research, could be self-sustaining shortly after 2020.

	2009	2010	2011	2012
New hydrogen stations funded	10	9	11	10
Total station costs (millions)	$30.8	$37.5	$51.2	$59.5
Cumulative total station costs (millions)	$30.8	$68.3	$119.5	$179.0
Gov't cost share for stations (millions)	$23.4	$27.2	$35.9	$31.1
Regulatory development and outreach costs (millions)	$1.0	$0.5	$0.5	$0.5
Cumulative gov't cost (millions)	$24.4	$52.1	$88.5	$120.1
Total cumulative costs (millions)	**$31.8**	**$69.8**	**$121.5**	**$181.5**

Government funding can come from local, state and federal sources. *By investing $100 million of California's alternative fuel funding toward hydrogen fuel stations through 2012, beginning with $40 million total in 2009 and 2010, CEC can demonstrate California's commitment to continue as a leader in hydrogen fuel cell vehicle commercialization.* This commitment will send a strong signal to the federal government that their additional investments in California's hydrogen infrastructure are made in the right place at the right time to start a transition to the broader national market.

Sincerely,

Catherine Dunwoody
Executive Director

Hydrogen Fuel Cell Vehicle and Station Deployment Plan: A Strategy for Meeting the Challenge Ahead

Action Plan

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This document establishes CaFCP's current consensus plan for deploying fuel cell vehicles and hydrogen stations in California. This consensus vision does not necessarily represent the organization views or individual commitments of CaFCP members.

Executive Summary

Fuel cell vehicles and hydrogen stations are at the cusp of transition into the early commercial market. In 2000, the automakers and energy companies began small demonstration programs in California, New York, Michigan, Germany, Japan and Korea to prove out the vehicle and station technology. The demonstration programs have also revealed the technical and regulatory advances that must take place to transition to early market customers. The automakers are confident that they can build FCVs that meet customer demands for driving range, performance, durability and comfort and meet the nation's need for a domestic fuel that is better for the environment. They believe that California is the best place to begin the transition to a commercial market.

California must support this transition to meet the state's target of reducing greenhouse gas emissions by 80% below 1990 levels. Hydrogen fuel cell vehicles are electric drive vehicles that produce zero tailpipe emissions and greenhouse gases. From well to wheels, a fuel cell vehicle using hydrogen produced from natural gas reduces GHGs by about half compared to a conventional vehicle. When the hydrogen is produced from renewable sources, the well-to-wheel GHGs are virtually zero.

Major automakers plan to place fuel cell vehicles in early market areas in Southern and Northern California beginning in 2009. By 2017, nearly 50,000 California customers could be driving fuel cell vehicles. In a recent survey, automakers reported plans to deploy FCVs as illustrated in Table A.

TABLE A: Fuel Cell Vehicle Deployment in California

	2009	2010	2011	2012 – 2014	2015 – 2017
Northern CA	57	56	68	865	8,450
Southern CA	136	314	644	3,442	41,150
Total CA	**193**	**370**	**712**	**4,307**	**49,600**

To date, 250 demonstration vehicles—passenger and transit buses—have been placed on California's roads. They fuel at 26 hydrogen stations in the state. Most of these are small stations built to fuel a specific fleet of cars for a limited period. Only six of California's current stations are useable by all the automaker's FCVs. California will need 50-100 hydrogen stations in just eight years. To meet that demand, we must start now.

The early commercial fuel cell vehicles and hydrogen stations must be placed together in a manner that makes efficient use of limited government and industry resources to support a nascent industry, but also places stations slightly ahead of vehicle rollouts. Communities must be prepared so that permitting becomes routine, and fuel providers must see a path to a viable business plan for investing in infrastructure and realizing a profit from selling hydrogen as a retail fuel. The California Fuel Cell Partnership's strategy for a coordinated deployment specifies:

1. Developing early "hydrogen communities" for passenger vehicles with clusters of retail hydrogen stations in four Southern California communities: Santa Monica, Irvine, Torrance and Newport Beach, with additional stations to support the next identified communities and a network of connector stations
2. Expanding the transit program in the San Francisco Bay Area with new mixed-use stations that provide fuel for passenger vehicles and transit buses, as well as dedicated retail hydrogen stations for passenger vehicles.

3. Develop codes, standards and regulations with a state-of-the-art hydrogen station in the Sacramento area that will provide regulatory agencies with transparent access and fuel for passenger vehicles.

Other milestones must be met, including cost reductions, regulations for retail fuel sales and building a supply chain. Outreach and community education is essential to streamline the permitting process and enable stations to be built quickly.

Building 50-100 stations in eight years will require the collaborative efforts of multiple industry and government entities. A total investment of $182 million over a four-year period, beginning with $70 million in 2009 and 2010, will set California on the path to 50,000 hydrogen fuel cell vehicles on the road by 2017. Table B displays the costs of hydrogen stations in California through 2012.

TABLE B: Costs of hydrogen stations in California through 2012

	2009	2010	2011	2012
New stations funded	10	9	11	10
Total station costs (millions)	$30.8	$37.5	$51.2	$59.5
Cumulative total station costs (millions)	$30.8	$68.3	$119.5	$179.0
Gov't cost share for stations (millions)	$23.4	$27.2	$35.9	$31.1
Regulatory development and outreach costs (millions)	$1.0	$0.5	$0.5	$0.5
Cumulative gov't cost (millions)	$24.4	$52.1	$88.5	$120.1
Total cumulative costs (millions)	**$31.8**	**$69.8**	**$121.5**	**$181.5**

CaFCP expects that government and industry will both invest in the transition, with government support heavier in the early years and decreasing as more vehicles and stations are deployed. As station owners and operators, who are primarily small business owners, are able to sell fuel at a profit, the need for government support will decrease. Government support of $120 million through 2012, beginning with $52 million in 2009 and 2010, is needed to incent industry to begin this transition.

The National Hydrogen Association recently released a report called The Energy Evolution that compares 16 different combinations of alternative fuels and vehicles and their effect on the environment and the economy through the end of the century. The report concludes that the future holds a mixture of vehicle types and alternative fuels, but only the hydrogen-dominant scenario can simultaneously achieve petroleum independence, nearly eliminate urban air pollution and reduce greenhouse gases to 80 percent below 1990 levels.

The automakers, fuel cell technology companies and energy companies have made good progress over the past decade, and they understand the challenges and the next steps that are needed to bring fuel cell vehicles and hydrogen fuel stations to the commercial market, creating American jobs and business opportunities. Traditional and non-traditional station providers have expressed interest in building the first and second waves of retail-like hydrogen stations. A moderate investment today from industry and government will ensure that when major investments are required later, they are for the right reasons in the right places and at the right time. We must take those next steps now to prepare to meet California’s 2050 goals.

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Introduction

California is the national leader in pushing advanced transportation technologies to reduce air pollution. In addition, Californian's lead the world in new car purchases. The diversity of cultures, people and geography of state, residents' quest for the newest and most exciting technologies and attention to environmental impacts make this an ideal place to roll out advanced vehicle technologies

In June 2005 Governor Schwarzenegger signed Executive Order S-3-05 setting the goal of reducing greenhouse gas emissions to 80 percent below 1990 levels by 2050. To achieve this goal, all sectors of the economy must dramatically reduce emissions. Reducing greenhouse gas emissions from transportation will require a combination of reduced vehicle miles traveled, low-carbon fuels and advanced technology vehicles. Fuel cell vehicles powered by hydrogen are one of the few advanced vehicle technologies that can dramatically reduce well-to-wheels carbon emissions, criteria pollutants and dependence on petroleum.

California's Zero-Emission Vehicle[1] and Zero-Emission Bus[2] regulations require that the large automakers place passenger vehicles and large transit agencies purchase buses that have zero tailpipe emissions. Only fuel cell and battery electric vehicles meet the "gold" standard. Customers using either type of electric-drive vehicle will need easy and convenient access to fuel.

California is developing programs to require and provide incentives for advanced fuels. The Low Carbon Fuel Standard[3] and the Alternative and Renewable Fuel and Vehicle Technology Program[4] aid the development of a robust alternative fuel infrastructure that will support and encourage the successful implementation of advanced technology vehicles, including fuel cell vehicles.

The State's regulations and incentive programs must work together to support the advanced transportation technologies that are essential to reach the goal of reducing greenhouse gas emissions to 80 percent below 1990 levels by 2050. Regulations, though, don't make people buy one type of vehicle over another. People buy a car, truck or SUV because it fits their lifestyle and meets their expectations. In the next decades, Californians will likely have several new options, including fuel cell vehicles, battery vehicles and vehicles using advanced biofuels, each a dramatic change from the vehicles and fuels we use today. To achieve California's goals for reducing emissions, customers must do more than accept these advanced technologies. Customers must embrace them the same way they embrace today's vehicles.

It is too early to know exactly which types of vehicles customers will be driving in 2050. But we do know that to meet the 2050 goal, advanced technology must be in virtually every vehicle produced and sold by 2030, allowing 20 years to fully turn over the vehicle population. By 2020, automakers must begin introducing commercially viable technology into multiple production vehicle platforms.

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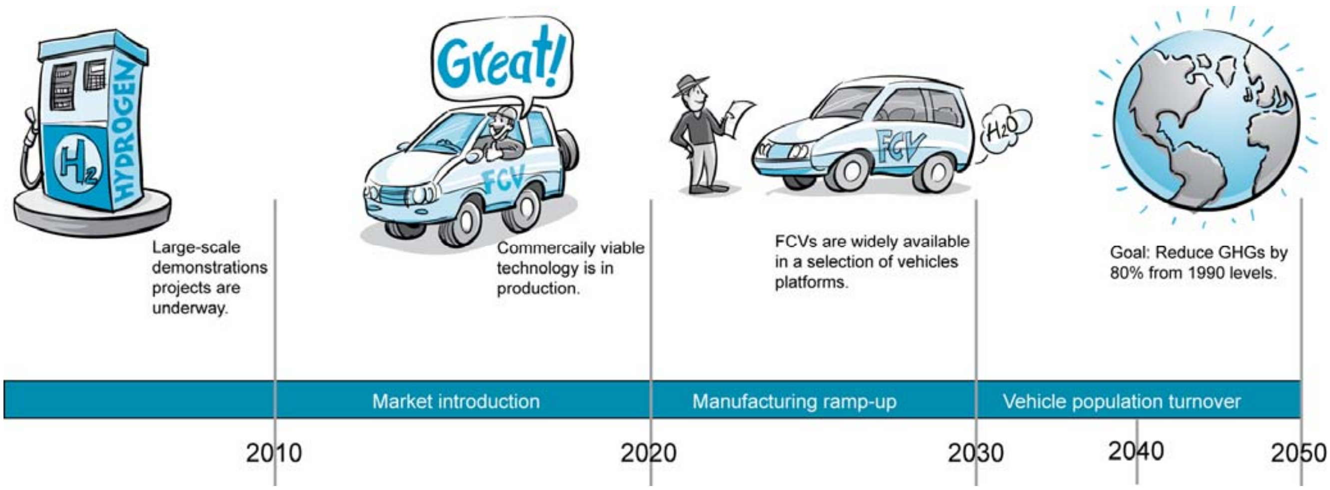
[1] http://www.arb.ca.gov/msprog/zevprog/zevprog.htm
[2] http://www.arb.ca.gov/msprog/bus/zeb/zeb.htm
[3] http://www.arb.ca.gov/fuels/lcfs/lcfs.htm
[4] http://www.energy.ca.gov/proceedings/2008-ALT-1/ and http://www.energy.ca.gov/ab118/index.html

FIGURE 1: Path to commercial success to meet 2050 goals



By 2017, the automakers expect that they will have placed almost 50,000 FCVs in customer hands—80 percent of those in Southern California. To provide fuel for these vehicles, California will need 50-100 new stations in just eight years[5]. These stations must sell fuel to daily commuters, soccer moms and weekend travelers. To reach 50-100 stations, we must start now.

With fuel cell buses, transit agencies can implement clean, efficient buses that use domestically produced fuel, helping to meet the Federal Transit Administration's electric drive vision for the future[6]. Transit agencies will start with phased deployments of increasing numbers of fuel cell buses to further prove out durability, reliability and fueling protocols in preparation for commercial launch by 2015.

California can continue be the epicenter for FCV rollout, bringing jobs and technology to the state, and creating a model for the rest of the country to follow. In the next few years, California needs to:

- Build retail hydrogen stations in the Southern California cities where passenger FCVs will first be introduced.
- Support an innovative fuel cell bus program in the San Francisco Bay Area.
- Develop and implement the codes, standards, regulations and permitting processes that will enable the retail sale of hydrogen as fuel, streamlined permitting for stations and enable the use of best-available technology for stations.

Ten years ago, the automakers along with energy companies, fuel cell technology companies and government agencies formed the California Fuel Cell Partnership. Through CaFCP, the members work together to uncover and address challenges and identify opportunities for success. Through careful collaboration with its members, CaFCP has developed a plan to rollout vehicles and stations together.

This document details the investments and actions needed through 2012, including annual evaluations and other deployment milestones. It is a blueprint for transitioning to a fuel cell vehicle and hydrogen future and creating a commercial market that is self-sustaining.

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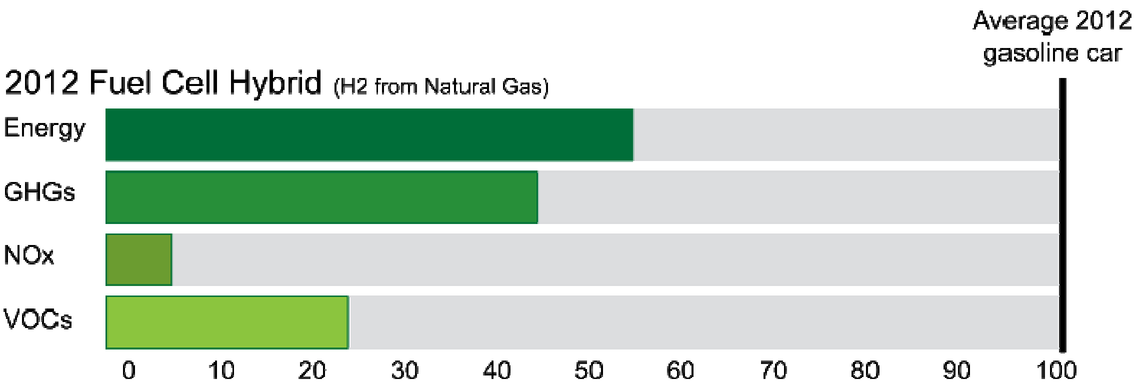
[5] 50,000 vehicles will require 50,000 kg/day hydrogen. This could be provided by fifty 1000 kg/day stations or one hundred 500 kg/day stations, or some other combination.

[6] http://www.electricdrive.org/sites/conf2008/index.php?ht=a/GetDocumentAction/i/10337

Why hydrogen and fuel cell vehicles, and why now?

Hydrogen is a domestically produced low-carbon fuel and has demonstrated the ability to be a zero-carbon fuel when produced from renewable resources. A kilogram of hydrogen contains about the same amount of energy as a gallon of gasoline. When used in a fuel cell, hydrogen has 2–3 times the overall efficiency compared to a gasoline vehicle. As Figure 2 shows, when produced from conventional energy sources like natural gas and used in a fuel cell vehicle, "well to wheels" hydrogen uses less energy and produces far fewer greenhouse gases and criteria pollutants than gasoline vehicles. Low- and zero-carbon methods of producing hydrogen, such as from biomass or wind, yield even greater reductions.

FIGURE 2: Well-to-wheels comparison of a fuel cell vehicle using hydrogen from natural gas to a conventional vehicle using gasoline



Data source: CEC-600-2007-004-REV, August 2007

Fuel cell vehicles are electric-drive vehicles that can provide all the performance and convenience drivers demand. Fuel cell technology is scalable, powering forklifts and airport tugs, passenger vehicles of all sizes and heavy duty vehicles like transit buses. All of the major automakers have fuel cell vehicle programs, and the technology has rapidly advanced over the past decade. Through 2008, the automakers have successfully operated more than 250 fuel cell vehicles in California that have driven about 2.5 million miles. Automakers have deployed even more vehicles worldwide.

FCVs have made good progress towards meeting the goals set by the US Department of Energy. Some first-generation FCVs have shown 1,900 hours of real-world durability, which indicates significant progress toward meeting the 2009 goal of 2,000 hours[1]. Current generation vehicles are well-poised to show significant durability improvements. Bench-scale durability has already exceeded the U.S. Department of Energy's 2015 goals[2]. Current vehicles are close to meeting DOE's 2015 range target of 300 miles[3]. These programs have proven that hydrogen fuel cell vehicles and transit buses can meet customer demands. (See Appendix C.)

[1] To 10% voltage degradation (http://www.nrel.gov/hydrogen/docs/cdp/cdp_1.ppt)
[2] 3M membrane electrode assembly with >7300 hour durability. 2015 goal is 5000 hours.
[3] EPA certified Honda Clarity vehicle range at 280 miles (http://www.fueleconomy.gov/feg/fcv_sbs.shtml)

Hydrogen and fuel cell vehicles will also bring jobs and create business opportunities in California. A 2008 U.S. Department of Energy report[4] projects that the United States will see 375,000-600,000 net new jobs from hydrogen, many from the high-tech sector, but also in automobile sales and service, construction of stations and manufacturing of equipment. Overall, the report projects that California could see up to 25,000 new jobs by 2050 compared to the all-gasoline scenario.

According to the California Service Station & Automotive Repair Association, California has approximately 9,000 gasoline stations, and 7,000 are independently owned and operated. In December, 2008, CaFCP conducted an online focus group of independent station owners and operators. The participants all characterized their business as “service providers” instead of retailers. Most have owned their stations for a decade or more. They see themselves a vital part of the community and take pride in responding to customer needs. They view adding hydrogen and biofuels as a way to transform their businesses and meet the needs of new customers.

Hydrogen fuel cell vehicles are one of the few vehicle technologies that can significantly reduce greenhouse gas emissions and local air pollutants, while also diversifying our energy sources to reduce petroleum dependency. A recent study from the National Research Council[5] found that that levels of petroleum use and greenhouse gases continued to decrease for scenarios with larger numbers of hydrogen fuel cell vehicles, but leveled off after just a few decades for scenarios that emphasized hybrids and biofuels. In their analysis, NRC found that hydrogen FCVs resulted in the deepest cuts to oil use and GHGs in 2040. The study found that commercialization can begin in 2015 and could result in a maximum of two million FCVs on the road by 2020. The National Hydrogen Association recently evaluated the potential for hydrogen fuel cell vehicles to meet goals for reducing oil consumption, greenhouse gas emissions, and local air pollution[6]. Figures 3 and 4 demonstrate that FCVs are essential to meet our long-term goals. To achieve these goals, hydrogen and FCVs immediately need targeted investments and supportive policies.

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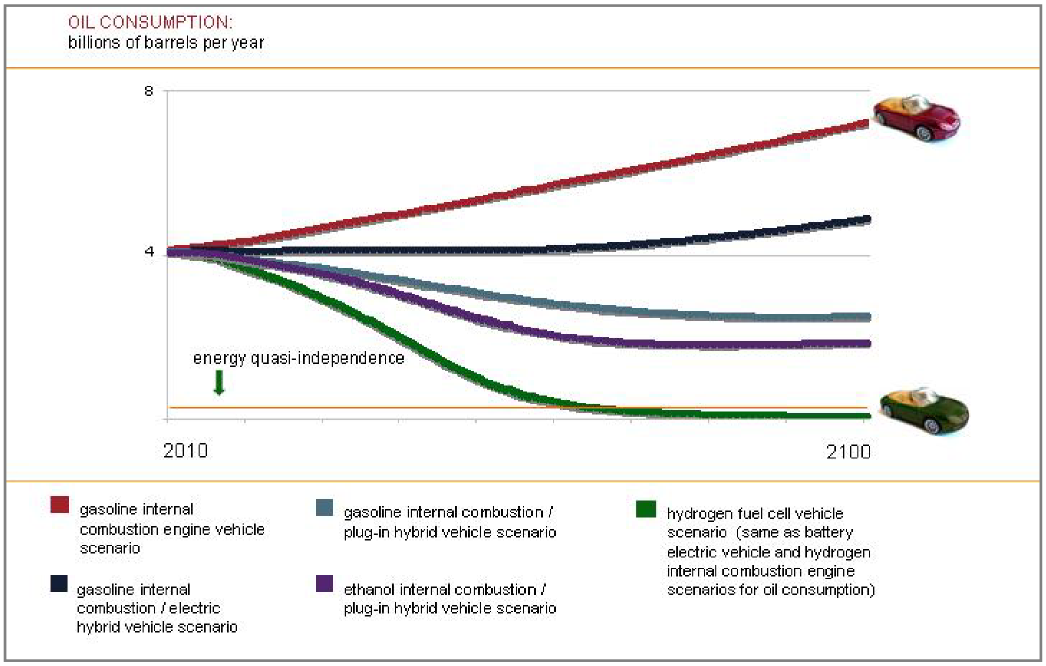
[4] Effects of a Transition to a Hydrogen Economy on Employment in the United States http://www.hydrogen.energy.gov/pdfs/epact1820_employment_study.pdf

[5] Transitions to Alternative Transportation Technologies--A Focus on Hydrogen, 2008, http://www.nap.edu/catalog.php?record_id=12222

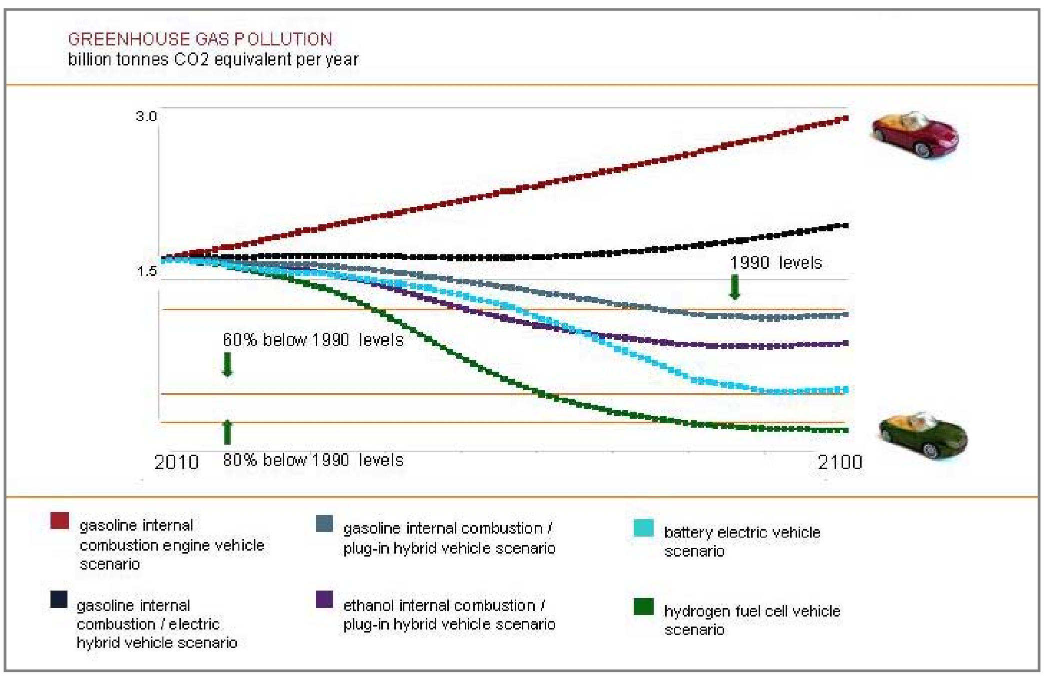
[6] From The Energy Evolution, National Hydrogen Association, 2009

FIGURE 3: Oil consumption if FCVs are commercialized in 2015



Source: National Hydrogen Association's Energy Evolution report

FIGURE 4: GHG emissions if FCVs are commercialized in 2015



Source: National Hydrogen Association's Energy Evolution report

Facts about fuel cell vehicles

Fuel cell vehicles are advancing rapidly and are poised to enter the early commercial market. Specific examples of recent progress include:

- The Honda FCX Clarity—a four-door sedan—has an EPA range of 280 miles. The FCX Clarity fueled with hydrogen made from natural gas has the same well-to-wheels energy efficiency as a battery electric vehicle charged with electricity made from natural gas.
- Kia introduced its second-generation vehicle, Kia Borrego, with 400+ mile range at the 2008 Los Angeles Auto Show. It completed a drive from San Francisco to Los Angeles in December, 2008 without refueling.
- Toyota reports a 350+ mile range for their fuel cell SUV when driving at freeway speeds. Toyota will introduce fourth-generation vehicles to California in March 2009.
- Two current generation Nissan SUVs have passed 100,000 kilometers durability on a single fuel cell stack with little degradation.
- GM has 110 Chevy Equinox FCVs on the road in Project Driveway. All of the Equinox customers love the vehicle and none have returned it before the end of the lease. Customers report no problems starting the vehicle in below-zero temperatures.
- Daimler has more than 100 fuel cell vehicles on the road with customers. In January 2008 Daimler's CEO, Dieter Zetsche, announced that in mid-2009 Daimler will begin small series production of fuel cell cars with 270+ mile driving range. The company foresees that it is possible to reach annual production numbers of 100,000 vehicles in 4-5 years at a competitive cost.
- Fuel cell buses operating in the San Francisco Bay Area and Palm Springs are continuing to run 16-hour shifts and are achieving twice the fuel economy of a diesel bus.
- Volkswagen recently brought 24 fuel cell vehicles to Sacramento, including two VW models, an Audi model and several vehicles built in China and used during the 2008 Olympic Games.

Fuel Cell Vehicle Deployment and Hydrogen Demand

Automakers' technical advances and planned deployments are highly confidential, a sure sign that automakers are serious about commercializing fuel cell vehicles. In early 2009, CaFCP surveyed its nine automaker members to collectively identify where, when and how many FCVs they plan to deploy in the next few years. The results of the survey were aggregated to ensure no individual automaker's plans could be specifically identified. Table 1 presents an overview of the survey results.

TABLE 1: CaFCP FCV Deployment Survey Results: Number of Passenger FCVs in operation*

	2009	2010	2011	2012 – 2014	2015 – 2017
Northern CA	57	56	68	865	8,450
Southern CA	136	314	644	3,442	41,150
Total CA	**193**	**370**	**712**	**4,307**	**49,600**

**total number projected on the road in each year or phase*

In the early years, automakers identified specific communities where they expect to have the first fuel cell vehicle customers. Some FCVs will be in the Sacramento and San Francisco Bay Area, but automakers plan to place about 80 percent of the passenger vehicles in Southern California. During 2009-2011, the automakers identified that the majority of their vehicles will be placed with customers in Santa Monica, Irvine, Torrance, and Newport Beach, as Table 2 represents.

TABLE 2: Projected Number of FCVs operating in Southern California communities

	2009	2010	2011	2012-14*
Santa Monica	30	87	169	900
Irvine	31	71	144	770
Torrance	19	47	107	570
Newport Beach	9	46	104	560
Other So Cal	47	63	120	640
Total So Cal	**136**	**314**	**644**	**3,442**

**projected based on proportion of 2011 vehicles in each community*

In addition to passenger vehicles, five California transit agencies are operating or will soon operate fuel cell buses in demonstration programs. Under the California Air Resources Board's Zero-Emission Bus (ZBus) regulation, California's largest transit agencies will be required to purchase zero-emission buses. The number of fuel cell buses is projected in Table 3.

TABLE 3: Estimated number of FCBs under CARB ZBus regulation

	2009-2011	2012-2014	2015-2017
Number of FCBs	Up to 15	20 to 60	150

Through 2012, fuel cell buses will be deployed in the San Francisco Bay Area. Other transit agencies may deploy FCBs, but will not make that decision until 2010 or later. This document includes only stations for the buses that are planned for deployment in the Bay Area.

Fuel Demand

To project the demand for fuel, we assumed that each passenger vehicle will use 1 kg per day, which includes actual projected use plus a small reserve supply[7]. Hydrogen stations for passenger vehicles need to supply fuel at two pressures: 35 MPa (350 bar) and 70 MPa (700 bar). CaFCP assumed median numbers of fuel cell buses and 25 kg/day demand for each bus. Hydrogen stations for transit buses need to provide fuel at 35 MPa pressure only. Table 4 presents the expected daily hydrogen demand.

TABLE 4: Number of FCVs, FCBs and Daily Hydrogen Demand

	2009	2010	2011	2012 – 2014	2015 – 2017
Number FCVs	193	370	712	4,307	49,600
Number FCBs	4	12	15	60	150
H2 required *(kg/day)*	293	670	1,087	5,807	53,350

[7] Passenger vehicles are expected to use an average of 0.7 kg/day. Stations are expected to operate at about 70% of full capacity. CaFCP to assumes passenger vehicles use 1 kg/day to adjust volumes for the station utilization factor.

California's Current Hydrogen Stations

Hydrogen stations are not a "one-size-fits-all" technology. Some stations make fuel on site by reforming natural gas or electrolyzing water. Other stations dispense hydrogen made at a central production facility. Some stations dispense only hydrogen, while others dispense it along side other fuels. A stationary fuel cell system can make electricity and heat for buildings, and hydrogen for vehicles. (See Appendix A for detailed station descriptions.)

In January, 2009, California had 26 operational hydrogen stations. Many of the stations in California were built to prove out different technologies for making and dispensing hydrogen. The technologies have rapidly improved over a short time, and many of the early stations have served their original purpose and will soon close. Other stations are private, are unable to expand their capacity, unable to provide 70 MPa fuel or are nearing the end of their funding. (See Appendix D.)

Only six of California's stations are useable by all automakers and their customers: Riverside, Burbank, West Los Angeles, Irvine, West Sacramento and Thousand Palms. Only the Irvine station provides 70 MPa fuel. The Burbank station is upgrading to 70 MPa and due to be open in early 2009. When projecting need for additional infrastructure, CaFCP assumed that these stations will continue to be available at the existing or planned supply.

Three publically accessible stations funded in part by the California Hydrogen Highway Network are currently in planning stages: Fountain Valley, Los Angeles and Emeryville. These stations will provide both 35 and 70 MPa fuel. The Fountain Valley station will provide 100% renewable hydrogen made using biogas from a water treatment plant. The Emeryville station will provide 100% renewable hydrogen from solar power for passenger vehicles. This plan assumes these three stations will be operational as planned by the end of 2009.

It can take up to two years to plan, permit and construct a hydrogen station. While local communities refer to federal and state guidelines, they retain local control in final permitting approval. For a new type of structure, like a hydrogen station, the permitting process can take a few months to nearly a year, depending upon the officials' familiarity with hydrogen projects and the overall workload at the office. Streamlining the process for permitting and inspections can speed station deployment by months.

California is currently the only state that regulates hydrogen as a transportation fuel. Before station owners and operators can sell hydrogen as a retail fuel, the California Department of Food & Agriculture, Division of Measurement Standards must be able to verify the fuel quality and certify dispensers to sell hydrogen by weight. DMS is working with standards development organizations to define test methods and certification procedures that will be accepted nationally by late 2011. (See Appendix B.) Until then, hydrogen station owners need an interim solution to realize income until they can sell hydrogen fuel in the same manner that other regulated fuels are dispensed.

How much do hydrogen stations cost?

Hydrogen stations for light-duty vehicles range in cost from $1.5-5.5 million, including equipment, site preparation, engineering and permitting. The type of station, station capacity and number of dispensers directly affect costs. Stations for passenger vehicles must supply hydrogen at 35 and 70 MPa. According to a study by UC Davis Institute of Transportation Studies, costs for hydrogen station equipment begins to decrease by about 20 percent once 16 stations are in the building phase[8], which CaFCP projects will be in about 2012 for most types of stations.

Actual operating and maintenance (O&M) costs vary depending on the size and type of station. This analysis assumes annual average O&M costs are 12 percent of the station capital costs, including maintenance, insurance and taxes. Land costs for hydrogen stations in the Southern California area are assumed to be $130,000-$430,000 per year, depending on station size.

Hydrogen stations that provide renewable hydrogen can be more expensive that those that provide hydrogen produced from natural gas. This is the difference between using a brand-new technology compared to a proven production method, such as creating ethanol from corn compared to ethanol from cellulosic materials. The State of California requires that state-funded hydrogen stations provide 33 percent renewable hydrogen[9], a requirement not made of any other fuel. To meet this requirement, smaller capacity stations (<100 kg/day) could use renewable electrolysis, which has an added cost of photovoltaic equipment. Larger capacity stations (100 kg/day+) could use biofuel or biogas feedstocks for on-site reformers or stationary fuel cells, or in a central production of liquid hydrogen (e.g. located at a landfill). In the future, biomass gasification or wind electrolysis may be a commercially viable option. CaFCP did not include any added capital cost for renewable hydrogen stations, but did include the cost of renewable feedstocks when calculating fuel costs.

Table 5 presents the station capital and operating cost assumptions that CaFCP used to prepare this rollout strategy.

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[8] Weinert, Jonathan X. and Timothy E. Lipman (2006) An Assessment of the Near-Term Costs of Hydrogen Refueling Stations and Station Components. Institute of Transportation Studies, University of California, Davis, Research Report UCD-ITS-RR-06-03

[9] SB1505 (Lowenthal) 2006

TABLE 5: Average Estimated Capital and O&M Costs for a Hydrogen Station

		2009-2011		2012 & after	
Station Type	Capacity (kg/day)	Avg. Capital Cost*	Avg. O&M**	Avg. Capital Cost	Avg. O&M
Portable fueler	50	$1.5 m	$310k		
Permanent	100	$3.0 m	$490k	$2.4 m	$418k
Permanent	200	$3.5 m	$650k	$2.8 m	$566k
Permanent	400	$4.0 m	$880k	$3.2 m	$714k
Permanent	1,000			$5.5 m	$1.0 m
Permanent (mixed use***)	400 /60	$5.5 m	$990k		

**Capital cost includes equipment, site preparation, engineering design, and permitting*
***Operating costs include equipment maintenance, land lease, insurance and property tax.*
****Mixed use stations supply hydrogen for transit buses and passenger vehicles*

Who will build the stations?

Today's hydrogen stations have been built by the energy companies, Shell, Chevron and BP; by industrial gas companies, Air Products, Praxair, Air Liquide and Linde; and by governments and universities. As stations transition to retail, it's likely that the energy companies and industrial gas companies will remain strongly involved and that new companies will become interested in providing alternative fuel stations.

In 2008, CALSTART, working in conjunction with the California Fuel Cell Partnership, identified seven teams that are interested in building and operating hydrogen stations. These teams include owner/operators of biofuel stations, natural gas stations and major retail chains. The January 2009 solicitation from the California Air Resources Board for grant money to support hydrogen stations drew 16 responses. Companies are interested in getting in on the ground floor of providing alternative fuels, creating new business opportunities for California. Co-funding equipment, construction and operating costs will help them make the commitment to start.

A Strategy for Meeting the Challenge Ahead

Currently, eight major automakers have fuel cell vehicles in demonstration programs and with early commercial customers in the Los Angeles, San Francisco and Sacramento areas. Some of the vehicles are in municipal or private fleets. Others are leased to individuals. Some of the demonstration programs are part of the DOE's Technical Validation Program, others are wholly sponsored by the automakers. The purpose of the demonstration programs was to prove out the technology on the road and gauge customer acceptance of the vehicles and fuel. Many automakers are now ready to transition from demonstration programs to an early commercial market.

By 2017, about 41,000 customers in Southern California and 9,000 in Northern California may be driving fuel cell vehicles. They will need multiple retail hydrogen stations in locations convenient to home, work, and recreational destinations. In just eight years, California must grow its hydrogen infrastructure from today's six useable stations to 50-100 retail-like hydrogen stations, and even more stations in the years to follow.

Immediate actions should focus on meeting the needs of current FCV customers and building fuel stations to meet demand through 2014. CaFCP recommends targeting investment in three areas:

- Specific "hydrogen communities" for passenger vehicle rollout. Based on the CaFCP automakers survey, the first fuel cell vehicle customers will be in Santa Monica, Irvine, Torrance and Newport Beach
- Transit stations in the San Francisco Bay Area. Based on projections of transit agency fleet purchases the San Francisco Bay Area will continue to roll out a progressively larger fleet of fuel cell buses.
- Regulation development in the Sacramento area. Based on needs from the California Department of Agriculture, Division of Measurement Standards and other regulatory and codes and standards organization, it's vital to have a state-of-the-art station actively supplying fuel as a source of open and transparent data.

Passenger Fuel Cell Vehicle Strategy

CaFCP's strategy for passenger fuel cell vehicles is to first focus on Santa Monica, Irvine, Torrance and Newport Beach, adding additional Southern California communities and connector stations through 2014 to meet the needs of a growing fuel cell vehicle fleet. California must meet immediate fuel needs of FCV drivers and plan for the future. In this roll-out scenario, hydrogen supply will temporarily exceed customer demand, but the excess capacity will diminish over time as automakers place more vehicles in the "hydrogen-ready" communities.

Hydrogen stations could be deployed according to a variety of scenarios regarding number of stations per community, station size, timing and location of connector stations between communities and destinations. CaFCP evaluated five scenarios for placing stations to meet demand in 2014.

1. A scenario that closely matches hydrogen supply with customer demand, which limits excess hydrogen supply and therefore constrains consumer options.
2. A small station approach that maximizes consumer fueling options (more stations), but at a higher cost.
3. A large station approach that maximizes the business case for station providers, but provides fewer fueling options for consumers (fewer stations).
4. An approach that uses mostly portable stations, which could minimize the investment risks.

5. A balanced approach uses features of all these scenarios to maximize customer satisfaction and minimize costs.

TABLE 6: Summary of CaFCP sensitivity analysis results

	# Stations	kg/day Supply	Govt. $	Total $	2014 % of Total Demand
Balanced	45	9,601	$117.4	$179.0	223%
Smaller stations	63	9,601	$155.4	$234.2	223%
Larger stations	36	9,601	$98.9	$150.8	223%
Primarily portable stations	59	10,001	$131.5	$196.5	232%
Limiting excess supply	44	6,001	$107.4	$177.2	139%

For this plan, CaFCP used the “balanced” scenario for number of stations and resulting costs. This ensures that customers have several fueling options within each community and builds stations of sufficient size to be attractive to fuel retailers. The oversupply of fuel in 2014 prepares communities for the next large wave of vehicles to be introduced beginning in 2015.

In this scenario, using existing stations and placing portable stations in the target communities in 2009 will meet customer needs through 2010. Permanent stations (100-200 kg/day) for these four communities must be funded in 2009, and larger stations (200-400 kg/day) must be funded each year from 2010-2012. This pace of investment will match growing demand and meet the needs of hundreds of vehicles in each community by 2014. Industry, local officials and the public in the four communities will gain knowledge and experience that can be passed along to the next communities and shorten the permitting process.

Other permanent stations and smaller connector stations must be funded starting in 2011 to build out emerging hydrogen communities and provide a fully functional network of connecting stations so that customers can move around the Southern California region and travel to recreational destinations in outlying areas. The first 1,000 kg/day station must be funded in 2011 to prove out this larger station design in anticipation of many more large stations being needed to support the 2015-17 vehicle deployments.

As the permanent stations come online, the portable fuelers can be moved to new communities or serve as connector stations. Additional permanent stations for Burbank and Downtown LA must also be funded in 2010 and 2011 to augment existing stations so that these communities are ready to meet 2014 needs.

Beyond the six Southern California communities currently identified, more communities will need to be prepared beginning in 2011. CaFCP will annually survey automakers’ expected market locations to assess which hydrogen communities should receive hydrogen stations next.

Urban space is scarce and driving habits of future FCV drivers are unknown. Forecasting the perfect size and location for every hydrogen station is impossible, but using information from the automaker survey, CaFCP can project the needs for the first few years. Not all of the hydrogen stations need to be traditional retail fueling sites. Some may be built at grocery or big box stores. Fueling dispensers may also be co-located at other hydrogen sites such as with transit stations, forklift fueling or with renewable power generation.

Transit Strategy

California transit agencies are currently wrapping up a "field testing and design shakedown" phase with 1-3 fuel cell buses. The San Francisco Bay Area transit program, a unique collaboration among five transit agencies, is moving forward to jointly own and operate 13 fuel cell buses by the end of 2009. With funding support from the Federal Transit Administration, these clean, quiet and highly efficient buses will serve passengers in San Jose, San Francisco, Marin County, Oakland, Berkeley and communities in between. This is the next step in validating FCBs—the "full-scale demonstration and fleet-ready reliability testing" phase[1] with 10 or more buses per location.

The next step, from 2012-14, is the "limited production" phase[2] to facilitate a larger FCB fleet of 20-60 buses in one region. By grouping FCBs in one region, multiple transit agencies can use coordinated and shared fueling and maintenance facilities, leveraging maximum learning and benefits with limited resources. This phase is needed to prove out reliability and durability of systems prior to commercialization in 2015. In 2015-2017, Daimler and UTC expect that FCBs will be cost competitive with diesel buses[3].

FCB fleets require large-volume hydrogen stations that can quickly dispense hydrogen at a cost-competitive level. Government financial support will help develop stations that can meet these requirements. Fueling protocols for short duration high-volume fills are still in development, and the Bay Area transit agencies will provide important test data to standards development organizations such as SAE as they finalize and prove out these protocols.

The transit stations will be mixed-use stations; they will have at least one dispenser for passenger vehicles. Learning from the experience of mixed-use CNG fueling, the passenger vehicle dispenser will be in an accessible area away from the transit yard. One mixed-use transit station is already in construction in Emeryville. The 13-bus fleet will need a second mixed-use station funded by 2009 and three more funded in 2010-2012 to support the buses and passenger vehicles coming by 2014.

[1] Fuel Cell Buses in U.S. Transit Fleets: Current Status 2008, L. Eudy, K. Chandler and C. Gikakis. (December 2008)
[2] Ibid
[3] 5th International Fuel Cell Bus Workshop, May 29-30, 2008, Reykjavik, Iceland

California Hydrogen Communities

The following sections describe specific plans for each of the priority communities according to information provided by the automakers and transit agencies. Planning vehicle deployment is a dynamic process. Placing the first wave of stations will impact the locations for the second wave. Vehicles may be more popular in one community than in another. CaFCP will survey automakers annually to ensure that the next wave of stations are being constructed at the most desirable locations for the coming customers.

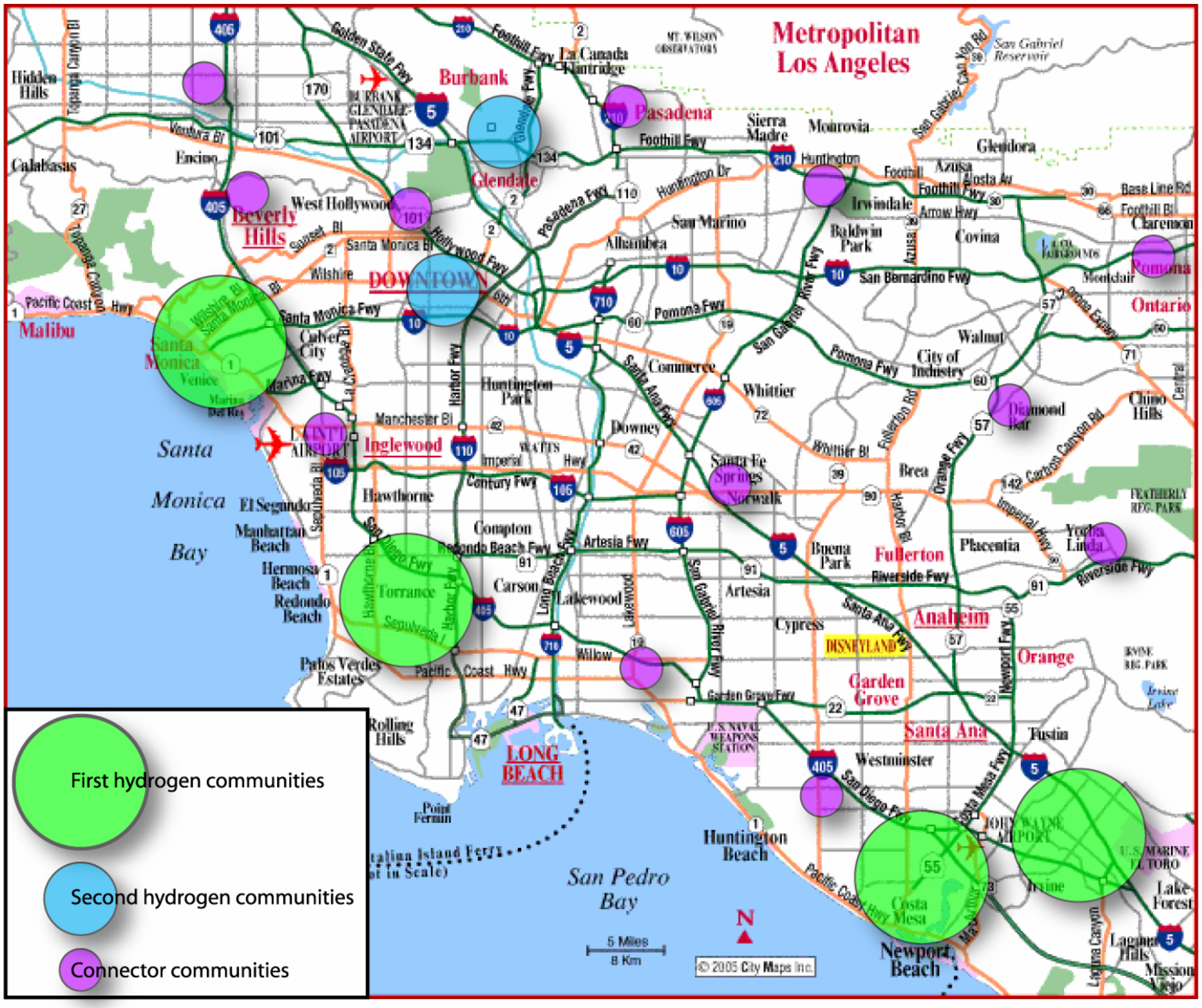
Local governments will benefit from becoming a hydrogen community. FCVs and hydrogen stations will bring new jobs and economic opportunities into the community while providing residents with new consumer choices that address environmental and economic concerns. Hydrogen community leaders can coordinate and share resources to maximize their effectiveness. Incentives or other benefits will encourage the community leaders to:

- Identify and develop methods to leverage local and outside resources
- Develop more detailed plans that match their own community's unique attributes and qualities.
- Lead efforts to inform and prepare their community, develop appropriate policies, and coordinate activities among local stakeholders.

Being connected to the rapidly advancing alternative transportation technology in its early stages will encourage the hydrogen communities to lay the foundations of this new commercial market.

Figure 5 provides an illustrative example of locations for Southern California hydrogen communities and connector stations in 2014.

FIGURE 5: Conceptual hydrogen station network for passenger vehicles in 2014



Santa Monica

The California State Department of Finance places the city's population at 91,124 people in 2007. According to the United States Census Bureau, the city has a land area of 8.3 square miles. There are approximately 20 new car dealerships and 23 gasoline stations within the city of Santa Monica.

Currently, two automakers have FCV customers in Santa Monica. They use the 30 kg/day Shell station in West Los Angeles, which offers a "retail-like" refueling experience that is convenient to customers, but has limited capacity and no plans for expansion.

From automaker survey data, CaFCP expects that by 2014, 900 customers in Santa Monica will be driving FCVs. Using the "balanced" scenario, Santa Monica hydrogen stations can be deployed as follows:

2009	One portable refueler that can supply 50 kg/day	
2010	A second 50 kg/day portable refueler	
2011	One permanent station providing 200 kg/day	
2012	One permanent 400 kg/day station Move both portable fuelers to new communities	
2013	One permanent 200 kg/day station	
2014	One permanent 400 kg/day station	

This deployment schedule will provide customers with multiple fueling locations and provide fuel ahead of customer demand. The following table illustrates the automakers' rollout plans and the available daily hydrogen supply if stations are deployed on schedule:

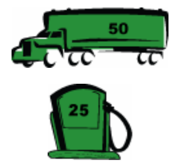
	2009	**2010**	**2011**	**2014 (estimate)**
FCVs in Santa Monica	30	87	169	900
Daily H_2 supply	50kg	100kg	300kg	1,200kg
% of demand met	167%	115%	178%	133%

Irvine

As of 2008, the population of Irvine was 209,806 people. When the El Toro Air Base closed, the city annexed the property, giving it a land area of 69.7 square miles. There are approximately 13 new car dealerships and a large auto mall, and 41 gasoline stations within the city limits.

Currently, several customers in the Irvine area are driving fuel cell vehicles. All fill at the 70 MPa publically accessible station at UC Irvine. The station has limited capacity, 25 kg/day, and does not have plans to expand.

From automaker survey data, CaFCP expects that by 2014, 770 customers in Irvine will be driving FCVs. Using the "balanced" scenario, Irvine hydrogen stations can be deployed as follows:

2009	One portable refueler that can supply 50 kg/day The existing station that supplies 25 kg/day	
2011	One permanent station providing 200 kg/day	
2012	One permanent 400 kg/day station Move portable fueler to new communities	
2013	One permanent 200 kg/day station	
2014	One permanent 400 kg/day station	

This deployment schedule will provide customers with multiple fueling locations and provide fuel ahead of customer demand. The following table illustrates the automakers' rollout plans and the available daily hydrogen supply if stations are deployed on schedule:

	2009	2010	2011	2014 (estimate)
FCVs in Irvine	31	71	144	770
Daily H_2 supply	75kg	75kg	275kg	1,225kg
% of demand met	242%	106%	191%	159%

Torrance

Torrance is the sixth largest city in Los Angeles County and the 34th largest in the state of California. The 2005 census puts the city's population at 142,000 people. According to the United States Census Bureau the city has a land area of 20.5 square miles. There are approximately 18 new car dealerships and 16 gasoline stations (mostly convenience stores) within the city of Torrance.

Two automakers have facilities in Torrance that include private stations for their own vehicles. The stations are not open to other automakers or customers.

From automaker survey data, CaFCP expects that by 2014, 570 customers in Torrance will be driving FCVs. Using the "balanced" scenario, Torrance hydrogen stations can be deployed as follows:

2009	One portable refueler that can supply 50 kg/day	
2011	One permanent station providing 100 kg/day	
2012	One permanent 200 kg/day station Move portable fueler to new communities	
2013	One permanent 400 kg/day station	
2014	One permanent 200 kg/day station	

This deployment schedule will provide customers with multiple fueling locations and provide fuel ahead of customer demand. The following table illustrates the automakers' rollout plans and the available daily hydrogen supply if stations are deployed on schedule.

	2009	2010	2011	2014 (estimate)
FCVs in Torrance	19	47	107	570
Daily H_2 supply	50kg	50kg	150kg	900kg
% of demand met	263%	106%	140%	158%

Newport Beach

As of 2008, the population of Newport Beach was 84,554 people. According to the United States Census Bureau the city has a land area of 14.8 square miles. There are approximately 26 new car dealerships and 35 gasoline stations within the cities of Newport Beach and Costa Mesa, which is immediately adjacent.

Currently, the closest hydrogen station to Newport Beach and Costa Mesa is the 70 MPa publically accessible station at UC Irvine.

From automaker survey data, CaFCP expects that by 2014, 560 customers the Newport Beach area will be driving FCVs. Using the "balanced" scenario, Newport Beach hydrogen stations can be deployed as follows:

2009	One portable refueler that can supply 50 kg/day	
2011	One permanent station providing 100 kg/day	
2012	One permanent 200 kg/day station Move portable fueler to new communities	
2013	One permanent 400 kg/day station	
2014	One permanent 200 kg/day station	

This deployment schedule will provide customers with multiple fueling locations and provide fuel ahead of customer demand. The following table illustrates the automakers' rollout plans and the available daily hydrogen supply if stations are deployed on schedule:

	2009	**2010**	**2011**	**2014 (estimate)**
FCVs in Newport Beach	9	46	104	560
Daily H_2 supply	50kg	50kg	150kg	900kg
% of demand met	555%	109%	144%	161%

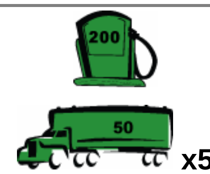
Other Southern California areas

With thousands of vehicles planned by 2014, more Southern California communities must be prepared. Automakers identified Downtown Los Angeles and Burbank as two other communities in which they will sell or lease passenger fuel cell vehicles. CaFCP considers these secondary early market communities because the numbers of vehicles planned through 2011 are much lower than in Santa Monica, Irvine, Torrance and Newport Beach.

The existing station at Burbank is upgrading to fuel at 35 MPa and 70 MPa and increase capacity to 116 kg/day. If a new owner will take over from BP at the end of 2009, the Burbank station can meet customer demand through 2011. The planned station near Downtown Los Angeles (at CSULA) will provide 60 kg/day and can support initial vehicles planned for Downtown LA. The portable fuelers that were first deployed in Santa Monica, Irvine, Torrance and Newport Beach in 2009 and 2010 should be relocated into other communities by the end of 2012. One of the portable fuelers may be required in Burbank until a new permanent station is built in 2013.

Two additional early market communities may be West Hollywood and Pasadena. Annual surveys of automaker deployment plans will help determine where hydrogen stations are needed next to support the growing vehicle markets. The first 1,000 kg/day station will be needed in 2013 in a Southern California location to be determined by 2011. This first large capacity station will prove out large volume fueling for passenger vehicles and serve an area with the highest hydrogen demand. A second 1,000 kg/day station is needed in 2014 and together these large capacity stations will lay the groundwork for building the multiple retail hydrogen stations needed to fuel tens of thousands of vehicles by 2017.

Based on overall vehicle numbers in Southern California planned by 2014, additional stations are needed as follows:

2010	One portable refueler that can supply 50 kg/day (connector)	
2012	One permanent station providing 200 kg/day (LA) Five portable fuelers relocated from first four communities (connectors)	
2013	One permanent station providing 100 kg/day (new communities) Two permanent stations each providing 200 kg/day (Burbank & LA) One permanent station providing 1,000 kg/day (location tbd)	
2014	One permanent station providing 100 kg/day (connector) One permanent station providing 200 kg/day (new communities) One permanent station providing 1,000 kg/day (location tbd)	

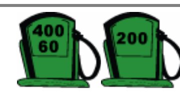
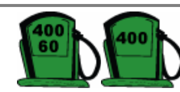
San Francisco Bay Area

The fuel cell buses in the current Bay Area transit programs fuel at two stations; one in Santa Clara and one in Oakland. Both stations are due to close at the end of 2009. AC Transit is in the process of commissioning an additional station in Emeryville, which is funded in part with California Hydrogen Highway Network funds. The station will serve FCVs as well as fuel cell buses, and will play a vital role in advancing the technical capabilities of fueling equipment and processes. Another station must be funded in 2009 to meet the demands of the 13 FCB fleet 2011. Three more stations are needed by 2014 to meet the needs of the “limited production” phase of 20-60 FCBs in 2012-14.

In addition to more transit stations, the Bay Area will require stations dedicated to passenger vehicles. OEMs report that they plan to place vehicles in the San Francisco Bay Area as follows:

2009	2010	2011	2014
14	27	37	677

CaFCP expects that hydrogen stations are needed in the Bay Area in the following manner:

2011	One mixed-use station providing 400/60 kg/day (FCB/FCV)	
2012	One mixed-used station providing 400/60 kg/day (FCB/FCV) One FCV-only station providing 200 kg/day	
2013	One mixed-used station providing 400/60 kg/day (FCB/FCV) One FCV-only station providing 400 kg/day	
2014	One mixed-used station providing 400/60 kg/day (FCB/FCV) Two FCV-only stations providing a total of 600 kg/day	

Sacramento

The existing station in West Sacramento will serve the vehicles in the Capital City area, and an upgrade in late-2009/early-2010 will provide open and transparent data for regulatory bodies and standards development organizations.

By upgrading the West Sacramento hydrogen station to 70 MPa and using state-of-the-art technology, the California Department of Food and Agriculture’s Division of Measurement Standards and other regulatory bodies will have access to technology that is going into public stations. The West Sacramento station is less than 15 miles from the DMS Sacramento office, providing easy and routine access for testing and development work. The CaFCP/DMS collaboration will expedite the development of weights and measures regulations and allow a successful completion before 2012. DMS’ development of hydrogen fuel standards will directly affect the addition of hydrogen fuel dispensing specifications and tolerances to Handbook 44, a crucial step for commercialization. (See Appendix B.)

The West Sacramento station will continue to provide fuel for FCV customers in the Sacramento area. The other two Sacramento-area stations, which are not useable by all automakers and their customers and have very small capacity (8-12 kg/day), are scheduled to close. Once the testing required for the regulatory process is complete, CaFCP intends to move the West Sacramento station equipment into a retail station. In addition, to support vehicles coming by 2014, a second permanent station providing 200 kg/day must be funded in 2011.

Station evaluation criteria

During the station build-out, planners should use a set of evaluation criteria to help assure that the next wave of stations meet customer needs and are built in the optimum locations. “Network enhancement criteria” should include the following:

- Does it add capacity in one of the early market communities in the timeframes needed?
- Does it support automakers plans for customer locations?
- Does the station have a stated plan for customer service enhancements (hours of operation, on-site attendant, signage, etc)?
- Does it help bridge a distance between several other existing stations?
- Does it include new hydrogen production or storage technology identified by CEC, CARB or DOE as a need or transitional technology?
- Does it provide renewable hydrogen?
- Does it provide fuel for non-vehicle applications (combined heat/power, forklifts, etc)?
- Does it provide opportunities for local business or local jobs?

Costs and Timeline for Hydrogen Stations

By 2017, California must achieve an effective network of stations to support tens of thousands of passenger fuel cell vehicles and hundreds of buses. A primary goal of this plan is to build stations through 2014 that can demonstrate high-volume fueling, make the siting and permitting process more routine, and bring equipment and operating costs down to a level where the retail and manufacturing economics require less government support.

Plans and funding for hydrogen stations must begin immediately in 2009 and maintain a steady investment pace each year. This plan identifies funding needs through 2012, with a primary goal of achieving well-placed hydrogen stations to provide ample supply to customers driving the number of fuel cell vehicles projected by 2014. With the exception of six portable fuelers in 2009 and 2010, this plan focuses on building permanent stations (100, 200, 400 and 1,000 kg/day) to begin operation as early as 2011. Building larger stations ahead of vehicle demand is a more cost-effective use of funds than building smaller stations to closely match supply and demand in any given year. Although these stations will provide more fuel than needed in some early years, they will become more fully utilized by 2014 and will provide a start for supporting the first of the 50,000 vehicles expected in California by 2017.

In the early years, government should fund 100 percent of six portable fuelers that can be immediately deployed to create 50 kg/day stations. For permanent stations, government needs to supply 70 percent of the funding for capital and operating costs. In 2012, the government cost share can decrease to 50 percent for stations using previously deployed technology. Government support will likely need to remain at 70 percent for stations with 1,000 kg/day capacity or use new technology, such as composite storage tanks or revolutionary design.

For stations funded under this plan, CaFCP's cost analysis includes operating costs at 12 percent of capital costs for maintenance, taxes and insurance, beginning the year the station is deployed. Land lease costs are assumed to begin the year after the station is funded, and are calculated assuming $5/sf/mo lease rate for retail land in Southern California. Station footprint sizes are based on the US Department of Energy's H2A model. Fuel costs are calculated using projected vehicle demand for hydrogen in a given year, assuming an average $6/kg fuel cost[4]. To meet the renewable hydrogen requirement, CaFCP determined that using biogas and green electricity would increase the cost of hydrogen to an average $8/kg for 33 percent of the fuel supplied[5]. (See Appendix F)

The six useable stations currently operating in California—Riverside, Burbank, West Los Angeles, Irvine, West Sacramento and Thousand Palms—also need annual operations and maintenance (O&M) funding to ensure they remain open for early passenger vehicle customers. CaFCP included $200,000 per year in operating costs for these existing stations. O&M funding is assumed to begin in 2009 for UC Irvine, Riverside and Thousand Palms, 2010 for Burbank and West Sacramento, 2011 for West LA. Operating costs for Emeryville, Los Angeles and Fountain Valley are not needed until 2013[6]. Table 7 shows the number of stations and funding needed to meet vehicle demand in 2014.

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[4] Fuel cost for liquid delivery stations at $10/kg, for SMR stations at $2/kg (based on $12/mmBTU natural gas and $0.10/kWh electricity feedstock). To calculate an average cost, CaFCP assumed 50% of the stations would be liquid delivery, 50% SMR.

[5] Biogas cost at $24/mmBTU and renewable electricity at $15/kWh

[6] Operating costs for these three stations, currently under development, are included in the original CaH2Net award through 2012

TABLE 7: Summary of stations and funding needed through 2012

	2009	2010	2011	2012
New stations funded	10	9	11	10
Cumulative stations funded	10	19	30	40
New stations deployed	5	2	5	7
Cumulative stations deployed	5	7	12	19
New station capital cost (millions)	$27.5	$30.5	$40.0	$33.1
O+M cost (millions)	$2.0	$4.2	$8.3	$14.3
Fuel (including renewable) (millions)	$1.2	$2.9	$3.0	$12.1
Total cost (millions)	$30.8	$37.5	$51.2	$59.5
Cumulative costs (millions)	$30.8	$68.3	$119.5	$179.0
Gov't cost (millions)	$23.4	$27.2	$35.9	$31.1
Cumulative gov't cost (millions)	$23.4	$50.6	$86.5	$117.6

Portable fuelers funded 100% by government
Permanent stations funded 70% by government through 2011, 50% beginning in 2012.
Operating and fuel costs funded 70% by government through 2011, 50% beginning in 2012.

Specific plans and funding for meeting the needs of the vehicles to be deployed by 2017 are not included in this analysis but clearly must be driven by commercial viability and competitive attractiveness to business.

Other funding needs

Renewable hydrogen. California law requires that 33 percent of hydrogen used for transportation be made from renewable sources, a legislative requirement that did not include funding support. As with other fuels, making hydrogen from renewable sources, including solar, wind, geothermal energy, biomass and biogas, is more expensive than through traditional sources. Some renewable conversion methods, such as from algae, or via thermolysis and photolysis, are less mature but have huge potential to meet future hydrogen demand. These technologies, along with biomass gasification, will require research and development support and funding for future commercial demonstrations. Stationary fuel cells using waste gas to produce electricity, hydrogen and heat, such as the Fountain Valley project, and SMR systems for making hydrogen from landfill gas are mature but require funding support to be implemented on a commercial scale. Investing in these and other practical methods of using California's abundant renewable energy resources will be essential to achieve cost-effective renewable hydrogen fuel for transportation at large volume.

Education. Educating various stakeholder groups is a significant component to commercializing hydrogen and fuel cells for transportation. These groups include emergency responders, building and code officials, and state and federal elected officials as well as the general public in communities that have or will have hydrogen stations. Examples of outreach needs include:

- Staff in each early market community (“hydrogen city managers”). This function could be accomplished by current Clean City Coordinators.
- A statewide outreach coordinator to network with hydrogen community officials (city council, permitting officials) and work with the California Fuel Cell Partnership to coordinate outreach to stakeholders and the general public
- A resource to the state fire marshal to integrate hydrogen training into the state fire curriculum

CaFCP estimates $500,000 is needed annually to fund staff and activities for coordinated outreach beginning in mid-2009.

Regulations. The California Division of Measurement Standards (DMS) is working on regulatory standards and new testing procedures to allow for hydrogen sales as a vehicle fuel in California. To accomplish this DMS will require funding for sampling, evaluation and laboratory equipment costing approximately $700,000. This will allow DMS, along with standards development organizations, to conduct necessary research and testing to update existing dispensing specifications and enable hydrogen to be sold to the public as a vehicle fuel. This funding is needed immediately in 2009.

Other Deployment Milestones

In addition to deploying stations ahead of customer demand, CaFCP has identified other milestones to meet during the next eight years:

- Annually
    - Conduct surveys of automaker vehicle marketing plans and track station planning and deployment activities. Recommend adjustments to the roll-out plan as needed.
- In 2012
    - Regulations for selling hydrogen as fuel are in place
    - The first hydrogen communities have established permitting practices for hydrogen stations
    - Hydrogen stations can be insured at a reasonable cost, either through standard insurance underwriting or via a government-backed risk pool
    - SDOs have completed metrology standards, hydrogen quality standards, and vehicle and station components standards
    - Government cost share is reduced to 50 percent for stations using previously deployed technology
    - Station costs have decreased by at least 20% for stations using previously deployed technology
    - Annual station operating costs are well defined and stations can cover at least 50% through hydrogen sales
    - CaFCP and its members have a detailed plan for the next phase of vehicle rollouts and station deployments
- By 2014
    - Nearly 4,500 people are driving fuel cell passenger vehicles

  - Some of the automakers will have completed their first technology development cycle to prove out and optimize hardware and build customer acceptance
  - Commercially viable technology will be in production vehicles, which means that components will have been standardized and the automakers will have their supply chains identified
  - California's first 1,000 kg/day station serving passenger vehicles is open
  - Hydrogen stations are able to cover 100% of operating costs through hydrogen sales
  - Automakers are building their sales and service chains
  - A second large transit agency has purchased fuel cell buses
- By 2017
  - The commercial market will begin with nearly 50,000 FCVs already on the road
  - Auto companies begin selling (vs. leasing) FCVs with 10 year warranties
  - FCV drivers have convenient access to fuel wherever they travel in Southern California
  - Station equipment is smaller, more reliable and capable of dispensing at 1,500 kg/day
  - Station owners can cover recover costs of equipment, land, and operating costs
  - Renewable hydrogen is profitable in 20% of the cases
  - New facilities for manufacturing hydrogen for vehicles are commercially viable
  - Other states are following the California model for rolling out fuel cell vehicles, and stations are being built along major interstate freeways
  - Automakers are on track to place fuel cell technology into several vehicle platforms for 2020 sales

Funding Summary

To successfully launch the early market for fuel cell vehicles and hydrogen, the following government investments are needed in California beginning in 2009:

2009 Funding—Total government costs: $24.4 million

 x4	Four portable fuelers	Santa Monica, Irvine, Torrance and Newport Beach
 x2	two 200 kg/day stations to be operational by 2011	Santa Monica and Irvine
 x2	two 100 kg/day stations to be operation by 2011	Torrance and Newport Beach
	one 400/60 kg/day mixed-use transit/passenger vehicle station	San Francisco Bay Area
	one 100 kg/day regulatory station upgrade	West Sacramento
	O&M costs for three existing stations and four portable fuelers	Stations in Irvine, Riverside and Thousand Palms
	DMS testing and standards equipment	
	Outreach coordination beginning in mid-2009	

2010 Funding—Total government costs: $27.7 million

 x2	two portable fuelers	Santa Monica and other Southern California location
 x4	four 200 kg/day stations to be operational by 2012	Torrance, Newport Beach, Downtown LA and SF Bay Area
 x2	two 400 kg/day stations to be operational by 2012	Santa Monica and Irvine
	400/60 kg/day mixed-use transit/passenger vehicle station	San Francisco Bay Area
	O&M costs for five stations and six portable fuelers	Stations in Irvine, Riverside, Thousand Palms, Burbank and West Sacramento
	Outreach coordination	

2011 Funding—Total government costs: $36.4 million

	one 100 kg/day station to be operational by 2013	Southern California
x5	five 200 kg/day stations to be operational by 2013	Sacramento, Burbank, Downtown LA, Santa Monica and Irvine
x3	three 400 kg/day stations to be operational by 2013	San Francisco Bay Area, Torrance and Newport Beach
	one 400/60 kg/day mixed-use transit/passenger vehicle station	San Francisco Bay Area
	one 1,000 kg/day station to be operational by 2013	Southern California
	O&M costs for 11 stations and six portable fuelers	
	outreach coordination	

2012 Funding—Total government costs: $31.6 million

	one 100 kg/day station to be operational by 2014	Southern California
x4	four 200 kg/day stations to be operational by 2014	Southern California and SF Bay Area
x3	three 400 kg/day stations to be operational by 2014	Southern California and SF Bay Area
	one 1,000 kg/day station to be operational by 2014	Southern California
	one 400/60 kg/day mixed-use transit/passenger vehicle station	San Francisco Bay Area
	O&M costs for 18 stations and six portable fuelers	
	outreach coordination	

Conclusion

Fuel cell vehicles and hydrogen fuel are an excellent solution to help our country meet its goals for cleaner air, reduced greenhouse gas emissions, less dependence on petroleum and providing local jobs and business opportunities. FCVs are not a quick fix, but a long-term, durable change in the worldwide transportation system. The investment by government today will help ensure that California creates a model that the rest of the country—and rest of the world—can quickly adapt to bring this technology to market in time to meet our 2050 goals.

One day in the future, millions of people could be driving fuel cell vehicles…commuters, taxi drivers, delivery van drivers, police officers, bus drivers and vacationers in rental cars. The vehicles they drive will be clean—no tailpipe pollution or greenhouse gases—and quiet. People will go 300-500 miles on a tank of domestically produced fuel and fill at convenient stations—or even fuel at home. Drivers will get all the style, power and performance they want from their vehicles and have great fuel economy.

Decades of experience in other alternative fuels (e.g. ethanol, natural gas, electric vehicles) provides valuable lessons to the commercialization of hydrogen fuel cell vehicles. Alternative fuel stations and electric charging stations have often been inconvenient, unreliable or difficult to use. Transit, municipal and utility fleet programs have not brought light duty consumer vehicles to the mass market. We must do better with fuel cell vehicles.

Market transition years are clearly the most difficult, particularly in these economic times. Transition requires dedication and commitment when the return on investment is years in the future. Milestones and timetables help assess and correct to make sure that investments are used wisely and actions yield results.

By 2030, fuel cell vehicles (and other electric-drive technologies) must be affordable, plentiful and meet customer expectations. This allows 20 years to turn over the majority of the light-duty vehicles in California and meet the goal of reducing greenhouse gases by 80% from 1990 levels.

Appendix A: Types of Hydrogen Stations

Hydrogen is a diverse fuel, produced from a number of feedstocks. In California, most hydrogen is produced from natural gas, a safe and cost-effective production method used for nearly 60 years. Hydrogen can also be produced by electrolyzing water or from biomass. When using state funds to build hydrogen transportation infrastructure, California law[1] requires that 33 percent of hydrogen be produced using renewable sources. When the total amount of hydrogen in the state exceeds 500,000 kilograms the requirement applies to all hydrogen dispensed in California.

Most hydrogen worldwide is produced via fossil fuel-based methods, primarily steam reforming of natural gas (also called SMR). On a well-to-wheels basis, hydrogen produced using natural gas and used in a fuel cell vehicle reduces greenhouse gas emissions by about 55 percent compared to a gasoline combustion vehicle. When produced from renewable energy sources, wind, geothermal, hydro, photovoltaic, and biomass, the GHGs are near zero.

Hydrogen stations themselves are diverse, as Table 1A illustrates. Hydrogen stations can be deployed as mobile fuelers, portable stations, modular units or permanent installations., Flexibility in design is a true advantage, but makes it difficult to draw broad generalizations about hydrogen stations.

Some permanent stations have their fuel delivered from a central production plant; others create fuel on site. Mobile fuelers and portable stations are relatively easy to move and have their own on-board fuel storage that must be replenished. Modular stations are ISO containers that do not have their own fuel source, thus requiring a separate fuel source.

TABLE 1A: Different type of current and planned stations

Station Type	Capacity (kg/day)	GHG reduction*
Liquid delivery	1,000	33%
Pipeline delivery	100	55%
Onsite reformation	100–1,000	<55%
Onsite electrolysis**	30–100	66%
Biomass pipeline delivery	100	88%
Mobile fueler or portable unit	50	Not included
Energy station	100-1,000	Not included

** well-to-wheels for a fuel cell vehicle comparable to a 2012 sedan at 450 g/m GHG from California Energy Commission's "Full Fuel Cycle Assessment: Well-to-Wheels Energy Inputs, Emissions and Water Impacts" (Rev. 4)*

*** at 70% renewable power*

Following are some specific discussions of hydrogen production and delivery options with near term applicability to California goals and markets:

[1] www.leginfo.ca.gov/cgi-bin/postquery?bill_number=sb_1505&sess=0506&house=B&author=lowenthal

Liquid delivery station

Hydrogen is produced at a central production plant. In California, all central plants steam reform natural gas (often referred to as steam methane reformation or SMR). The hydrogen is then cooled to a liquid form and delivered in a tanker truck. Stations store the liquid hydrogen in a tank similar to a liquid propane tank. When needed, the station uses ambient air temperature to warm the fuel to a gaseous state, compresses the gas and dispenses it into the fuel tank.

The California Energy Commission's "Full Fuel Cycle Assessment: Well-to-Wheels Energy Inputs, Emissions and Water Impacts" (Rev. 4) shows that hydrogen produced using this method reduces greenhouse gases from 450 g/m for a gasoline car to 300 g/m for an FCV.

Pipeline delivery station

Hydrogen is produced at a central production plant and delivered to the station in a gaseous state from an existing hydrogen pipeline. When needed, the station pulls the hydrogen via the pipeline, compresses the gas and dispenses it into the fuel tank.

The CEC well-to-wheels report shows that hydrogen delivered by pipeline reduces GHGs more than half: 450 g/m for a gasoline car and 200 g/m for the FCV.

Onsite reformation

Hydrogen is produced at the station using a small steam reformer and natural gas. The hydrogen gas is compressed and stored in tanks until dispensed into the vehicle's fuel tank.

The CEC well-to-wheels report shows that on-site SMR reduces GHGs to less than 200 g/m, compared to 450 g/m for a gasoline car.

Onsite electrolysis

Hydrogen is produced at the station using deionized water and solar or wind energy, or a combination of the two. The hydrogen gas is compressed and stored in tanks until dispensed into the vehicle's fuel tank.

The CEC well-to-wheels report shows that electrolysis using 70 percent renewable power reduces GHGs to about 150 g/m, compared to 450 g/m for a gasoline car. Well-to-wheels analyses done by Argonne National Labs, EUCAR and others use 100% renewable power, which brings GHGs to zero.

As a note, the CEC report also included electrolysis using grid electricity, which results in more GHGs than the gasoline vehicle. Currently, the Burbank, LAX, Riverside and Santa Monica hydrogen stations use grid electrolysis and green offsets.

Biomass

Hydrogen is produced at a central facility and delivered to the station as a gas through a pipeline or as a liquid from a tanker. Currently, two large-scale biomass experiments are underway. In Canada, Linde is making hydrogen from landfill gas and delivering it via tanker truck. In Orange County, the OC Sanitation District is bringing a project online that will make hydrogen from sewage gases and deliver the gaseous hydrogen via pipeline.

The CEC well-to-wheels report shows that pipeline biomass reduces GHGs to about 50 g/m, compared to 450 g/m for a gasoline car. The report did not consider liquid biomass delivery.

Mobile Fuelers and Portable Units

Mobile fuelers are trailers that are equipped with a hydrogen storage tank and a dispenser. A small unit holds 150 kg of gaseous hydrogen, a larger unit holds 300 kg. When the tank is so low that the pressure is not high enough to dispense fuel, a driver takes the truck to the nearest facility that can refill its tank. Mobile fuelers can be deployed quickly and provide fuel for a day, months or even years. Currently mobile fuelers are only available in 35 MPa.

Portable units are similar to small shipping containers. The “box” contains hydrogen storage, a compressor, and the dispenser. A portable unit can hold up to 500 gallons of liquid hydrogen (134 kg). When empty, a tanker truck refills the storage tank. Portable units can be deployed quickly and provide fuel for months or years while a permanent station is under construction.

Modular Stations

Modular stations are small to large containers similar to portable units. The difference is that modular stations require a separate fuel source, such as liquid hydrogen storage, electrolyzer or reformation unit, instead of using onboard storage. This means they can be moved but not as readily as a portable unit. Another difference is that these units are typically ISO containers, meaning they are recognized as safe and certified units by the International Standards Organization. Because these stations use a separate fuel source they can provide larger amounts of fuel than smaller portable units.

Tri-generation Station

Another option for producing hydrogen is stationary fuel cell systems that produce electricity, heat, and hydrogen. When integrated with a building, a tri-generation system can supply reliable electricity onsite, heat rooms and water within the building, and produce a “slipstream” of hydrogen for vehicle fuel. Because the fuel cell generates revenue from multiple products, it reduces hydrogen cost and investment risk compared to other onsite production technologies. Larger, high-temperature fuel cell systems (solid oxide or molten carbonate) integrated with buildings such as hospitals, warehouses, big box stores or office buildings achieve higher efficiency. The excess hydrogen can be stored, compressed and dispensed to fleet or public vehicles. Preliminary analysis by the National Renewable Energy Laboratory (NREL) suggests that integrated combined heat and power systems could supply approximately 100-300 kg per day of hydrogen for each 1000 kW of installed fuel cell electricity capacity.

Appendix B: Policies and Support Mechanisms for Commercialization

Requirements for the Commercial Sale of Hydrogen Fuel

Developing legal metrology standards is crucial for selling hydrogen as a retail fuel. Currently consumers in California are confident in their petroleum purchases because the commercial sale of the fuel is regulated by the California Department of Food and Agriculture, Division of Measurement Standards (DMS) as an automotive fuel. Commercial transactions of hydrogen as a vehicle fuel currently can not be regulated under the existing Device Compliance and Petroleum Products Programs used for gasoline, which must be updated now that hydrogen is listed as an automotive fuel.

DMS is currently leading the effort to establish these necessary regulatory standards. CaFCP members and the National Institute of Standards and Technology (NIST) are working with DMS in the US National Working Group for the Development of Commercial Hydrogen Standards (USNWG). The group is working on three potential reference standards and test procedures: gravimetric, volumetric, and master meter standards.

> The USNWG goal is to promote, encourage, and participate in the establishment of a comprehensive set of standards for commercial measurement of hydrogen for vehicle and other refueling applications, including (1) device design, accuracy, installation, and use; (2) method of sale requirements; (3) reference standards; and (4) field test procedures.[1]

Once approved by the larger body, the National Conference on Weights and Measures, the standards will be written into NIST Handbooks 44 and 130 to be used by regulatory bodies across the United States. January 2011 is the earliest possible target date for adoption.

DMS created a hydrogen fuel quality regulation that became effective on September 11, 2008[2]. This regulation, however, is an interim standard until an ANSI-approved organization, such as SAE International, publishes a hydrogen quality standard. The analytical methods to test to the hydrogen quality standard are being developed at ASTM International.

Insurance / liability

Hydrogen has an excellent safety record as an industrial gas and has had no significant safety incidents in limited use as a vehicle fuel. Fueling vehicles with hydrogen is new, and the data and experience are insufficient to satisfy insurance underwriters that the inherent risks are comparable to conventional automobiles.

Every insurer relies on a method known as "experience rating" to determine a rate for a particular policy. Experience rating is defined as "The process of setting rates partially or in whole on evaluating previous claims experience for a specific group." The greater the number of vehicles and years of loss data, the more accurately an underwriter can predict future losses and calculate a rate comparable to the actual exposure a risk presents.

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[1] U.S. National Work Group Meeting for the Development of Commercial Hydrogen Measurement Standards August 26-27, 2008 APPENDIX B

[2] CDFA DMS Hydrogen fuel standards. http://www.cdfa.ca.gov/dms/hydrogenfuel/HydrogenFuelFinalText.pdf

To date, nearly all the fuel cell vehicles deployed in California are insured under the liability umbrella of each automaker. Individual insurance carriers have little to no interest in providing a quote for a policy. One automaker was successful in getting a quote, but the rates were triple those for insuring a conventional vehicle. The high rate for liability insurance of fuel cell vehicles will likely deter early consumers if some method of offsetting the high costs can not be found.

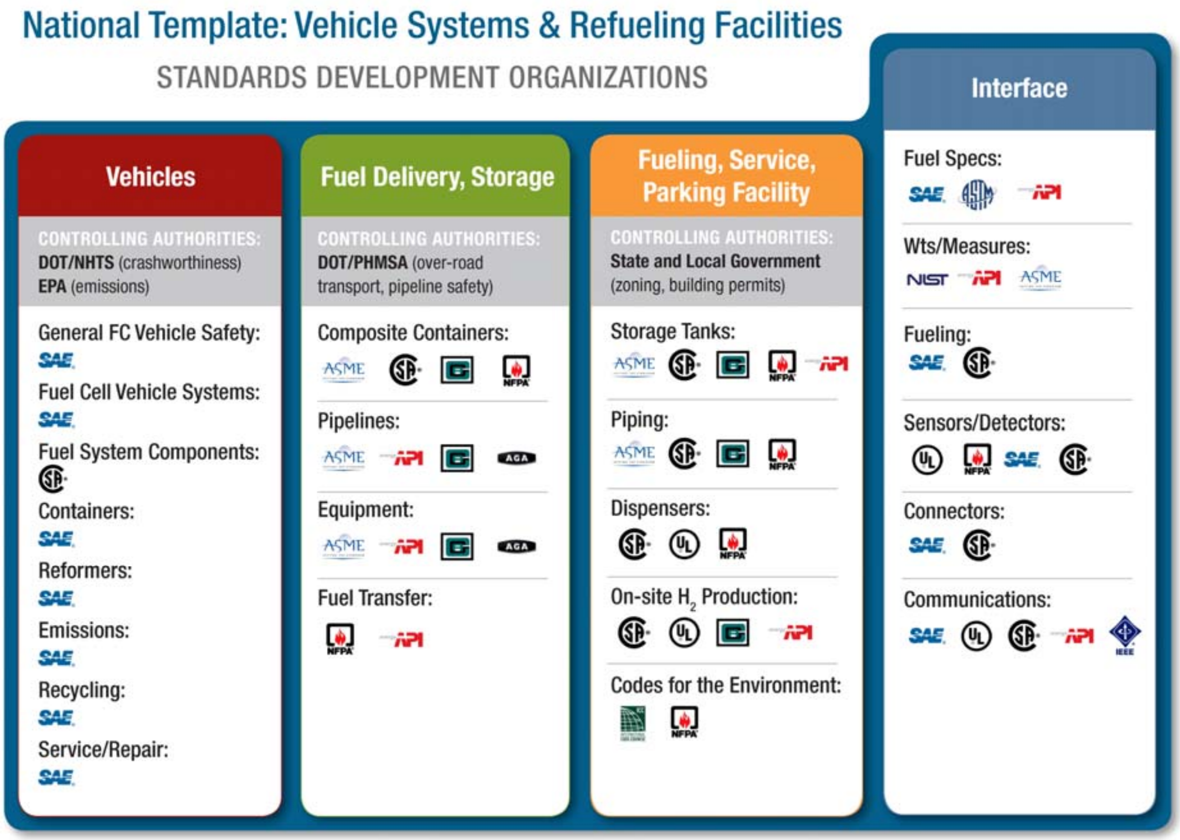
The State of California could consider a risk pool for insurance of hydrogen technologies that includes vehicle operators and station operators. Insurance carriers are typically willing to underwrite smaller liability limits provided excess coverage can be secured. If the State were willing to provide funding to serve as excess liability monies for approximately 10 years, liability rates would likely be comparable to conventional automobiles. Ten years of more of (safe) and credible loss data will provide enough for experience rating, which will lower rates and introduce competition between insurance carriers for this new line of insurance.

Large insurance brokerages are set up to administer such a program including underwriting, legal, marketing and claims administration. Captive insurance companies are set up whereby seed money serves to build excess surplus to fund liability losses as they occur.

Codes and standards

For any technology to be successful, appropriate codes and standards must be in place. Currently few standards pertaining to hydrogen fuel cell vehicles and hydrogen fueling stations have been published. Multiple technical information reports and committee drafts are set to be published as standards in the 2010-2011 timeframe. Most committees are currently preparing for the 2010 review cycles. Since many standards reference standards from other organizations, it is vital that all of the Standard Development Organizations (SDOs) are working together. The DOE Hydrogen Program coordinates these various activities.

The National Template provides a quick guide for SDOs responsible for standards for vehicle systems and refueling facilities. The template includes ANSI-approved SDOs that are widely adopted in the United States, namely: Society of Automotive Engineers International (SAE), Canadian Standards Association (CSA), American Society of Mechanical Engineers (ASME), Compressed Gas Association (CSA), National Fire Protection Association (NFPA), American Petroleum Institute (API), American Gas Association (AGA), Underwriters Laboratory, Inc. (UL), International Code Council (ICC), American Society for Testing and Materials International (ASTM), National Institute for Standards and Technology (NIST), and IEEE Standards Association (IEEE).



National Template Courtesy of National Renewable Energy Laboratory

Additional national and international SDOs are developing similar codes and standards for other countries. Failure to develop codes and standards in the appropriate timeframe will greatly impede the hydrogen industry.

Appendix C: Department of Energy Milestones

The Department of Energy sets goals for all new technologies. Through R&D and technology validation programs, DOE gathers technical data and reports progress towards the goals. The most recent progress report[1], published in January, 2009, shows progress from the labs and vehicle data from more than 250,000 individual trips, travelling more than 1.5 million miles with about 40,000 kg of hydrogen produced or dispensed.

Goal for fuel cell efficiency: 60% for commercialization
Progress: 52.5-58.1% efficiency from four test teams in the technology validation program

Goal for fuel cell durability: 2,000 operating hours in 2009; 5,000 operating hours for commercialization
Progress: Through DOE's Technology Validation program, some first-generation FCVs have shown 1,900 hours of real world durability, which indicates significant progress toward meeting the 2009 goal of 2,000 hours. To achieve overall system durability targets, the durability of components such as membranes and membrane electrode assemblies (MEA) must be improved. In 2008, these areas have seen major improvement, including one manufacturer's MEA operating in the lab for 7,300 hours—well beyond the 5,000 hour target. Technology validation demonstrated real-world MEA durability of 1,900 hours (about 57,000 miles) in 2007.

Goal for fuel economy: Undefined
Progress: "Window-sticker" fuel economy range of 42 to 56.5 miles/kg hydrogen from four test teams in the DOE Technology Validation program

Goal for vehicle range: 250 miles in 2009; 300 miles for commercialization
Progress: Actual range of 100-190 miles from the four teams in the technology validation program. (Second generation vehicles introduced in late-2007 have above-250 mile range and some 2008 vehicles have demonstrated greater than 300-mile range.)

Goal for refueling rate: Similar to conventional fueling (about 1 kg/minute)
Progress: The median fueling time is .86 kg/minute, which is about the same flow rate for gasoline and other fuels. DOE concluded that hydrogen refueling rates are close to being acceptable.

Goal for fuel cell cost: $30/kW by 2015
Progress: Projected high volume fuel cell stack cost has been reduced from $275/kW in 2002 to $73/kW in 2008. Manufacturing R&D will also be required to help lower costs of components and integrated fuel cell systems.

Goal for cost of delivered hydrogen: $3/gge
Progress: Reduced from $5/gge in 2003 to a projected $3/gge, assuming high-volume production of 500 units at 1,500 kg of hydrogen per day.

[1] DOE's *Hydrogen and Fuel Cell Activities, Progress, and Plans Report to Congress*
http://www.hydrogen.energy.gov/congress_reports.html

Appendix D: California's Current and Planned Hydrogen Stations

Expansion of the hydrogen fueling infrastructure using existing stations will be challenging. Existing stations are mostly dedicated to fleet vehicles, located behind a fence, provide limited supply and are not located in the automaker or transit agencies priority early market areas.

All hydrogen stations currently operational in California were built as R&D and testing efforts by individual car manufacturers or through public-private partnerships. These government and industry partnership activities included financial support from the California government (CaH2Net program), the U.S. Department of Energy Hydrogen Program Technology-Validation program, the South Coast Air Quality Management District "Five Cities Program," or a combination of these.

On January 31, 2009, 26 hydrogen stations were operational in California. These stations are generally research and demonstration stations with the following characteristics:

- equipment design meets specific vehicle program fueling needs, not comparable to ease of use of conventional fueling stations,
- fueling capacity to serve a limited number of vehicles,
- complex and onerous liability
- located on private or limited-access property (behind the fence),
- accessible to a limited number of users,
- designed to operate for a limited period of time, with a planned closure at the completion of the research and demonstration project,
- limited funding.

Despite the use of public funding to help pay for some of these stations, many of them are not open to the public. Because of the difficulty in arranging access to these non-public stations, the actual number of usable stations is significantly reduced.

When evaluating all 26 stations based on essential accessibility factors, it appears that only five of these "program" stations have a confirmed availability for usable access beyond January 2010, all of which are located in Southern California (see Table 1D). The key accessibility factors are:

- Open and easy access for all automakers and their customers
- 24/7 or expanded hours of operations
- Shared liability
- Location proximity to major highway or road
- Sufficient capacity or ability to upgrade
- Secured funding for operations.

The locations and network functions of these stations are:

- Burbank (permanent connector/support station)
- Irvine (permanent main station)
- Riverside (permanent connector/support station)
- Thousand Palms (permanent transit/connector station)
- West LA (permanent network support station)

Only five of the remaining limited access stations in Southern California have the potential to be usable past 2010 and should be discussed with the project partners and South Coast Air Quality Management District for potential funding extension, relocation or upgrading. The current locations of these stations are:

- Diamond Bar (upgrade as permanent connector/support station)
- Long Beach (relocate as mobile fueler support station)
- Ontario (relocate as mobile fueler support station)
- Santa Ana (relocate as mobile fueler support station)
- Santa Monica (relocate as permanent support station)

In Northern California, three additional stations should be reviewed for this same purpose and reason. The locations of these stations are:

- Oakland (upgrade as permanent transit/support station)
- Davis (upgrade as permanent connector/support station)
- West Sacramento (upgrade as main station)

Another point to consider is that many automakers are building vehicles that require fuel at a pressure of 70 MPa, while FCBs and some FCVs will continue to use 35 MPa. Presently only three stations in California are 70 MPa capable, with one of these dedicated to a private fleet. All stations should provide both 35 and 70 MPa hydrogen fuel.

The final issue to consider for the existing hydrogen station network is individual station capacity. Without considering accessibility, most stations operational today have a dispensing capacity ranging from 8 to 160 kg/day, with few capable of dispensing more than 50 kg/day. Given that the average fuel cell vehicle can store about 4kg, larger stations will be needed to support the number of vehicles planned for deployment prior to 2014, let alone the significant expansion plans beyond that date. New stations must expand beyond current capacities and begin developing 200, 400 and 1,000 kg/day stations. Larger stations will not only be able to support the growing vehicle deployments, they are necessary to begin developing infrastructure that makes a business case for the private sector.

In conclusion, expansion of the hydrogen fueling infrastructure by using existing stations is limited due to the aforementioned characteristics. For this reason the focus should be on building new stations using a mix of government and industry funding and to evaluate the potential for upgrading or relocating the few applicable existing stations to facilitate the build up of an infrastructure in the six priority areas (Santa Monica, Torrance, Irvine, Newport Beach, San Francisco Bay Area and Sacramento area).

TABLE 1D: Status of Current and Planned Hydrogen Stations in California

Evaluation of Accessibility*

#	Northern California	Funding ends	Capacity kg/day	MPa	Access details: public/hours/etc.
High	**West Sacramento**	Dec 2009	150	35	Daylight hours
Medium	**Davis**	2009	8	35	Business hours/limited access
Medium	**Oakland**	Dec 2009	150	35	Transit station, business hours, limited use FCVs
Low	**Arcata**	N/A	12	35	Business hours, 250+ miles to nearest hydrogen station
Low	**Sacramento**	Mar 2010	12	35	Private station
Low	**San Jose**	Early 2009	1000+	35	Transit station ONLY
#	**Southern California**				
High	**Burbank**	Sep 2009	116	35(/70)	24/7 public access, City to continue operation past Sep 2009
High	**Irvine**	2011	25	35/70	24/7 public access
High	**Riverside**	Dec 2009	12	35	24/7 public access
High	**Thousand Palms**	Beyond 2010	160	35	24/7, public access
High	**West LA**	Jul 2010	30	35	24/7, public access
Medium	**Chino**	Sep 2009	9	35	5 FCVs/day ONLY
Medium	**Diamond Bar**	Jun 2009	12	35	Business hours, public access
Medium	**Rosemead**	Sep 2009	35-40	35	Business hours, limited access
Medium	**Santa Monica**	Dec 2009	12	35	Business hours, limited access
Medium	**Ontario**	Dec 2009	50	35	Mobile fueler, difficult city yard location/access, business hours
Medium	**Santa Ana**	Dec 2009	50	35	Mobile fueler, difficult city yard location/access, business hours
Low	**Chula Vista**	End of 2008	72	35	Closes early 2009
Low	**Irvine**	N/A	3	35	No access, unit behind fence
Low	**Long Beach**	Month-to-month	50	35	Mobile fueler, limited access through liability, high cost of use

		contracts			
	Los Angeles	N/A	50	35	**single automaker** ONLY
	Los Angeles	Dec 2008	24	35	Closes early 2009
	Oxnard	N/A	N/A	N/A	Liquid hydrogen ONLY, NO access
	Torrance	N/A	4	35	**single automaker** ONLY, low capacity
	Torrance	N/A	4	35	**single automaker** ONLY, low capacity
	Torrance	Beyond 2010	N/A	35	Out of service due to upgrade

**** Assume that at any given time, 20% of stations are down. i.e. maintenance, repairs, etc.***

High	Accessible to all automaker vehicle users
Med	Access issue
Low	No access, closure, other significant access issue

New Stations: Expected Commission Dates

#	Location	Operation Begins	Capacity kg/day	MPa	Preliminary access details: public/hours/etc.
27	**Emeryville**	Jan. 1, 2010	60	35/70	24/7 public access
28	**Oceanside**	Spring, 2009	30	35	Delayed opening
29	**CSU LA**	Jan. 1, 2010	40-60	35/70	24/7 public access
30	**Fountain Valley**	Jan. 1, 2010	100	35/70	24/7 public access

Appendix E: Fuel Cell Bus Strategy 2009-2014

California fuel cell bus (FCB) demonstration programs have shown impressive successes; 40 -foot buses have achieved nearly twice the fuel economy of comparable diesel buses and reliable operation in regular service[1]. Currently, the large Bay Area transit operators[2] are coordinating and collaborating to expand their fleet of fuel cell buses by 2010, and beyond.

Under the CARB zero-emission bus (ZBus) regulation, all transit agencies operating more than 200 buses (see Table 3E) will be required to purchase zero-emission buses as part of their total new bus purchases[3]. As a result of this regulation, transit agencies could purchase and operate up to 60 fuel cell buses (FCBs) by 2015 (see Table 1E), as battery only buses are currently not a viable option due to cost, reliability, weight, availability and charging characteristics interfering with transit logistics.

TABLE 1E: Estimated Number of Fuel Cell Buses in California

	2009-2011	2012-2014	2015-2017
Number of FCBs	Up to 15	20 - 60	150

Daimler Europe's bus division and UTC Power, the only FCB systems developer and manufacturer in the U.S., expect that FCBs will be cost competitive with diesel buses in 2015-2017, if a sufficient number of demonstration programs are implemented to advance and test FCB technology,[4] and if infrastructure is in place.

Currently, California transit agencies operating FCBs are in the "field testing and design shakedown" (one to three vehicles) phase. The largest Bay Area operators are entering the next phase with 13 new FCBs by the end of 2009, with the financial support from the Federal Transit Administration. The Bay Area program forms the largest component of the US wide effort to develop FCB technology (see Table 2E for an overview and timeframes). The lessons learned from this fleet contribute to the "full-scale demonstration and fleet-ready reliability testing" phase[5] (10 or more vehicles per station location). This phase is the next step in the validation process of FCB system components.

[1] Alameda-Contra Costa Transit District (AC Transit) Fuel Cell Transit Buses: Third Evaluation Report, K. Chandler and L. Eudy. (July 2008)

[2] The transit program in the San Francisco Bay Area is a unique collaboration among five transit agencies. With funding support from the FTA, they will jointly own and operate 13 fuel cell buses serving San Jose, San Francisco, Marin County, Oakland, Berkeley and surrounding communities.

[3] Pending Summer 2009 ZBus technology evaluation

[4] 5th International Fuel Cell Bus Workshop, May 29-30, 2008, Reykjavik, Iceland

[5] Fuel Cell Buses in U.S. Transit Fleets: Current Status 2008, L. Eudy, K. Chandler and C. Gikakis. (December 2008)

TABLE 2E: Operational fuel cell bus projects in the US: 2008-2011[6]

NREL Hydrogen Evaluations for DOE and FTA

Site/Locations	State	Eval. Funding	2008				2009				2010				2011			
			1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
AC Transit/SF Bay Area	CA	DOE Tech. Valida-tion						CA ZEB Advanced Demo 2009										
SunLine/Thousand Palms	CA		FCB Ext. Service															
SunLine/Thousand Palms	CA								Advanced FCB Project									
CTTRANSIT/Hartford	CT		**CT**TRANSIT FCB Demo															
City of Burbank/Burbank	CA							Burbank										
AC Transit/Oakland	CA	FTA National Fuel Cell Bus Program	Accelerated Testing															
SunLine/Thousand Palms	CA										American FCB Demo							
CTTRANSIT/Hartford	CT									**CT** Hybrid FCB Demo								
Columbia/Site 2/**CT**TRANSIT	SC/CT						Dual Variable Output Hybrid FCB											
Logan Airport/Boston	MA										MA H2 FCB Fleet							
TBD/NY	NY										Lightweight FCB Demo							
TBD/NY	NY										NYPA H2 Powered FCB							
SFMTA/San Francisco	CA										FC APU Hybrid							

Demonstration sites color coded by geographic area: California, New England, Western NY, Southeast, South

The main challenges for FCB fleet projects are hydrogen infrastructure and dispensing hydrogen at a cost competitive level, because hydrogen station equipment is currently more costly than traditional diesel or CNG fueling station equipment[7]. To bring the cost down in the near term, financial support of up to $20 million[8] from industry and government sources is needed to develop large capacity technology stations[9], which will result in lower equipment costs sooner through increased speed of progress in equipment development through testing and demonstrations. During this period further refinement on collocating transit and light duty fueling will occur, to prove out the benefits of developing these in tandem where possible.

The next step, from 2012-2014, is the "limited production" phase[10], which is the phase before commercialization in 2015, for buses. Large demonstration projects lasting for at least three years are needed to get to the required reliability and durability of bus fuel cell systems[11]. This next phase anticipated by Bay Area transit agencies is to facilitate the demonstration and operation of a larger FCB fleet (20-60 buses) in one region. By grouping FCBs in one region, multiple transit agencies can use coordinated and shared fueling and maintenance facilities, leveraging maximum learning and benefits with limited resources. This and all demonstration phases will be used for subsequent deployments.

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[6] National Renewable Energy Laboratory, December 2008 - "Hydrogen Fuel Cell Bus Evaluations" website: http://www.nrel.gov/hydrogen/proj_fc_bus_eval.html

[7] A transit hydrogen fueling station for 10-15 buses is estimated to cost approximately $5 million, based on an estimate from the "Zero Emission Bay Area Advanced Demonstration Project Capital Budget" by AC Transit in September 2007.

[8] Three stations x $5 million/station = $15 million, four stations x $5 million = $20 million

[9] See Action Plan: hydrogen production technologies section to evaluate which technology is preferred to meet demand and cost targets.

[10] Fuel Cell Buses in U.S. Transit Fleets: Current Status 2008, L. Eudy, K. Chandler and C. Gikakis. (December 2008)

[11] A minimum of three years under the same operational schedule as diesel or CNG-bus fleets is needed to achieve several thousands of hours of fuel cell system operation, which has not been achieved to date, due to the duration of current FCB programs and the limited operation of FCBs during each 24-hour cycle.

During this phase, four 400 kg/day stations in the San Francisco Bay Area deployment region must be constructed and fully operational by the time the FCBs are in service (see Table 2E for details).

TABLE 3E: Projected hydrogen demand from fuel cell buses

	2010	2011	2012	2013	2014	2015	2016	2017
Number of FCBs [a]	Up to 15		20 - 60			150		
Projected H_2 demand (kg/day) *for buses* [b]	Up to 375		500 - 1500			3750		

[a] *Based on ZBus regulation and number of vehicles projected to be bought by AC Transit, Santa Clara VTA, SF Muni, Golden Gate Transit, and SamTrans.*
[b] *Assuming 25 kg/day per fuel cell bus, 350 bar delivery pressure.*

Additional to financial support required to build hydrogen fueling stations for transit agencies, an important challenge to resolve is related to the technical capabilities of the fueling equipment. Currently it is unknown how fast hydrogen buses can be fueled safely within the operational time constraints of transit logistics. Transit operations must meet high-volume fueling demand during the short time period when buses return to the yard at the end of their shifts. Fueling protocols for short duration high-volume fills are still in development, and the Bay Area transit agencies will provide important test data to standards development organizations such as the Society of Automotive Engineers (SAE) while they finalize and prove out these protocols. Extensive controlled lab testing to understand this issue is required, as the solution for this challenge will open the door for building stations that can facilitate large numbers of buses. Funding from industry and government sources is also needed to accomplish this, because it is beyond the scope of transit agencies' budgets.

TABLE 4E: Overview of buses at California metropolitan transit agencies

Transit Agency	Fuel Path	Fleet size (as of Jan 2005)
Long Beach Transit	diesel	191
Golden Gate Transit	diesel	221
San Mateo County Transit District	diesel	347
Santa Clara Valley Transportation Authority	diesel	531
Alameda/Contra Costa Transit	diesel	672
San Francisco Municipal Railway	diesel	893
North County Transit District	alternative	155

Santa Monica Big Blue Bus	alternative	174
Omnitrans	alternative	176
Sacramento Regional Transit District	alternative	253
Foothill Transit	alternative	306
San Diego Metropolitan Transit System	alternative	451
Orange County Transportation Authority	alternative	612
Los Angeles County MTA	alternative	2563

Appendix F: Cost and Sensitivity Analysis

CaFCP developed a model to evaluate five station build-out scenarios based on cost and percentage of supply to demand: a small station scenario, a large station scenario, a primarily portable scenario, the balanced scenario referenced in the rollout strategy, and a scenario in which stations are built to very closely match demand and limit excess supply. The results from the sensitivity analysis are shown in Table 1F.

The scenario developed to limit excess supply and the large station scenario yielded the lowest government investment. The most expensive scenario is the small station scenario, followed by the portable station scenario. Both are based on placing a high number of stations with small capacity in the first three years, resulting in more stations overall. The balanced scenario had a mid-point cost for sufficient supply to meet 2014 demand and begin preparing for 2017, while providing enough stations in early market communities to give drivers several fueling location options.

All scenarios used the following assumptions:

- 50kg/day portable stations come online within a year. All other stations take two years past the funding date to come online
- Stations costs include equipment, site preparation, engineering and permitting as follows:
    - Portable 50 kg/day stations are $1.5M
    - 100 kg/day stations are $3.0M
    - 200 kg/day stations are $3.5M
    - 400 kg/day stations are $4.0M
    - 1,000 kg/day stations are $5.5M
    - 400/60 kg/day transit stations are $5.5M.
    - 1,000/100 kg/day transit stations are $7.5M.
- The operating and maintenance cost is 12 percent of the capital cost for equipment maintenance, insurance and taxes beginning in the year after the station is deployed.
- Land lease costs are assumed to begin the year after the station is funded, and are calculated using $5/sf/mo lease rate for retail land in Southern California. Station footprint sizes are based on the US Department of Energy's H2A model (2,200 sf for 100 kg/day rising to 7,200 sf for 1,000 kg/day).
- Fuel cost averages $6/kg based on hydrogen cost for liquid delivery stations at $10/kg and onsite reformation (SMR) stations at $2/kg. SMR hydrogen costs use $12/mmBTU natural gas and $0.10/kWh electricity (0.154 MBTU NG/kg H2 x $12/MBTU + 2.9 kWh/kg H2 x $.10/kWh = $2.14/kg). CaFCP assumed 50% of the stations would be liquid delivery, 50% SMR.
- To meet the renewable hydrogen requirement, CaFCP determined that using biogas and green electricity would increase the cost of hydrogen to an average $8/kg for 33 percent of the fuel supplied[12]
    - SMR H2: 0.154 MBTU NG/kg H2 x $24/MBTU + 2.9 kWh/kg H2 x $.15/kWh = $4.14/kg.
    - Liquid delivery H2: $10/kg + 0.154 MBTU NG/kg H2 X $12/MBTU incremental + 10 kWh/kg H2 (liquefaction) x $0.05/kWh incremental = $12.35/kg
    - Assume ½ of stations are SMR, ½ liquid delivery, so average cost = $8.25/kg

[12] Biogas cost at $24/mmBTU and renewable electricity at $15/kWh

- After 2012 costs of the 100, 200, and 400 kg/day stations are decreased by 20 percent to account for economies of scale.
- In 2012 the portable stations in the priority areas are relocated to Southern California areas as connector stations.
- In 2012 government cost share decreases from 70/30 to 50/50 for most types of stations.

Table 1: Overview of Sensitivity Analysis

	# Stations	2014 kg/day Supply	Govt. $	Total $	2014 % of Total Demand
Balanced	45	9,601	$117.4	$179.0	223%
Smaller stations	63	9,601	$155.4	$234.2	223%
Larger stations	36	9,601	$98.9	$150.8	223%
Primarily portable stations	59	10,001	$131.5	$196.5	232%
Limiting excess supply	44	6,001	$107.4	$177.2	139%