Alternative and Renewable Fuel and Vehicle Technology Program

Central Coast Alternative Fuel Vehicle Readiness Plan

Encompassing the Counties of Ventura, Santa Barbara, and San Luis Obispo

Prepared for: California Energy Commission

Prepared by: EV Alliance in collaboration with the County of Santa Barbara and the Central Coast Alternative Fuel Vehicle Coordinating Council

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DISCLAIMER

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PREFACE

Assembly Bill 118 (Núñez, Chapter 750, Statutes of 2007), created the Alternative and Renewable Fuel and Vehicle Technology Program (ARFVT Program). The statute, subsequently amended by AB 109 (Núñez) Chapter 313, Statutes of 2008), authorizes the California Energy Commission to develop and deploy alternative and renewable fuels and advanced transportation technologies to help attain the state's climate change policies. The Energy Commission has an annual program budget of about $100 million and provides financial support for projects that:

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

The Energy Commission provided funding opportunities under the ARFVT Program to produce a comprehensive Alternative Fuel Vehicle Readiness Plan for the tri-county central coast region, including Ventura, Santa Barbara, and San Luis Obispo Counties, to support the mass deployment of Alternative Fuel Vehicles.

ABSTRACT

This Alternative Fuel Vehicle Readiness Plan for the California Central Coast is intended to guide the development of AFV readiness policies and infrastructure for the tri-County Central Coast region, including the counties of Ventura, Santa Barbara and San Luis Obispo. The development and deployment of AFV-ready infrastructure, policies, and incentives on the Central Coast will encourage local residents and fleet managers to purchase and utilize Alternative Fuel Vehicles with improved environmental attributes over conventional vehicles. Key benefits of adopting AFVs include improvement in local air quality, reduction of greenhouse gas emissions that impact climate change, increased use of local and renewable energy sources, including solar energy and sustainable biofuels, more efficient use of existing grid energy via off-peak PEV charging and energy storage, and increased energy security through reduction in the use of petroleum fuels.

Keywords: California Energy Commission, Plug-In Vehicle, AFV Readiness Plan, Central Coast, Ventura County, Santa Barbara County, San Luis Obispo County, Chargers, Charging Infrastructure

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Introduction

The Central Coast Alternative Fuel Vehicles Coordinating Council ("the Council") was formed in 2014 and includes representatives from stakeholder organizations in San Luis Obispo, Santa Barbara, and Ventura Counties. The Council's mission is to encourage the adoption of alternative fuel vehicles (AFVs) in the Tri-Counties region through a public-private collaborative network of leaders from counties, cities, public entities, community organizations, private industry, and utilities. In 2014, members of the Council applied for and received a grant from the California Energy Commission to oversee an initiative known as the Central Coast Alternative Fuel Ecosystem Project. The grant was administered by the County of Santa Barbara on behalf of the Central Coast AFV Steering Committee. The steering committee includes the County of Santa Barbara (as lead agency), the three Air Pollution Control Districts of Santa Barbara, Ventura, and San Luis Obispo Counties, the Clean Cities Coalition of the Central Coast (C5), the Community Environmental Council of Santa Barbara, and Plug-in Central Coast. Key consultants on the AFV Ecosystem Project included EV Alliance for AFV Readiness Plan development, Reach Strategies for deployment of EV Ride and Drive activities, and the Center for Sustainable Energy in collaboration with the Community Environmental Council of Santa Barbara for delivery of training and education to AFV stakeholders.

The goals of the AFV Ecosystem project have been to accelerate the adoption of AFVs, support local planning for Alternative Fuel Infrastructure (AFI), and serve as a blueprint for regional public and private actions to help achieve state emissions reduction and AFV goals. Measurable objectives of Plan implementation include: increased AFV sales; reductions in greenhouse gas emissions, criteria pollutant emissions, and petroleum consumption; and increased jobs and economic activity.

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Overview and Key Recommendations

Alternative Fuel Vehicles and infrastructure have enormous potential to help meet California's environmental, economic, and energy security goals, and to improve the quality of life on the Central Coast. The *Central Coast Alternative Fuel Vehicle (AFV) Readiness Plan* is a blueprint to guide public and private action in the transition toward cleaner vehicles and a more sustainable future. This plan, funded by the California Energy Commission, will help align regional and local action with the state's AB 32 goals for Greenhouse Gas (GHG) reductions – an 80% reduction below 1990 levels by 2050 – as well as Governor Brown's goal to reduce petroleum use 50% by 2030. Accomplishment of these goals will in turn provide an economic boost to Central Coast communities -- as more vehicles are powered by local renewable sources such as solar, wind, and biofuels – and consumers benefit from the long-term trend toward lower total cost of ownership for most Alternative Fuel Vehicles.

AFVs encompass numerous fuel types -- including electricity, hydrogen, natural gas, and biofuels. The environmental attributes of these fuel types vary depending on the type of feedstock used for fuel production. For example, electricity to power EVs and to formulate hydrogen (for Fuel Cell Vehicles) can in turn be produced by hydropower, solar, wind, or geothermal resources, or by natural gas, including both fossil-based or Renewable Natural Gas (RNG). Likewise, biofuel sources for "flex fuel" or diesel-powered vehicles can be derived from a wide array of organic matter, from corn to switchgrass to woodchips to recycled vegetable oil, each with their own lifecycle carbon impacts. In terms of vehicle choice, Plug-in Electric Vehicles (PEVs) encompass Battery Electric Vehicles (BEVs) and Plug-in Hybrid Vehicles (or PHEVs) – which include both an electric motor and an internal combustion engine for extended range operation.

Given the increasing diversity of vehicles in the Alternative Fuel Vehicle spectrum, understanding which vehicles and complementary infrastructure will best address state policy goals and consumer preferences is becoming increasingly complex. Yet it is urgent that local leaders sort through this complexity, as the stakes are high. The latest scientific data show that human-caused climate change, powered primarily by the burning of fossil fuels, will bring extremely harsh consequences if emissions are not reduced quickly. Severe drought, wildfires, hurricanes, sea level rise (now projected at three to ten feet by 2100), food insecurity, and temperature and weather extremes across the globe and in California are projected to get much worse without a dramatic reduction in use of fossil fuels. Further, in the California context, transportation-related emissions accounts for more than one third of the state's carbon footprint (and more than one half in our urban areas). Accordingly, the California Air Resources Board has mandated a reduction in vehicle emissions of 80% by 2050.

The Central Coast Regional AFV Readiness Plan in Statewide Context: The Central Coast AFV Readiness Plan is one in a series of regional readiness plans being developed throughout the state to help accelerate the shift from conventional vehicles to lower-carbon Alternative Fuel Vehicles. This AFV Readiness Plan in turn builds on the *Central Coast PEV Readiness Plan* developed in 2014 (with combined CEC and Department of Energy funding), which provided a detailed set of policy recommendations to accelerate PEV adoption as well as an EV charging station siting guide. The current AFV Plan includes key elements of the earlier PEV Readiness Plan, while making additional recommendations regarding the potential of other AFV types (hydrogen, natural gas, and biofuels) to further accelerate reductions in GHG emissions, air pollution, and petroleum use.

The Central Coast AFV Coordinating Council: The *Central Coast AFV Coordinating Council* was developed by the joint efforts of its Steering Committee, which includes the County of Santa Barbara, C5 – the Clean Cities Coalition of the Central Coast, the Community Environmental Council of Santa Barbara, and the Air Pollution Control Districts of Ventura, Santa Barbara, and San Luis Obispo Counties, and the University of California at Santa Barbara. (In 2012, these same organizations also established *Plug-in Central Coast,* which is the region's PEV Coordinating Council.) Under the auspices of the *AFV Coordinating Council,* an AFV Readiness Planning grant was received from the California Energy Commission (CEC) in 2014 for the purposes of preparing this Plan and developing complementary AFV market-accelerating programs and policies. The AFV Readiness planning grant has been administered by the County of Santa Barbara on behalf of the *Central Coast AFV Council Steering Committee.* The Council's mission is to increase the deployment of Alternative Fuel Vehicles with the greatest environmental and community benefit. To advance this mission, the Council convened a public-private collaborative network of leaders from interested public agencies, community organizations, private industry, and utilities, and these stakeholders provided essential input to the creation of this Plan.

Need for a Central Coast AFV Readiness Plan: The growth of Alternative Fuel Vehicles and infrastructure in the Central Coast region has been slow. While the region has invested substantial resources in AFV adoption via Air District grant programs in all three Counties, as well as consumer participation in federal and state incentive programs (notably the federal PEV tax incentives and the state Clean Fuel Vehicle Rebate program), alternative fuel vehicles still comprise less than 1% of the total fleet and less than 2% of new vehicle sales, according to CVRP data. The need for an accelerated approach to the PEV and general AFV transition has been clearly articulated by the County of Santa Barbara, as well as other local jurisdictions, and support for an accelerated effort is strong in the tri-County region. Within the County of Santa Barbara, the Energy and Climate Action Plan Summary indicates that on-road transportation constitutes the greatest percentage of emissions in the County, and that Alternative-Fuel Vehicles and Incentives (Measure T3) will be considered by policy makers as part of a package of strategies to achieve a proposed reduction of at least 15% by 2020 through a combination of voluntary, phased, and mandatory reduction measures.[1] The Santa Barbara County Air Pollution Control District has also received a complementary planning grant from the California Energy Commission to develop a detailed hydrogen-specific plan which will be released in 2017. In the 2017-18 period, it is intended that the AFV and Hydrogen plans will in turn attract additional resources to further build out the Central Coast Alt Fuels infrastructure -- and further accelerate adoption of AFVs by public and private fleet operators, and the public at large.

Summary Recommendations on Accelerated AFV Deployment: The Central Coast AFV Coordinating Council has determined that local AFV programs be guided by these principles:

- ***Environmental and community benefit:*** Proposed AFV policies and programs should be focused on those technologies that have the greatest potential for reducing greenhouse gas emissions and criteria pollutants at a reasonable economic cost.

- ***Readiness for mass adoption:*** Policies and programs should initially focus on AFVs that have the highest potential for mass adoption in the 2016-2020 period. Criteria should include model choice, price/performance, and fuel availability and convenience.

Given the framework provided above, the AFV Coordinating Council has divided its recommendations into three broad categories: *Regional Planning, Local Government Policies,* and *Market Development.* Recommendations on *Regional Planning* and *Market Development* represent actions that partners on the Council have already committed to undertake, with resources provided by the California Energy Commission. Recommendations regarding *Local Government Policies* are provided for the consideration of City Councils and County Boards of Supervisors, and senior staff. To spur consideration of these measures, the Council will broadly disseminate this Plan and present its key findings to the Board of Supervisors of Santa Barbara County, which is the lead administrative sponsor of the Plan.

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[1]County of Santa Barbara, Energy and Climate Action Plan Summary Information, p. 23, March 12, 2013. http://longrange.sbcountyplanning.org/programs/climateactionstrategy/docs/Hearing_attachments/BOS%20031213/Attachment%203%20ECAP%20Summary%20Information%20Final.pdf.

Summary Recommendations		
Domain	**Recommendation**	**Lead**
1. REGIONAL PLANNING		
1.1. Regional AFV Coordination	**1.1.1. Develop and sustain the *Central Coast AFV Coordinating Council*** to accelerate the deployment of Alternative Fuel Vehicles and infrastructure. The Council will continue to act as a coordinating body for AFV-related policy and resource development to advance the region's Alternative Fuel ecosystem.	**Central Coast AFV Coordinating Council**
2. LOCAL GOVERNMENT ACTIONS		
2.1. AFV Fleet Procurement Policies and Planning	**2.1.1. Develop goals for public fleets to be powered by the most sustainable alternative fuels**, taking into account C02e and air quality impacts, economy of operation on a life-cycle basis, and operational requirements.	**City Councils** **Public Works & Fleet Managers**
2.2. AFV Fleet Management	**2.2.1. Create Green Fleet Spreadsheets** that identify the actions, AFV investments, fuel and operating cost savings available through accelerated deployment of Alternative Fuel Vehicles. **2.2.2. Revise and update green fleet plans on an annual basis** to assess the economic and environmental benefits of AFV fleet procurement. **2.2.3. Collect fleet baseline data and analyze specific opportunities for optimization** related to vehicle specifications, route characteristics, etc. **2.2.4. Deploy best Green Fleet management policies relative to each alternative fuel type,** including but not limited to: a) idle reduction and elimination; b) downsized vehicle engines and platforms tailored to specific duty cycles; c) state-of-the-art fleet pooling/sharing tools employing advanced telematics; and d) combined routes and missions to reduce fleet redundancy.	**Fleet Managers**

Domain	Recommendation	Lead
2.3. Electric Vehicle Infrastructure	**2.3.1. Develop a charger permit form identifying key required** elements (utilizing model forms providing in the Central Coast EV Readiness Plan) **2.3.2. Provide EV charger installation process guidance and checklists** (based on forms provided in the Central Coast EV Readiness Plan **2.3.3. Establish reasonable – and flat – charger permit fees** (less than $150) **2.3.4. Establish phone or online permit and inspection appointment systems** that streamline process of EV charging installation **2.3.5. Implement local codes that mandate pre-wiring for EV Charging Stations** in new construction and in major remodeling. Consider potential adoption of these ratios of EV Charging Station "stub-outs" to parking stations:	**City Planning and Building Departments**

BUILDING TYPE	% of PARKING SPACES
Multi-household residential	10% (1 min.)
Lodging	3% (1 min.)
Retail, eating and drinking establishment	1%
Office, medical	3% (1 min.)
Industrial	1%
Institutional, Municipal	3% (1 min.)
Recreational/Entertainment/Cultural	1%

Domain	Recommendation	Lead
	2.3.6. Coordinate with the PEV Council to access funding for EV chargers and coordinate installation activities with utilities and EV service providers	
	2.3.7. Provide standard specifications for on-street and off-street EV charging stations aligned best practices defined in the *California ZEV Readiness Guide* published by the Governor's Office of Planning and Research. **2.3.8. Deploy code language to discourage non-electric vehicles from occupying charging stations**, and to regulate pricing and hours of operation for EVCS (see template language in the Central Coast *PEV Readiness Plan)* **2.3.9. Deploy guidelines for ADA access** consistent with guidance provided by the California Governor's Office of Planning and Research	**City Planning and Building Departments**

Domain	Recommendation	Lead
2.4. CNG Vehicles & Infrastructure	**2.4.1. Assess potential of CNG vehicles to meet local GHG reduction, cost, and sustainability goals** -- taking into account the most recent and authoritative research on GHG and air quality impacts and integration of NGV readiness into General Plans, Climate Plans, and other sustainability related plans as appropriate **2.4.2. Determine need for additional local CNG fueling infrastructure** (if any) to meet planned CNG fleet needs **2.4.3. Partner with other cities and the Central Coast AFV Council to outreach to CNG fuel providers** to develop CNG fueling sites (if applicable) -- utilizing the *Drive Natural Gas Infrastructure Guide* from the California Natural Gas Vehicle Partnership to ensure consistency with applicable codes (ANSI, National Fire Protection Association, and Uniform Building, Fire, and Plumbing Codes) **2.4.4. Develop a comprehensive best-practice based maintenance plan for CNG vehicles,** ensuring that NGV maintenance facilities conform to National Fire Protection Association requirements	**Planning Departments** **Fleet Departments**
2.5. Biofuel Vehicles & Infrastructure	**2.5.1. Assess potential of biofuel vehicles to meet local GHG reduction, cost, and sustainability goals** -- taking into account the most recent and authoritative research on GHG and air quality impacts and integration of biofuel vehicle readiness into General Plans, Climate Action Plans, and other sustainability related plans as appropriate **2.5.2. Determine need for additional local biofuels production**, distribution, and fueling infrastructure to meet planned biofuel fleet needs as demand increases **2.5.3. Partner with other cities and the AFV Readiness Council to outreach to potential biofuel/biodiesel fuel infrastructure developers** and operators to develop potential fueling sites (if applicable)	**Planning Departments** **Fleet Departments**

Domain	Recommendation	Lead
2.6. Fuel Cell Vehicles and Infrastructure	**2.6.1. Assess potential of Fuel Cell Vehicles (FCVs) to meet local GHG reduction, cost, and sustainability goals** -- taking into account the most authoritative research on GHG and air quality impacts and integration of FCV readiness into General Plans, Climate Plans, and other sustainability related plans as appropriate.	**Planning Departments** **Fleet Departments**
	2.6.2. Assess local hydrogen fueling infrastructure needs & siting options in cooperation with the AFV Council and the California Fuel Cell Partnership (where relevant based on planned station locations)	**Planning Departments**
	2.6.3. Participate in local government staff training on hydrogen vehicle and fueling safety, code, and standards utilizing best practices such as: a) the DOE online training: *Introduction to Hydrogen for Code Officials*; b) *H2BestPractices.org;* c) the *Regulations, Codes and Standards Template for California Hydrogen Dispensing Stations;* and, d) CA Fuel Cell Partnership resources.	**Planning Departments with AFV Coordinating Council and CA Fuel Cell Partnership**

3. MARKET DEVELOPMENT ACTIVITIES

Domain	Recommendation	Lead
3.1. Consumer Outreach and Education	**3.1.1. Produce ongoing Green Car Shows and "Ride and Drive" events to introduce consumers to the full spectrum of AFV types.**	**Central Coast AFV Coord. Council** **Community Environmenta l Council**
3.2. Education of Key Decision-Makers and Stakeholders	**3.2.1. Develop AFV training workshops targeting fleet operators, first responders, planners, and decision-makers**. Seminars will introduce key stakeholders to the most recent authoritative information on the full spectrum of AFVs, fueling infrastructure, incentives, and their economic and environmental benefits and operating characteristics.	**Central Coast AFV Coordinating Council**

Integration of State, Regional, and Local Action: As the foregoing recommendations make clear, much of the AFV agenda that is locally actionable falls into the domain of codes and standards related to fueling infrastructure, fleet policy and procurement, consumer outreach and education, and market development. However, an essential "force multiplier" for local action is effective coordination and resource development in partnership with regional and state agencies, and private industry. To provide a more synoptic view of the cross-cutting roles of these key actors, the following chart summaries relevant actions by stakeholder group.

Table 1: Central Coast AFV Market Development Roles and Actions -- State, Regional, Local, & Industry				
Domain	**State**	**Regional Agencies**	**Local Government**	**Industry**
Alternative Fueling Infrastructure				
EV Charging	▪ **Grants for EVSE** (CEC) ▪ **Inter-regional Fast Charge planning** (CEC) ▪ **Vehicle-Grid Integration support** (CEC, EPIC)	▪ **Outreach to charging station site hosts, grant development** (AFV Coord. Council, Air Districts, Counties)	▪ **EV charger mandates in building code** (Cities & Counties) ▪ **EV charger permitting & inspection streamlining** (Cities & Counties)	▪ **Utility programs for rate-based EVSE** (pending -- PG&E, SCE) ▪ **Innovative financing for "no money down" EVSE** (EV Service Providers)
Hydrogen	▪ **Grants for FCV fueling stations** (CEC) ▪ **Statewide planning assistance** (Fuel Cell Partnership, GoBiz)	▪ **Planning for infrastructure & market development** (AFV Coord. Council, County of S. Barbara) ▪ **Potential grants for fueling stations from AB 2766 or other sources** (Air Districts)	▪ **Siting, permitting, and inspection of potential fueling sites** (Cities & Counties) ▪ **Training of first responders and other staff in alternative fuel safety and regulatory compliance issues** (Cities and Counties)	▪ **Co-funding of fueling infrastructure** (fueling companies and auto OEMs) ▪ **Development of affordable vehicle leasing pilot programs** (auto OEMs and financing intermediaries)
Natural Gas	▪ **Grants for CNG/LNG fueling** (CEC)			
Biofuels	▪ **Grants for biofuels production & distribution** (CEC)			
Alternative Vehicle Initiatives				
Consumer Incentives & Outreach	▪ **Rebates for AFVs** (CARB & CEC) ▪ **Market Development grants** (CEC)	▪ **Ride & Drive and AFV Outreach Events** (AFV Council, Comm. Env. Council of SB)	▪ **Preferential parking for AFVs** (Cities, Counties, and public agencies)	▪ **Participation in Ride & Drive events** (auto OEMs) ▪ **Dealer Education re. AFV benefits** (auto OEMs)
Fleet Activities	▪ **AFV volume procurement opportunities** (State agencies, e.g. DGS)	▪ **Vehicle incentives from AB 2766 or other sources** (AQMDs)	▪ **Green Fleet Procurement & Mg't Plans** (all public agencies)	▪ **AFV fleet analysis, pricing & financing** ▪ **AFV fleet telematics**
Education & Training	▪ **AFV Strategic Issue Workshops** (CEC, CPUC)	▪ **AFV education for decision-makers** (AFV Council, CSE)	▪ **Staff participation in AFV education** (all relevant agencies)	▪ **AFV training for dealers and support technicians** (auto OEMs)

CHAPTER 1: State, Regional, and Market Context for Alternative Fuel and Vehicle Planning

1.1. California's State Climate and Clean Transportation Goals and Policy Context: By providing major metro regions in California with grant support for Alternative Fuels related planning and promotion activities, the California Energy Commission seeks to align local, regional, and state policy goals on climate and clean transportation. With a state population of nearly 39 million, California also hosts nearly 26 million passenger vehicles and light trucks, and almost 1 million medium- and heavy-duty vehicles. According to the most recent data available (2012), the transportation sector emits 36 percent of the total greenhouse gases in the state and about 83 percent of smog-forming oxides of nitrogen (NOx). Given the urgency of both the climate crisis and ongoing "non-attainment" of federal air quality standards in large areas of the state, California has established a strong leadership position in setting robust GHG reduction goals – and providing ongoing funding to help accelerate the shift away from fossil fuels and towards clean, renewable resources in both the energy and transportation sectors. The state has set overall climate goals in the Global Warming Solutions Act of 2006 (Núñez, Chapter 488, Statutes of 2006) that cap economy-wide California greenhouse emissions at 1990 levels by 2020 and in Executive Orders (S-3-05 and B-16-2012), which call for reductions in greenhouse gas emissions to 80 percent below 1990 levels by 2050. Further, the federal Clean Air Act calls for an 80 percent reduction in NOx emissions by 2023. Last but not least, Governor Brown has established two additional transportation and energy goals to be accomplished by 2030: an increase from one-third to 50 percent our electricity derived from renewable sources, and a reduction in petroleum use in cars and trucks by up to 50 percent. It is important to note in this context that additional "greening" of the California electricity grid will further extend the significant environmental advantage of cars powered by electricity. Of course, meeting these ambitious goals will require the retirement of older, high-polluting, inefficient vehicles and replacing them with near zero- and zero-emission technologies. To enable that transition, the state has developed a strong array of incentives and policies which will have growing impact on local government policy makers, drivers, and fleet managers on the Central Coast.

1.2. State Alternative Fuels Policies and Incentives: Assembly Bill 8 (Perea, 2013) will provide more than $2 billion through 2024 for clean transportation investment programs such as the Alternative and Renewable Fuel and Vehicle Technology Program of the CEC (originally authorized as AB 118) – which includes funding for AFV-related research and development, manufacturing, vehicle incentives, fueling infrastructure, market development, and state, regional, and local planning and policy work. In the period from 2010 through 2014, investments by the CEC Alternative Fuels program and complementary investments from CARB have made a substantial difference in accelerating the deployment of both Alternative Fuel Vehicles and infrastructure, notably through the California Clean Vehicle Rebate Program. This rebate program, which is ongoing, now provides incentives of $1,500 for Plug-in Hybrids (PHEVs), $2500 for Battery Electric Vehicles (BEVs), and $5,000 for hydrogen Fuel Cell Vehicles (FCVs). With the aid of these incentives, the chart below indicates the statewide progress made in AFV deployment since the ramp-up of key CEC and ARB programs.

1.3. State-Funded Alternative Fuel Vehicle and Infrastructure Growth: 2010 – 2014

Table 2: State and Regional Alternative Fuel Vehicle and Public Infrastructure: 2010 – 2014				
Domain	**Fuel Type**	**2009-2010 Baseline**	**2015 California Public AFV Fueling Sites** (counting only those supported by state $)	**Central Coast Public AFV Fueling Sites** (data provided by CEC-SB)
AFV Infra-structure	**EV Charging**	2,540 charge points	4,129 public/workplace Level 2 Chargers 109 DC Fast Charger	369 total charge points 342 public/workplace 32 Level 1 stations 301 Level 2 stations 27 DC Cast Chargers
	Biofuel: E85*	39 fueling stations	161 fueling stations	4 fueling stations
	Natural Gas	443 fueling stations	60 stations	15 stations
	Hydrogen	6 public fueling stations	51 fueling stations (by Dec. 2015)	1 fueling stations
Domain	**Vehicle Type**	**2009-2010 Baseline**	**2015 AFVs Supported by California State Funding**	**2015 AFV Registrations in Central Coast Area**
Alter-native Fuel Vehicles	**Electric Cars**	13,268 *(mostly neighborhood EVs)*	110,314 (including 21,000 via ARFVTP** and 89,314 via AQIP***)	6,404 (BEVs + PHEVs)
	Electric Trucks	1,409	160	29 (Electric-Diesel Hybrids)
	Natural Gas Trucks	13,995	2,725	237 (CNG)

Sources: California Energy Commission, *2014 Integrated Energy Policy Report* and *Proposed 2015-16 ARVTP Investment Plan*, p. 11.
*E85 is a blend of 85 percent ethanol and 15 percent gasoline **ARFVTP is the Alternative Renewable Fuels and Vehicle Technology Program, administered by the CEC ***AQIP is the Air Quality Improvement Program administered by the ARB.

There are significant variations in adoption of PEVs and other Alternative Fuel Vehicles by metropolitan region and also by County. The Central Coast has lagged behind the Bay Area, Los Angeles, and San Diego in per capita PEV deployment. Reasons for this differential may include: longer travel distances, lower density of public chargers, and relatively limited utility of the "white sticker" program (which permits single-occupant BEVs to gain access to carpool lanes), and fewer high-income environmentally-motivated households characteristic of the first wave of EV "early adopters." In any case, the following chart indicates that PEV uptake in the three Counties is in its early stages.

1.4. Central Coast Electric Drive Vehicle Deployment by County

Table 3. Central Coast Electric Drive Vehicle Deployment by County* (Table 3)					
Vehicle Type	**Santa Barbara**	**Ventura**	**San Luis Obispo**	**Total Central Coast**	**Estimated 10% Correction****
Plug-in Hybrid Electric Vehicles (PHEVs)	405	910	263	1578	See total below (includes base CVRP data + 10%)
Battery Electric Vehicles (BEVs)	217	1019	130	1366	
Fuel Cell Electric Vehicles (FCEVs)	9	3	5	17	
Total Plug-in Electric Vehicles (PEV	631	1932	398	2961	3257

*December 2014 data from the California Vehicle Rebate Program. See https://energycenter.org/clean-vehicle-rebate-project
**The Center for Sustainable Energy estimates that approximately 10% of EV buyers do not apply for the California Vehicle Rebate Program (CVRP), and this number may skew higher in areas with a high proportion of Tesla sales. In addition, early models of the Chevrolet Volt were not eligible for the rebate program, and thus were not counted in the statewide PEV totals.

1.5. California Climate, Clean Air, and Clean Transportation Goals: As the AFV deployment numbers above indicate, California and the Central Coast are just at the beginning of what is envisioned as a dramatic transition to alternative fuel vehicles, predominantly with electric drive. This transition will be required to meet the 80% 2050 carbon reduction goal, keeping in mind that with an average fleet turnover of 12 years, nearly 100% of all new vehicles sold by the mid-2030's will need to be electric drive. Further, the AB 32 goal is not the only policy mandate incorporated into state and federal statutes. The following chart (from the 2015-16 CEC Alternative Fuel Program Investment Plan) indicates the full range of key laws and policy mandates.

1.6. State of California Greenhouse Gas, Fuel, and Air Quality Goals and Milestones (Table 4)		
Policy Basis	**Objectives**	**Goals and Milestones**
AB 32	GHG Reduction	Reduce GHG emissions to 1990 levels by 2020
Executive Order S-3-05	GHG Reduction	Reduce GHG emissions to 80 percent below 1990 levels by 2050
Low Carbon Fuel Standard	GHG Reduction	Reduce carbon intensity of transportation fuels in California by 10 percent by 2020
State Alternative Fuels Plan	Petroleum Reduction	Reduce petroleum fuel use to 15 percent below 2003 levels by 2020
Bioenergy Action Plan	In-State Biofuels Production	Produce in California 20 percent of biofuels used in state by 2010, 40 percent by 2020, and 75 percent by 2050
Energy Policy Act of 2005; Energy Independence & Security Act of 2007	Renewable Fuel Standard	36 billion gallons of renewable fuel by 2022 (nationally)
Clean Air Act	Air Quality	80 percent reduction in NO_X by 2023
Executive Order B-16-2012	ZEV Mandate	Accommodate 1 million electric vehicles by 2020 and 1.5 million by 2025*

Source: California Energy Commission. * Senate Bill 1275 (De León, Chapter 530, Statutes of 2014) subsequently established a target of 1 million zero-emission and near-zero emission vehicles in California by 2023, as well as increasing access to such vehicles for disadvantaged, low-income, and moderate-income communities and consumers.

AFV Deployment Goals and CEC Investment Strategies to Meet Them: Of all the benchmarks defined above, perhaps the most aggressive – and the most directly relevant to regional AFV readiness planning – is Governor's Executive Order to put 1 million EVs on the road by 2020, and 1.5 million by 2025. AFV vehicle deployment numbers above indicate, PHEVs and BEVs are gaining the greatest market traction. But the California Energy Commission is committed to a strategy that includes a robust role for all AFV types – including hydrogen, natural gas, and biofuels. Two charts below indicate the depth and breadth of that commitment. Over the past five years, the CEC has invested over $150M in biofuels and gasoline fuel substitutes, $84M in hydrogen vehicles and infrastructure, more than $77M in CNG. CEC investments in light-duty EVs and infrastructure have totaled $67M+, with additional support for rebates coming from the California Air Resources Board via the Air Quality Improvement Program (AQIP.) Going forward, the 2015-16 Alternative & Renewable Fuel Vehicle and Technology Program Investment Plan proposes just $20M out of the $100M annual budget to be focused on Electric Vehicle and Infrastructure deployment, supplemented by additional support from the CARB Air Quality Improvement Program (AQIP) for EV and FCV rebates. This reflects the state's long-term commitment to hydrogen, biofuels, and CNG, which are viewed as essential for emissions reduction in the medium and heavy-duty sector, as well as (in the case of biofuels) increased uptake of cleaner fuels within the existing fleet of diesel and flex-fuel vehicles.

1.7. CEC Investments in Alternative Fuel Vehicles and Infrastructure

Table 5: California Energy Commission Investments in Alternative Fuel Vehicles and Infrastructure: 2009 - 2014

Category	Funded Activity	Cum. Awards	EV	CNG	Hydrogen	Biofuels	# of Projects or Units
Alternative Fuel Production	Biomethane Production	$51.00				$51.00	15 Projects
	Gasoline Substitutes Production	$27.30				$27.30	12 Projects
	Diesel Substitutes Production	$53.30				$53.30	17 Projects
Alternative Fuel Infrastructure	EV Charging Infrastructure	$38.00	$38.00				9,365 Charging Stations
	Hydrogen Refueling Infrastructure	$84.70			$84.70		48 Fueling Stations
	E85 Fueling Infrastructure	$14.60				$14.60	161 Fueling Stations
	Upstream Biodiesel Infrastructure	$4.00				$4.00	4 Infrastructure Sites
	Natural Gas Fueling Infrastructure	$16.70		$16.70			60 Fueling Stations
Alternative Fuel and Advanced Technology Vehicles	Natural Gas Vehicle Deployment**	$54.30		$54.30			4,470 Cars and Trucks
	Propane Vehicle Deployment**	$6.40		$6.40			514 Trucks
	Light-Duty EV Deployment	$25.10	$25.10				10,700 Cars
	Med- & Heavy-Duty EV Deployment	$4.00	$4.00				150 Trucks
	Med. & Heavy-Duty Vehicle Demos.	$58.70					31 Demonstrations
Related Needs and Opportunities	Manufacturing	$47.00					18 Manufacturing Projects
	Emerging Opportunities	†					†
	Workforce Training & Development	$25.20					55 Recipients
	Fuel Standards & Equip. Certification	$3.90					1 Project
	Sustainability Studies	$2.10					2 Projects
	Regional Alt. Fuel Planning	$4.30					18 Regional Plans
	Centers for Alternative Fuels	$4.60					4 Centers
	Technical Assistance & Evaluation	$5.60					5 Agreements
Total*		**$530.80**	**$67.10**	**$77.40**	**$84.70**	**$150.20**	

Source: Calif. Energy Commission, *2015-16 Investment Plan Update for the Alternative & Renewable Fuel & Vehicle Technology Program*, p. 2.
*Note that some investment programs above cross over AFV types and are not assigned to a single AFV area. Therefore, differential investment levels per AFV type are illustrative rather than definitive. Also, ARB investments in Clean Vehicle rebates (primarily benefiting PEVs) are not included here.

1.8. Proposed ARFVTP Investment Plan

Table 5: Proposed 2015-16 Alternative & Renewable Fuel Vehicle and Technology Program Investment Plan				
Category	**Funded Activity**	**2013-2014**	**2014-2015**	**2015-2016 (Proposed)**
Alternative Fuel Production	Biofuel Production and Supply	$23	$20	$20
Alternative Fuel Infrastructure	Electric Charging Infrastructure	$7	$15	$18
	Hydrogen Refueling Infrastructure	$20	$20	$20
	Natural Gas Fueling Infrastructure	$1.5	$1.5	$5
Alternative Fuel and Advanced Technology Vehicles	Natural Gas Vehicle Incentives	$12	$10	$10
	Light-Duty Electric Vehicle Deployment	$5	$5	-
	Medium- & Heavy-Duty Vehicle Technology Demonstration & Scale-Up	$15	$15	$20*
Related Needs and Opportunities	Manufacturing	$5	$5	
	Emerging Opportunities	$4	$6	$4
	Workforce Training and Development Agreements	$2	$2.5	$3
	Regional Alternative Fuel Readiness and Planning	$3.5	-	-
	Centers for Alternative Fuels and Advanced Vehicle Technology	$2	-	-
Total		**$100**	**$100**	**$100**

Source: California Energy Commission, *2015-16 Investment Plan Update for the Alternative & Renewable Fuel & Vehicle Technology Program,* page 2.

1.9. Air Quality Improvement Program: Assembly Bill 118 created the Air Quality Improvement Program (AQIP) to be administered by the Air Resource Board (ARB) at the same time as it created the CEC-managed Alternative and Renewable Fuel and Vehicle Technology Program (ARFVTP). The ARFVTP is focused primarily on GHG reduction within the transportation sector, while the AQIP is primarily responsible for reducing specific transportation-related air pollutants, such as oxides of nitrogen (NOx), the primary contributors to smog, and diesel-related Particulate Matter (PM), which are implicated in asthma and lung disease. While the two ARB and CEC managed programs have jointly contributed funds toward Clean Vehicle Rebates, other program areas are differentiated. The CEC has invested in light-duty electric vehicle charging infrastructure, regional planning, manufacturing projects, and the demonstration of early hybrid and electric truck and bus models. The AQIP has provided deployment incentives for such vehicles through its Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP), and loans to assist fleets in diesel modernization projects. The AQIP also provides grants for demonstration and testing of emission reduction technologies, with projects addressing railroads, tugboats, and other applications. Cumulative funding from the AQIP is summarized below.

1.10. AQIP Funding: 2010-2015

Table 6: Air Resources Board (ARB) Air Quality Improvement Program (AQIP) Funding: 2010 - 2014	
Project Category	**Funding Through June 2014** (in millions)
Clean Vehicle Rebate Project	$123.8*
Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project	$69.4**
Advanced Technology Demonstration	$6.3
Truck Loan Assistance Program	$54.0
Other Emission Reduction	$4.7
Total	**$258.2**

Source: Calif. Energy Commission, *2015-16 Investment Plan Update for the Alternative & Renewable Fuel & Vehicle Technology Program,* p. 20. *ARFVTP funding provided a total of $43.6 million to backfill CVRP needs. **ARFVTP funding provided $4 million in added incentives for electric truck deployment.

1.11. CEC and CARB Perspectives on AFV Types and Contributions to GHG Reduction and Vehicle Deployment Goals: Together, the CEC and CARB have, in the 2010 – 2014 period, invested more than $750 million in California's Alternative Fuel Vehicle ecosystem, spanning a broad range of strategies from R&D to manufacturing, vehicle incentives, regional planning, and market development. Moreover, the state's investment – particularly in total expenditures on vehicle incentives – is poised to increase substantially as cap and trade revenues ramp up in coming years. To take full advantage of state investments that are often awarded on a competitive basis, it is important for regional stakeholders to gain a clear understanding of investment and policy priorities for the state, and the role envisioned for various alt fuels and vehicles. Below, we provide a brief overview of the state's current perspectives on leading AFV fuel types, followed by a discussion of the differentiated roles and actions to be carried out by state, regional, and local government and industry stakeholders. The following summary is derived from the CEC's *2014 Integrated Energy Policy Report*, as well as the CEC *2015-26 ARFVTP Investment Plan,* the *ZEV Action Plan*, and fuel-specific state roadmap documents. Additional detail is provided in the separate chapters of this Plan focused on each major fuel type (electricity, biofuels, hydrogen, natural gas.)

1.12. Hydrogen Vehicle Outlook: After many years of development, as of mid-2015, there are currently three light-duty FCVs on the market (or soon to be available): the Hyundai Tuscan (a cross-over), the Honda Clarity, and the Toyota Mirai (both four door mid-size sedans). Pricing of the Mirai is typical for all of the initial FCVs, with the MSRP set at $58,325. However a combined $13,000 in federal and California incentives will drop the price to about $45K. Toyota expects that approximately 90% of Mirai customers will choose the $499-per-month lease with ~$3650 due at signing.

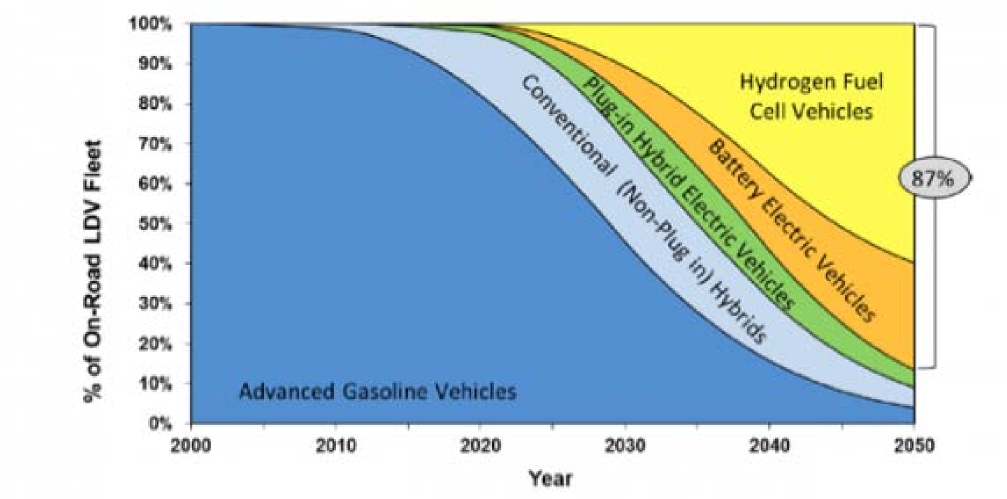
Hydrogen Fueling Infrastructure: According to the California Fuel Cell Partnership, there are scheduled to be 59 FCV fueling stations in operation by January 2016, including stations in Santa Barbara and San Juan Capistrano. (See http://www.cafcp.org/stationmap) Statewide, a total of 100+ are on the drawing boards to be funded with assistance from the California Energy Commission. With station costs in the range of $2+million, building out a network of stations large enough to meet the needs of California motorists has been the most significant challenge for FCV development, along with vehicle cost reduction.

Environmental Attributes: FCVs are sometimes referred to as Fuel Cell Electric Vehicles, because the engine is electric and there are consequently zero tailpipe emissions, as is the case with a Battery Electric Vehicles (or a PHEV in all-electric mode). Most FCVs are currently powered by hydrogen formulated with natural gas, although it is possible to produce hydrogen with renewable sources of methane gas, extracted from landfill emissions or other industrial processes. When compared with EVs using grid power, FCVs with natural gas formulated hydrogen are significantly less clean. However, the hydrogen production with renewable feedstocks can produce much more favorable results. Critical questions about cost and scalability of the cleaner fuel supply chain for hydrogen (as well as CNG and biofuels) are highly complex and will be considered in further detail in this Readiness Plan. Importantly, the rapid re-fuelability of hydrogen vehicles holds long-term potential for fueling in the medium and heavy-duty vehicle sector, where the current weight-to-horsepower ratio of batteries and recharging times are prohibitive for longer-haul applications at this time.

1.13. State Expectations for Fuel Cell Vehicle Market Growth: Beginning in 2011, the ARB and California Energy Commission documents have included the following chart indicating that by 2050, as many as half of all new vehicle sales in California could be FCVs.

1.13. State Expectations for Fuel Cell Vehicle Market Growth by 2050 (Table 7)

Figure 1. On Road Light-Duty Vehicle Scenario to Reach 2050 Goal



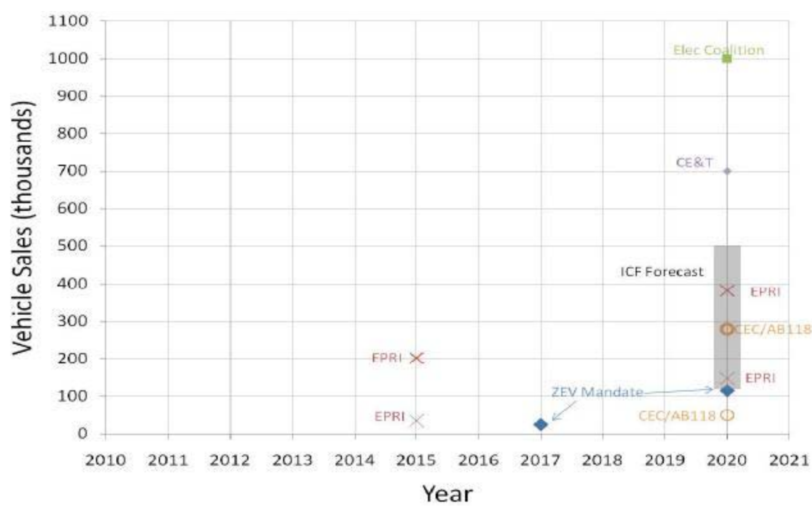
Source: Advanced Clean Cars: Initial Statement of Reasons, ARB December 2011

The specific assumptions or rationale for these projections have not yet been fully detailed in state policy documents. However, it is likely that rapid refueling (once the requisite core of FCV stations have been established statewide) has been foremost in the minds of Air Resources Board policy makers and elected officials who have continued to invest strongly in the hydrogen vision. The ARB Advanced Clean Car Program summary indicates that the robust 50% penetration projection reflects just "one scenario" for achieving the 80 percent transportation emissions reduction target. By contrast, nearer term sales projections from auto manufacturers are relatively modest (in the single digit thousands per each FCV model over the coming five years.) Given the relatively large number of PEVs on the market today (more than 20 in 2015 and likely double that number by 2017), it appears that PEVs are at least five years ahead of FCVs on the pathway to mass market adoption.

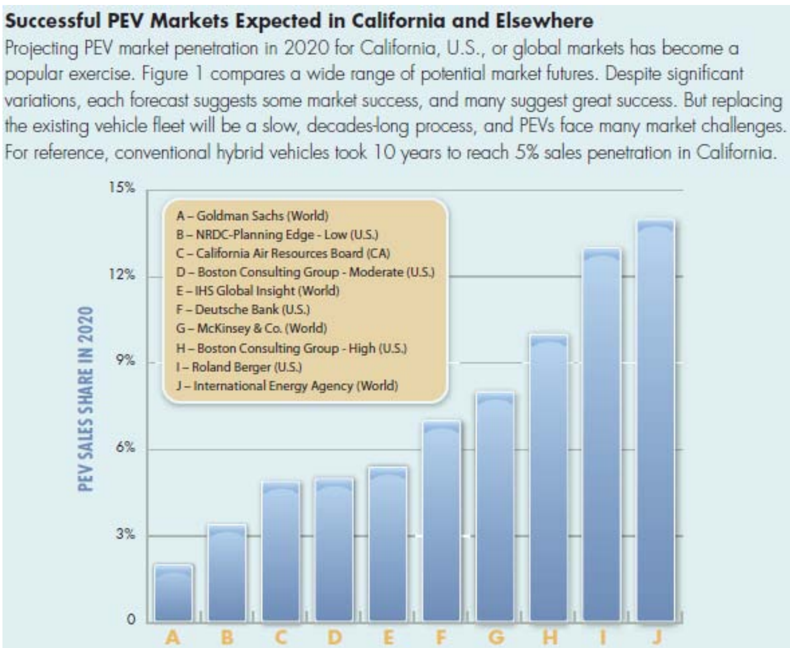
1.14. FCV vs. PEV Market Penetration: Long-term trends for FCVs and other AFVs are notoriously difficult to predict, as they involve multiple variables including the pace of future technology developments, macroeconomic conditions, competing fuel prices, state and federal incentives and regulations, private and public investment in fueling infrastructure, and consumer preference. Because PEVs have been in the marketplace for more than five years, and many manufacturers have announced future vehicle and battery plans, it is relatively easy to consider how the primary "competition" for FCVs (in the low-carbon space) could develop. According to leading manufacturers, battery technology and cost breakthroughs will enable a 200 mile range vehicle by 2020 priced around $30,000 before incentives, as announced by Tesla (for their Model 3) and Chevy (for their upcoming Bolt). These models and others in this price/performance band could make a difference in overall PEV market penetration. Across the industry as a whole, the federal Department of Energy expects price parity of conventional internal combustion engine (ICE) vehicles and EVs by the early 2020's, which would make EVs cheaper than ICEs if state and federal incentives continue. Further, expected improvements in battery performance (weight to energy ratios and kWh/$) are likely to make 350 mile range batteries relatively commonplace at the high end of the market, at prices comparable to today's much smaller range batteries. Further, if gas prices resume their historic climb above $4.00/gallon, the cost differential in fueling EVs vs. ICEs will again become prominent buying considerations, as EVs can typically be fueled today for approximately $1 per gasoline gallon equivalent (GGE), or less than a third of the current operating cost of equivalent ICE vehicles.

1.15. California PEV Sales Projections (Table 8): Projecting adoption rates between now and 2020 is an inexact science at best, as illustrated in the ICF Consulting and California PEV Collaborative charts below that demonstrate the range of expert views, and the potential elasticity of demand under different scenarios analyzed by the Electric Power Research Institute (EPRI), the CEC, the Electrification Coalition, and ICF itself. Taking into account the full range of forecasts identified above, ICF judged the "high-side" forecast for California to be 500,000/year by 2020, or 38.5% of new car sales, with the "low-side" being just a fifth of that total, at 8.8%. On the high side, the *cumulative* electric vehicle population would reach 10.2% by 2020[5]. For purposes of comparison, total California sales in the pre-recession peak years of 2007-08 were in the range of 1.6 million units, while 2009-10 sales were in the range of 1.1M to 1.3M units. Thus, even new car sales units as a whole can vary as much as 40% year over year. Further, there is an ongoing trend toward consumers keeping cars longer, reflecting better build quality. Thus, an ongoing economic downturn could permanently shift the replacement rate and promote greater retention of dirtier vehicles.

EV Adoption Forecasts – ICF International



As ICF explains in its study, the low forecast assumes that EVs will continue to command a significant initial price premium, and that governments will limit subsidies. The mid-level scenario assumes ongoing higher incentives on vehicles and charging. The high penetration scenario assumes significant consumer interest, rapid cost reductions, significant government subsidies continuing to 2020 and beyond, and a major increase in gasoline prices, and/or new regulatory requirements. Given these variables, rather than picking a single estimate for future EV penetration, California's *PEV Collaborative* – the most important network of public and private sector EV stakeholders in the state – has simply publicized the range broad range of scenarios that have been issued by different research organization, leaving it to stakeholders to make estimates for their own purposes.



Source: *Taking Charge: Establishing California Leadership in the Plug-in Electric Vehicle Marketplace* The California PEV Collaborative, Dec. 2010

1.16. EVs, GHG Impact, and the ZEV Mandate: Both BEVs and FCVs are considered by CARB to be ZEVs. However, the "zero emissions" label is somewhat misleading. Strictly speaking, on a "well to wheels" basis, most electric drive vehicles, if they are running on a typical mix of California grid power, are consuming electrons fed into the grid from a range of generation sources that typically include some natural gas and nuclear power, as well as clean renewable sources, such as wind, solar, geothermal, and hydro. Specific GHG intensities for a given vehicle in a given location actually vary considerably based on the time of fueling. By fueling at night, drivers are more likely to increase the proportion of wind energy used to fuel their vehicles, and if refueling in the mid-day on a sunny day, they are likely to be consuming a disproportionate share of solar power in those utility territories, such as San Diego Gas & Edison, that are experiencing a super-abundance of solar energy on sunny days. Incentives and information related to "smart and green" charging can boost the share of low-carbon sources used by EVs, and minimize the problematic scenario that EV's could require utilities to add additional naturl gas "peaker plants" to serve EV related loads due to peak hour charging. Fortunately, the issue of smart charging is receiving substantial attention from the California Public Utilities Commission (CPUC), the California Independent System Operator (CAISO), utilities, and EV Service Providers, such that strong incentives are emerging to encourage EV charging at the most economically and environmentally favorable times of day. Moreover, as the California grid grows greener in response to the ratcheting up of Renewable Portfolio standards for electric generation, the CO2e content of the energy used to power PEVs will steadily decrease. Finally, increasing numbers of EV drivers are linking their home solar panels to their vehicles and (soon) to home-based stationary batteries, which will make EV driving potentially near-zero carbon. Another strategy for achieving near-zero carbon driving is being made possible by the increasing number of utilities that are offering 100% renewable tariffs, which enable consumers to "green up" their electricity sources for a relatively small additional charge (typically 5% to 10% additional on the monthly bill – or about $7/month for the average California household).

Partial Zero Emission Vehicles: In the world of California Air Resources Board incentives and regulation, Plug-in hybrid vehicles (PHEVs) are considered "Partial Zero Emission Vehicles" or PZEVs. However, the GHG and emissions of PHEVs in turn varies substantially based on the portion of miles driven in all-electric mode, which varies with the size of the battery and other vehicle characteristics. Various studies indicate that the Prius Plug-in, for example, with just 13 miles of all electric range, may be achieving a fleetwide average of approximately 20% all-electric vehicle miles travelled (e-VMT), while the 40-50 mile range of the Chevy Volt battery is providing closer to 70% e-VMT, which translates to an EPA e-MPG rating of well over 100 e-MPG. Currently, Californians are purchasing PHEVs and BEVs in approximately equal numbers, with the South Coast favoring PHEVs and Northern California favoring BEVs, likely due to the longer commute distances in the Los Angeles basin.

1.17. Comparing GHG Emissions Across All Alternative Fuel Types: Of course, to compare FCVs, PEVs, and other alt fuel vehicles, it is necessary to translate an efficiency measure, such as e-MPG to an "apples to apples" measurement – which is typically rendered as "grams of Co2e per mile" with the carbon intensity of fuels measured on a "well to wheels" basis that takes into account the energy used in all phases of production, refining, distribution, delivery, and utilization of the fuel in the vehicle. Based on this approach, a further simplification of the presentation can be achieved by comparing all alternative fuels to standard gasoline. In the following chart, the most prevalent fuel feedstocks are highlighted for biofuels and hydrogen. In the fuel-specific chapters that follow, additional detail will be provided about the many varieties of biofuel inputs, each with their own carbon profile and scalability, as well as more exotic approaches to renewable and low-carbon hydrogen production, which also present scalability challenges and opportunities that are likely to become more relevant in the 2020 period and beyond, when FCVs move toward full commercialization. Currently, the greatest reduction in GHGs and use of fossil fuels across the fuel supply chain is achieved by Battery Electric Vehicles (BEVs).

1.18. Full Fuel Cycle Comparison of Alternative Fuels to Standard Gasoline

Table 9: Full Fuel Cycle Comparison of Alternative Fuels to Standard Gasoline			
Alternative Fuel	Full Fuel Cycle Analysis		
	GHG Reduction	Petroleum Reduction	Fossil Fuel Reduction
Biodiesel (B20)	**10-13%**	**15-17%**	**n/a**
Renewable Diesel (RD30)	**20%**	**29%**	**n/a**
Electricity			
Hybrid Electric	**25%**	**25%**	**25%**
Plug-in Hybrid	**48%**	**60%**	**46%**
Battery Electric	**72%**	**99.8%**	**65%**
Ethanol (E85)			
Midwest Corn	**15-28%**	**70-73%**	**27-45%**
California Corn	**36%**	**70-73%**	**27-45%**
Cellulose	**60-72%**	**73-75%**	**72-80%**
Hydrogen			
Electrolysis	**26%**	**99.7%**	**13%**
Natural Gas	**54%**	**99.7%**	**41%**
Natural Gas			
CNG – light-duty vehicle	**20-30%**	**>99%**	**4-13%**
CNG – heavy-duty	**11-23%**	**>99%**	**2-8%**

Source: Full Fuel Cycle Assessment: *Well-to-Wheels Energy Inputs, Emissions, and Water Impacts,* TIAX LLC. Prepared for the California Energy Commission, June 2007 Energy Commission-600-2007-004-F

As summarized above, Battery Electric Vehicle (BEV) emissions are estimated by CARB to be nearly 75% lower than the average conventional gasoline-powered vehicle, and 55% lower than the average conventional hybrid vehicle. Plug-in Hybrid Electric Vehicle (PHEV) emissions (in the case of PHEVs with a 20 mile all-electric range) reduce GHGs by 60% compared to a conventional vehicle, and 30% compared to a standard hybrid.[2] As noted above, the EV emissions advantage will increase over time. By 2020, California's grid is expected to have 40% lower emissions than the grid in 2008, due in large part to an increase in near-zero carbon renewable generation from 11% to 31%. This will reduce grid carbon emissions from 447 grams/CO2 per kWh to 261 grams/C02 per kWh by 2020.[3]

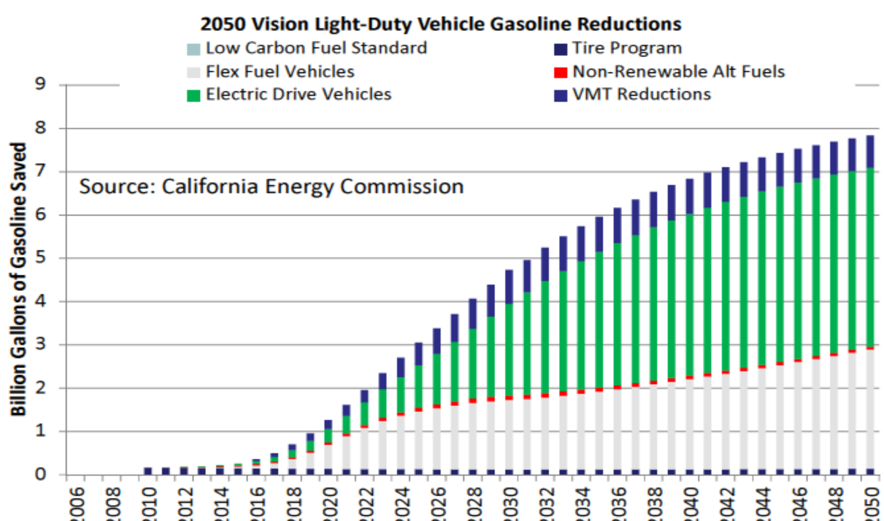
Discussion of Assumptions for GHG Reduction Analysis: To compute the GHG savings of new Electric Vehicle deployments, for the BEV class of vehicles, it is assumed that vehicles are driven at a monthly rate of 1,000 miles. For comparative purposes, it is assumed that the average consumption of gasoline powered vehicles is 27.5 MPG and that the CO2 emissions from one gallon of gasoline is 19.4 lbs. (In fact, actual mileage for California drivers will vary based on economic factors and the overall aging of the fleet over the coming years. The 27.5 MPG number is significantly above current fleet fuel economy standards and reflects the enhanced mileage expected by 2020. Therefore, this average number is very conservative relative to the comparative advantage of other AFVs.) For PHEV, we assume an average of 80

[2] *Taking Charge: Establishing California Leadership in the Plug-in Electric Vehicle Marketplace;* The California Plug-in Electric Vehicle Collaborative, December 2010, p. 17.
[3] Ibid, p. 17.

MPG equivalent based on 70% all-electric miles. This number is also difficult to predict going forward, because manufacturer battery sizes on PHEVs will likely fluctuate based on future battery pricing and the availability of public charging. However, it is notable that a recently introduce BMW i3 PHEV variant has nearly 100 miles of all-electric range, whereas a coming first generation of larger PHEV sedans and SUVs from BMW, Mercedes, Porsche, and Mitsubishi are all expected to provide approximately 25 miles of all electric range.

1.27. State Expectations for Growth of the Plug-in Electric Vehicle Market by 2050 vs. Other Sources of GHG Reduction in On-Road Transportation: California continues to lead the nation in PEV sales, and the variety of models now entering the market will help drive continued strong growth. There are now 20 PEV models (counting both BEVs and PHEVs) offered by almost every manufacturer. As of December 2014, more than 118,000 PEVs were sold in California, about 40 percent of nationwide PEV sales. However, the state is seeking to drive even steeper sales growth, given the urgency of replacing California's existing fleet of *26 million* passenger vehicles and light trucks in order to meet the 80% reduction in GHGs required in the transportation sector (and economy-wide) to meet the AB 32 mandate. In their *2050 Alternative Fuels Vision,* CARB and the California Energy Commission developed the following strategic pathway to the requisite reductions -- illustrating that the preponderance of savings are projected to come from electric drive vehicles. In the PEV chapter of this report, current barriers and proposed solutions to acceleration of PEV market development at the regional level will be discussed in depth. Note that this particular chart does not distinguish between FCVs and PEVs. However, it does show the important contribution (nearly 40% of planned GHG reductions) that are expected to come from a dramatic ramp-up of biofuels utilized in flex-fueled vehicles.

1.20. CARB 2050 Vision Light-Duty Vehicle Gasoline Reductions (Table 9)



Source: California Energy Commission, *2050 Alternative Fuels Vision*

It is noteworthy that reduction in vehicle miles travelled (VMT), while viewed as a highly desirable policy goal for a variety of reasons, is not anticipated to save much gasoline even after the full implementation of SB 375 "smart growth" and transportation demand management reforms.

1.21. State Perspectives on EV Charging Infrastructure: Consumer surveys show that initial purchase price and range anxiety continue to be the leading challenges limiting broader PEV adoption. Purchase price is a function of manufacturing and component costs (less state and federal incentives), and is not amenable to large-scale shifts by regional stakeholder action. By contrast, public and residential electric vehicle charging infrastructure deployment , which continues to be a key challenge, does invite regional and local action in concert with state and private investment. As noted in the state's *2014 Integrated Energy Policy Report,* EV charging station deployment in residential multi-dwelling units (MDUs) are one of the biggest barriers to increased plug-in electric vehicles adoption, given that more one half of all Californians live in MDUs and rental property (with that figure increasing to nearly 2/3 in larger cities where shorter-range BEVs might otherwise be a good match for local driving needs). The challenges facing expanded charging in MDUs include cost, electrical capacity and location, parking and payment management, homeowner association requirements, and laborious decision-making processes. While commercial, "destination," and workplace charging are easier to address than MUDs, the costs and limited willingness of property owners to embrace EV charging has limited deployment in these areas as well. In the coming 2015-16 Investment Plan, the state plans to allocate a very significant portion of the proposed $18M set-aside for PEVs to public and multi-unit charging infrastructure infrastructure, which is a significant increase over prior years.

1.22. The Potentially "Game-Changing" Expansion of Utility Roles in EV Charging: By the end of 2015, it is likely that a decision will be forthcoming from the California Public Utilities Commission (CPUC) that authorizes some level of utility ownership of electric vehicle charging infrastructure. This will be a potentially momentous change in the level of investment in EV charging in California, and a "game changer" for PEV market development. As of mid-2015, parties to the EV proceedings at the CPUC are still refining their proposals and responding to stakeholder input. However, the initial proposals put forward by the three largest Investor-Owned utilities in California are exceedingly ambitious, and involve raising basic energy costs to pay for both the equipment and installation, so that the equipment can be provided at no charge to site hosts. This "rate-basing" approach is controversial with some consumer groups, who do not believe that electricity ratepayers in general should subsidize EV drivers. Some (but not all) EV Service Providers also object to what they view as potential monopoly control over EV charging. Southern California Edison (SCE) proposes a build-out of 30,000 Level 2 chargers (at a cost of $333 million), while PG&E proposes to install 25,000 Level 2 chargers and 100 DC Fast Chargers across its service area (which currently includes more than 60,000 PEVs.)[4] In both cases, the chargers and installation would be provided at no cost to the site host. PG&E proposes to own all of the infrastructure, but contract with third parties to build, install and

[4] http://www.pge.com/en/about/newsroom/newsdetails/index.page?title=20150209_pge_proposes_major_build-out_of_electric_vehicle_charging_stations

maintain the chargers and manage customer billing. SCE proposes to directly perform the electrical capacity upgrade work, and to provide equipment rebates, but to allow third party ownership of the EV charging equipment itself.

The three investor-owned utilities (PG&E, SCE, and SDG&E) expect that their initial programs (which propose an aggregate investment of more than $750 million dollars) will take about five years to complete following approval by the CPUC. In PG&Es case, the impact on rates would be to increase the average bill by approximately a tenth of a cent per kilowatt-hour over five years, such that a typical residential customer would pay about 70 cents more per month over the period 2018 to 2022. PG&E and SCE have promised to build on the EV charging siting analysis undertaken by regional PEV Coordinating Councils, including *Plug-in Central Coast.* If approved, the impact on the availability of both public charging and multi-unit residential charging will be substantial, although details are needed on pricing, business models, and operational details before a full impact assessment is possible.

1.23. Smart Charging and Vehicle-Grid Integration: One of the key drivers of utility interest in EV charging (in addition to the revenue potential) is the attractiveness of EVs as "controllable load" to help manage the integration of intermittent renewable energy sources on the grid, notably the potential "over-generation" of solar in the mid-day, and over-generation of wind at night (when the wind picks up but demand is very low). To "flatten the load curve," EVs can act as smart loads in response to utility needs, turning on and off their charging sessions within user-defined parameters that still enable the driver to meet their charging need within a specified time window. All of the major utilities now have funded pilot projects to explore "smart" charging in conjunction with major automakers and other intermediaries. The California Energy Commission is currently investing more than $26 million in smart charging and Vehicle-Grid Integration (VGI) pilot programs, in conjunction with a utility ratepayer funded innovation program, known as the *Electric Program Investment Charge* (EPIC). As the number of electric vehicles grows, the importance of smart charging and more ambitious VGI strategies, potentially include two-way energy flow from the battery to the grid, will help manage the integration and storage of distributed renewable energy and provide balancing resources for the grid as a whole. Opportunities for Central Coast stakeholder participation in these developments will be discussed in further detail later in this Readiness Plan.

1.24. The Role of Clean Medium- and Heavy- Duty Vehicles: There are more than 900,000 medium- and heavy-duty vehicles in use in California, including such diverse vehicle type as long haul tractors, refuse hauling trucks, package delivery vans, medium-duty work trucks, and shuttles and buses. In 2012 they comprised about 3.7 percent of the total vehicle population in California, yet consumed more than 20 percent of the total fuel and are responsible for approximately 23 percent of transportation-related GHG emissions and 30 percent of total nitrous oxide (NO) emissions. State funding has been focused on reducing the GHG and air quality impact of trucks by advancing cleaner medium- and heavy-duty vehicle technologies across multiple fuel types -- including natural gas, electric drive, hydrogen, and hybrid drivetrains. Market uptake of the cleanest trucks remains slow, primarily due to cost and limited availability of clean technologies across all model types. In addition to existing state funding, targeted incentives are being provided by the state's Air Quality Management Districts and Air Pollution Control Districts through AB 2766 programs. The AB 2766 Subvention Program (initiated in 1991) levies a $6 fee per each motor vehicle registration that enables cities and counties to meet requirements of federal and state Clean Air Acts, and for implementation of motor vehicle emission reduction measures in the local Air Quality Management Plan. CARB requires a cost-effectiveness to ensure that emission reduction costs are less than $20,000/ton or $10/pound of emissions reduced. Within these constraints, local Air Districts have funded primarily biofuel and CNG vehicles within the medium and heavy-duty truck domains.

1.25. Uncertainty Regarding the GHG Impact of Natural Gas Fueling: Although natural gas can provide positive results as an alternative fuel source relative to diesel when considering a variety of criteria air pollutants, especially particulates, this fuel pathway has recently come under greater scrutiny from state regulators and research institutions. Recent studies on methane leakage rates in the fuel pathway demonstrate that "well to wheels" leakage rates (primarily in gas production and distribution) may be much higher than previously reported (e.g., 3%+ vs. a previously assumed 1.3%.) If these studies are further confirmed at the 3% range, and pending federal EPA regulations to reduce leakage are not fully deployed and strongly enforced, it may be determined that natural gas provides no advantage (or even a net disadvantage) against other fuel types *from a GHG perspective*. The methane leakage rate controversy also undermines certainty with regard to the advantage provided by natural gas as a substitute for coal in energy generation (although some other important criteria air pollution benefits would remain), and would likewise cause at least a modest recalculation of the carbon intensity of electricity as an alternative vehicle fuel (although the declining share of natural gas in the state's portfolio of electricity feedstocks limits the impact on GHG intensity.) As a signal of the seriousness of this issue, CARB and the California Energy Commission noted in their most recent 2014 *Integrated Energy Policy Report* (IEPR) that these studies have:

> *raised questions about the potential benefits of natural gas due to uncertainties about methane leakage along the natural gas distribution and transmission pipeline systems and upstream at the production wells and gas collection systems. Many research efforts are underway to reduce uncertainties regarding how much methane is being emitted from the natural gas system and where leaks are located. Continued engagement and research support on this issue will be critical as the state continues to initiate solutions to transform its heavy-duty vehicle sector. (2014 IEPR, pp. 3-4.)*

1.26. Outlook for Biofuels: The state views biofuels as critical to reducing carbon emissions from the transportation sector and achieving AB 32 goals. Plant and waste-derived biofuels are typically blended with gasoline or diesel in percentages designated by the biofuel labeling system. B20 denotes a blend of 20% biofuel and 80% conventional petroleum fuel, while B80 is 80% bio-fuel based, and 20% conventional. B100 (100% biofuel) can be used in some vehicles. Growth in the production and utilization of biofuels being spurred by regulations combined with government incentive funding through the federal Renewable Fuel Standard, the California Low Carbon Fuel Standard (LCFS), a federal blender's tax credit for biodiesel and renewable diesel sales, and CEC grants for development of biofuel production plants.

First-generation biofuels used food-based feedstocks such as corn and soy. Taking into account the fossil fuel inputs and carbon intensity of these crops, GHG benefit for some first-generation biofuels was limited at best. Advanced second- and third- generation biofuels include both liquid fuels and renewable or low-carbon biogas. These are sometimes called "drop-in fuels" as they utilize a wide array of urban and agricultural waste streams with very low carbon intensity values, and they can be blended (as a "blendstock") or used as stand-alone fuels. The California biofuels industry is growing rapidly, especially in the market for biodiesel and renewable diesel. However, scaling biofuels to a meaningful proportion of conventional fuels will prove challenging due to feedstock limitations on waste-based oils and greases (among fully renewable sources), as well as agricultural limitations imposed by California's long-term drought. Finally, biogas production challenges include safety and economic concerns regarding the injection of biogas injected into existing distribution pipelines.

CHAPTER 2: Electric Vehicles: Barriers and Solutions to Accelerated Market Development

2.1. Key Market Barriers: As noted in the Overview above, PEV adoption has been slower than some original market forecasts due primarily to high initial purchase price of some models, and range anxiety. Each of these issues is discussed below.

Perceived high cost: At market launch in 2011, "entry-level" PEVs initially carried MSRPs ranging from $29,000 - $40,000. Price reductions in 2013 lowered prices to MSRPs of $23,000 - $35,000, with Federal and State incentives reducing this cost by approximately $9,000 - $10,000. This challenge has been significantly mitigated by price cuts from many manufacturers, plus the beginnings of a robust used EV market. New PEVs in California are now available at prices of $13,000 after incentives, and modestly used Nissan Leafs can be had in the used market for as little as $10K or less. Many new PEVs are now less expensive than the average new vehicle, at $31,000 in 2013. However, some potential buyers may not have the tax liability to take all of the federal tax credit. One solution to this challenge is leasing, as manufacturers can take the incentives and offer a more attractive lease offer. The majority of California EV owners are in fact leasing, using the $2,500 California rebate to contribute to the down payment. Over the next several years, battery prices are expected to decline, driving overall vehicle price reductions. The federal Department of Energy (DOE) projects price-parity with internal combustion engine vehicles by 2022, based on battery pricing dropping from the current range of $500 per kWh of capacity to approximately $200/kWh or even less. Ongoing advances in lightweight design and materials will also enable cars to go farther and perform better per unit of power available.

Public Charging Infrastructure: According to a 2011 survey by Deloitte and Touche, for more than 80 percent of respondents, convenience to charge, range, and cost to charge were all "extremely important" or "very important" considerations for buying an EV. Charging time of two hours or less were critical for 55 percent of respondents, and widespread availability of public charging stations was very important for 85 percent of respondents. To address this issue, the Central Coast PEV Coordinating Council, partner organizations, and private site hosts have increased the number of EV charging stations in the region. In addition, Plug-in Central Coast has outlined a range of policies and initiatives that local governments are encouraged to adopt, which include:

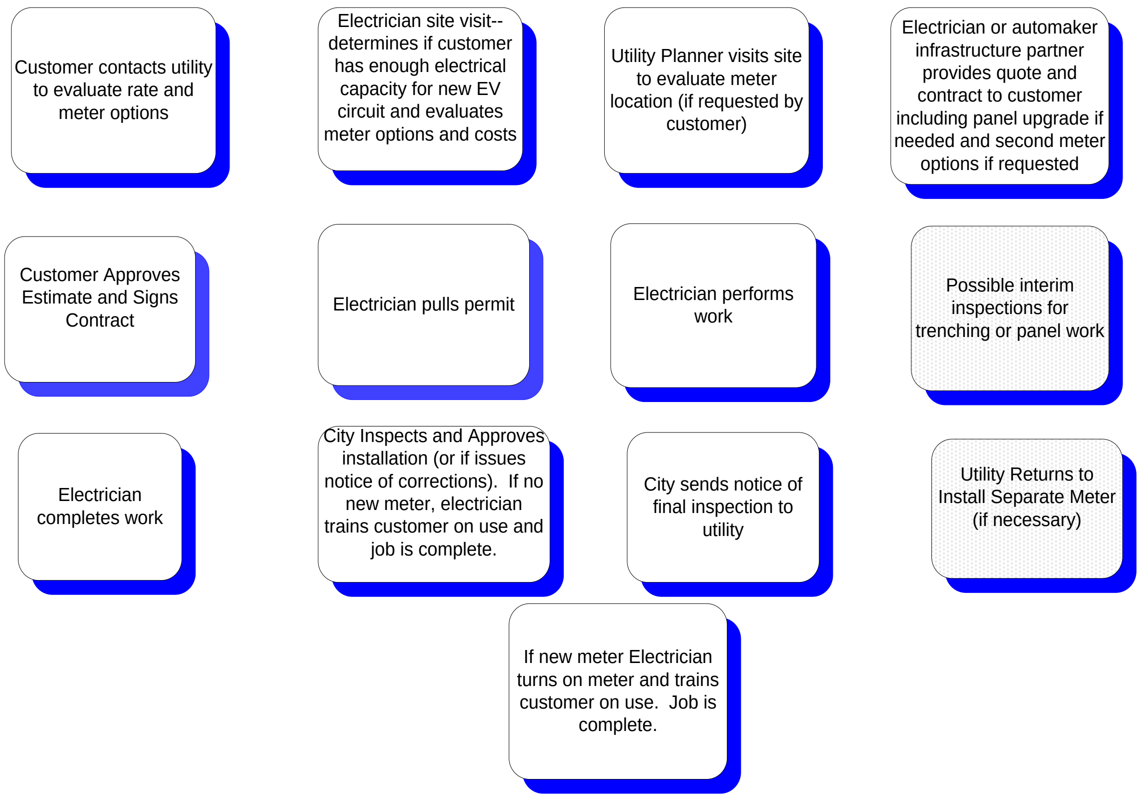
- Streamlining single-family residential charger installation
- Developing charging options for multi-unit developments
- Creating more comprehensive public EV charging networks
- Promoting EV-ready buildings and parking lots

Each of these challenges is discussed briefly below, along with policy recommendations for consideration by the PPC Steering Committee.

2.2. Single-Family Residential Charger Installation Streamlining Overview: Residential charging is the backbone of the EV charging infrastructure. It is the most convenient option for most drivers, and the least costly based on availability of special EV or "time-of-use" (TOU) utility rates. Overnight charging also poses a reduced burden on the utility grid, including its generation and distribution systems. Unfortunately, installation costs for charging at home can be highly variable, and generally these costs are passed on directly to the customer. Depending on the age and condition of electrical infrastructure in a particular residence, the installation costs can vary widely. For example, a simple Level 2 installation, including hardware, may cost as little as $1200. However, if total electrical load of the home exceeds safety standards, a panel upgrade may be required. This can cost as much as $500 to $2500 additional. If conduit or trenching is required, these can add additional costs. Because of this expense, many PHEV drivers and BEV drivers that travel less than 50 miles per day are opting for Level 1 charging at home. This can often be done for free by using the portable charging equipment that comes with their car and a 110 volt outlet in a garage or driveway, though some homes may need a dedicated or new 110 outlet in a convenient location installed, which may cost a few hundred dollars.

To access a less expensive EV-specific electricity rate, SCE and PG&E customers can specify a "time-of-use" or TOU rate for their home or business, or purchase a separate meter to access a special EV-only rate. For all charging installations, contractors must pull a permit at the beginning of the job and – depending on the complexity of the work involved – they may be required to schedule an inspection with the local permitting authority to sign off on the work. In some cases, the combination of permitting, inspection, and utility "hand-offs" can result in significant delays before a charger installation is complete. The following chart indicates the complex set of "handoffs" required in many charging station installation scenarios.

Residential Installation Process



2.3. Recommendations for Streamlining Residential EV Charger Installations: Given the challenges that customers may face in installing residential EV charging stations, it is recommended that jurisdictions establish low and flat fees for installation of charging stations and undertake additional streamlining recommendations identified below, with explanatory discussion following the chart.

Recommendations for Streamlining Residential EV Charger Installations	
Recommendation	**Next Steps**
R.1. Develop a charger permit form identifying all required elements **R.2. Provide installation process guidance and checklists**	**1A. Distribute model PEV application and checklists to city/county leads. (See Appendix 1 for sample application).** **2A. City/ County leads to modify and adopt.**

R.3. Establish reasonable – and flat – charger permit fees.	**3A. Present information on existing fee structures and recommendation for standardization where feasible and appropriate.** **3B. Report on any fee adjustments by localities.**
R.4. Waive plan requirements for simple installations.	**4A. Present evidence on plan waiver feasibility.** **4B. Report on waiver policy adjustments by localities.**
R.5. Participate in training on EVSE technologies and installation	**5A. Host EVSE product information and installation workshop for prospective site hosts and contractors.**

Discussion of Recommendations

R1. Develop a charger permit form identifying all required elements: Because of the relative novelty of EV charging equipment, some jurisdictions in the tri-County area may be uncertain regarding the appropriate format of the electrical permit to be issued. For jurisdictions that want to highlight EV charger-specific issues to guide contractors, site hosts, and inspectors, a sample charger-specific permit is provided in Appendix 1. This generic permit form highlights relevant sections of the National Electrical Code, and has been co-developed with the National Electrical Manufacturers' Association (NEMA).

R2. Provide installation process guidance and checklists: The International Code Council and its various regional chapters have provided guidance for local permitting authorities on plan check and inspection procedures for both residential and commercial chargers. Exemplary guidance documents for California jurisdictions have been developed by the Tri-Chapter Uniform Code Council of the greater Bay Area, which is highlighted as a statewide model in the *Ready, Set, Charge California! Guidelines for EV-Ready Communities.* These guidance documents are included in Appendix 2 (for residential installations) and Appendix 3 (for commercial and multifamily installations).

R.3. Establish reasonable – and flat – charger permit fees. Currently, permitting fees for Central Coast communities vary significantly. To encourage charger station adoption, communities with higher fees should consider targeted fee reductions that will help reduce the overall cost of EV ownership, and to reflect the reduced societal cost burden that EVs impose by virtue of their reduced greenhouse emissions and contributions to energy security.

R4. Waive plan requirements for simple installations. Many jurisdictions have recognized that most EV charging installations are as simple and straightforward as a typical water heater installation, and that they need not be subject to automatic plan submission and plan check requirements. Further, where plans are required without due cause, a substantial cost and time burden is imposed on would-be EV drivers and electrical contractors. It is recommended that

Central Coast jurisdictions follow the lead of many major cities in California in waiving plan submission and plan check requirements for simple installations.

R.5. Provide training on EVSE technologies and installation: EV chargers and technologies are unfamiliar to many electrical contractors and building officials. To address this information gap, Plug-In Central Coast proposes to host a workshop for contractors and permitting officials in each County.

2.4. Multi-Unit Residential Charger Installation Challenges and Solutions: EV stakeholders face a more complex set of challenges in facilitating charger installations in multi-dwelling units (MDUs) – including condominiums, apartments, townhomes, and "garage-less" dwellings. A good introduction to the process of multi-family charger installation has been provided by San Diego Gas and Electric at their website:
http://sdge.com/sites/default/files/documents/PreppingMultiUnitsforPlugInVehicles.pdf

Depending on local circumstances, multi-unit dwelling residents and building owners may be challenged by these problems. For each problem, there is a mitigation, if not a perfect solution, but good will is required on both owner and tenant to work toward a fair and efficient allocation of costs and benefits.

- **Limited parking:** When lots are crowded or spaces are assigned or deeded, finding feasible spaces for chargers may require re-shuffling of designated parking or other use-policy changes. In the cases of deeded parking spaces, HOA's may be justified in requiring that local residents pay the full cost of initial installations. However, in apartments, some cost-sharing may be feasible if building owners exercise their right to exact a surcharge on energy used at the site, or to charge a monthly lease fee for equipment that is retained by the apartment owner and re-assigned to future EV driving tenants.

- **Distance between utility meters, parking, and electrical panels:** A new 240V charging circuit typically requires a connection between the charger location and the EV owner's electrical panel. In multi-family dwelling units, the electrical panel may be inside the residential unit and located at a long distance from the parking area. This can impose significant cost barriers. In new construction, provisions for EV readiness can be built in at nominal cost by running appropriate conduit and pre-wiring for EVSE. This will be discussed in the section to follow on updated building codes. For existing multi-unit buildings, a new program to develop 10,000 "make-ready" EV charging sites is being undertaken by NRG, an energy company now investing in California as part of its settlement of a lawsuit with the California Public Utilities Commission. These make-ready improvements will bring adequate power and stub-outs to the designated sites. In the first 18 months following the completion of the make-ready site, the site host is obligated to contract exclusively with NRG to install a Level 2 charger, after this time they could install a charger from any company.

NRG will also initiate installation of the charger once a specific EV driver is identified who will commit to utilize that site on a regular basis, e.g., as an employee of a business on the site, or as a resident of a multi-unit development on the site. During this 18 month NRG exclusive period, the prospective charge station user must sign up for the NRG monthly subscription program to trigger the installation of the EVSE. In a legal settlement (related to past monopolistic pricing behavior of their Dynegy subsidiary), NRG is mandated to invest $100 million dollars to develop both "make-ready" sites and to install 200 Fast Chargers around the state. At this point, only Ventura County is eligible for the DC Fast Chargers (and the first one was installed in Camarillo), as installations will be focused on the greater Bay Area, the South Coast area, and the Central Valley. However, Central Coast communities are encouraged to pro-actively contact NRG to identify possibilities for potential development of the free "make-ready" sites.

- **Challenges to accessing off-peak charging rates:** Off-peak EV charging rates may require a new meter and utility service. Most MDUs have meters clustered in a central location. There may not be space to add another meter. In such cases, landlords or building managers may be permitted to simply establish a flat monthly fee for energy use. Alternative load management technologies for multi-unit scenarios are also available from EverCharge, a company that specializes in multi-dwelling EV charge management. EverCharge provides a "powershare" hardware device that can shift the electrical load among a number of charging devices and ensure that existing electrical panels are not overloaded. See www.EverCharge.net for more details. Other charger companies, including Coulomb Technologies, have billing solutions that work on multiple charger platforms to apportion energy costs to EVSEs among different multi-unit tenants and management. (See http://www.coulombtech.com/products-apartments.php for details.)

- **Limited electrical capacity:** Level 2 chargers typically require a minimum of a 40 amp circuit. Upgrading capacity can be costly and may trigger requirements to bring the property up to current building code. In these circumstances, power-sharing technology to enable multiple chargers to charge sequentially (rather than simultaneously) may reduce the burden, as referenced above. Another low-cost option is to deploy dedicated Level 1 chargers, which are already present in some garages and car ports. Level 1 charging may be adequate for overnight charging of EV owners that drive less than 50 miles per day. If common power is used in car ports, some condo living EV owners use low cost devices such as the "Kill-a-watt" meter, which is less than $20 to track energy use and reimburse the HOA.

Cost mitigation strategies can include placement of charging equipment in guest parking or other common areas. Where feasible, property management organizations or Home Owners' Associations (HOAs) can adopt policies to install charging stations in common areas serviced by the same master meter that covers other common services such as landscape lighting. Rates can be established for RFID or credit card payment to the property management group and/or HOA to cover electricity costs based on vehicle time-of-use and maintenance costs.

Multi-family installations sometimes require engineered drawings that include: a) a site plan; b) a layout showing the electrical work needed and; c) specifications for the equipment. A plan check is usually required, including sign-off from a city engineer, planning and/or building departments, and the city or county fire marshal. With safety issues paramount, significant consolidation in the number of inspections may not be feasible. However, local jurisdictions can streamline approval processes by considering and implementing the streamlining recommendations below, adapted from the statewide *Ready, Set, Charge California! Guidelines* (see www.ReadySetCharge.org for additional information).

2.5. Recommendations for Multi-Dwelling Residential Charger Installation

To summarize, EV stakeholders, including local governments, advocates, and property management associations will need to work closely together to develop a range of MDU solutions that will necessarily be site specific in most instances, and based on voluntary cooperation toward shared goals for a healthy environment and an energy-secure community. Where appropriate, municipalities and counties with larger numbers of residents in multi-unit dwellings may also wish to consider stronger policy options that could mandate multi-unit development stub-outs or actual charger installations, either in the context of new construction, major remodels, or at the time of sale. While these options are considered, additional education and outreach activities will be developed through the PCC partners, as identified in the initial recommendations below.

Recommendations for Multi-Dwelling Residential Charger Installation	
Recommendation	**Next Steps**
R.6. Outreach to HOAs and property managers to offer MDU solutions	**6.A. Develop HOA solutions** with utilities, industry experts, and installation contractors
R.7. Adopt building code amendments to mandate pre-wiring for EVSE in new and remodeled multi-unit buildings.	**7.A. Present model EV-friendly building code amendments to city staff** **7.B. Report on results of outreach and engagement process**

Discussion of Recommendations

R.7. Develop HOA solutions: Owners, building managers, and renters who may wish to install EV charging stations need access to information about their charging needs, options, and potential solutions. To address these needs, Plug-in Central Coast will work with local stakeholders to present solutions for multi-unit developments. Solutions for multi-unit developments are inherently complex, insofar as MDU installations must typically conform to the association's or development's architectural standards and existing parking layout; economically access adequate power, with potential "re-shuffling" of parking assignments to permit cost-effective installations of EV charging stations for EV-driving tenants; develop protocols for cost-sharing of both capital and operating costs for the station, including energy and other maintenance and operational expenses.

To prepare for the possibility of installing EV charging equipment, stakeholders in a multi-unit complex may find it helpful to undertake these activities (adapted from guidance provided by San Diego Gas and Electric):

1. **Conduct a poll and provide information to residents on EVs:** Find out how many people in the building may be interested in EVs and when they might wish to buy one. It may help to provide some general information on EV costs, benefits, and availability, which can be found at www.pluginamerica.org.

2. **Access utility and EV advocacy organization resources:** Plug-in Central Coast, Southern California Edison (http://www.sce.com/info/electric-car/default.htm?from=pev), and the Community Environmental Council (http://www.cecsb.org/pluginsb) offer information and periodic workshops to help consumers learn about EV charging options, costs, and business models. It will be helpful to access online or workshop resources to inform stakeholders of the latest programs and technologies for EV charging. Charging technologies for multi-unit use range from simple "plug and charge" standalone units that are open to all users, to networked units with automated user ID and payment systems. Chargers with more advanced communication and scheduling can provide metering capabilities to track users' use; access control; user-specific billing and service fee options; and remote control and monitoring capabilities. Single or multiple cord sets may be housed in a box mounted to a wall, pole, ceiling or floor, depending on site-specific needs. To get an idea of the wide array of EVSE options that are available for residential and commercial charging, visit Plug In America at www.pluginamerica.org/accessories, Advanced Energy at www.advancedenergy.org/transportation/evse, or GoElectricDrive at www.GoElectricDrive.com.

3. **Identify the challenges:** To address the needs at a site, practical obstacles need to be identified and addressed one by one. This list of prompts can help a MDU team identify the issues to be addressed:

- How well will the property layout – including the location and type of electric metering, wiring and parking spaces – accommodate the desired charging equipment?
- What existing rules in the covenants, conditions and restrictions ("CC&Rs") would affect the installation of charging stations in common areas and private areas?
- Which assigned and unassigned parking spaces could accommodate EV charging equipment?
- What local regulations relate to common area use of charging infrastructure?
- Will some charging units, sidewalks, parking spaces need to meet Americans with Disabilities Act (ADA) standards for accessibility?
- How should property owners deal with initial equipment and service costs versus future tenant demands and needs?
- Consider partnering with an EVSE vendor, such as NRG, which may be able to offer installation, maintenance, and power as part of a monthly subscription program for the EV driver. (See www.evgonetwork.com for information on the free "make-ready" program for multi-unit residential developments in California.)

4. **Develop consensus on the scope of work:** The installation of EV chargers in a multi-unit development will require shared decisions by property owners, property managers and(in come cases) residents. To provide potential contractors a starting point for cost estimation, the MDU site host needs to determine:
   - Estimated number of spaces to be served by charging equipment and in what configuration: Level 1 charging (at 110 volts, requiring a 10-12 hour recharge time), or Level 2 charging (requiring 240 volts and a 4-6 hour recharge time). Level 2 chargers are typically preferred and may be essential for Battery-Electric Vehicle (BEV) owners, whereas Level 1 charging may be adequate for PHEVs.
   - Charger management preferences (networked with multi-party billing options, or non-networked without smart billing allocation).
   - Suggested location(s).

5. **Choose a qualified contractor:** When selecting an installer for charging equipment, consider the contractor's experience, licensing, insurance and training, such as the EVSE installation training offered through organizations like the National Electrical Contractors Association, International Brotherhood of Electrical Workers and Underwriters Laboratories.

6. **Coordinate on-site evaluation:** Prospective contractors will need to visit the site to answer any remaining questions about project requirements before providing estimates. As part of the evaluation, the contractor should calculate power loads with the added charging stations, decide whether existing electric panels need to be upgraded or

replaced, and see whether the utility needs to upgrade electric service or install new electric meters. The contractor should coordinate with the utility for review of the project design and, if necessary, an on-site visit.

7. **Begin installation:** Once the contractor's price quote is approved, the contractor will order the selected charging stations, obtain any necessary permits, place the utility service order, schedule installation, coordinate the project and arrange for any required inspections by SCE or PG&E and the city. (The chart below summarizes the critical pathway for project completion.)

8. **Inform residents:** Current and future residents should receive information on where, when, and how to use the new charging stations.

As the flow chart below indicates, there are a large number of steps involved in the installation of charging in a multi-unit development. To move through the process, it is helpful to reach out to charging station vendors and utility staff with hands-on experience in solving the many challenges in multi-unit building installations. Leading EV charger companies can be expected to provide some consulting assistance in cases where end users will be specifying their equipment.

R.7. Adopt building code amendments to mandate pre-wiring for EVSE in new and remodeled multi-unit buildings. A strong policy approach to advancing deployment of chargers in multi-unit development is mandated pre-wiring. The City of Beverly Hills was the first to mandate pre-wiring in 2011, and their policy can viewed at http://www.beverlyhills.org/business/constructionlanduse/commercialbuildings/electricvehiclecharging

Other jurisdictions, such as the City of Palo Alto, the County of Santa Clara, Sunnyvale, and Emeryville, are adopting similar standards, though no such building codes have been adopted yet on the Central Coast. The threshold for mandated pre-wiring can be set at new construction or at the time of a major re-model. In its role as an EV planning consultant to the Southern California Association of Governments (SCAG), the Luskin Center for Innovation at UCLA has also made a policy recommendation for the SCAG region (which includes Ventura County) that EV charging stations – not merely pre-wiring (also known as "stub-outs") be required of all multi-unit developments at the time of an ownership change. This may not be viewed as politically feasible even in the context of the EV planning process. However, in light of the

NRG settlement requirement to develop 10,000 "make-ready" sites, it is likely that mandating actual EVSE installations may not be more costly over the next several years than mandating pre-wiring would be, since an EVSE can be procured and installed at a pre-wired location for potentially in the range of $1,000 to $3,000 per charger. Of course, all decisions regarding local building code enhancements that exceed the California building code (CalGreen) are under the jurisdiction of cities or (in the case of unincorporated areas) the relevant county. Therefore, recommendations of the PCC would be advisory to cities and counties, and it would likely require mobilization of additional political support to achieve the adoption of either a pre-wiring mandate or an actual charger installation mandate.

2.6. Comprehensive Regional Charging Network Development – Challenges and Solutions: As noted above, Plug in Central Coast and its partner network has been quite successful in building an initial network of EV chargers. The Coordinating Council actively sought out and encouraged sites to install equipment through various federal and state grant programs, and there are now over 200 public EVSE's in our region, including two DC Fast Chargers in Thousand Oaks and Camarillo and most cities have Level 2 public charging facilities. This initial backbone of public charging is only starting to meet the needs of the region's PEV drivers in 2015 and beyond. To address the situation, Plug-in Central Coast is actively pursuing grant opportunities to increase public charging opportunities and is encouraging workplaces, cities, businesses, multi-unit residential, and other property owners to invest in charging infrastructure.

To help further guide and catalyze the growth of a robust charging network in the Central Coast region, the PCC infrastructure plan has mapped existing charging stations and identified potential new sites for infrastructure, including a minimum level of DC Fast Chargers. With completion of the CEC and DOE funded infrastructure planning process, Plug-in Central Coast is expanding its outreach to ensure continued co-investment by both public and private entities in the development of the region's EV charging infrastructure. In addition, local incentives to support PEV charging infrastructure -- including deployment of Level 2 and DC Fast Charge stations -- is available. Since 2013, all three APCDs in Ventura, Santa Barbara, and San Luis Obispo counties have formed EV Infrastructure grant programs with substantial resources available for local EV infrastructure.

Encouragement of Local Charger Investment: In addition to leveraging publicly funded infrastructure deployed through larger EV charger companies, individual site owners in the PCC region are encouraged to invest their own resources in publicly accessible charging. Additional outreach activities will be conducted at the annual Green Car shows developed by the Community Environmental Council and C5. Plug-in Central Coast, the Santa Barbara CEC, and the Center for Sustainable Energy will also jointly produce EV Readiness workshops in each Central Coast county.

Private Partnership Funded Projects: EV charging infrastructure can also be deployed by local property owners via partnership arrangements with a charge station vendor (such as

Chargepoint) or charge network operator (such as NRG) that may be willing to install, maintain, and operate the charging equipment at no cost to the owner. The vendors can collect monthly subscription plan fees (with unlimited charging privileges) or per session fees from EV drivers.

2.7. Recommendations for Comprehensive Charger Network Development: Siting recommendations for the regional EV Plan are based on the principle that Battery Electric Vehicles (BEVs) need charging to extend the range of their vehicles and plug-in hybrid owners strongly prefer to drive in EV mode over gas mode. In short, a robust public charging network enables more electric miles to supplant gas miles. To support enhanced electric range for all types of PEVs, including those with Fast Charge capability, both the Central Coast and Monterey Bay PEV Readiness Plans focus on highway corridors that connect Southern and Northern California along the 101 Freeway, workplace charging, regional commercial centers, and destination charging sites. Corridor charging locations with DC Fast Chargers located every 30 or 40 miles from Ventura County through Santa Barbara County and on to San Luis Obispo County will enable Battery EVs to take longer trips and recharge from near empty to 80% charge in approximately thirty minutes.

Workplace charging can most effectively increase electric range for those PEV drivers whose effective all-electric range is less than their roundtrip commute distance to work. The PCC regional plan has identified prime locations in the tri-county region to host workplace charging. In addition, “destination charging” sites include popular shopping centers, parks, harbors, airports, train stations, colleges, government buildings, downtowns, beaches, and cultural facilities. Another key category for EV charging infrastructure is multi-unit developments (MUDs), discussed in Section 2C.

Charger Network Development Recommendations	
Recommendation	**Next Steps**
R.8. Pro-actively meet with EVSE providers to ensure PCC sites are prioritized	8A. Coordinate plans for Central Coast charger network deployment with key vendors, e.g., NRG, ChargePoint as part of ongoing site development processes. (PEV Coordianting Council)
R.9. Develop building code amendments that promote EV-ready <u>and</u> solar-ready buildings, parking facilities, and public works for new construction or major renovations.	9A. Promote model ordinances and guidelines specifying: -- minimum levels of pre-wiring (going beyond the raceway and conduit in the voluntary 2012 CalGreen standards) -- minimum levels of EV-ready parking, such as a 3% minimum for office, lodging, medical, and governmental; 1% minimum for retail, recreational, and cultural facilities; and 10% minimum for multiple-dwelling units, based on recommendations of the PCC and local stakeholders.

R10. Integrate PEVs into local fleets	10A. Support participation by fleet managers in Green vehicle showcases hosted by Community Environmental Council and Clean Cities Coalition of the Central Coast (C5) 10B. Track and promote opportunities for special fleet lease/purchase deals offered by major OEMs

Discussion of Recommendations R-12 – R-14 to Advance Integrated EV Ecosystem Planning by Industry and Government: The PCC Steering Committee and many cities and counties have benefitted from grant funded charging station projects, and new grant programs continue to be introduced through California Energy Commission solicitations. Priorities that are currently being addressed by vendors and PCC Steering Committee members include the following:

- **Corridor planning**: PCC has assessed high-priority siting options for DC Fast Charging on key travel routes. Of most importance is a corridor of charging stations along Highway 101, connecting our largest cities approximately every 30 miles. A second tier of sites include additional locations along Highway 101, as well as sites on other regional highways, some in key corridors connecting to I-5. Maps of suggested DC Fast Charging sites were included in the PEV Readiness Plan site element, developed by the Ventura County APCD, and key sites are being installed in the 2016-17 timeframe under the sponsorship of the California Energy Commission. These new DCFC installations funded by the CEC are mandated to include dual compatibility between the current dominant DCFC standard – known as CHAdeMO (supported by Japanese manufacturers)-- and the SAE Combo fast charging capabilities now being introduced by American and European manufacturers.
- **Outreach to employers and fleet EV users:** As part of the EV and AFV Readiness Planning efforts, outreach efforts have been made to fleet managers and employers to inform them of AFV incentives and grant opportunities, to enable best practice sharing among fleets, and to provide training for first responders to AFV-related incidents.
- **Coordinated response to upcoming CEC or other solicitations:** PCC community stakeholders benefit from coordination of funding proposals among local agencies and prospective charging network operators. The AFV Coordinating Council members are monitoring solicitations and communicating options to local stakeholders as opportunities arise.
- **Possible deployment of subscription plans**: Subscription plans may raise issues of interoperability with other charging networks. Currently, some EV network vendors have made commitments to development of inter-operable networks – whereby consumers can have access to any charge station in a manner similar to the STAR system for Automated Teller Machine (ATM) inter-operability. These include the ROAM partnership launched by ChargePoint, NRG, and multiple other EV Service Providers. However, these agreements have not yet been formalized across all vendors, and communication, clearance, and settlement protocols are not yet fully developed. EV

advocacy groups have pointed out that drivers will not be well-served if they must join multiple networks and pay multiple monthly network fees to have full access to California's public EV chargers. The California Energy Commission has required open standards for grant opportunities, and progress is expected in the 2016-17 timeframe.

- **Common protocols for identification of network operating and usage status**. Drivers need to know if charging stations are in operation or if they are being utilized. A National Electrical Manufacturers Association (NEMA) EV technical committee is working to develop and deploy these protocols, likely in the 2016-17 timeframe.
- **Possible deployment of reservation systems**, particularly for Fast Chargers. This issue is being discussed as part of the ROAM partnership, and standards are likely to emerge in 2017.

As noted in Recommendation #13 above, the EV infrastructure planning process will benefit from the inclusion of both public sector and industry input to ensure that selected sites meet community needs, and that installation, operation, and maintenance cost factors are all considered in evaluating public charging site opportunities. To that end, the Community Environmental Council, on behalf of all PCC stakeholders, has reached out to key network operators, including NRG, Chargepoint, AeroVironment, and others, to ensure regional coordination of charger siting and program opportunities.

2.8. High-Level Siting Recommendations: The following high-level siting recommendations are provided as a framework to guide ongoing siting work..

1. Financial feasibility: Select sites must be financially feasible given available installation incentives, or provide other real benefits to the site owners. (Note that average Level 2 installation costs are typically in the $3,500 to $4,500 range, although a broader cost range can sometimes be accommodated for larger-scale deployments.)

2. Visibility and accessibility: Select highest-utilization, highest-visibility, publicly accessible locations for the first few chargers. Examples include government office buildings, shopping malls, restaurants, hotels, parks, marinas, municipal parking garages, colleges, schools, and airports.

3. Power supply: Select a location where Level 1 (120/15A) or Level 2 (240V/40A), or Fast Charge (480 volt) electrical supply is or can be made available with relative ease and minimal cost.

4. ADA Access: Consider and comply with ADA guidelines for disabled access, and take precautions to ensure that charger cord management is optimized to reduce risk of accident or injury.

5. Security: Select secure locations with adequate lighting.

6. Signage: Provide enforcement and other signs that comply with the Manual on Uniform Traffic Control Devices (MUTCD) and California Vehicle Codes (CVC).

7. Equipment Protection: EV chargers should be placed where they can be best protected from physical damage by such measures as curbs, wheel stops, setbacks, bumper guards, and bollards, while simultaneously taking into consideration ease of access to the charger, mobility of users, and foot traffic in the area.

In the Appendices below, sample language is provided addressing the following key elements of PEV infrastructure:

- **Standard plans, details and specifications** for public infrastructure projects to accommodate EV charging stations.
- **Ordinance language** requiring the installation of electric vehicle charging stations when significant development or redevelopment occurs.
- **Zoning code amendment language** requiring a percentage of parking spaces in new multi-unit dwelling projects to include EVSE.
- **Building and electrical code guidelines** requiring that:
  - Electrical supply infrastructure and equipment be scaled to accommodate PEVs
  - All new residential units should include basic infrastructure, such as conduits, junction boxes, wall space, and electrical panel and circuitry capacity to accommodate future upgrades for both EVSE and PV systems.

2.9. Ratio of Charging Stations to PEVs: The Electric Power Research Institute (EPRI) has conducted research on how much EV charging infrastructure is needed to serve a given level of PEVs, with a focus on workplace and public usage. EPRI developed a "benefits tested scenario" to arrive at a recommendation to guide planners seeking to establish a ratio of charging stations per vehicle. EPRI's analysis yields a scenario in which the charging station-to-vehicle ratio ranged from 0.01 to 0.15 for BEVs and PHEVs. Applying this forecast to a long-range PEV regional estimate of 23,000 (which could be achieved by the early 2020s) yields the following EVSE deployment goal.

Estimated Non-residential Level 1 and 2 EVSE to Support Sample PEV Population in the Early 2020s

Vehicle Forecast		L1 and L2 EVSE		
		Estimates		EPRI Method (mid-level)
PHEV	BEV	low	high	
18,854	4,753	2,647	9,412	4,323

Based on analysis conducted by ICF International for the greater Bay Area PEV Readiness Plan, installation costs of Level 2 EVSE were estimated to range from $900-$2,350 for deployment at MDUs or workplaces. However, cost range can increase significantly for publicly-accessible charging, depending on site characteristics. For instance, trenching and cutting costs can increase the installation costs by upwards of $3,000-$5,000 for Level 2 EVSE installations. Costs can be much lower if EVSE are installed as part of new construction.

The level of investment required to support the forecasted PEV populations for the Region is difficult to estimate for many reasons. The most significant reasons include: a) it is unclear what the split between Level 1 and Level 2 charging needs will be as the market develops and expands; b) the costs of installation will vary considerably based on site characteristics; and c) the level of charging that will be required based on PEV technology and deployment trends is uncertain. If real-world ranges of 200 miles or more become the norm after 2020, the demand for public Level 2 charging may decline on a per vehicle basis, as an even higher percentage of charging will occur at home or at Fast Charge and (potentially) at switch stations. It is also important to note that Level 1 and Level 2 AC charging costs do not exist in a vacuum. DC Fast Charging and other emerging charging technologies may put downward pressure on the price and need for Level 1 and Level 2 charging.

Plug-in Central Coast stakeholders are pro-actively responding to opportunities for state and federal investment in charging infrastructure, in order to further extend the region's charging network. PCC will continue to cultivate prospective sites and match them with EV Service Providers that use sustainable business models for the development and operation of a viable regional charging network that will leverage private and public resources for the benefit of the community as a whole.

2.10. Promotion of EV-ready (and Energy-Efficient) Buildings and Parking Lots: The highly variable cost of installing Level 2 EV infrastructure (ranging as widely as $2,000 or less to $10,000 or more) is due in large part to the fact that garages and parking areas – in residential and commercial structures – have not been consistently prepared with the requisite conduit and panel capacity to support a 240 volt plug in a convenient location. By requiring new conduit and stub-outs or plugs with appropriate capacity in the next generation of buildings and public works, the cost of new EV charger installations can be dramatically reduced. In response to this opportunity, many jurisdictions in California and beyond have adopted ordinances requiring the installation of EV charger (and solar photovoltaic) pre-wiring in new or substantially remodeled commercial and residential structures. Additionally, effective in July 2012, Title 24 of the state building code, also known as the CalGreen standards, recommended a voluntary standard that calls for new residential units to include a raceway and conduit from the subpanel or main service to the proposed location for the charging system, terminated into a listed box or cabinet. For multi-unit developments (greater than 2 units), the CalGreen standard recommends at least 3 percent of the total parking spaces, but not less than one, to be capable of supporting future EVSE for Level 2 charging (Part 11 A4.106.2). The current voluntary standards may be recommended for mandatory implementation in 2016.

Going beyond the CalGreen standards, local agencies may wish to add additional requirements for pre-wiring (as opposed to just the raceway and conduit). In addition, some jurisdictions are also specifically requiring actual installation of EV infrastructure for larger developments (e.g., over 10,000 square feet), as in the ordinance language developed by the city of Mountlake Terrace in Washington.

Proposed Requirements for EV Charger Deployment	
Land Use Type	**Percentage of Parking Spaces**
Multi-household residential	10% (1 minimum)
Lodging	3% (1 minimum)
Retail, eating and drinking establishment	1%
Office, medical	3% (1 minimum)
Industrial	1%
Institutional, Municipal	3% (1 minimum)
Recreational/Entertainment/Cultural	1%

As a starting point for PCC consideration, Recommendation R.14 above recommends a 3% "EV make ready" minimum for office, lodging, medical, and governmental; 1% minimum for retail, recreational, and cultural facilities; and 10% minimum for multiple-dwelling units.

2.11. EVs and Solar PV Connections: EVs and distributed photovoltaic charging are highly complementary technologies, particularly when EV drivers switch to Time-of-Use rates that enable inexpensive nighttime "super off-peak" charging of EVs, with rates as low as 9 cents/kWh and use their solar array to feed valuable "on-peak" power to the grid, being credited at rates of 20-46 cents/kWh. By charging at night and allowing solar power to flow to the grid at the most lucrative daytime rates, EVs and solar operate in a synergistic manner to decrease the cost and quicken payback times for both technologies.

Given the environmental and economic synergy between EVs and renewable electricity, communities, NGOs, and industry partners should build on existing public education strategies that link outreach and awareness efforts on EVs and solar PV where feasible and appropriate. The Community Environmental Council is reinforcing this message through their "Driving on Sunshine" campaign. This slogan captures the benefits of EV + PV in an easy to understand and remember tagline and features blog posts on local residents that have solar and EVs, highlighting the economic, environmental and energy security advantages of using a local solar power array on a rooftop to power an EV (more information in section 4 below, and stories are available at http://www.cecsb.org/tag/blog/driving-on-sunshine). At recent Green Car Shows, solar carports have been displayed, further linking the connection between solar and EVs in an exciting visual display seen by tens of thousands and information provided by solar companies.

Solar should also be encouraged at public charging sites, along with the addition of fixed battery storage that can enable stored solar power to supplant more expensive, peak rate, higher-carbon power from the grid. Solar and storage can also lessen the cost of higher daytime electricity rates often faced by public charging, along with exorbitant demand charges that local utilities charge, particularly for DC Fast Charging. Additional barriers could be reduced by policy initiatives that link pre-wiring for EV chargers and solar PV, and mandated pre-wiring for EV chargers in new construction or major remodels. Future solar installations will be made easier by a new Title 24 energy code provision starting January 1, 2014, for new construction and major remodels. These code now requires solar readiness, with provisions such as requiring a SE to W facing part of roofs be "solar ready" with pathway for conduit from the solar zone to the main service panel and sufficient space reserved for solar at the service panel.

2.12. Charger Accessibility Issues and Americans with Disabilities Act (ADA) Compliance: EV Charging Stations must comply with provisions of the Americans with Disabilities Act. Unfortunately, there is not yet definitive state-level legal guidance on how provisions of the ADA will be applied to all of the specific issues that arise in EV charging. However, the statewide *Ready, Set, Charge! Guide for EV Ready Communities* represent the most authoritative guidance document to date, and was reviewed by a technical committee of leading EV experts. The guidance for ADA compliance is contained in Appendix H of this document. Local communities are strongly urged to follow the recommendations contained in this guidance.

2.13. EV-Related Signage: EV related signage can provide a substantial boost to EV community awareness. By providing signs for each EV charging station that comprehensively cover the surrounding streets, community members will be reminded that EVs are a mainstream mobility option, and that the community is "EV-ready." Signage must conform to state and federal guidelines, which are discussed extensively in the Appendix. Central Coast communities are strongly recommended to budget adequately for signage as part of each newly approved EV charging station. A typical rule of thumb is to plan for sign costs of $250 each, multiplied by the number of signs needed. Signage guidelines can be found at the website of the Governor's Office of Planning and Research.

2.14. Summary Checklist of EV-Friendly Policies and Practices for Central Coast Jurisdictions: The following checklist summarizes the recommendations above, while adding a final recommendation on the key issue of EV fleet deployment: *Integrate PEVs into Local Fleets.* Additional information on this recommendation and on the issue of EV fleets is contained in the Guidelines for EV Fleets later in this Plan.

Checklist of EV-Friendly Policies and Practices for Central Coast Jurisdictions		
Recommended Practice	**Current Status**	**Next Steps (with target dates)**
R.1. Develop a charger permit form identifying all required elements		
R.2. Provide EV charger installation process guidance and checklists		
R.3. Establish reasonable – and flat – charger permit fees		
R.4. Waive plan requirements for simple installations		
R.5. Participate in training on EVSE technologies and installation issues		
R.6. Outreach to HOAs and property managers to offer multi-unit development solutions		
R.7. Adopt building code amendments to mandate pre-wiring for EVSE in new and remodeled multi-unit buildings		
R.8. Pro-actively meet with EV charging network operators to ensure local sites are prioritized		
R.9. Develop building code amendments that promote EV and solar-ready buildings, parking, and public works for new construction or major renovations.		
R.10. Integrate PEVs into local fleets		

2.15. Effective PEV Marketing and Outreach: Consumer surveys indicate that a principal barrier to PEV deployment is initial purchase price of PEVs relative to equivalent ICEs. However, when consumers are introduced to the full range of PEV models, and understand the very low-cost leasing deals now available, interest can be effectively sparked. Individual regions within the state, as well as the state as a whole, are now developing "Go EV" campaigns that provide "ride and drive" opportunities to bring PEVs directly to consumers via special PEV-only events at workplaces, malls, fairs, and other community events. These events build on existing networks of grass-roots organizations, including environmentally conscious businesses, environmental and consumer advocacy groups, EV organizations, Clean Cities coalitions, and others. Central Coast stakeholders are now working to expand PEV ride and drive events with additional state and local match funding.

Encouraging Adoption of PEVs via "EV 101" Activities, Green Car Shows, and other Educational Programs: PCC is actively educating the public, major employers, and fleets through Green Car Show and other events. The largest events include Green Car Shows in Ventura and Santa Barbara produced by the Community Environmental Council and, in San Luis Obispo, by the C5 Clean Cities Coalition. The annual Green Car Shows are expected to collectively draw over 50,000 people in conjunction with Earth Day festivities in Santa Barbara and the 4th of July Street Fair in Ventura, and include as many as 40 models of green cars featuring virtually all major EV models on the market. The Santa Barbara event also includes a large-scale "ride and drive" that enables 600-900 people the opportunity to drive or ride along in an electric or hybrid car. Green car shows also include "owner's corners" where people can talk to local owners of various EV models, solar carports and solar companies that explain the benefits of driving on sunshine, charging station displays, and othereducational opportunities. Details on the 2013 events are available at http://sbearthday.org/festival-highlights/green-car-show.

The other local major EV educational events occur during National Plug in Day in September, which was celebrated in 2012 in Santa Barbara and expanded to Santa Barbara and Ventura in 2013, organized by PCC members. These events occurred in high profile shopping centers and at a farmer's market, and included owners displaying over a dozen different models of EVs, ride and drives from dealers, solar company displays, and showcase displays in the food court of the mall with educational signage and owners answering questions from the public.

PCC members also periodically host workshops on EV 101 and EV policies, which include information on: EV product options (current and forthcoming); EV life-cycle costs; vehicle purchase incentives; EV infrastructure choices, costs, and incentives; the EV economic and environmental value proposition for the region; the current state of EV-readiness planning and EV-friendly policy deployment; and ways to connect with EV vendors.

Educational efforts on the web and through social media are also a large component of the PCC education campaign. The website, www.PlugInSB.org, highlights the above information and also links to charging station maps, blog stories, and other resources. The Plug in Santa Barbara Facebook page is liked by over 300 local followers and gets the word out about new charging stations and advances in the EV world. The Driving on Sunshine blog stories and other social media posts highlight the economic, environmental and energy security advantages of using a local solar power array on a rooftop to power an EV (stories are available at http://www.cecsb.org/tag/blog/driving-on-sunshine). These blog stories are also shared on Facebook, Twitter, and other social media and are some of the most popular blog and Facebook posts that CEC does. People like reading about their neighbors, and envisioning how new technology could work for them. In addition, when profiled community members share these stories on their own Facebook pages and through their own networks, this peer to peer education and leadership has shown to be highly effective in encouraging others in their network to go solar and EV.

Outreach to Inform and Encourage Workplace Charging: EV 101 events described above are now also including significant outreach to employers that are most likely to respond to the EV value proposition and the imperative to provide robust EV charging infrastructure throughout the region. These include larger employers, property managers, retail establishments, businesses concerned with their sustainability profile and green image, public employers such as colleges, universities, and medical centers, transit agencies, and community-based organizations. The PCC is holding EV 101 lunch and learns at select workplaces that already have charging infrastructure installed, highlighting that many long distance commuters can see significant cost savings by switching to a 100 mpge+ EV. The workshops also introduce local employee EV drivers to prospective EV drivers in a parking lot display of EVs, which helps establish peer to peer expert relationships with "EV champion drivers" in each workplace. In some cases, local commuters (such as http://www.cecsb.org/item/phillips-are-driving-on-sunshine) are saving hundreds of dollar per month by switching to an EV and solar versus their gas car and high monthly gasoline costs. Workplace charging and fleet resources, such as the U.S. Department of Energy (DOE) Clean Cities guide to EV fleets (http://www.afdc.energy.gov/pdfs/pev_handbook.pdf) and the companion guide to workplace charging (http://www.afdc.energy.gov/pdfs/51227.pdf) are made available, along with complementary local information on the websites of the Air Pollution Control Districts and the Community Environmental Council

Development of Information Resources on EVs, Incentives, Charging, Utility Programs, and Support Services: As noted above, information resources on EVs, incentives, charging, utility programs, and support services are being communicated at the Plug-in Central Coast EV outreach workshops (in 2015-16 and ongoing), and at annual Green Car events in Santa Barbara. Additionally, information resources are hosted on the three Air Pollution Control District websites and the Community Environmental Council website, with links to additional resources, including Southern California Edison, PG&E, EV automakers, Plug-in America, and GoElectricDrive, among many others.

Plan for Outreach and Education for Building Inspectors, Utilities, Facilities, Public Works Personnel, and First Responders and Public Safety Officers: As noted above, Plug-in Central Coast will be hosting *EV infrastructure and readiness workshops* as part of the EV Readiness project, developed in collaboration with the Center for Sustainable Energy. These workshops bring together building inspectors and other local government staff (e.g., planners, sustainability officers, and city managers), along with utilities, facilities and public works personnel to address:

- EVSE location issues
- EVSE operations and product types
- EVSE Safety
- Inspection and compliance issues
- Installation process streamlining

- PEV-friendly public works guidelines
- PEV-friendly building codes

2.16. Recommendations for PEV Fleet Procurement and Management

Context: Central Coast fleet operators will be a key stakeholder group that can help to drive the EV transition across the region. EV adoption within fleets will provide direct benefit to fleet operators *and* the community -- through reduced emissions, enhanced energy security, and improved operating economies. Importantly, by lending their organizational "stamp of approval" to EVs, fleet operators will help communicate the message to consumers generally that the EV value proposition is strong and EV charging infrastructure will continue to grow. Therefore, the final recommendation of EV-related actions for consideration by local government stakeholders is to *Integrate PEVs into Local Fleets.*

Purchase and Evaluation Criteria: Total Cost of Ownership, Environmental Criteria, and Climate Action Plan Considerations: The current pipeline of EV models is dominated by light-duty vehicles (LDVs). However, an increasingly large variety of medium duty vehicles (MDVs) and heavy-duty vehicles (HDVs) are also on their way. Both public and private fleet operators are potential targets for EV procurement. Thus, for local governments, *greening the fleet* with PEVs is a key part of becoming *EV-ready,* and will give local government staff invaluable hands-on experience with the benefits and challenges of the EV transition.

Historically, "clean fleet" or "green fleet" efforts have focused on fuel and emissions reduction, conventional hybrid vehicles, and natural gas vehicles (NGVs). What distinguishes green fleet initiatives in the era of electrified transportation is that new PEV models are beginning to appear with significantly improved environmental and operating cost advantages over conventional hybrids <u>and</u> other alternative fuel vehicles, including biofuels and NGVs. Given the increased diversity of available PEVs – and their steadily improving price/performance profile relative to conventional vehicles, green fleet programs will increasingly focus specifically on accelerated integration of PEVs into the fleet mix.

While PEVs are a logical focus for green fleet programs, the structure of green fleet initiatives can best be stated in terms of over-arching goals, rather than specific technology choices to achieve those goals. Thus, green fleet programs are typically focused on:

- Reducing costs
- Preparing for future conditions (including potential fuel price spikes or supply disruptions) and regulatory requirements
- Reducing the fleet's harmful impact on the environment and human health
- Support the advancement of AB 32 goals, SB 375 Sustainable Communities Strategies, and municipal and county-level Climate Action Plans

Emissions Reduction Potential: The advantages of electricity over other fuel sources has been well-documented by the California Air Resources Board, given the relatively low carbon content of California's electricity grid. However, biofuel and hybrid emissions comparisons can be complex given the multiplicity of criteria air pollutants and greenhouse gases. To arrive at specific impacts, fleet managers can insert their own fleet variables into an emissions calculator based on the industry-standard model accepted by the DOE and the EPA, available through the Argonne National Labs at: http://greet.es.anl.gov/fleet_footprint_calculator**.** Additional information on GHG impacts resulting from PEV deployment in the Central Coast area is available in Appendix P of this document (GHG Impact Analysis).

Cost Comparisons: At current prices, PEV fueling costs are significantly less than competing fossil fuel or biofuel options. While the *initial* purchase price of PEV fleet vehicles is typically higher than comparably equipped conventional vehicles, PEV buyers often enjoy lower total cost of ownership, based on reduced fuel costs, insulation from fossil fuel price shocks, and significantly lower maintenance costs (in the case of BEVs). These advantages are leading many fleet managers to embrace PEVs as a core element in their green fleet plans. For pure Battery-Electric Vehicles (BEVs), the maintenance burden is significantly reduced compared to either internal combustion engine (ICE) or plug-in hybrid (PHEV) alternatives. BEV motors have fewer parts than internal combustion engines. Exhaust systems are non-existent, cooling systems radically simplified, and complex clutches and transmissions replaced with simplified units.

Operating Cost Comparison ICE vs. BEV	**Internal Combustion (ICE)** TYPE: 5 passenger RANGE: 400 mi. with 16 Gallon tank GASOLINE: $3.50 Gallon FUEL COST/TANK: $56.00/ 400 m	**Battery Electric Vehicle (BEV)** TYPE: Nissan LEAF ~ 1kWh = 4 mi. driving distance RANGE: 96 mi. w/ 24kWh battery ELECTRICITY: $0.056 / kWh (off-peak PG&E summer	**Usage Pattern** TERM: 6 Yrs. USAGE: 18,000 mi. / Year TOTAL Mileage: 108,000
Fuel	**Gasoline (ICE)**	**Electric (BEV)**	**Fuel Cost Savings**
Cost (per mile)	**$0.140** Avg. 25 MPG – reg. gas Cost per mi.: $56/400 miles = 14 cents/mile	**$0.014** Electricity cost of 5.6 cents per kWh. 1kWh = 4 Mi. of driving distance = 1.4 cents per mile	**10x less**
Lifetime Costs (6 yrs./108k miles)	$15,120	$1,512	**$13,608 savings in 6 Yrs.**
Maintenance	**Gasoline (ICE)**	**Electric (BEV)**	**Maintenance Savings**
Est. routine service and engine wear Lifetime Costs (6 Yrs./	~$6,000	~$2,000	**$4,000 savings in 6 Yrs.**
Ownership	**Gasoline (ICE)**	**Electric (BEV)**	**Ownership Savings**
Est. Insurance (6 Yrs./108K mi.)	~$6,000	~$5,000	**$1,000 savings in 6 Yrs.**
Est. DMV Smog (6 Yrs./108K mi.)	~$400	~$0	**$400 savings in 6 Yrs.**
TOTALS	~$27,520	~$8,512	**~$19,008/6 Yrs.**

Operating costs for ICE v BEV

Even with a $10,000 to $15,000 or more price differential between a light-duty BEV and the equivalent ICE vehicle, total life-cycle cost savings based on the heavier usage typical of many fleet vehicles can be compelling. The above example from the Business Council on Climate Change[5] uses a conservative $3.50/gallon gasoline cost and still produces a substantial savings over the vehicle life-cycle that more than makes up the difference in initial purchase price.

[5] http://www.bc3sfbay.org/uploads/5/3/3/9/5339154/electrify_your_business.pdf

Recommended Steps to Advance EV Fleet Deployment: To engage a PEV-focused fleet initiative, it is recommended that fleet managers:

- Develop fuel efficiency targets (which are convertible to GHG and other criteria pollutant emissions factors)
- Analyze fleet duty cycles in comparison with available PEVs with regard to range, charging requirements, and operating costs
- Develop a comprehensive green fleet plan that includes goals, milestones, staff responsibilities, commitments from top management, and monitoring and implementation strategies.
- Assess opportunities for joint procurement with other public and private fleet operators, in cooperation with the California PEV Collaborative and statewide Clean Cities Coalitions.

Commercial PEV Technologies and Fleet Charging Challenges: As noted above, commercial classes of PEV vehicles are evolving rapidly and encompass nearly every class of vehicle. As of late 2013, PEV models include examples from every class of vehicle – from high-performance motorcycles (Vectrix, Zero, et. al.) to medium-duty cargo vans (Smith Electric) to heavy duty Class 8 (Navistar), to SUVs, cross-overs, pickups, vans, compacts, sports cars, and luxury cars. Given the rapidly evolving alternative fuel vehicle fleet market, fleet operators are advised to obtain the latest information from organizations such as Plug-in America[6], which tracks all classes of PEVs, and CalStart[7], which focuses on medium and heavy-duty options.

Co-Location of Fleet Charging with Publicly Accessible Charging: Fleet vehicle charging options span the full range from AC Level 1, AC Level 2, and DC Fast Charge options, depending on vehicle type and specific applications. As with any commercial charging arrangements, fleet managers need to be cognizant of utility surcharges known as demand charges, as well as utility time-of-use rates to select an optimum configuration for their needs. Where light-duty vehicles are likely to be stationary for 12 hours or more, AC Level 1 charging options may be most appropriate, as these may not require the same level of power supply upgrade costs as Level 2 charging. For vehicles needing the fastest turnaround for demanding applications such as shuttle or taxi services, DC Fast Charging may be a high-priority need and worth the extra cost. It is important to note that it can be mutually advantageous for the general public and public fleet operators to co-locate fleet charging where practical. Specifically, many fleet vehicles may be gone most of the day and visitors could occupy charging stalls in the meantime. When visitors depart at closing time, then the fleet vehicle can be parked in that stall overnight.

Publicly Accessible Charger Cost Factors: The table below provides some indication of the range of costs likely in different charging circumstances:

[6] http://www.pluginamerica.org/
[7] http://www.calstart.org

Charger Type	Charge	Time to Charge Vehicles at Various States of Charge			Charger Hardware Costs[8]	Installation Costs[9]	Typical Range of Total Costs	Average Total Costs
		Volt 16 kWh	Leaf 24 kWh	Tesla 53 kWh				
AC Level 1 1.4 kW	Half	6 hrs	8.5 hrs	19 hrs	$300 - $500	$300 - $500	$600 – $1000	$900
	Full	11 hrs	17 hrs	38 hrs				
AC Level 2 7.5 kW 240V	Half	1 hrs	1.5 hrs	3.5 hrs	$500 - $1500 home $2000 - $6000 commercial	$500 - $2500/home $3,000 – 5,000 commercial	$1500 – $4,000/home $4,000 - $11,000	$2200/ home $8000/ commercial
	Full	2 hrs	3 hrs	7 hrs				
DC Fast 50 kW 480V	Half	10 min	15 min	35 min	$25,000 $55,000	$15,000 - $30,000*[10]	$40,000 $85,000	$65,000
	Full	20 min	30 min	70 min				
DC Fast 150 kW 480 volts	Half	5 min	8 min	17 min				
	Full	10 min	16 min	35 min				

Estimated Vehicle Charging Times and Charger Hardware and Installation Costs

Fleet Charging and Management: Several manufacturers, including Aerovironment, Chargepoint, GE, and others, currently have or plan to offer PEV fleet charging software of varying levels of sophistication. For example, the Coulomb Network Fleet Manager provides status and location of PEVs in the fleet via its fleet management application, indicating whether the vehicle is fully charged, charging, or not plugged in. E-mail or SMS summaries are available along with driver and vehicle workflow management. Analytics enable tracking and reporting of GHG reduction, fuel efficiency, and other data to manage and measure fleet performance by driver, vehicle, department, or fleet. Data on charge duration, start and stop times, and e-fuel use are available to be exported or integrated with other applications.

Targets for PEV Fleets, Fleet Adoption Rates, and Strategies to Overcome Adoption Barriers: Surveys of major fleets in the tri-county area are ongoing annually through the Central Coast Clean Cities Coalition, and provide data that local fleet managers can use to benchmark progress toward cleaner fleets. To advance PEV plans, Central Coast fleet operators may wish to consult these key resources:

- U.S. DOE Clean Cities EV fleet handbook
  http://www.afdc.energy.gov/pdfs/pev_handbook.pdf

[8] Hardware costs are trending downward quickly
[9] For hard-to serve installations, costs can vary upwards
[10] Higher-cost units have multi-car charging capability

- U.S. DOE Clean Cities EV and Alternative Fuel Vehicle (AFV) case studies
  http://www.afdc.energy.gov/case/

- American Public Works Association (APWA) fleet resources
  http://classic.apwa.net/ResourceCenter/index.asp?Section=equipment&SectionName=Equipment+%26+Fleet+Management

- California Energy Commission (CEC) links to funded fleet initiatives and infrastructure initiatives:
  http://www.energy.ca.gov/drive/projects/electric.html

2.17. Current PEV Fleet Adoption in the Central Coast: Fleet adoption of Plug-in Electric Vehicles on the Central Coast is modest as of late 2013. Surveys conducted on behalf of Plug-in Central Coast (conducted by the Central Coast Clean Cities Coalition and the Community Environmental Council) found that a total of approximately 170 PEVs are currently deployed among major fleet operators responding to the survey, and the majority of these are low speed neighborhood electric vehicles at educational institutions. In fact, to our knowledge there are likely fewer than a dozen freeway capable EVs in Central Coast municipal fleets, with a handful in private fleets. (See the table on the following page.) There are very few major private fleet operators in the region, and the largest national entities – UPS, and the US Postal Service, FedEx – have not yet deployed PEVs in the region or announced plans to do so. However, these entities are testing PEVs in other regions and it is anticipated that national fleet deployment plans may be announced in the 2014-15 period based on the results of current testing with Medium Duty Vehicles from suppliers such as Smith Electric and Boulder Electric Vehicles. As part of its dialogue with stakeholders and the overall regional planning effort, Plug-in Central Coast has assessed barriers to increased PEV fleet adoption, and identified strategies to encourage adoption. These are articulated following the fleet table. Only larger public and private fleets with some Alt Fuel and/or PEV penetration were included in the table.

AFV Fleet Adoption on the Central Coast									
Fleet Operators	Vehicle Types (ICE)						Alt. Fuel Vehicles		
	Total Fleet	2-Wheel	Light-Duty	Truck/ SUV	Bus/ Van	Other	Hy-brids	PEV	Biofuel/CNG
Higher Education									
UCSB - TSV	285		22	191			8	10	23
UCSB - DOV	60		7	34			1	7	9
Santa Barbara City College	47		6	29	12				4
Westmont College	91		27	46	6	12		63	
CalPoly SLO		72	22	220	96	53	2	57	1
Government/Corporate									
City of Goleta	14	4	4	6			2		
City of Carpinteria	20	1	4	9	1	2	1	2	
City of Ventura	359	10	83	149	7	84	15	11	
City of San Luis Obispo	268	10	48	117	18	71	4		
City of Grover Beach	35		7	28					1
City of Arroyo Grande	78	2	50	10		10			
City of Oxnard	850		139	225			21		18
City of Thousand Oaks	244						55		12
City of Camarillo	80		4	44		25	7		
City of Moorpark	17		3	7	1	5	1		
City of Simi Valley	214				26				27
Metro. Trans. District (MTD)	136		27	3	106		18	20	
SB County	1,109	5	335	372	103				
SLO County									
Ventura County	1355		568	155	184	104	157	2	
Southern California Edison (Ventura Santa Barbara Area)	309		191	175	56	78	12	1	
TOTAL	**5,571**	**104**	**711**	**1,477**	**270**	**252**	**287**	**173**	**1,683**

2.18. Barriers to Adoption and Strategies to Address the Barriers

- **Vehicle Cost Barriers:** Initial purchase price remains the primary obstacle to broader adoption of PEVs in fleets. However, fleet owners are more likely than individual consumers to consider the total cost of vehicle ownership. Therefore, efforts to address infrastructure, fueling, and vehicle costs in a holistic manner may prove more effective than targeting just one component of the PEV ecosystem.

- **Cost Strategies:** Existing state and federal incentives that lower the initial purchase price are enhancing PEV attractiveness for fleet PEV deployment. In some regions, including the Bay Area, South Coast, and Monterey regions, the local Air Districts are providing additional rebates for PEVs in fleets, based on AB 2766 and other programs. Regional air districts in the Central Coast area may wish to consider a pilot program to incentive PEV fleet deployments through buy-down of either vehicles or associated infrastructure. In addition, pro-active outreach to fleets, as is already done through the Central Coast Clean Cities Coalition and other partners, is helping to keep fleet operators current on PEV total cost of ownership. Based on many common fleet duty cycles and recently announced special fleet leasing programs, the TCO of a lower-cost BEV, such as a Nissan Leaf and Mitsubishi i-miev, is significantly advantageous compared to the ICE equivalent. As this data become more widely shared, it is anticipated that PEV fleet adoption in fleets will pick up. It is also important to note that fleet turnover rates are lengthening, such that PEV purchase opportunities will be emerging incrementally over the coming years.

As PEV costs are reduced, and TCO advantages increase year over year, it is anticipated that fleet adoption in the light-duty segment will increase significantly. In addition, according to recent testimony by the UPS National Fleet Manager, the TCO on a PEV variant of the UPS medium duty cargo van is very close to level with ICE versions based on the current incentive structure. As additional scale economies are achieved in the coming two to three years, a cross-over point is likely to be reached, and PEV deployment in the MDV segment will likely increase significantly.

- **Infrastructure and Fueling Cost Barriers**: Infrastructure and electric fueling costs can also pose barriers to adoption. For some companies, charging vehicles at night does not significantly increase peak electricity costs because the charging is occurring when other operations are closed or operating at reduced levels. However, for major delivery firms like UPS, peak charging time for PEVs–from about 7 PM to 4 AM–coincides with peak operations at warehouse and processing sites. As a result, new electricity infrastructure may be required and capacity charges would likely increase. Also, outreach to local government fleets indicates that many of the buildings where vehicles are currently located are at or near electrical capacity – as a result, additional panel upgrades and/or new transformers may be required. Although there are incentives available for EVSE installation, these incentives do not always cover the costs of electrical upgrades.

- **Infrastructure and Fueling Cost Reduction Strategies:** Infrastructure costs in some cases can be reduced if fleet chargers can be co-located with publicly accessible EVSE, where public charging revenue may be available during the day to offset capital and operating costs, while much fleet recharging would be done at night. In addition, battery-backed and solar-linked charging systems may provide additional revenue for grid services (such as frequency regulation) or solar net metering. For these installations, the Self-Generation Incentive Program (SGIP) is available for batteries, while a variety of California solar incentives are available for solar PV. Time of use rates available from PG&E and Southern California Edison can substantially lower e-fueling costs. Finally, flexible leasing terms recently announced by Chargepoint are likely to be available for other EVSE vendors as well, which will make it possible for fleet operators to spread out EVSE payments over 5-8 years, thereby reducing or eliminating up-front expenditures. For private site owners, the 30% federal investment tax credit on EVSE may be available in future years, depending on Congressional action. In addition, some public entities with large procurements of qualifying equipment and vehicles may be able to participate in transactions where the value of the tax credit is reflected in the purchase price.

- **Limited PEV Models and Resale Value Uncertainty.** Limited PEV options, particularly in the medium and heavy-duty categories, as well as pick-up trucks, bucket trucks, and other utility vehicles, restrict purchasing opportunities for fleet operators with diverse needs. Further, newer versions of vehicle models currently in use tend to be purchased to replace older models, and PEV equivalents are still limited. Uncertainty about PEV resale value is also a challenge for fleet operators who need to forecast total cost of ownership with high accuracy.

- **Strategies to Address Limited PEV Models and Resale Value:** As a response to the issue of ambiguity regarding total cost of ownership, CALSTART is working on a total cost of ownership calculator to assist in determining cost when considering the purchase of PEVs. To more fully define operating cost, and to enhance operating revenue and resale value, PG&E has recently issued a Request for Proposals (RFP) to major automakers that calls for a demonstration fleet deployment that will develop new models for the integration of PEVs into Demand Response (DR) programs, whereby fleet operators could be provided discounts on energy costs or direct payments for fleets that agree to modulate charging in response to signals from the grid operator. Additionally, the PG&E pilot will work with automakers and fleet operators to assess the value of the battery when redeployed in a grid services configuration at the end of its useful vehicle life. This could enhance resale value of the vehicle or enable economic replacement of the battery.

- **EVSE Availability and Charge Time.** The operational range of PEVs work well for many fleet applications. However, some have less predictable day-to-day routes and some operators may have concerns about vehicle range in a region without widespread EVSE availability. In fact, some local fleets limit the geographic area employees can drive EVs, which reduces electric mileage per year and hinders payback. There may also be concerns about the lengthy charging time of some PEVs if fleet vehicles are operated on a higher mileage basis.

- **Strategies to Address EVSE Availability and Charging Time.** To address EVSE availability and charge time management issues, fleet operators have a range of EVSE options that can be carefully tailored to their needs based on specific duty cycles. For example, some fleets may be able to specify vehicles with smaller battery packs if, on fixed routes, they are able to deploy or co-locate either Level 2 or Fast Charge facilities that work for mid-day recharging. The savings on reduced battery needs could help pay for the necessary infrastructure. Also, for vehicles that rarely need recharging during the day, fleet operators can deploy Level 1 charging, which works well for overnight charging scenarios. While Level 1 equipment typically costs almost as much to procure and install, in many cases it will not require the panel or transformer upgrades that a bank of Level 2 chargers often requires. In such situations, the cost savings can be dramatic.

- **Accounting Practices**. The accounting practices of some fleets limit their ability to include fuel savings as part of their decision-making process for purchasing new vehicles. Therefore, their purchase decisions do not reflect effective amortization of the higher costs of PEVs through fuel savings. To address this challenge, fleet operators can be introduced to updated accounting practices where fuel cost, vehicle price, and maintenance cost are considered as part of a total cost of ownership platform, making it easier to develop a business case for the purchase of PEVs in a fleet.
- **ADA Compliance**. Fleets interested in deploying PEVs may choose to make the associated EVSE publicly accessible. In this case, fleets will have to ensure that publicly available parking is compliant with ADA requirements. In some cases, this may increase the investment required significantly. To address this barrier, the Governor's Office of Planning and Research is working on an electric vehicle charging station accessibility guidelines document (the draft is available at: http://opr.ca.gov/docs/PEV_Access_Guidelines.pdf).

2.19. EVs in Rental Fleets: Integration of PEVs in rental fleets is a high priority for PEV ecosystem development, as market exposure to PEVs can be greatly accelerated if a broad variety of PEVs is available via major rental companies. In the Central Coast, the primary PEV rental experience to date is with Enterprise. On a national basis, Enterprise has 200+ PEVs in service, about 35 of which are in Southern California, with several in the city of Thousand Oaks (Ventura County). EVs were available at the Santa Barbara location until recently, when they were discontinued due to low utilization. Available PEVs include Leafs, Teslas, and a few Volt or Prius PHEVs. Enterprise is in discussion with Tesla about securing additional vehicles. Approximately ten locations are served with Type 2 chargers as of the end of 2013.

The biggest challenge Enterprise has faced is utilization; occupancy for BEVs in particular is far below standard offerings, and the firm is unable to make up for this gap via additional rate surcharges. Most customers are reluctant to take a chance with range issues while driving a BEV, and are not willing to pay a premium for the service. While market acceptance is improving, Enterprise would like to see it ramp up faster. According to a local Enterprise manager: "Range is the big show-stopper right now- they believe the range of a BEV is insufficient. However, many people are fine renting a PHEV as long as they don't have to plug it in. That said, people in the know like the HOV lane access of the PEVs. No doubt the sands are shifting, and I have every expectation that broader market acceptance will be here, whether in the form of BEV, PHEV, or even fuel cell form."

2.20. Multi-Unit Development Charging -- Cost Factors and Policy Options

Overview: The challenge of installing PEV charging in multifamily residences -- including apartments and condominiums -- is a key obstacle to full market penetration of EVs. The problems of multi-dwelling unit (MDU) charging include: insufficient number of parking spaces, constrained electrical room capacity, expensive installation costs, and multiple EV charging station users. Since much of the Central Coast's urban population lives in some form of multi-unit residential building, EV owners in these buildings will need to find inexpensive and reliable ways to charge their EVs. The following discussion provides further detail on cost factors, MDU challenges from building owner and resident perspectives, and policy approaches adopted in Los Angeles, which can be considered by Central Coast stakeholders.

It should be noted that work on the MDU challenge in California has only just begun. The CEC has recently issued its first solicitation specifically targeting MDU issues. In addition, advisory documents have recently been developed by the California PEV Collaborative, available at http://www.evcollaborative.org/MuD. Given the resources now available via the PEV Collaborative, the discussion in this appendix is intended to summarize key opportunities for driving down costs through local policy approaches, especially mandated stub-outs and charger installations in new buildings and major remodels.

The City of Los Angeles was among the first municipality in California to begin tackling the MDU challenge, by adopting a Green Building Code mandating that all new single family and multifamily construction be equipped with the required electrical infrastructure and designated parking spaces to accommodate PEVs in the context of larger residential multi-family buildings. Of course, this initiative does not address existing housing stock. Therefore, in Los Angeles as on the Central Coast, property managers and homeowner association (HOA) boards must proceed on a voluntary basis until more robust legal requirements are in place, and cost factors must be addressed realistically.

Cost Range for Level 2 in MDU Contexts: Currently, EV charger installations in a multifamily building can range anywhere from $2,000 for a low- cost multifamily installation, to $10,000 or more for an apartment building requiring trenching to install a new conduit, a new circuit, and electric meter. One approach to reducing these costs is to carefully assess whether Level 1 (110 volt) charging may be adequate, as these equipment and installation costs are typically a fraction of the Level 2 requirement. This will be explored further in Phase II of the Central Coast plan development process, as level 1 charging installations are just now being deployed in California, and industry understanding of cost, energy management, and liability factors are still evolving.

Choosing Charging Levels in MDU Contexts: EV charging requirements are influenced by the type of EV (BEV vs. PHEV), daily distance driven, electricity prices, driving style, load, and conditions such as temperature and grade. Battery charging times for the Nissan Leaf and Chevrolet Volt are indicated below for illustrative purposes.

Vehicle Model	Battery Capacity	Hours to Fully Charge From Empty	
		Level 1 (110/120V)	Level 2 (220/240V)
Nissan Leaf (1)	24 kWh	20	7
Chevrolet Volt (2)	16 kWh	10	4

Sources: https://en.wikipedia.org/wiki/Nissan_Leaf https://en.wikipedia.org/wiki/Chevrolet_Volt

Drivers who are depleting the battery on a daily basis need to charge nightly. But if drivers deplete one third of the battery per day, they may only need to charge at a slower Level 1 (110 volt) rate. Further, drivers charging at work and at businesses that offer EV charging may not need to charge as frequently. The combination of all of these factors will impact the feasibility of a Level 1 vs. Level 2 charging station. A Level 1 charging station will typically be more suitable for PHEVs and other vehicles with smaller battery sizes similar to the Chevrolet Volt, while a Level 2 charging station is typically more suitable for larger batteries, as in the Nissan Leaf. Level 1 charging typically may not require any new installation costs, as the charging device is portable and a 110 outlet is often available in an existing parking lot or garage. Further, the liability for the charger equipment more clearly rests with the tenant insofar as the portable charger is his or her property as part of the vehicle.

Construction Constraints: Parking access considerations are a crucial determinant of charging station installation costs. Installations are typically less expensive for parking spaces located a short distance from the electrical panel, and more expensive for parking spaces located farther away. Running a line from the electrical panel to the charging station can be the most difficult step in assuring power delivery to an EV. The crux of the problem lies in whether or not there is an existing conduit from the panel to the parking space. If a conduit does not exist, the farther away the charger is from the panel, the more creative, and the more expensive, the solutions become.

In many cases, building electrical panels are fully utilized and do not have any room to add new circuits. This problem can be overcome by adding panel capacity. Adding more than 400 Amps will typically trigger a plan review, meaning the applicant will incur higher costs. In addition, electrical room space can be a limiting factor. In apartment buildings, panels are usually located in electrical rooms, which are also where electricity meters can be located. Adding another panel can be an issue for some buildings that have small electrical rooms. Additionally, if the building owner decides to meter a circuit separately (i.e. sub-metering), then a new meter would have to be provided.

Capital Cost Recovery: HOAs, building managers, and building owners often oppose installations because of upfront capital costs and concern about ongoing utilization rates, particularly if the original tenant or unit owner moves away. Thus, the potential to at least break even on the installation is a key issue. Estimates by the Luskin Center at UCLA project breakeven monthly fixed costs under low cost ($3,600) and high cost ($11,600) installations, assuming a 7-year loan term, with and without financial incentives of $2,000 each toward the total charger project. The fixed cost includes a relatively low-priced Level 2 charging station ($1,500), a city permit ($100), and low ($2,000) or high ($10,000) installation costs.

Financing EV Charging Stations: Most charging station installations in multifamily buildings will be financed by some entity representing the building's ownership. For example, an HOA would finance the purchase and installation of a charging station in a condo, and a building owner would finance it in an apartment building. In both cases, the investing entity will pass costs onto users, and some entities might want to earn a profit. EV charging station users can pay a fixed cost to service the loan and pay for taxes. Payment can be made on a monthly basis, similar to the payment cycle for rental apartments and HOA fees, or it can be made incrementally during each EV charging session, with a fee assessed on a time-basis (e.g. by the second, minute or hour the EV is charging). Most HOAs are tax-exempt entities and would not typically seek a profit, but an apartment building managed by a real estate investment trust (REIT) may require a profit or break-even scenario. In many other circumstances, HOA dwellers with their own garages or deeded and immediately adjacent carports, the resident may be able to add an EV charging station without concern for HOAs.

Negotiation Factors: As representatives of a building's common spaces, and as forums for residents to voice private interests, many HOAs may be willing to facilitate EV parking access solutions to the greatest extent possible. Parking spaces are negotiable and have a price – it is simply a matter of what concessions each party is willing to make, and what prices are deemed acceptable. The transaction could be between individuals, or between the HOA and individuals. For example, EV owners desiring a specific parking space might be willing to pay for it, or swap spaces with the owner of the parking space in question, if acquiring the space lowers the total cost of installing charging stations. If several EV owners are interested in sharing a single space, the HOA, or even a new third party entity, could purchase the space, and recover costs by charging EV charging station users. Opportunities to make "fair" transactions should be explored first in order to minimize EV charging station installation costs.

Electricity Cost Factors: To ensure fairness to other tenants, charging station users must pay for the electricity consumed to charge their EVs. Using low time-of-use (TOU) rates, average monthly electricity costs are roughly $30 for seven-hour bi- nightly charging and $75 per month for seven-hour nightly charging, assuming a 24kWh battery and a Level 2 charging station. Total monthly costs, including electricity and fixed costs could range from slightly more than $75 to more than $400 per month. Apartment owners and managers can pass on the costs in the form of charges to users, but because of the transient nature of renters, and the small number of EV owners currently living, or wanting to live, in apartments, cost recovery within the tenancy of a particular apartment dweller will be challenging in many cases.

Requiring EVSE Installations at Point of Sale: Given the cost factors typically involved in a Level 2 installation scenario, the Luskin Center has proposed a mandate on multi-family building owners to upgrade their infrastructure at the time of sale, when a variety of other upgrades can be financed in a packaged approach. The applicable code language could emulate the existing Green Building Code, which applies only to certain types of new construction. This recommendation is considered a relatively bold and politically challenging approach.

Mandated EV Charging Code Options: The City of Los Angeles Green Building Code (Chapter IX, Article 9, of the Los Angeles Municipal Code), adopted on December 14, 2010, mandates newly constructed "low-rise" (single family residences, duplexes, and townhouses) and "high-rise" residential buildings to be charging station- ready. For low-rise buildings with private parking, either a 208/240 Volt 40 Amp outlet must be installed for each unit, or panel capacity and conduits for future installation of a 208/240 Volt 40 Amp outlet. All outlets must be located "adjacent to the parking area." For low-rise buildings with common parking, the following options are available:

- **A minimum number of 208/240 Volt 40 Amp outlets**, equal to 5 percent of the total number of parking spaces, to be located within the parking area; or
- **Panel capacity for the future installation of 208/240 Volt 40 Amp outlets**, equal to a minimum of 5 percent of the total number of parking spaces, with a conduit terminating in the parking area; or
- **Additional service capacity, space for future meters, and conduit for future installation** of electrical outlets, equal to 5 percent of the total number of parking spaces, with the conduits terminating in the parking area.

High-rise buildings are required to provide 208/240 Volt 40 Amp outlets equal to 5 percent of the total number of parking spaces, with the outlets located in the parking area.

Developing Nearby Public Infrastructure: Apartment renters and residence owners (including live-aboard boat owners) who own EVs, but often do not have access to a dedicated parking space in the building, park curbside, or park in off-street lots, will have to think creatively about where to charge their vehicle. Allowing EV owners to use charging stations installed in public lots, or installed curbside, is one possible solution. Private lots, such as those belonging to schools, religious institutions, and businesses may present opportunities in particular locations. Building or property owners may be incentivized to install EV Charging Stations by collecting additional fees (above the cost of electricity) that would help pay for the EVSE over time.

City of Los Angeles Green Building Code - EV Sections Pertaining to Multi-Unit Dwellings

ORDINANCE NO. 181480

An ordinance amending Chapter IX of the Los Angeles Municipal Code by adding a new Article 9 to incorporate various provisions of the 2010 California Green Building Standards Code (CALGreen Code).

THE PEOPLE OF THE CITY OF LOS ANGELES DO ORDAIN AS FOLLOWS:

Section 1. Chapter IX of the Los Angeles Municipal Code is amended by adding a new Article 9, Green Building Code, to read as follows:

ARTICLE 9, DIVISION 4

MANDATORY MEASURES FOR NEWLY CONSTRUCTED LOW-RISE RESIDENTIAL BUILDINGS

99.04.106.6. Electric Vehicle Supply Wiring.

1. For one- or two- family dwellings and townhouses, provide a minimum of:

    a. One 208/240 V 40 amp, grounded AC outlet, for each dwelling unit; or
    b. Panel capacity and conduit for the future installation of a 208/240 V 40 amp, grounded AC outlet, for each dwelling unit.

The electrical outlet or conduit termination shall be located adjacent to the parking area.

2. For other residential occupancies where there is a common parking area, provide one of the following:

    a. A minimum number of 208/240 V 40 amp, grounded AC outlets equal to 5 percent of the total number of parking spaces. The outlets shall be located within the parking area; or
    b. Panel capacity and conduit for future installation of electrical outlets. The panel capacity and conduit size shall be designed to accommodate the future installation, and allow the simultaneous charging, of a minimum number of 208/240 V 40 amp, grounded AC outlets, that is equal to 5 percent of the total number of parking spaces. The conduit shall terminate within the parking area; or
    c. Additional service capacity, space for future meters, and conduit for future installation of electrical outlets. The service capacity and conduit size shall be designed to accommodate the future installation, and allow the simultaneous charging, of a minimum number of 208/240 V 40 amp, grounded AC outlets, that is equal to 5 percent of the total number of parking spaces. The conduit shall terminate within the parking area.

When the application of the 5 percent results in a fractional space, round up to the next whole number.

ARTICLE 9, DIVISION 5

FOR NEWLY CONSTRUCTED NONRESIDENTIAL AND HIGH-RISE RESIDENTIAL BUILDINGS

99.05.106.5.2. Designated Parking. Provide designated parking, by means of permanent marking or a sign, for any combination of low-emitting, fuel- efficient, and carpool/van pool vehicles as follows:

Table 5.106.5.2

Total Number of Parking Spaces	**Number of Required Spaces**
0-9	0
10-25	1
26-50	3
51-75	6
76-100	8
101-150	11
151-200	16
201 and over	At least 8 percent of total [1]

[1] When the application of this regulation results in the requirement of a fractional space, round up to the next whole number.

99.05.106.5.3.1. Electric Vehicle Supply Wiring. Provide a minimum number of 208/240 V 40 amp, grounded AC outlet(s), that is equal to 5 percent of the total number of parking spaces, rounded up to the next whole number. The outlet(s) shall be located in the parking area.

I hereby certify that this ordinance was passed by the Council of the City of Los Angeles, at its meeting of DEC 14 2010.

JUNE LAGMAY, City Clerk

By ______________________
Deputy

Approved DEC 15 2010

____
Mayor

2.21. Guidelines for Workplace Charging: *The following overview of workplace charging is designed to inform employers, building owners, facility managers, and other key stakeholders about a broad range of issues pertaining to EVs at the workplace. Because workplace charging is so essential to the growth of the EV ecosystem, many organizations are beginning to provide resources on this important topic. Plug-in Central Coast has drawn on materials made available by the Minnesota Pollution Control Agency, Advanced Energy of North Carolina, the Electric Power Research Institute, and EV Charging Pros, among others. A full list of resources on this and other EV issues is included at the end of this document.*

As Electric Vehicles come to the market in ever-greater numbers, EV drivers will increasingly need and expect to recharge at work. While it is expected that the majority of charging will continue to occur at home at night -- when it is most convenient and affordable, the importance of workplace charging should not be underestimated. Individuals especially dependent on workplace charging will include drivers of BEVs and PHEVs with smaller-capacity batteries, employees who may not have ready access to home charging, corporate EV fleet users, and visitors who need to recharge to return to their destination or continue on their journey. Companies that provide charging are considered "leading edge" today, but soon the emphasis may shift, so that workplaces without charging resources will be considered "behind the times."

Workplace charging also plays an important role in the overall public charging ecosystem, and in the public perception of EVs as a reliable and convenient mode of transport. The EV Project – a federally funded large-scale EV charging infrastructure project (led by Nissan and EcoTality) has demonstrated that the percentage of EV owners charging their vehicles outside the home grows as more publicly accessible charging becomes available. In other words, as more charging becomes available, more "electric miles" replace gasoline miles. Workplace charging can be an important component of the overall public charging network by providing additional "opportunity charging" for drivers who are running errands and need to give their EV a quick range-extending charge.

Research strongly supports the need for workplace charging opportunities. The Electric Power Research Institute (EPRI) estimated that 54% of non-residential parking occurs at the workplace -- where vehicle dwell time is typically between four to eight hours. This extended period can be an ideal time to provide EV owners with an extension in range. Workplace charging can typically provide EV owners an extra 15 – 70 miles of range depending on the charging infrastructure available. This matches well with the characteristics of typical commuters today, of whom 90 percent drive less than 40 miles one-way to work.

Getting Started: Successful efforts to increase workplace charging depend on EV drivers, their employers, and building owners being fully informed of the key program and infrastructure design issues involved. With this knowledge, workplace charging programs can pay for themselves over time, and be an effective marketing tool for a business or a building owner to attract and retain their highest value employees, tenants, and customers. The following guideline provides a summary of the initial issues that must be considered in developing an effective workplace charging program. Each of these issues will be considered in further detail below.

1. **Survey employees' interest** in a workplace-charging program.
2. **Discuss survey findings** and EV charging needs amongst employees and key decision-makers: supervisors, building owner/manager, facilities technicians, and legal counsel.
3. **Examine EV charging equipment options** and compare the benefits and costs (e.g. Level 1, Level II, Fast Charging).
4. **Decide who will own the EV charging equipment**. It could be the company, the building/parking lot owner, or a 3rd party EV service provider.
5. **Identify incentives and investment sources** for workplace EV charging infrastructure.
6. **Create an EV charging policy** addressing workplace charging. Issues to be addressed include: who should get priority access to the chargers, when they will be accessible, how much charging will cost, and who will oversee ongoing operations and maintenance.
7. **Contract with a certified electrician** or EV consultant to determine ideal location(s), deal with local permitting, and install the equipment in an accessible location.
8. **Install signage**, alert employees and start charging!

Workplace Charging Benefits for Employers and Building Owners

The provision of workplace charging offers significant benefits for both employers and their current and future employees, visitors, and customers. Today, the provision of EV charging helps to differentiate a workplace as environmentally friendly, socially responsible, and technologically cutting-edge. As many workplaces begin to deploy EV charging infrastructure, EV charging may come to be seen as expected, just as a well-lit visitor parking lot is now considered essential to a welcoming and secure workplace. For the immediate future, however, workplace charging hosts can gain comparative advantage and enjoy these benefits as part of the EV vanguard:

- **Employee attraction & retention** - Many employees now or in the future will be driving EVs to make a personal contribution to environmental sustainability and energy security, and to enjoy the benefits and cost savings of electric drive. By installing EV chargers, employers can help retain current employees and attract new ones by staying on the leading edge of technological development and social responsibility.

- **Publicity & green credentials -** Showing leadership in supporting cutting-edge, clean transportation can raise the environmental profile and positive public perception of a business. In some construction and retrofit scenarios, LEED points are available for the installation of EV charging equipment. By deploying chargers in visible locations, a workplace also creates immediate awareness and "green curb appeal" for the organization and property. This awareness can be extended through promotional and marketing materials. In combination with solar installations, businesses can go even further in showcasing the coming era of "fossil-free" transportation and clean energy.

- **Fleet cost savings** - Going beyond EV charging for employees, a business can realize cost savings by transition its own fleet of company cars to EV, and charging them at the workplace. Studies show significant operating savings potential for EVs from both fuel savings and reduced service costs, leading to a substantial reduction in fleet total cost of ownership (TCO).

- **Triple Bottom Line Financial Reporting** – Triple bottom line (TBL) performance metrics -- reflecting people, planet, and profit -- are being used to communicate the economic, ecological, and social success factors of a business, government, or nonprofit organization. With the ratification of the United Nations TBL standard accounting practices in 2007, and ongoing deployment of carbon accounting measures in California and nationwide, many organizations with a corporate social responsibility (CSR) initiative or specific obligations under AB 32 will need to report their greenhouse gas reduction results. EV charging facilities will encourage more "carbon-free commuting" and EVSE software can quickly and simply report the results in tons of GHG reduction.

Workplace EV Charging Benefits for EV Owners

- **Range security** - The opportunity to charge at work helps EV drivers to achieve "range security." Knowing that they will be able to have the full range of the EV when they leave work is important -- and in some instances critical – for those faced with long commutes or a lack of residential charging.

- **Range extensions** – For drivers of PHEVs, workplace charging can double daily "all electric" driving range – enabling extended driving before having to turn on the gas generator.

- **Preheating/cooling** - Using workplace charging can enable EV owners to preheat or pre-cool the car without draining the battery.

- **Increased incentive to purchase an EV** – The availability of workplace charging helps make the EV purchase decision easier – especially for BEV owners with longer commutes.

2.22. Planning and Executing a Workplace EV Charging Program

Implementing EV workplace charging is easiest when the employer is in full control of their entire campus. Singular control of the parking area, building, and electrical service streamlines decision-making and cost allocation. However, many employers confront more complex ownership and management scenarios that may involve a building that is owned by one entity, maintained by another entity, and with yet another entity operating the parking facility. For these more complex scenarios, the guidelines below will have to be modified to fit the specific ownership situation. One key to an effective program launch is to ensure the comprehensive education and engagement of all the relevant parties at the outset of the planning process.

Successful efforts will depend on both employer and employee engagement. Most of the workplaces that now offer EV charging for their employees began as an initiative of an existing or prospective EV driver, "evangelizing" the benefits of EV, ultimately leading to a top-level decision to provide workplace charging. In small organizations, informal conversation between colleagues is often enough to get the ball rolling. Medium and large-sized businesses may require a more formal process, and more complex ownership scenarios will typically require the convening of a management level designee, the building owner (if different from the employer), parking lot operator (if necessary), facilities operation staff, human resources, and legal counsel. Together, this team will need to assess employee interest in EV charging as a first step.

Evaluating Interest in Workplace EV Charging

To "right size" an EV workplace charging effort, a survey will help determine both short- and longer-term interest in owning EVs -- and the need for charging options at the workplace. Potential questions include:

- Do you own an electric vehicle?
- Is your vehicle a BEV or PHEV, and what is its "all electric" range?
- What is your commute length (one way)?
- How often do you drive your EV to work?
- Would the option to charge your car at work be desirable?
- How much time would you expect to charge your EV at work, assuming a Level 2 charger?
- Are you considering purchase or lease of an electric vehicle in the future?
- How soon do you plan on buying or leasing your next vehicle (any type)?
- If workplace charging were an option, would you be willing to pay for the service?

Company decision-makers should evaluate results and determine the potential number of charging stations that might be needed. EV ownership is expected to grow rapidly over the coming decade as production of EVs ramps up significantly, so implementing a workplace charging program should be done deliberately and with an eye for potential expansion in the future. For example, Google has a near-term goal that 5% of their employee parking spots will be equipped with EV charging.

For employers who do not own their buildings or control their parking facility, the parking operator and building management must be engaged. Lease renewals are often a good time to address these issues.

Santa Barbara's Workplace and Public Charging Program

The City of Santa Barbara is a regional leader in EV charging, with Mayor Helene Schneider and the City Council supporting the installation of eight chargers in four locations, which became operational in April, 2012. The City plans on expanding the network as demand grows in future years. With assistance from the Community Environmental Council, the City was able to take advantage of grants associated with the ChargePoint program, which covered the full cost of both hardware and installation via grants from the California Energy Commission, the federal Department of Energy and the Santa Barbara County Air Pollution Control District. To ensure that installation costs could be fully covered by the available grant funds, the City picked locations that had adequate power and conduit nearby, with a very low cost of $25,000 for installation of the eight chargers.

Each location has two Level 2 chargers (some also have Level 1 availability) and include two large covered downtown lots on Anacapa Street, where parking is free for 75 minutes, then $1.50/hour; a free lot on Helena Street, managed by the City's Parking Division; as well as a lot at the harbor that charges $2/hour. EV drivers must pay these same parking fees as other drivers, plus energy costs of $1 per hour of charging. According to a recently adopted municipal ordinance, if EVs are not actively charging, they can be ticketed. However, this policy has not yet been actively enforced. Currently, downtown lots are experiencing an average of three to four charge sessions per day, while the waterfront lot has much less utilization.

The City has assessed their parking lots to find an appropriate DC Fast Charging site. The lowest cost site is at the Amtrak depot, but its historic site designation has created additional challenges. New Level Two locations are also being scouted at the City's commuter lots -- on Castillo Street and on the corner of Cota and Santa Barbara. However, power constraints may make installations impractical in the near-term. At this point, the City is looking primarily to private site owners to further expand Santa Barbara's charging network. As a member of the Plug-in Central Coast regional EV Coordinating Council, the City will be cooperating in efforts to get the word about its own positive experiences with EV charging and EVs in the City fleet, and to assist in identification of viable sites for future EV charging network growth.

UC Santa Barbara Charging Stations: In addition to the City program, UCSB has installed EV charging stations in Parking Structures 10, 18, and 22 on the UCSB campus, sufficient to charge a total of 12 EVs concurrently. Two, dual port stations are available just inside the main entrance to each parking structure. The easiest way to use the charging stations is with a ChargePoint *ChargePass* card, available at www.ChargePoint.net, though users can also call a toll-free number or download the ChargePoint App to a smartphone (free). In addition to activation through ChargePoint, a valid UCSB parking permit is required to park on campus. The parking permit dispenser closest to the charging station will vend an electric vehicle charging station permit at the rate of $1 per hour over and above the cost of any UCSB parking fees. Users who already have a valid UCSB parking permit or in-vehicle parking meter must purchase and display a short-term "EV Power Only" permit, available near the EV Charging Stations, which cost $1 per hour. EVs must be actively charging to use the charging spaces – and are currently available on a first-come, first-served basis. If demand outpaces supply, the University is considering allocating some stations on a reservation basis.

The University's EV charging stations were with funding from the U.S. Department of Energy, California Energy Commission, Santa Barbara Air Pollution Control District, and the UCSB. The Green Initiative Fund (TGIF). One additional EV charging station is in the planning states in Parking Lot 22, as part of the Student Resource Building solar array project. For more information about the EV charging at UCSB, contact TAP@tps.ucsb.edu or call 805-893-5475.

While the City of Santa Barbara and UCSB operate the largest networks of charging stations in the region, many other businesses also provide charging. As of late 2013, there were at least 50 Level 2 charging stations in the greater Santa Barbara area (approximately 200,000 inhabitants), which gives Santa Barbara the distinction of having some of the most public charging stations per capita in the nation. These stations are located at hotels, workplaces, shopping centers, beaches, parks, and other destinations.

Identifying Charging Equipment Needs and Charging Levels: Determining what type of charging option to provide is critical to meeting driver needs. Factors such as EVSE system cost, electricity needs, potential electric supply upgrades, EVSE security, and maintenance will influence decisions. Survey results will inform decisions on charging needs. Where specific survey data is not available, national data may be useful. According to the US Department of Transportation *Omnibus Household Survey* the average commuter travels approximately 15 miles one way to work. Two out of three commuters (68 percent) reported a one-way commute of 15 miles or less, 22 percent traveled between 16 and 30 miles and 11 percent traveled more than 30 miles.

Expansion of Level 2 charging (providing 8-20 miles per hour of EV range) is a preference that many EV owners share. Level 2 EVSE at the workplace provides robust range security and can enable one EVSE unit to serve multiple vehicles through the day if procedures are in place for owners to move cords between adjacent parking slots, and/or to swap vehicle locations at lunch or break times. With a host of popular EV smart phone apps, users can be notified when their EV is charged up.

While Level 2 charging is often the preferred solution, Level 1 often has significant cost advantages. Given the long time periods that many EV owners are parked at work, and the significant charge remaining on the batteries of short-haul commuters, Level 1 charging -- providing 2-5 miles per hour of EV range -- can be an excellent workplace charging solution. Implementing Level I charging at the workplace is a viable entry point for companies that want to get a feel for the technology and how it works before investing resources in faster charging solutions.

A Level 1 EVSE can be as simple as a three-pronged extension cord plugged into a standard grounded 110 outlet, utilizing the standard Level 1 portable charging device that comes with all

EVs. Level 1 charging can be the easiest and most cost-effective way to rapidly expand EVSE infrastructure. Because of its simplicity and low costs, analysts predict in 2017 that 2.9 million of the total 4.1 million charging stations in the U.S. will be the Level 1 type. However, there a range of issues that must be taken into account by site hosts before moving toward the Level 1 solution.

Level 1 charging equipment solutions ranges widely in cost from the cost of an extension cord where adequate grounded outlets already exist, to $1,000+ per space for new conduit and electrical upgrades, depending on the power situation at the workplace. At the low end of the scale, a workplace can provide access to a three-pronged plug and the driver can use the charging cord set that comes standard with every vehicle. Alternatively, a workplace can procure a dedicated Level 1 EVSE with a J1772 connector for approximately $800, as is available from Clipper Creek. These devices can be either mounted on the wall or attached to a light pole for easy installation in the parking environment. However, use of plugs rather than J1772 connectors introduces greater hazards for the driver and potential liabilities for the site host. Furthermore, much of the cost advantage of the Level 1 installation can be eliminated if a J1772 charging station with a payment system is installed.

Level One Payment Systems: One of the impediments to wider use of Level One charging is that lower-cost "dumb" EV chargers do not have point-of-purchase transaction systems (such as credit card billing). However, IRS rules may require employers to track EV charging as a benefit. Further, many companies do not want to provide free charging, even at low-cost EV rates. To find a workaround to this problem, a company called Liberty Access Technologies has introduced a relatively inexpensive add-on keypad and customer code generator that enables site hosts to control access to "dumb" chargers or charging outlets, without paying the more costly network access fees imposed by some EVSE vendors. The charge authorization code can be issued by the site host or purchased from a payment kiosk or a mobile payment system via a mobile phone and credit card payment.

Each code is unique and cannot be reused once it has expired, protecting the lot owner and the consumer from potential fraud. Codes can be issued for periods ranging from several minutes to several months. A credit-card transaction fee is charged on a per transaction basis. Charging fees can also be directly debited from an employee's expense account. One Liberty data system provides access control for up to ten Level One or Level Two chargers, enabling use of the far cheaper "dumb" chargers now on the market from companies like Eaton, Clipper Creek, AeroVironment, Leviton, and many others. (See www.liberetyplugins.com)

Power Availability: Another significant consideration for both Level 1 and Level 2 charging is power availability. Most Level 1 charging equipment requires that a 15 amp dedicated circuit breaker be installed in the electrical panel to support the equipment. However, if the workplace has determined via an employee survey that there is a need for multiple Level 1 stations, additional power supply may be required to support multiple, simultaneous charging sessions. In some environments, a workplace might need to install a dedicated 120/240 volt electrical panel, with a service rating of 120 to 200 amps to support the projected long-term demand for

Level 1 charging. In addition, the location of the power room and distance relative to the proposed charging locations is critical to budgeting for a workplace charging installation. Additional cost considerations involve the distance of conduit requirements, the type of cable to be used to bring power to the locations, and possible cutting, trenching, and replacement of sidewalks and pavement.

Using Level 1 as a stepping stone, an employer can gain experience about how their employees are using workplace charging, gauge their satisfaction with Level 1 charging, and then make an informed choice to move (or not) to faster charging options.

Hardware Cost Factors and Available Tax Credits: Level 2 charging equipment has a wider range of costs, from $500 to $6,000 for the equipment (plus $1,500 to $5,000 or more for installation) depending on the physical layout of the parking area, the existing electric infrastructure, and the type of equipment purchased. The higher cost of some Level 2 chargers is typically due to the inclusion of support for credit card billing, as well as network charging software. Network software enables a variety of access protocols and flexible pricing for the units (e.g. differentiated costs for network subscribers, tenants, or drive-up "opportunity charging"), and can provide reservation features and more robust reporting functions.

There are also many different form factors available for Level 2 equipment -- from wall and bollard mounts to units with retractable cords. Some EV charging units are also available in dual port stations, which provide the ability to charge two vehicles simultaneously from a single device. Of course, Level 2 EVSE require a higher level of dedicated power than Level 1. Generally a dedicated 40 amp circuit breaker is required for each charger in the electrical panel. If a dual charger is being considered, then 80 amps of available power and two dedicated breakers must be installed.

At the end of 2014, the Investment Tax Credit for EV charging equipment expires, with 30% of the purchase price available as a tax credit. The specifics of the rebate and applicability to your tax situation should be assessed with a qualified tax professional or accountant. In certain circumstances, nonprofit or public organizations may be able to work with a financial intermediary to monetize some of the credit, though this is not always feasible.

EV Charging Equipment Options – Information and Resource: Decision makers looking at charging options can use online resources to assess the growing offerings of EVSE manufacturers and service providers. One of the most extensive listings of EV charging equipment is available via Plug-In America at http://www.pluginamerica.org/accessories. Another strong listing is at Plug-In Recharge: http://www.pluginrecharge.com/p/ evse-vendors.html

There are a growing number of vendors that sell EVSE equipment and offer turn-key installation and ongoing service. Some of these vendors and network operators require users who purchase their equipment to subscribe to a charging service and to make payment via credit card or radio-frequency identification (RFID) devices which control access to the EVSE and enable the owner to collect usage data. Charging can also be set up to be free for all or some users. The EVSE vendor typically shares in the revenue generated by the EVSE and charges service fees for managing payment transactions, maintenance and troubleshooting services for the EVSE.

Fast Charging (sometimes called Level 3) is less likely to be a good match for most workplace situations at this time due to the high equipment and installation cost. However, like most EV equipment, hardware cost is declining rapidly, and more EVs will likely be shipping with Fast Charging options (either the Japanese Chademo connector standard or the American and European SAE Combo 2 standardIf a workplace is located on a property with multiple buildings or a very large number of EV tenants, it might be feasible to provide a L3 solution, which could permit a large number of drivers to charge their vehicles throughout the day. (Google is planning a Level 3 installation, for example.) Currently, Level 3 costs are in the range of $20,000 - $40,000 for hardware, and $15,000 - $30,000 for installation.

EVSE Installation Budgeting – Factors to Consider: Itemized costs for workplace EVSE will vary for each site. Factors such as trenching, new electrical circuits, surface refurbishment, panel upgrades, and permitting will play a role. In some locales, there may be state or federal grant or incentive programs to help cover the cost of workplace charging. A typical budget might include the following line items:

- Material/Incidentals
- Equipment Rental (trencher for conduit)
- Sidewalk Demolition/Repair
- Labor (in-house)
- Labor (outside)
- EVSE (charging station)
- Incentives (if available to offset costs)
- Optional EVSE equipment (e.g. RFID card reader)
- Signage and/or Paint

Company Workplace Charging Policies: It is important to develop clear internal company policy about workplace EV charging. Issues that should be considered include the following:

Access to Charger-Equipped Parking: Signage should clearly indicate that the EVSE parking space(s) are only to be occupied by EVs charging their vehicles. Access privileges can be extended to both employees and visitors, at the discretion of the employer. A policy regarding time limits per car may need to be defined if there is more demand than supply of charging. For more information about site signage requirements, please see Section I on *EV-Related Signage Guidelines* in the Appendix of this document. Additional information can be found in Ready, Set, Charge California document available at
http://www.baclimate.org/images/stories/actionareas/ev/guidelines/readysetcharge_evguidelines.pdf

Registration and Liability Forms: Some workplace charging programs require users to register to use the equipment and sign a standard waiver of liability. A registration form could includes language requiring vehicle owners to agree that the business is not responsible for any costs related to vehicle purchase or repairs, nor for any damage to the vehicle while parked at the charging station. It could also provide a specific timeframe within which the business would be obligated to correct maintenance issues with the charging stations upon notice of the problem.

Time Restrictions on EVSE Access: Employers must decide whether the EVSE can be used outside of normal business operating hours. A company may also decide to put the locations of the chargers on charging network maps, such as those operated by the Department of Energy or EV Charging News. These resources will make EV charger information available to the general public and enable a potential revenue flow for charging outside of business hours.

Equipment Security: Level 1 charging often involves connectors and cables owned by the EV driver. Some of these cables can cost as much as $600, so it will be important to create as secure an environment as possible to prevent vandalism and theft. A commercial building in Silicon Valley with both workplace and public retail tenants has taken the step to enclose the workplace-only charging units inside a fenced off area, providing a key to authorized drivers to unlock the equipment. This measure has effectively segregated the equipment from the public, while giving authorized drivers access. Other workplaces report little if any interference with driver-supplied charging equipment.

Managing Access Following Complete Charging: Employers must also decide what policies should govern EV drivers once EVs are fully charged. Must employees move their vehicles to enable another EV to use the charger? Many companies are asking drivers to sign an "EV Drivers' Code of Conduct" that includes instructions on how to share spaces and notify other EV users that the spot is available. For example, most EV's have easily readable dashboard lights that can be seen by anyone looking at the vehicle to indicate if the vehicle is currently charging. With appropriate protocols, some workplaces have policies that permit other drivers to move the charging device from one vehicle to another when a complete charge is indicated. Other policies call for notification via smartphone app, while leaving the responsibility for decoupling the charger to the original driver.

Auto manufacturers are also educating new EV drivers on standard "charging etiquette" For example, the Ford Motor Company has recently produced EV Etiquette documents which can be found here: http://blog.ford.ca/2013/01/04/ev-etiquette-a-whole-new-ballgame/ Many drivers also use timecards that can be displayed in vehicle windows indicating when the charger might be disconnected and used by a vehicle in the adjoining spot, as illustrated here: http://blog.ford.ca/wp-content/blogs.dir/1/files/2012/12/Ford-EV-Etiquette-Plug-In-Card.pdf.

EV drivers understand that they are not parking and charging their vehicles in a spot for the full day, that they are actually occupying an "alternative fueling station" and are ready and able to calculate the time required to charge their vehicles and make arrangements in their schedule to move their vehicles when their charging sessions are over. A growing set of smart phone apps may enable EV drivers to plan, monitor, and schedule the charging of their vehicle. While it is up to the workplace to determine whether they want to limit car switching when charging is completed these applications often include reservation systems so cars can be scheduled and moved by the drivers as necessary. Ideally, the charging spot should be used as efficiently as possible so that any vehicle in the spot is actually charging up.

Charging Money for Charging EVs – Policy Options for Employers: Many EV workplace charging programs are free for employees. Since the number of EVs on the streets today is relatively small, this can be an affordable approach to initially incentivize employees to make a clean transportation choice. As the penetration of EVs expands, providing free charging may have to be reconsidered. Capital and operational costs for EV charging can be recovered over time through a charge-per-use or setting a monthly/yearly subscription rate. Level 2 charging equipment usually includes management software that allows workplaces to set the fee for a kWh of energy, a pre-defined length of a charging session, or to allow access to the unit for no fee during certain hours of the day. In the largest survey to date, the California Center for Sustainable Energy (CCSE) and the California Air Resources Board (ARB) found that California EV owners are willing to pay 40% – 70% more for public and workplace charging compared to standard residential electricity rates.

The cost of the electricity used to charge a single EV is minimal, comparable to per employee costs for coffee or snacks in a break room. For example the energy cost per kilowatt hour (kWh) in the United States as reported by the Bureau of Labor statistics is .12 cents, in Los Angeles it is .20 cents. A Nissan LEAF goes approximately 3.5 miles per kWh of energy used. In order to obtain 20 miles of range (longer than the typical one-way commute in California) the Leaf would require 5.7 kWh of electricity, which would cost .68 cents at the national average electrical rate and up to $1.14 in Southern California Edison (SCE) territory. For comparison, a vehicle with an internal combustion engine might consume between $2.00 and $5.00 in gasoline to drive 20 miles. Given the 3.3 kWh charging unit in the LEAF, it would take close to two hours of charging to receive 20 miles of range in the battery. For an employee in SCE territory who utilizes workplace charging for five days/week, the total charge for energy would be $5.70 per week, for a 4 week working month the cost of energy would be $22.40 and a for 50 weeks a year the employee's vehicle would consume $285 worth of energy.

It should be noted that if a company decides to make EV charging free for its employees, some legal experts think that it could be considered a reportable employee fringe benefit. Most Level 2 chargers include management reporting capabilities can provide individual statistics for each vehicle that has charged, including the time to charge and the amount of energy consumed. These reports can be used to provide information for employee benefit reporting.

Some companies have decided not to burden themselves with tracking individual vehicle energy consumption and instead have added an electric vehicle-charging component into an Employee Alternative Transportation initiative. Under this type of program, an individual employee is not charged directly for the energy their vehicle consumes, however a taxable benefit of $30 per month (or more as appropriate) is added to their benefit package. In either scenario, the cost of energy for an individual vehicle is relatively small. Given that EV charging may be a tax liability to your employees and require an employer reporting mechanism, consulting a tax attorney or advisor is recommended.

EV Charging in the City of Ventura

The City of Ventura leads the Central Coast in the number of public EV charging stations installed, with 14 installed as of early 2013, of which 12 are available to the public and two are reserved for City fleet use only. Locations include the Metrolink station, downtown, and City Hall. As in the case of Santa Barbara, the City was able to take advantage of the ChargePoint grant program, which included California Energy Commission and federal Department of Energy funding for both hardware and some installation costs. Additional installation funding was provided by the Ventura County Air Pollution Control District (for the Metrolink project). Installation was done by Clean Fuel Connection and ABM, two companies certified by ChargePoint to undertake installs of their equipment.

The City's robust charging program has the full support of the Mayor and City Council, which is promoting EVs as part of an ambitious Climate Action Plan, and green initiatives throughout the transportation sector. Future charging station installations are being considered for the Community Park and Aquatic Center areas. The City's average installation cost ranged from $7,500 to $10,000 per station for the installation alone. Therefore, additional grants will be sought to cover future network expansion.

As part of its EV commitment, the City also purchased three Prius Plug-in Hybrid Electric Vehicles (PHEVs), which have a 12 mile all-electric range, and very high-MPG ratings under regular combustion power. They also continue to operate a model year 2000 Toyota RAV 4 EV, which has proven very reliable. The Prius PHEVs were purchased with federal Recovery Act stimulus funds.

The City recognizes that its position on the 101 corridor between Los Angeles and San Francisco is a key strategic location for EV charging, and the City is cooperating with NRG and other stakeholders to identify appropriate locations for future EV Fast Charging.

2.23. EVSE Siting, Installation, Signage, and Utility Notification: The workplace charger siting process should begin with the electrical contractor performing the initial site inspection. The contractor can pinpoint existing power supply options and upgrade requirements, and identify charging spots closest to the existing electrical infrastructure. Attention to ADA (Americans With Disabilities Act) requirements is important at this point, especially since ADA compliance requirements are subject to local interpretation. (The guidelines are available at http://www.baclimate.org/images/stories/actionareas/ev/guidelines/readysetcharge_evguidelines.pdf and should be consulted for a full discussion of ADA issues.) Many municipalities and local ordinances require that the first in a series of charging stations be accessible and use the

ADA standard as their permitting guideline. Building an accessible EVSE spot also includes making sure that wheelchair users are able to access the charging station and cables and outlets are installed at accessible heights.

Aside from following ADA and National Electric Code guidelines on installation, safety considerations should also include efforts to reduce the potential of people tripping over EVSE cords, proper and sufficient lighting, potential shelter from weather, general personal/property security, clearly visible signage, and sufficient barriers to prevent a car from colliding with the EVSE.

For more information about where a charging station should be installed, ADA and site signage requirements please see the following sections of the Appendix to this document: Section C - *Charger Installation Guidance for Commercial and Multi-Family Installations,* Section H - *Guidelines for Accessibility and ADA Compliance* and Section I - *EV-Related Signage Guidelines* . Additional information can be found in Ready, Set, Charge California document available at http://www.baclimate.org/impact/evguidelines.html.

EVSE Installers and Contractors: A certified electrician should carry out EV charger installations. When hiring a contractor to install EVSE at a workplace, select one who is familiar with the National Electric Code Guidelines found in NEC Article 625, the specific guidelines for EV charging equipment and installation. Be sure to have key decision makers and key employees that will use the EVSE walk through the parking area with the certified electrician/contractor prior to beginning the installation. The electrician or general contactor will likely be the point person in coordinating local permitting, inspections, utility upgrades (if needed), equipment purchasing and installation of the EVSE. After installation, the electrician should walk through the EVSE and its operation with the owner of the equipment.

With the growing interest in EVs, targeted training and certification programs for EVSE installations are expanding. For example, UL (formerly Underwriters Laboratories) now offers an online and hands-on programs to familiarize technicians and safety inspectors with a wide range of electric vehicle products and technologies, including Section 625 of the National Electrical Code. The national electrical industry also has created the Electrical Vehicle Infrastructure Training Program (EVITP) to train and certify EV equipment installers. This has become the leading training program for EV charger installation – with co-sponsorship by the National Electrical Contractors Association (NECA) and the International Brotherhood of Electrical Workers (IBEW).

Utility Notification Processes: It is important to notify the local utility when Level 2 charging infrastructure is being installed. Business locations for EV charging infrastructure generally have robust electric service -- so that the addition of the first one or two Level 2 EVSE will not likely impact the local electrical distribution network and equipment. However, additional chargers on a single transformer may require an upgrade, and it is important for utilities to track each new installation as it occurs for system planning purposes.

Utilities also offer special EV charging rates. Typically, these rates have been established to incentivize drivers to charge their vehicles during off-peak times when electricity consumption is lowest (e.g. overnight). However, some rate incentives may apply during portions of the daytime hours as well, particularly during morning hours.

Charger Signage: EV charger signage must clearly show that the parking spot is only to be used by an EV. One emerging practice is to choose the signs indicating EV charging in a green rather than blue color. Blue is often associated with ADA parking spots and some drivers of traditional vehicles often think that those spots are available for them to use. This helps alleviate a phenomenon which EV owners refer to as "getting ICE'd" when they come to a public charging station spot only to find an Internal Combustion Engine (ICE) parked there. The cost of signs will typically range between $15 – $80, plus installation. It can also be useful to paint the pavement of the parking space to provide further visual guidance for the EV charging space. The main consideration in painting the space is to use a high contrast color, so the information on the pavement is easily readable. For more information about site signage requirements please see Section I - *EV-Related Signage Guidelines* in the Appendix of this document. Additional information can be found in *Ready, Set, Charge California!* at http://www.baclimate.org/images/stories/actionareas/ev/guidelines/readysetcharge_evguidelines.pdf

EV Chargers and Renewable Energy: A unique benefit of driving electric is the capability to power them with clean, locally- produced solar or wind power. Use of renewable, green sources of electricity to power EVs is encouraged to prevent pollution from energy generation and to promote a robust local low-carbon energy economy. Installing a solar array adjacent to a plug-in charging station demonstrates that natural energy from the sun can be used to power vehicles. Solar power typically flows into the grid with a separate meter tracking how much electricity has been generated -- offsetting the grid power that is supplied to EVs through the EV charger.

The cost of a solar power is on a steep decline – such that some systems may be installed with no upfront investment by a financing mechanism known as a Solar Power Purchase Agreement (PPA). For example, a 2kW solar installation provides savings sufficient to power an EV for 10,000 miles per year – year after year -- with a one-time cost of approximately $7000 after incentives. Through a PPA, businesses also have the opportunity to own the asset by investing their own capital, or to enter into a PPA agreement whereby an energy company such as Solar City would own the asset but pass on some of the energy cost savings to the host business.

CHAPTER 3: Hydrogen Fuel Cell Vehicles and Infrastructure

3.1. Introduction

Hydrogen Fuel Cell Vehicles and fueling infrastructure have been in development for well over two decades, promising zero emissions at the tailpipe, rapid refueling, and – if renewable energy is used to produce hydrogen fuel – the potential for significant reductions in greenhouse gas and air pollution impacts. To convert this potential into reality on the ground, the state of California and major automakers are investing substantial resources in new vehicle and fueling technology, as well as robust state incentives of up to $5000 per vehicle. Thanks to these investments, the years 2015-17 will see key milestones reached in the development of a viable Fuel Cell Vehicle (FCV) ecosystem in the state. These milestones include the development of a growing network of fueling stations sufficient to serve the first wave of FCV early adopters. As of late 2015, an initial statewide network of nearly 100 fueling stations is in planning or under construction, timed to open progressively over the 2015-2023 period. The pace of station openings -- including one in Santa Barbara opening by the end of 2015 -- is designed to keep pace with the launch of several light-duty FCVs from major manufacturers.

To assess the future potential of hydrogen vehicles in the Central Coast, and the actions that regional and local stakeholders can take to support FCV readiness, this chapter covers these key issues:

- Overview of California's Hydrogen Vehicle and Infrastructure Strategy
- Hydrogen Fuel Cell Vehicles (FCVs) and related fueling infrastructure deployment in the region and statewide
- Environmental and economic characteristics of FCVs and potential contribution to air quality and GHG goals
- Operating attributes of FCVs
- Sources of funding for FCV infrastructure and vehicle incentives and potential market acceleration initiatives
- FCV training needs, resources, and activities
- Recommendations on FCV-related policies and programs for consideration by regional and local public agencies and other stakeholders

3.2. Overview of California's Hydrogen Vehicle and Infrastructure Strategy

The California Hydrogen Highway Network was initiated in April of 2004 by Executive Order S-07-04 under then Governor Arnold Schwarzenegger. The intent of the Order and associated investments in FCV technology by the California Energy Commission has been to ensure that hydrogen fueling stations will be in place to meet the needs of future FCV drivers, and to provide an additional fuel pathway for the advancement of Zero Emission Vehicles (ZEVs). Over the medium-term (5-10 years), hydrogen technologies also have potential to be deployed in medium and heavy duty vehicle segments, as well as the light-duty sector. To provide an overall strategic framework for FCV deployments across all vehicle types, the California Fuel Cell Partnership published *A California Road Map: The Commercialization of Hydrogen Fuel Cell Electric Vehicle* in 2012.[1] This Road Map (and subsequent updates) has articulated the core policy and program framework for FCV market development, including the all-important development of a new hydrogen fueling infrastructure.

The *Road Map* in turn served as a basis for Governor Jerry Brown's March 2012 executive order that directed California state agencies to support the accelerated deployment of the full range of zero-emission vehicles (ZEVs), including FCVs.[2] The state's comprehensive 2013 *ZEV Action Plan* provided further guidance on bringing FCVs to market.[3] Most recently, the passage of Assembly Bill 8 (Perea, 2013) was another pivotal step in FCV development, extending through 2023 the Air Resources Board's Air Quality Incentive Program (AQIP) and the Energy Commission's Alternative and Renewable Fuel & Vehicle Technology Program. AB 8 included a crucially important provision to fund at least 100 hydrogen stations via with up to $20 million a year in competitive grants and operating subsidies for fueling station developers, provided through the California (CEC). Since the passage of AB 8, three automakers (Honda, Toyota, and Hyundai) have announced plans to bring FCEVs to market in 2015-16, while several other automakers are ramping up new FCV technology collaborations, and are expected to enter the market in the 2017-2022 timeframe. FCVs have been embraced by key state policy makers because -- once an appropriate fueling infrastructure is in place -- they will combine the convenience and utility of conventional Internal Combustion Engine (ICE) vehicles, including diverse sizes, 300+ mile range and quick (gasoline-like) refill times, with some of the quiet and clean attributes of electric vehicles.

As discussed in depth later in this chapter, achieving some of the low-emissions attributes of EVs will require that sufficient quantities of renewably produced hydrogen fuel are economically available. Current state law mandates that 33% of hydrogen fueling supplies in state-supported stations be fueled by renewable hydrogen, but the majority of the balance of hydrogen fuel is derived from natural gas, limiting its environmental advantage relative to pure battery-electric vehicles (BEVs). With the potential to develop an even higher level of renewable and low-carbon hydrogen fuel supply chain, the state has produced another key policy document known as the *Vision for Clean Air* -- developed by several leading air quality management agencies -- to highlight strategies to accelerate the introduction of FCVs as well as EVs in the context of air quality policy and goals.[8]

Policies for FCV promotion will of necessity be driven primarily at the state level, as most cities, regional agencies, and Air Districts do not have resources to offer a substantial

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[1] *A California Road Map: The Commercialization of Hydrogen Fuel Cell Vehicles*, June 2012 *http://cafcp.org/sites/files/A%20California%20Road%20Map%20June%202012%20%28CaFCP%20technical%20version%29_1.pdf*

[2] Executive Order B-16-2012, March 23, 2012 *http://gov.ca.gov/news.php?id=17472*

[3] *ZEV Action Plan A roadmap toward 1.5 million zero-emission vehicles on California roadways by 2025*, February 2013. *http://opr.ca.gov/docs/Governor's_Office_ZEV_Action_Plan_(02-13).pdf*

quantity of vehicle incentives adequate for FCV incremental cost buy-down, or sufficient grant funds to independently subsidize H2 fueling infrastructure. That said, local and regional stakeholders can work together with hydrogen fuel suppliers and the California Fuel Cell Partnership to support and accelerate existing plans for H2 fueling station deployment, or even to develop new plans and funding applications to the CEC for hydrogen stations. In 2015, the CEC announced funding for 28 new stations, resulting in an anticipated 51 operating hydrogen fuel stations by the end of 2015 (more than doubling the previous number of State-funded stations). There will be new opportunities in 2016 to site additional H2 fueling infrastructure in the Central Coast, beyond the first station in Santa Barbara.

3.3. The Statewide Hydrogen Station Network

The *Road Map* and *ZEV Action* Plan together prescribe a minimum network of hydrogen stations to establish the foundation for robust, commercial-scale FCV adoption. Focused on "early adopter" areas in Southern California and the San Francisco Bay Area, the FCV station network includes "connector" and "destination" stations intended to anchor the evolving statewide network and enable north-south travel. As of mid-2015, eight stations are open to the public, with one in the San Francisco Bay Area, and the balance clustered in the greater Los Angeles/South Coast area. One station is being constructed in the City of Santa Barbara, planned for South La Cumbre Road (discussed further below). By the end of the 2016, the Fuel Cell Partnership estimates that more than 50 stations will be open, and 100 open by ~2020, per the schedule below. However, automakers such as Toyota, are indicating that approximately 40 will be open by the end of 2016. Thus, the dates provided on the Fuel Cell Partnership's website below (current as of mid-2015) may be considered optimistic. (Hyperlinks provide additional information on each station.) The state's rapidly growing infrastructure investment stands at $91 million since 2009, and nearly $200 million has been pledged by the state to help build out the planned 100 station network.[7]

California Hydrogen Station Locations and Opening Dates

STATION LOCATION	OPEN DATE	INFO
OPEN IN Q3 2015		
Burbank	2006	View
Emeryville - AC Transit	2012	View
Fountain Valley - OCSD	2010	View
Irvine - UC Irvine	2006	View
Los Angeles - Harbor City	2013	View
Newport Beach	2011	View
Thousand Palms - SunLine Transit	2000	View
Torrance	2011	View
OPENING Q4 2015 – Q4 2016		
Anaheim	Q1, 2016	View

Burbank (Upgrade)	Q2, 2015	View
Campbell	Q4, 2015	View
Chino	Q4, 2015	View
Coalinga	Q4, 2015	View
Costa Mesa	Q4, 2015	View
Diamond Bar	Q1, 2015	View
Foster City	Q2, 2016	View
Hayward	Q4, 2015	View
Irvine - UC Irvine (Upgrade)	Q4, 2015	View
Irvine - Walnut Ave	Q2, 2016	View
La Canada Flintridge	Q4, 2015	View
Laguna Niguel	Q1, 2016	View
Lake Forest	Q4, 2015	View
Lawndale	Q1, 2016	View
Long Beach	Q4, 2015	View
Los Altos	Q2, 2016	View
Los Angeles - Beverly Blvd	Q4, 2015	View
Los Angeles - Cal State LA	Q4, 2014	View
Los Angeles - Hollywood Blvd	Q4, 2015*	View
Los Angeles - LAX	Q2, 2015	View
Los Angeles - Lincoln Blvd	Q4, 2015	View
Los Angeles - Pacific Palisades	Q1, 2016	View
Los Angeles - West LA 2	Q2, 2015	View
Los Angeles - Woodland Hills	Q1, 2016	View
Mill Valley	Q4, 2015	View
Mission Viejo	Q1, 2016	View
Mountain View	Q2, 2016	View
Oakland	Q3, 2016	View
Ontario	Q1, 2016	View
Orange	Q1, 2016	View
Palo Alto	Q2, 2016	View
Redondo Beach	Q1, 2016	View
Redwood City	Q2, 2016	View
Riverside	Q1, 2016	View
Rohnert Park	Q1, 2016	View
San Diego	Q4, 2015	View
San Jose	Q4, 2015	View
San Juan Capistrano	Q4, 2015	View
San Ramon	Q1, 2016	View
Santa Barbara	Q4, 2015	View

Santa Monica	Q4, 2015	View
Saratoga	Q1, 2016	View
South Pasadena	Q1, 2016	View
South San Francisco	Q4, 2015	View
Torrance (Upgrade)	Q1, 2016	View
Truckee	Q4, 2015	View
West Sacramento	Q4, 2015	View
Woodside	Q1, 2016	View
BUS ONLY		
Emeryville - AC Transit (bus)	2011	View
Oakland - AC Transit (bus)	2014	View

The most recent update to the state's FCV *Road Map,* known as the *Hydrogen Progress, Priorities and Opportunities Report* has further refined the locational strategies of the Fuel Cell Partnership and its *Original Equipment Manufacturers (OEM) Advisory Group* – which includes Honda, General Motors, Hyundai, Mercedes-Benz, Nissan, Toyota and Volkswagen. As of June 2015, the OEM Group produced a consensus list of recommended priority locations for the next 19 hydrogen stations to be built in the state, to ensure that customer travel-time to the nearest station is minimized within a regional market, inter-regional travel is facilitated, and there is at least some redundancy in the network. It should be noted that these recommendations are preliminary and will likely be further refined through further consultation with stakeholders. Central Coast stakeholders will note that there are no additional stations recommended as a Primary Priority for this region, whereas just one station – in Ventura/Oxnard – is proposed as a Secondary Priority. This locational strategy is based on market analysis that suggests that early adoption will be strongly clustered in the Los Angeles and San Francisco Bay Areas, necessitating only a few connector stations in the rest of the state during the initial years of market development.

Primary Priority*	Secondary Priority*
Berkeley/Richmond/Oakland Beverly Hills/Westwood Fremont Lebec** Manhattan Beach Sacramento San Diego #2 San Diego #3 San Francisco Thousand Oaks/Agoura Hills Torrance/Palos Verdes	Culver City Dublin/Pleasanton Encino/Sherman Oaks/ Van Nuys Granada Hills Irvine South Los Banos** Palm Springs Ventura/Oxnard

*The locations are listed in alphabetical order and not ranked within the priority lists.
** These two locations will further strengthen the I-5 corridor

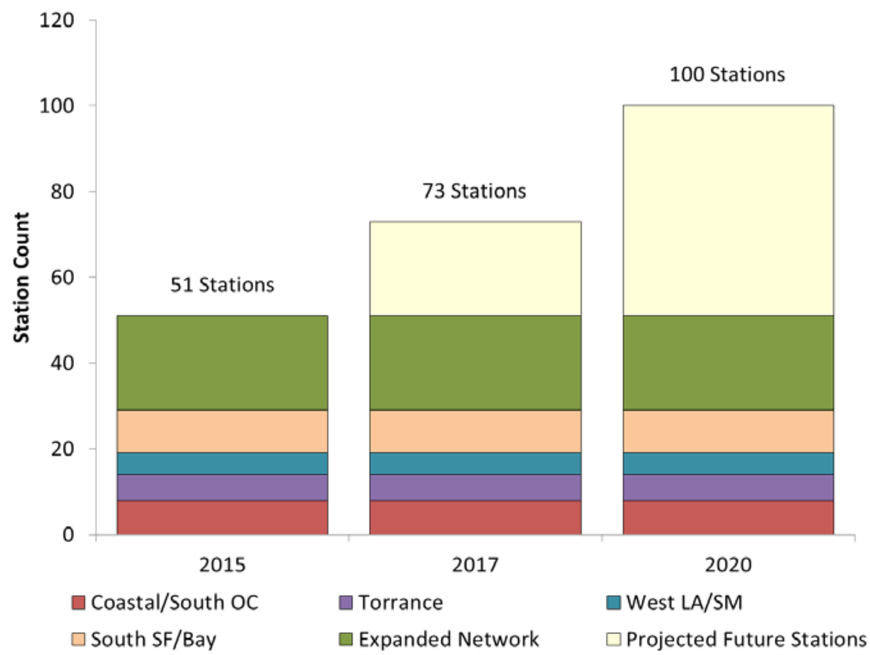
Source: California Fuel Cell Partnership.

3.4. H2 Fueling Station Cost and Regional Site Selection Process

Hydrogen fueling stations are estimated to cost between ~$1.2M and $2.4 million dollars on average. California's stations are typically constructed with a combination of public and private funds, including significant grants from the California Energy Commission. While the state encourages siting and building of stations in alignment with the state's cluster model, the complexities of siting are such that some stations may not be located within the designated clusters, and others will be difficult to site at locations that are otherwise considered optimum in terms of customer convenience. Stations are not expected to show a profit for up to 10 years or more, and therefore may require ongoing subsidy through both private and public sources.

The chart below illustrates California's hydrogen fuel station rollout through 2020; including both existing and proposed stations – segmented according to the five key regional clusters identified by CARB to plan the hydrogen vehicle roll-out. These clusters include the San Francisco Bay Area, Sacramento Area, Los Angeles/Orange County/Ventura, San Diego, and "Other" (encompassing the rest of California). The successful roll out of the 51 stations expected by the end of 2015 is intended to support and align with near-term hydrogen vehicle sales.

Projected Cumulative FCV Station Deployment

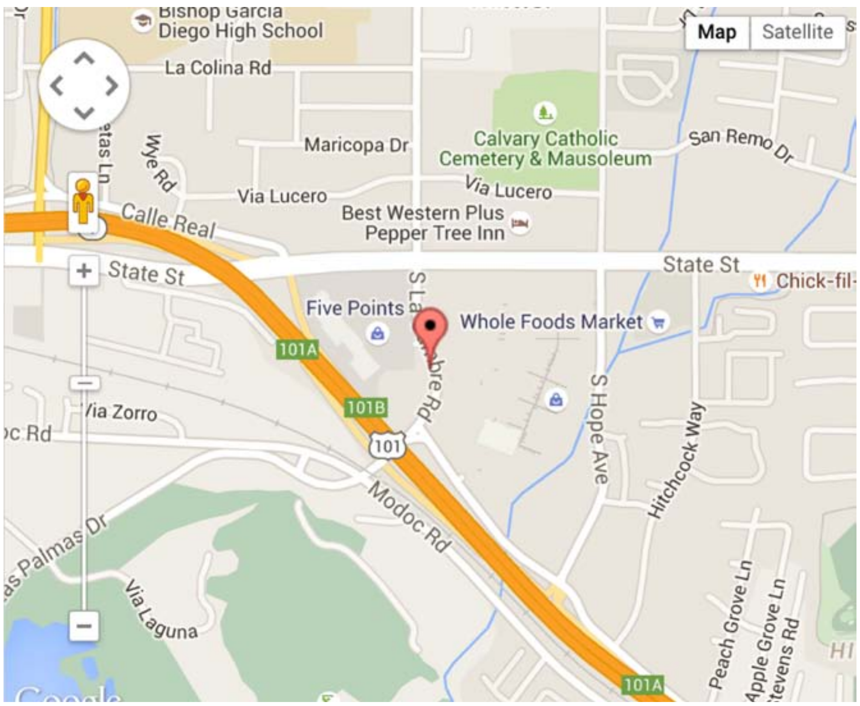


As illustrated above, the Central Coast/South Orange County geographies are estimated to have only approximately five stations beginning in 2016, expanding through the 2020 period to locations yet to be determined. To ensure ongoing functioning of the fueling network, the CEC has provided operations and maintenance costs for station operators to maintain their availability until sales revenue can cover costs and create a viable business case for private investment. The payback period for private investment in the stations is discussed in greater detail later in this chapter.

3.5. Current Status of Station Siting on the Central Coast/ Santa Barbara

The first hydrogen station planned for the Central Coast will be located in Santa Barbara at 150 South La Cumbre Road. First Element Fuels won a $27.6 million dollar contract with the California Energy Commission to develop this station along with a network of 19 additional hydrogen fueling stations in California. The project is being constructed and managed by Black and Veatch, a large engineering firm that managed development of Tesla's national Supercharger network. While the Santa Barbara project was initially planned for an October 2015 opening, it is now expected to be open by the end of the year. In its first two years of operation, fuel for the station will be provided by Air Products and Chemicals, with 33% of the hydrogen provided from renewable sources, per California state mandate. As in the case of most early H2 fueling stations, the California Energy Commission will also be providing Operations and Maintenance (O&M) funding during at least the first three years of operation, in order to enable sustained operation of the station while vehicle and fuel demand is still ramping up.

Santa Barbara Hydrogen Fueling Station Location: 150 South La Cumbre Road



3.6. Hydrogen Fueling and Vehicle Deployment in the National Policy Context

While California is an extraordinarily important market for FCV infrastructure, as in the case of EVs, the full commercial scale-up of hydrogen vehicles will only occur as a full nationwide market is developed that complements state-level efforts. To that end, the U.S. Department of Energy (DOE), automakers, hydrogen producers, and allied organization launched H2USA in March 2013, a public-private partnership focused on advancing hydrogen infrastructure. The partners, which include the California Fuel Cell Partnership and the State of California, are encouraging early adoption of FCVs with a focus on cost reductions and scale economies in both fuel production and FCV manufacturing. As in California, long-term national energy policy is beginning to focus on the role that FCVs could play in diversifying fuel supplies, reducing GHGs in the transport sector, and in particular providing a new low-carbon fuel for medium and heavy-duty trucks. In their 2013 report entitled *Transitions to Alternative Vehicles and Fuels*,6 the National Research Council assessed the potential of the light-duty fleet to enable an 80% reduction in petroleum consumption and GHGs by 2050, and indicated that FCVs ranked high among the various options. That said, it appears that the federal government is some years away from investing the scale of dollars – variously estimated at $50 billion or more – that could be required to extend a robust FCV fueling infrastructure nationwide. In the meantime, more modest R & D investments are being made in reducing fueling infrastructure costs and further developing promising technologies for producing renewable and lower carbon H2 fuel supplies.

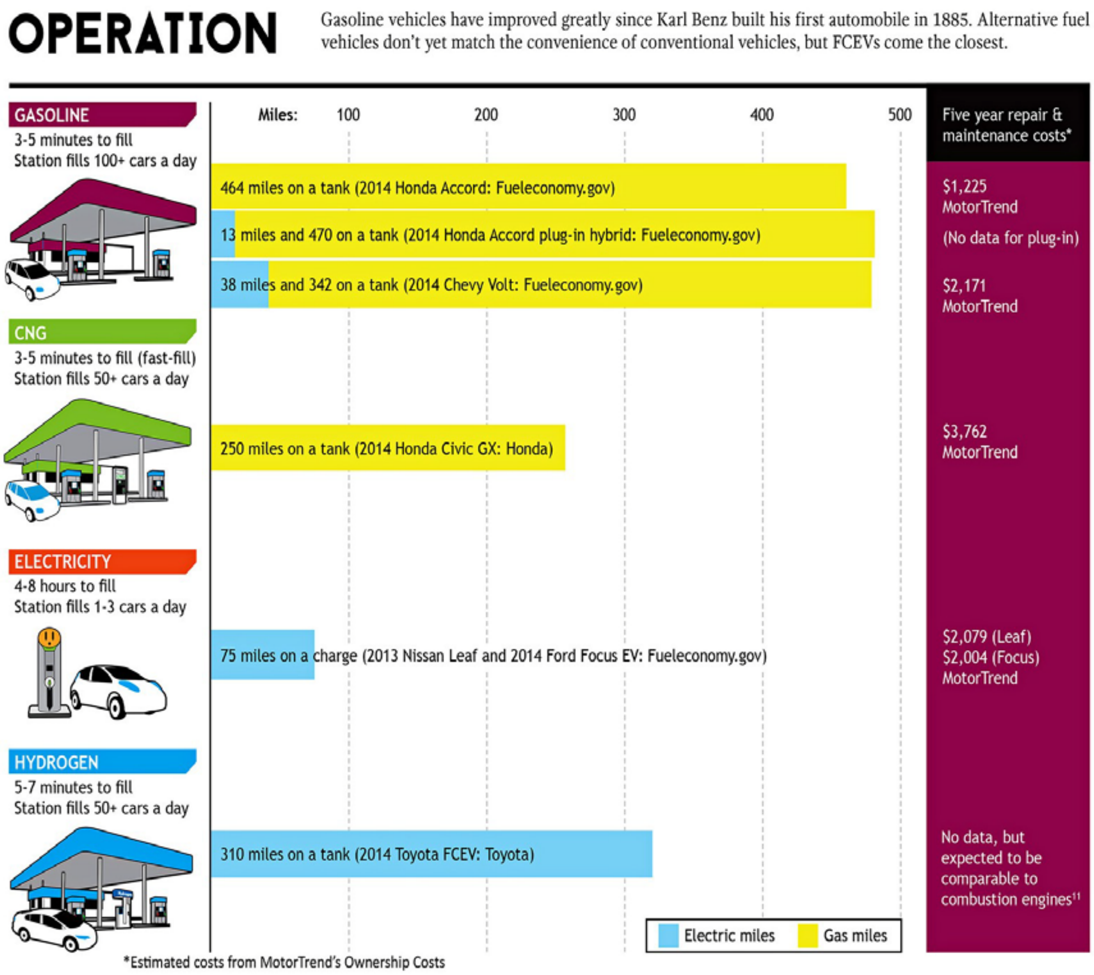
3.7. The Hydrogen Fueling Experience

Hydrogen fueling stations can be co-located with regular gasoline and diesel stations or they can be operated in stand-alone locations. The hydrogen fueling experience is similar in appearance, function, and timing with liquid fuels, although hydrogen fuel is delivered to vehicles in a gaseous state. FCVs are designed to accept hydrogen in gaseous form pressurized at two levels, either 350 bar (5,000 psi) -- known as H35 -- or 700 bar (10,000 psi) – known as H70. Currently, 700 bar (H70) gaseous onboard storage has been chosen for the first generation of commercial vehicles, while 350 bar (H35) is utilized for buses, forklifts, and other lift trucks. A hydrogen dispenser looks similar to a gasoline fuel dispenser and usually has one hose and nozzle for each pressure. Users cannot attach the high-pressure nozzle to a lower pressure receptacle, so there is no chance of fueling at the wrong pressure level. When a driver activates the dispenser, hydrogen flows from the storage tanks and through the nozzle into the vehicle in a closed-loop system. If filling with H70 (the light-duty vehicle standard), the hydrogen passes through a booster compressor and chiller before entering the dispenser. If the nozzle is not correctly attached, fuel will not flow. A full tank of hydrogen—4-6 kilograms—provides range of approximately 300+ miles, which is similar to a conventional ICE vehicle. Stations are designed for unattended operation.

While higher pressure fuel provides more energy density per kilogram of fuel and thus higher driving range, it is also more expensive per kilogram due to the additional cost of higher pressurization. H70 is currently in the range of $3.00-$3.50 per Gallon Gasoline Equivalent (GGE), although it is important to note that these prices reflect the significant operational subsidies now provided by the California Energy Commission to the initial generation of H2 station operators. Future H2 cost projections will be discussed later in this chapter. In recent years, H2 fuel costs have proven more stable than gasoline or diesel. As with conventional gas pumps, the dispensers are designed to accept credit cards and display sales information conforming to state weights and measures requirements. Volume is displayed in kilograms (kg). Fueling time is approximately 5 minutes for upwards of 300 miles of range per tank for a typical light duty vehicle. Like a gasoline dispenser, a hydrogen dispenser typically has two sides, each with a similar interface.

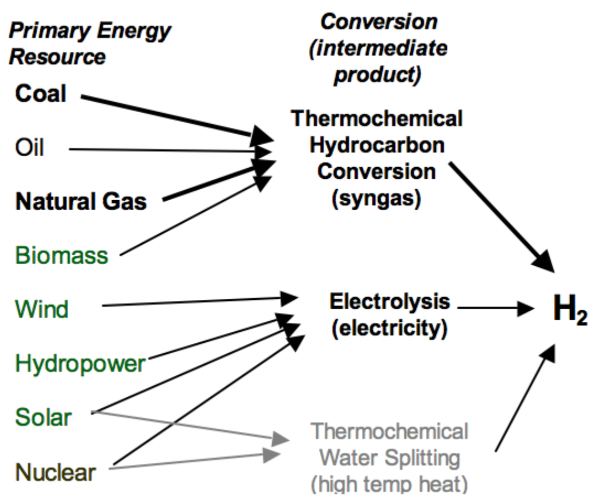
A hydrogen station has multiple safety systems to protect against fire, leakage, or explosion (described in more detail in the safety training section of this chapter). If flame detectors or gas sensors detect a fire or leak, safety measures turn on automatically, such as sealing the storage tanks, stopping hydrogen flow or—in the case of an extreme fire—safely venting the hydrogen. Strategically placed emergency stops will manually shut down hydrogen equipment. Retaining walls, equipment setbacks, and bollards are designed into the site plan to maximize safety.

The following simplified chart from *Motor Trend* magazine describes the H2 fueling experience and FCV operational cost in the context of other alternative fuel types. The expectation of FCV automakers, notably Toyota (which is aggressively marketing hydrogen against pure Battery EVs), is that the more convenient fueling experience will be a decisive factor for consumers unwilling to deal with the inconvenience of slower-to-refuel BEVs. Thus, some market analysts hold that the principal consumer competition in Alternative Fuel Vehicles will be between PHEVs (Plug-in Hybrids), which combine some of the advantages of both EVs and ICEs, and FCVs. Other analysts believe that if expected cost and performance improvements of batteries continue on their predicted course, there will be 200-300 mile range BEVs available in the early 2020s that will be price-competitive with ICEs and less costly than equivalent FCVs. At that point, the need for BEVs to rely on slower public EV charging will be reduced, and the principal advantage of FCVs will be perceived as relatively limited. However, it should be emphasized that at this early stage of market development – with near zero sales data and limited consumer awareness -- all estimates of FCV potential by both policy makers and auto OEMs must be considered to be educated guesswork at best.



3.8. Hydrogen Fuel Production Pathways

Unlike fossil fuels, hydrogen fuel does not occur naturally on Earth and thus is not considered an *energy source;* rather it is an *energy carrier.* Like electricity, hydrogen can be produced from diverse resources by using primary resources – such as coal, oil, natural gas or biomass – to power a thermochemical hydrocarbon conversion that creates an intermediate product known as syngas (or synthesis gas). In the United States, about 9 million metric tons of hydrogen are produced each year by this process, also known as steam reforming, mainly for industrial and refinery purposes. This is the equivalent amount of fuel required to power a fleet of about 35 million fuel cell cars. Steam reforming of natural gas is the most common method of hydrogen production today, accounting for about 95 percent of domestic production. However, as noted in the chart below, other primary energy resources, including renewable resources, can be used to produce hydrogen, with varying costs, environmental impacts, and technical complexity.



Production pathways for hydrogen
Source: *NextSTEPS White Paper: The Hydrogen Transition,* Institute of Transportation Studies, UC Davis, July 29, 2014, p. 15

3.9. Hydrogen Production Using Electricity and Natural Gas

While current hydrogen production is dominated by natural gas feedstocks, hydrogen can be produced with electricity via a process known as electrolysis -- in which an electric current splits water into hydrogen and oxygen. If the electricity used in this process is itself produced from renewable sources, such as solar or wind, the resulting hydrogen gas is considered renewable as well, with a more favorable emissions profile. Because renewable electricity is increasingly available in surplus in California -- typically in the form of excess wind at night and excess solar in the early afternoon -- "power-to-gas" projects are beginning to emerge. These renewable projects have the potential to become more economical as the market for hydrogen grows through expansion of both the fuel cell vehicle market and stationary fuel cell energy production for the grid. The timing of EV charging to respond to these grid surpluses is also expected to be an important part of the state's energy strategy going forward.

Notwithstanding the potential for surplus renewable energy to be dedicated to hydrogen fuel production, studies by the Institute for Transportation Studies at UC Davis indicate that natural gas rather than electricity will continue to be the least expensive and most energy-efficient resource from which to produce hydrogen through the 2020s.[4] Although the full GHG impact of natural gas is still under study (due to new data emerging about methane leakages in the natural gas supply chain),

[4] Joan Ogden, Christopher Yang, Michael Nicholas, Lew Fulton , *NextSTEPS White Paper: The Hydrogen Transition,* Institute of Transportation Studies University of California, Davis, July 29, 2014, p. 15
http://steps.ucdavis.edu/files/08-13-2014-08-13-2014-NextSTEPS-White-Paper-Hydrogen-Transition-7.29.2014.pdf

current estimates suggest that _natural gas based hydrogen fueled vehicles emit approximately half as much GHG as a comparable gasoline car on a well to wheels basis_ (Nguyen et al. 2013). The domestic shale gas boom has been a significant factor in keeping gas prices low, and further boosting policy maker interest in hydrogen. Of course, natural gas is also used as a significant electricity feedstock in California (and thus is an important factor in the emissions profile of both EVs and FCVs running on the standard California "grid mix"). However, FCVs fueled by electricity-produced hydrogen (via electrolysis) as well as EVs using the standard grid mix will benefit from the progressive greening of California's grid. The carbon intensity per kWh of electricity in California will steadily decline as Renewable Portfolio Standards ratchet up from the current 33% by 2020 to 50% or more in 2030 and beyond. That said, the full well-to-wheels calculation of the relative emissions of the two vehicle types must also take into account superior operating efficiencies in EVs, such that EVs will always environmentally outperform FCVs on a well-to-wheels basis, when comparable feedstocks are assessed. These issues are further discussed in Section 3.26 below, *Assessing the Environmental Attributes of Hydrogen Fuels on a Life-Cycle Basis.*

3.10. Onsite Production of Hydrogen Using Electrolysis

In addition to larger-scale "power to gas" projects located at renewable energy generation sites (such as wind or solar farms), hydrogen fueling companies can purchase renewably produced electricity for onsite hydrogen production from their local utility (if they have a renewable tariff) or via use of Renewable Energy Credits (RECs), which represent renewable power injected into the grid at another location. A compact production process can be installed at hydrogen fueling stations, consisting of an electrolyzer, a compressor, and a storage tank. A California company known as HyGen has opened a hydrogen fueling station in Orange County that features this relatively simple onsite hydrogen production process using renewable energy, illustrated in the diagram below. Renewable energy purchased from the utility is used to split water to obtain pure hydrogen, which is held in a buffer tank. Oxygen is the by-product of this process and is released to the atmosphere in the majority of on-site hydrogen stations. The next stage is to compress the hydrogen to pump the gas to storage vessels for delivery to the fuel pump.

Depending on production capacity requirements, the company claims a HyGen system can be installed for as little as $1.5 million, although a station of this size would have the capacity to fuel only up to 100 vehicles/week. Some experts maintain that onsite electrolysis is as much as twice as expensive per kilogram of hydrogen delivered as stations that procure hydrogen using natural gas.[5] However, stations can potentially be upgraded to produce onsite hydrogen as the economics improve. For example, a larger station developed with the support of Hyundai Motors in Chino in

[5] Julia Pyper, "Is electrolysis the pathway to reach totally carbon-free hydrogen fuel?," *Climatewire,* November 20, 2014. http://www.eenews.net/stories/1060009250

early 2015 has been designed to add a fuel cell, but currently uses hydrogen produced by ChevronTexaco from natural gas feedstocks. Like most hydrogen stations open now, operational costs are supported by government funds, in this case a cost-sharing arrangement with the federal Department of Energy. The University of California at Davis recently estimated that production of hydrogen through electrolysis will continue to be significantly more expensive than natural gas (even accounting for future carbon sequestration costs) through 2020[6] and that subsidies will be required for at least the first 5 to 7 years of operation. The California Energy Commission is providing Operations and Maintenance (O&M) funding along with their capital grants in recognition of the reality that FCV deployments will not be sufficient to support breakeven operation of the fueling stations until at least 2020 or later in most regions of the state.

3.11. The Potential to Utilize Excess Renewable Energy in Hydrogen Production

As noted above, a particularly promising way to make hydrogen from electrolysis both cleaner and more economically competitive is for companies to take advantage of surplus renewable energy production. In California, renewable energy currently makes up 20 percent of retail electricity sales and is mandated to reach 33%+ in future years. However, an overproduction of solar and wind during the middle of the day is already forcing the state to "dump" power, i.e., to pay out of state utilities to take power, when there is insufficient aggregate demand. The total amount of power dumped in 2014 was 19 gigawatt-hours of pre-purchased renewable energy, enough to refuel tens of thousands of cars with electrically produced hydrogen or via EV charging. For this reason, the California Public Utilities Commission has coupled their renewable energy mandates with a recent energy storage mandate that requires California utilities to provide 1.325 gigawatts of energy storage capacity. Additionally, utilities are mandated to develop much more robust "demand response" programs that would enable a variety of variable electric loads -- including potentially both Electric Vehicle charging systems, and hydrogen production facilities – to take power from the grid when there is excess energy supply, much of which is likely to be generated by intermittent solar and wind.

As attractive tariffs are established to encourage distributed generation and storage resources to plug into these time of use rates and demand response programs, electrolyzers will become more economical as they utilize this excess generation to make renewable hydrogen. Like a battery storage device connected to the grid, electrolysis is considered a "dispatchable load", which means the hydrogen fuel production system can rapidly adjust its power flow to stabilize electricity demand and supply. According to the National Renewable Energy Laboratory research,

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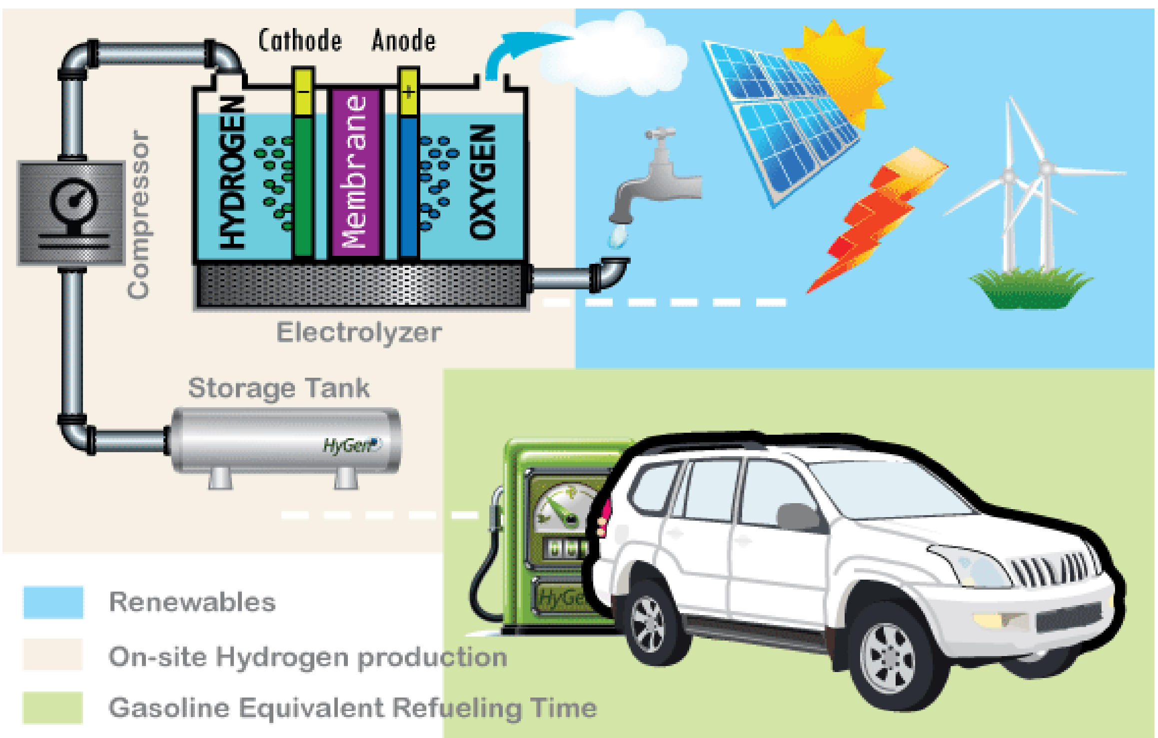
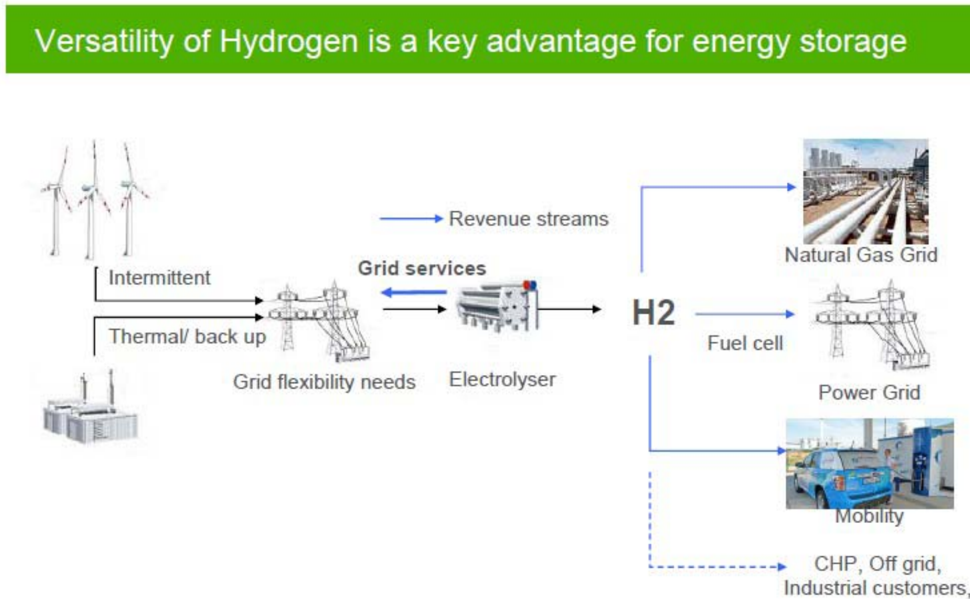
[6] Joan Ogden, Christopher Yang, Michael Nicholas, Lew Fulton , *NextSTEPS White Paper: The Hydrogen Transition,* Institute of Transportation Studies University of California, Davis, July 29, 2014, p. 12
http://steps.ucdavis.edu/files/08-13-2014-08-13-2014-NextSTEPS-White-Paper-Hydrogen-Transition-7.29.2014.pdf

electrolyzers are also able to respond fast enough to offer frequency regulation or ancillary services to the grid, which can provide new sources of revenue for hydrogen fuel producers via payments from California utilities and/or the California Independent System Operator (CAISO). The revenue from energy market participation is not considered sufficient to recuperate all the original investment in a renewable hydrogen project. However, electrolysis systems that offer ancillary services and sell hydrogen fuel will be more economically competitive. Further hydrogen energy storage has one significant advantage over batteries in that it can provide megawatt-hours of energy storage – enough to operate buildings and production facilities for days or even weeks at a time – thank. This capability can effectively turn intermittent renewables into more reliable "base load" capacity. One leading company in this field is Proton Onsite, which will begin distributing a Proton Exchange Membrane (PEM) electrolyzer with the capacity to produce enough hydrogen to store multiple megawatts of renewable energy. The company plans to begin shipping in 2015.





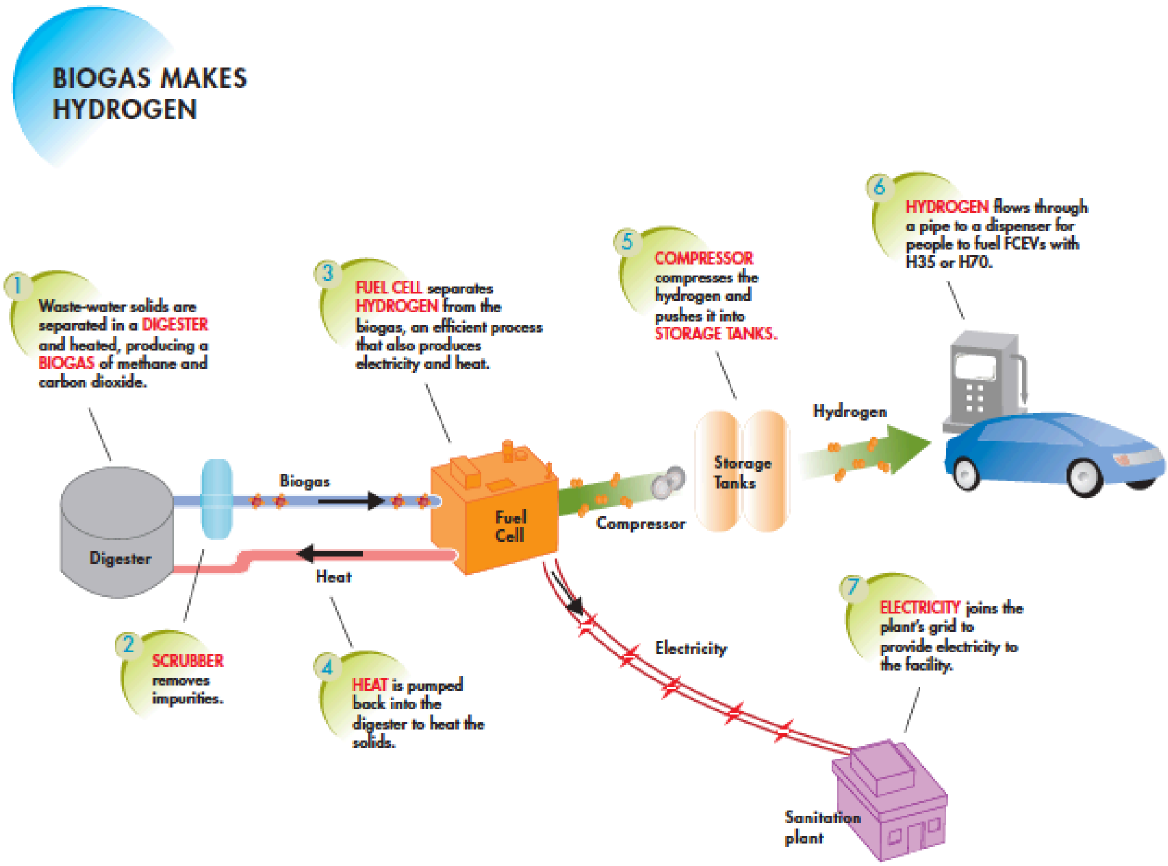
Options for using hydrogen to integrate intermittent renewables on the grid.

Source: P. E. Franc, "Financing Hydrogen Projects" Nov. 16, 2013, International Partnership for a Hydrogen Economy Conference, Seville, Spain.

3.12. Biogas, Biomass, and Coal to Hydrogen Production

Perhaps the most eco-friendly approach to hydrogen production is known as biogas to hydrogen. In this process, wastewater solids enter an anaerobic digester at a wastewater treatment plant. Microbes convert the waste into a biogas (CH_4) similar in composition to natural gas, but with more impurities. A scrubber removes many of the impurities, including carbon and sulfur. The purified biogas then enters a stationary fuel cell where heat and water vapor separate CH_4 into hydrogen and carbon dioxide. Separating the gas creates heat and water vapor, which is used to power the reaction in the fuel cell. Excess heat goes back into the digester. The fuel cell also produces electricity that can be sent to the grid. Hydrogen enters additional cleaning processes and is then compressed and stored for distribution via underground pipelines to a public station.

From well to wheels, a biogas system creates net zero greenhouse gases, virtually zero criteria pollutant emissions, and makes commercial use of hazardous waste. Because of the many environmental virtues of biogas to hydrogen production, the California Energy Commission is particularly interested in supporting such projects, and has invested in several throughout the state. Of course, the total amount of H_2 fuel that can be produced through this method is limited by the finite size of the waste stream, and hydrogen suppliers must compete with other productive uses of bio-waste, such as composting for use in agriculture and soil carbon sequestration.



Source: California Fuel Cell Partnership

A final method of creating hydrogen is known as syngas or synthesis gas. Syngas can be created by reacting coal or biomass with high-temperature steam and oxygen in a pressurized gasifier -- through a process called gasification. The resulting synthesis gas contains hydrogen and carbon monoxide, which is reacted with steam to produce more hydrogen. This approach is much less common than steam methane reforming with natural gas or other methods and is not yet viewed as cost competitive.

3.13. Distributing Hydrogen to Fueling Stations

Currently, most hydrogen is transported from the point of production to the point of use initially via pipeline, rail, or barge, with final over the road delivery by truck. As noted earlier, hydrogen can be delivered in either gaseous or liquid form before being converted to a gas and compressed to the appropriate pressure for final delivery to the car. Gaseous hydrogen is delivered by swapping storage trailers packed with fuel tubes, which are permanently mounted on the trailer. The driver opens the gate around the storage area, backs in a full trailer and connects it to the dispensing system. The driver then disconnects the empty tube trailer, hooks it to the tractor and drives away. Swapping trailers can take between 10 and 30 minutes. By contrast, liquid hydrogen is delivered by a tanker truck that looks much like a gasoline tanker. Because liquid hydrogen is at a cryogenic temperature, a vapor cloud often forms around the transfer point. Filling the storage tank typically takes around 30 minutes, depending on the size of the tank.

The location of hydrogen production has a significant impact on the cost of fuel, and on the choice of delivery methods to locally sited stations. A large, centrally located hydrogen production facility can produce H2 fuel at a lower cost, but a longer trip to final delivery can eliminate this cost savings. Local or on-site production facilities will typically reduce delivery costs while raising production costs.

Developing a ubiquitous hydrogen fueling infrastructure across the state (and ultimately, across the nation) poses significant challenges in the near-term. These include reducing delivery cost, increasing energy efficiency, maintaining hydrogen purity, and minimizing hydrogen leakage. Further research is underway to analyze the trade-offs between hydrogen production and delivery options when considered as a complete system. To address these challenges, the National Renewable Energy Laboratory and Sandia National Laboratories have announced the *Hydrogen Fueling Infrastructure Research and Station Technology (H2FIRST)* project – which is designed to reduce the cost and time of fueling station construction, increase station availability, and improve reliability.

The California experience with deployment of H2 fueling stations at scale, along with ongoing R&D, will eventually produce an economically and environmentally optimized formula for hydrogen production, distribution, and delivery. However, this optimized system is some years away. The initial generation of station operators and H2 stakeholders must choose among many alternative production and distribution pathways now available, with a variety of economic and technology profiles. The chart below highlights key advantages of each production and distribution approach.

The first choice facing operators is on-site production vs. delivery of fuel produced at a distance. The second key choice is delivery of H2 in either liquid or gaseous form. If the fuel is delivered in liquid form, it must be converted to a gas using onsite equipment, and both liquid and gaseous storage facilities are required. On-site production can lower delivery costs, while using less environmentally friendly natural gas or the standard California "grid mix" of electricity. Use of on-site renewables (such as solar) to power the electrolysis process, potentially in combination with battery energy storage, is environmentally preferably but requires a larger station footprint and may not be economically feasible at the current time. (Pathways for increasing the production of renewable hydrogen are discussed in more detail later in this chapter). The chart below illustrates the tradeoffs involved in the range of production and delivery options currently available.

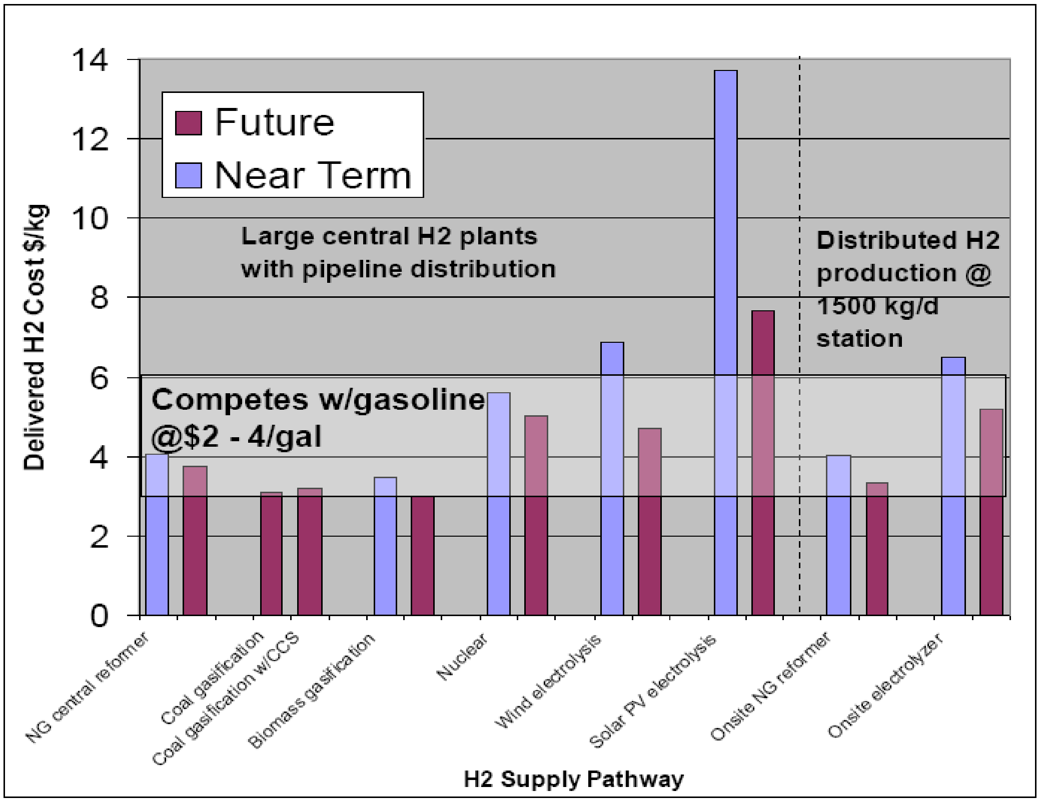
Comparison of Hydrogen Fuel Delivery Methods: Advantages vs. Disadvantages			
Method	**Equipment at Station**	**Advantages**	**Disadvantages**
Liquid Delivery	▪ Liquid storage tank ▪ Heat exchanger ▪ Compressor ▪ Gaseous storage ▪ Booster compressor ▪ Chiller ▪ Dispenser	▪ Can store more fuel	▪ Much larger footprint ▪ Potential for fuel to boil off ▪ Expense of two types of storage tanks (liquid & gaseous)
Gaseous Delivery	▪ Gaseous storage ▪ Compressor ▪ Chiller ▪ Dispenser	▪ Smaller footprint than liquid ▪ Equipment can be in various locations	▪ Least amount of storage capacity without multiple trailers/ storage tubes
On-site Electrolysis	▪ PV or wind system (optional) ▪ Water purifier ▪ Electrolyzer ▪ Compressor ▪ Gaseous storage ▪ Booster compressor ▪ Chiller ▪ Dispenser	▪ Make fuel on site ▪ Potential to sell carbon credits	▪ More equipment ▪ Larger footprint ▪ Can be more expensive
H2 from Pipeline	▪ Scrubber ▪ Gaseous storage ▪ Booster compressor ▪ Chiller ▪ Dispenser	▪ Larger capacity ▪ Can require less storage	▪ Station must be near ▪ pipeline ▪ More equipment ▪ Larger footprint
On-site Reforming	▪ Natural gas or biogas supply ▪ Scrubber ▪ Water purifier	▪ Make fuel on site ▪ Potential to sell carbon	▪ More equipment ▪ Larger footprint ▪ Can be more expensive

	▪ Reformer ▪ Compressor ▪ Gaseous storage ▪ Booster compressor ▪ Chiller ▪ Dispenser	credits	

Hydrogen Fuel and Station Companies and Suppliers: Of course, final decisions regarding H2 fueling infrastructure will involve both private station developers, state funders, and relevant permitting authorities. Local planners and permitting authorities are encouraged to reach out both to the California Fuel Cell Partnership for more information on local options for H2 fueling production and delivery infrastructure, as well as directly to the companies in the field. Key market actors in California including industrial gas companies such as Air Liquide, Air Products, and Linde, which provide equipment, design and construction of stations. Proton OnSite makes electrolyzers and SunHydro branded stations. Hydrogenics and Powertech also provide equipment. Two new start-up companies, First Element and Hydrogen Frontier, are designing stations and providing equipment, with Irvine-based First Element having recently won a very large contract with the CEC for installation of multiple stations, including the first station in City of Santa Barbara.

3.14. Future Hydrogen Fuel Costs and Pathways

The long-term success of the hydrogen project will be based in significant measure on the development of a low-cost, low-carbon, high-capacity hydrogen fuel supply chain. The extraordinary versatility of both the production and distribution pathways for hydrogen provide many options for stakeholders to advance the availability of hydrogen where regional clusters of stations will be located. As in the case of electricity, it is likely that diverse primary sources will be used to make hydrogen in different regions of the state. The chart below indicates the relative costs of various production pathways, based on a definitive 2014 study by the UC Davis Institute for Transportation Studies. Note that the chart illustrates the delivered cost of hydrogen for a variety of future supply pathways, *after large-scale deployments have enabled scale economies for all the fuel production approaches.* It is important to note that these cost projections do <u>not</u> reflect current pricing available in 2015-2017. It is also important to note that biomass may not be scalable beyond the early years of FCV deployment, due in part to competing uses.



Delivered Cost of Hydrogen: The grey shaded area indicates where the fuel cost per mile for hydrogen FCVs would compete with a gasoline hybrid. Costs assume that hydrogen supply technologies are mature and mass-produced. **Source:** *NextSTEPS White Paper: The Hydrogen Transition,* Institute of Transportation Studies, UC Davis, 2014.

3.15. The Business Case for Developing Hydrogen Fueling Stations

The California Energy Commission, CARB, and the California Fuel Cell Partnership have worked closely together to develop a "cluster strategy" for H2 stations, based on the idea of co-locating the first several thousand vehicles and tens of stations in likely early adopter areas within the state's larger metro areas (especially the South Coast, Bay Area, and San Diego). In the Southern California region, it was found that average travels times to stations of less than 4 minutes could be achieved with a relatively sparse initial regional network, amounting to less than 1% of gasoline stations. Targeted clusters represent only a fraction of the California population but reflect specific areas where fuel cell adoption is most likely. The table below illustrates a possible scenario for the 7-year FCV rollout and hydrogen station development in Southern California, based on the state's proposed cluster strategy. By year 7 the system serves 34,000 FCVs with a network of 78 stations.

Illustrative Regional Deployment of Hydrogen Stations Relative to FCVs							
	Year 1	*Year 2*	*Year 3*	*Year 4*	*Year 5*	*Year 6*	*Year 7*
# FCVs in fleet	**197**	**240**	**347**	**1,161**	**12,106**	**23,213**	**34,320**
H2 demand (kg/d)	**137**	**168**	**250**	**800**	**8,500**	**16,000**	**24,000**
# New Stations Installed per year by Station Size (kg/d) and Type							
Mobile Refuelers (100kg/d)	**4**	**0**	**0**	**0**	**0**	**0**	**0**
Compressed Gas Truck Deliveries/Station Size							
170 kg/d	**0**	**0**	**4**	**0**	**0**	**0**	**0**
250 kg/d	**0**	**0**	**0**	**10**	**0**	**0**	**0**
500 kg/d	**0**	**0**	**0**	**0**	**20**	**20**	**20**
Total station capacity (kg/y)							
	400	**400**	**1,080**	**3,580**	**11,580**	**21,580**	**31,580**
Total number of stations							
	4	**4**	**8**	**18**	**38**	**58**	**78**
Average travel time home to station (minutes)							
	4	**4**	**3.5**	**3**	**2.8**	**2.6**	**2.6**

Source: *NextSTEPS White Paper: The Hydrogen Transition*, Institute of Transportation Studies, UC Davis, July 2014, p. 25

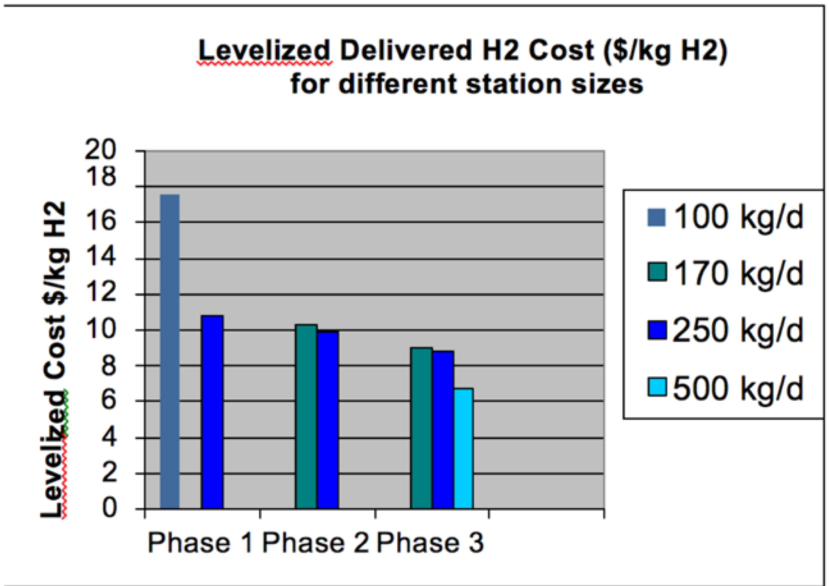
In the scenario illustrated above, hydrogen is supplied via truck delivery, building on the current industrial gas supply system -- and the hydrogen is largely derived from natural gas or industry by-products. Initially, hydrogen is supplied via mobile refuelers, a small-scale portable station incorporating storage and dispensers that can be towed to any site. After several years, a network of small fixed stations (170 kg/day) is established to ensure coverage, and as demand rises, larger stations (250 kg/d and then 500 kg/d) are added to the network. To put these quantities in perspective, a mid-size FCV consumes approximately 0.7 kg of hydrogen per day on average (if it is traveling 15,000 miles per year in a 60 mpg equivalent car). This would require a station capacity of perhaps 1 kg per day per FCV served, accounting for 70% station utilization. So a 100 kg/d station might serve a fleet about 100 FCVs, and a 500 kg/d stations about 500 FCVs.

The charts below illustrate both the capital cost and the estimated levelized cost of hydrogen assuming the stations are operated at their rated capacities (e.g., 100 kg/d, 170 kg/d 250 kg/d or 500 kg/d). Note that hydrogen fuel costs become more competitive as station technology develops and larger stations are deployed.

California Hydrogen Station Cost Model		
Time frame	**Capital Cost**	**Annual O&M cost $/yr**
Phase 1 (years 1-2) **100 kg/d** **250 kg/d**	**$1 million** **$1.5 million**	**$100 K (fixed O&M) +** **1 kWh/kgH2 x kg H2/yr x $/kWh (compression electricity cost)** **+ H2 price $/kg x kg H2/y**
Phase 2 (years 3-4) **170 kg/d** **250 kg/d**	**$0.9 million** **$1.4 million**	
Phase 3 (year 5+) **170 kg/d** **250 kg/d** **500 kg/d**	**$0.5 million** **$0.9 million** **$1.5-2 million**	

Assumptions: Truck gas delivery. 700 bar dispensing. Stations built at least 12 months prior to FCV deployment in significant numbers. **Source:** *NextSTEPS White Paper: The Hydrogen Transition,* ITS, UC Davis, July 2014, p. 26

In the UC Davis analysis, cash flow for station operators is negative initially, but after about year 7, it becomes positive. By year 9, the cumulative cash flow become positive as well, and the network can pay for itself, even though the initial years show a negative balance. The total capital investment for the proposed 78 station regional cluster in Southern California is about $113 million. H2 costs to enable station owners to earn a 12% rate of return are estimated below.

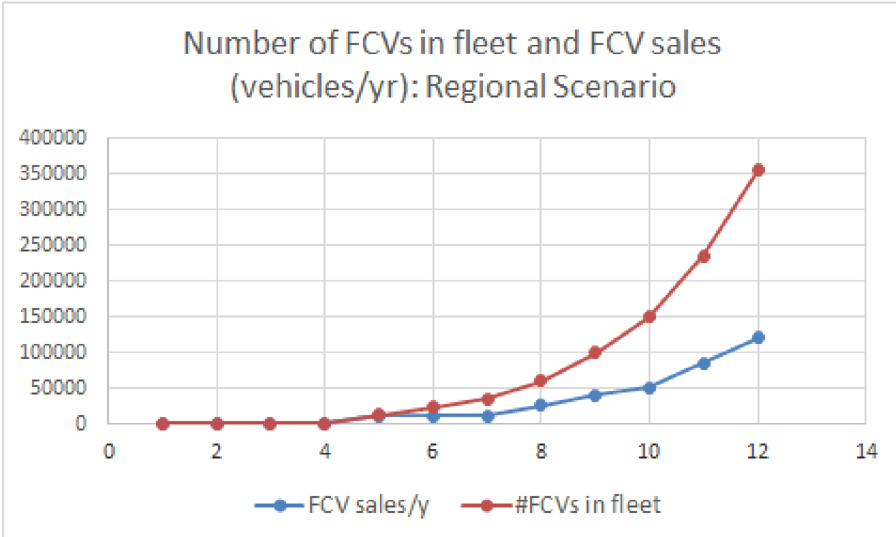


Source: *NextSTEPS White Paper: The Hydrogen Transition,* ITS, UC Davis, July 2014, p. 26

The assumptions in the cost model above include the following:

- Compressed hydrogen costs $6/kg truck-delivered to the station
- Rate of return = 12%
- Station life is 10 years
- The levelized cost is what the station would have to sell hydrogen for to make a 12% rate of return
- Stations dispense a fuel amount equal to their full capacity
- H2 costs decline due to reductions in capital costs and increased output.

If the FCV market accelerates rapidly, the UC Davis study indicates that larger (500 kg/d) station will have a business case that should attract investors. Whereas the earlier smaller stations (100 - 250 kg/d) involve more risk if FCV deployment is slow. The scenario sketched below illustrates a potential relationship between FCVs in the fleet, annual FCV sales, the total number of hydrogen stations in the network, and the average size of new stations likely to be built each year. This assumes that the Southern California regional FCV fleet grows rapidly from 34,000 in year 7 to 250,000 FCVs in year 11. In year 11, the on-road FCV fleet would be about 1% of all existing light duty vehicles in California, while new FCV sales would be ~6% of the state's annual light duty vehicle sales. (Ogden and Yang 2009). This is similar proportionately to the early growth rate for HEVs in the United States.



Deployment Scenario for regional FCV sales (Year 1 = start of commercialization/2016). **Assumptions**: After year 4, stations employ compressed gas truck delivery (500 kg/d) or onsite steam methane reformation (1000 kg/d). H2 costs at the pump are $5-8/kg -- competitive with gasoline vehicles on a cent per mile basis. **Source:** *NextSTEPS White Paper: The Hydrogen Transition,* ITS, UC Davis, July 2014.

In the Southern California regional model developed above, in year 9, 100,000 FCVs are on the road, served by 200 stations, hydrogen costs about $7.1/kg and the cumulative station capital investment is about $300 million. Approximately $150-300 million is needed to build the first 100-200 stations, serving 50,000-100,000 vehicles. According to this analysis, once this level of FCV and station deployment is reached, there will be a self-sustaining (no subsidy needed) economic case for building larger stations, assuming the market for FCVs continues to grow.

3.16. The Hydrogen Driving Experience

Fuel cell vehicles offer performance, range, and refill time similar to conventional gasoline vehicles, yet drivers also benefit from the quiet operation, zero tailpipe emissions, and power characteristics of battery electric vehicles. FCV acceleration is generally adequate (from 9 to 12 seconds for 0-60 times among first generation vehicles), and they cruise readily at highway speeds. Their MPG equivalent (MPGe) is approximately 50 to 70+ MPGe for a standard sedan. For example, the four-door Toyota Mirai sedan was recently EPA rated at 67MPGe, while the compact SUV Hyundai Tuscan has been rated at 50 MPGe . The more comprehensive measure of “well to wheels” energy efficiency is based on energy inputs across the entire fuel chain (from production, distribution, to end use) and depends on a variety of factors related to hydrogen feedstocks and production methods. The driving range of FCVs is also similar to combustion vehicles, 230-400 miles is typical depending upon the vehicle’s tank capacity. On the interior, FCVs are comparable to similarly sized EVs or ICEs. The controls are all familiar, although the dashboard gauge displays kilowatts instead of RPMs. Like EVs, the operation of FCVs is noticeably quieter than many ICEs.

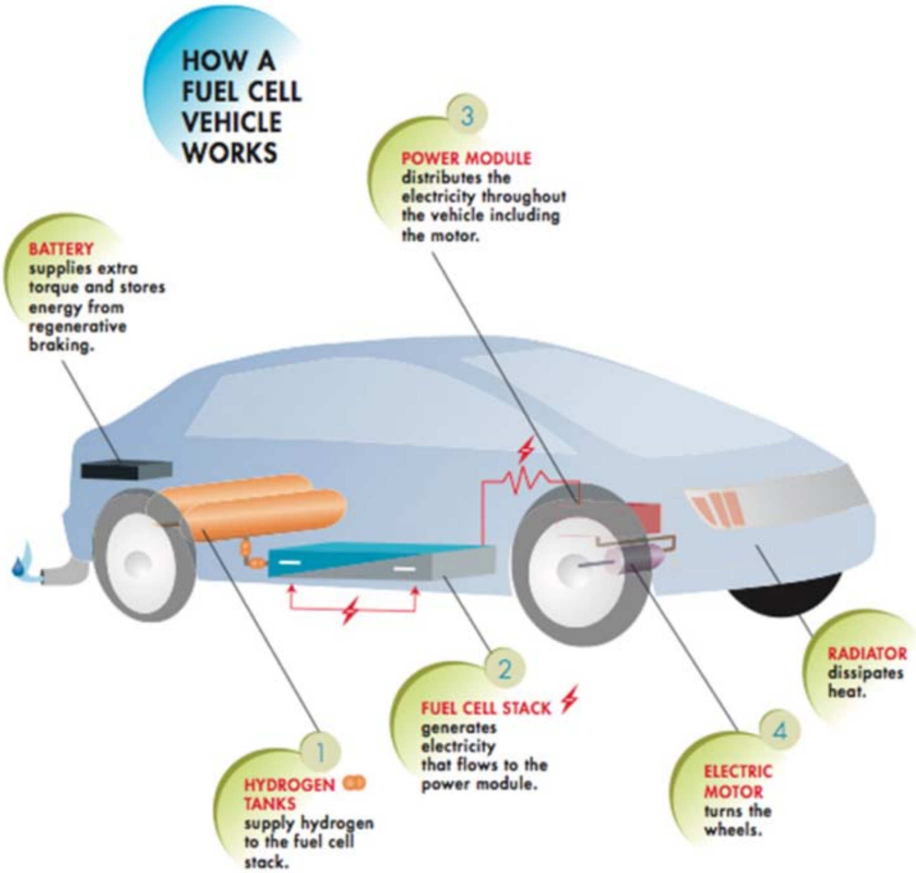
Off-board Power Options: Some FCVs will provide outboard power for appliances or potentially to power an entire home for a limited time period. The Toyota Mirai has an optional "power takeoff" DC outlet that allows the owner to draw power off of the fuel cell via an adapter module. On a full charge, the car provides up to 60 kWh to a home in case of a grid outage, which can potentially provide up to six days' worth of energy for a typical California residence.

Safety: Automakers and federal agencies have conducted extensive safety testing at the component, system and vehicle level. FCEVs have several safety systems designed for hydrogen and electric drive to protect passengers and first responders in case of an accident. FCEVs have been in real-world accidents and all performed as designed with safety rating equivalent to ICE vehicles. There have been no known catastrophic failures of hydrogen fueling equipment for vehicles.

Basic Operation of a Fuel Cell Vehicle: The California Fuel Cell Partnership has provided the following description of a typical FCV operation, which utilizes a proton exchange membrane (PEM) fuel cell.

Fuel cells create electricity from reactants stored externally. A proton exchange membrane (PEM) fuel cell uses hydrogen and oxygen as the reactants. In its simplest form, a PEM fuel cell is two electrodes— the anode and the cathode—separated by a catalyst-coated membrane. Hydrogen from the vehicle's storage tank enters one side of the fuel cell stack and air on the other side. The hydrogen is naturally attracted to the oxygen in the air. As the hydrogen molecule moves through the stack to get to the oxygen, the catalyst forces the hydrogen to separate into electron and proton. The proton moves through the membrane and the electron moves to the anode. The electricity flows into a power module, which distributes electricity to the electric motor that turns the wheels of the car. The power module also distributes electricity to the air conditioning, sound system and other on-board devices. At the cathode, the electron recombines with the proton, and the hydrogen joins with the oxygen to create the vehicle's only tailpipe emission—water. Fuel cells produce electricity as long as fuel is supplied. Credit: California Fuel Cell Partnership: http://www.fuelcellpartnership.org/carsandbuses/howitworks

The following diagram describes the workings of the various key components of a Fuel Cell Vehicle.


HOW A FUEL CELL VEHICLE WORKS
3
POWER MODULE
distributes the electricity throughout the vehicle including the motor.
BATTERY
supplies extra torque and stores energy from regenerative braking.
2
FUEL CELL STACK
generates electricity that flows to the power module.
1
HYDROGEN TANKS
supply hydrogen to the fuel cell stack.
4
ELECTRIC MOTOR
turns the wheels.
RADIATOR
dissipates heat.

3.17. Fuel Cell Vehicle Gallery

FCVs are currently available in sizes ranging from compact to intermediate to SUV and transit buses. Several of the leading models are pictured below.

First Generation Fuel Cell Vehicles Available in California

 **Honda FCX Clarity**	 **Mercedes-Benz B-Class F-CELL**
 **Toyota Mirai (FCV)**	 **Hyundai Tucson Fuel Cell**
 **AC FCV Transit buses**	 **SunLine Transit buses**

3.18. FCV Performance Relative to Electric Vehicles

From a technical standpoint, Fuel Cell Vehicles are considered to be a form of Electric Drive vehicle (and thus are often referred to as FCEVs or Fuel Cell Electric Vehicles.) However, consumers are likely to view FCVs in their own category, given their unique performance characteristics (fast fill-up, limited fueling infrastructure, highly differentiated technology.) Thus, a key issue for consumer adoption is how consumer perspectives on FCVs will compare to both plug-in hybrid electric vehicles (PHEVs) and battery electric vehicles (BEVs.) EVs clearly have a head start in consumer awareness, cost competitiveness, and infrastructure deployment. The following table compares the attributes of these vehicle types from a consumer perspective.

Comparison of Key Consumer Attributes of Fuel Cells and Plug-in Vehicles

	Hydrogen Fuel Cell Vehicles	**Plug-in Hybrid and Battery Electric Vehicles**
Refueling time	Shorter (3-5 minutes)	Longer (20 min to many hours), PHEV can refuel gasoline quickly
Vehicle sizes	Small to large vehicles	Small to midsize vehicles
Vehicle range	300+ miles per refill	10-200 miles of all electric range
Refueling paradigm	H_2 stations similar to gas stations	Chargers (home and public)
Fuel cost per mile	\$0.13/mile at \$8/kg H_2 \$0.08/mile at \$5/kg H_2	\$0.04/mile at \$0.12/kWh

Given the current market position of electric vehicles, under which circumstances might a consumer choose an FCV relative to a BEV? Given current battery costs, BEVs may be best suited for smaller commuter vehicles with localized driving patterns that fit within the vehicle's range, especially in a multi-car household. As more diverse FCV models are introduced, these could be particularly advantageous for drivers needing larger cars, light trucks, and SUVs, whose driving range is greater, and for whom fast refueling is critical. FCVs might also appeal to those who cannot charge an electric vehicle at home.

As noted in the UC Davis study, FCV sales are dependent on these diverse market factors and market actors:

- ***Vehicle costs*** – purchase prices, fuel prices, and incentives *(set by automakers, fuel providers, and government)*
- ***Consumer utility and convenience*** – vehicle characteristics, performance, range and availability of refueling locations *(determined by automakers and fuel providers)*
- ***Infrastructure availability*** – expansion of hydrogen station deployment to additional regions *(supported by automakers, fuel providers, and government)*
- ***Technology & environmental factors*** – future FCV technology, performance vs. other vehicle types, and environmental benefits *(automakers and government.)*

3.19. Future Fuel Cell Vehicle Product Diversity and Availability

Light duty fuel cell vehicles are becoming commercially available in 2015-16. FCVs will grow in product diversity and decline in costs in the period through 2020 as more manufacturers bring vehicles to market, in part to fulfill the Zero Emissions Vehicle (ZEV) mandates of CARB, which provide significant additional “compliance vehicle” credits for FCVs relative to Plug-in Electric Hybrid and Battery Electric Vehicles. While it is difficult to accurately predict specific manufacturer introductions, it is expected that Toyota, Hyundai, and Honda will all be putting vehicles into the market in the next two years. Toyota is expected to have its Murai in eight dealerships statewide (including Santa Barbara) by late 2015. Hyundai is providing a small number of vehicles into Southern California dealerships late in 2015, while Honda plans to release an FCV in Japan in March 2016 and in America later that year. Mercedes is operating a limited pilot program in 2015-16 with their B-Class FCV. BMW and Audi have demonstrated FCVs and plan to enter the market in future years, with BMW announcing plans for commercializing their FCV after 2020. A total of eight automakers have announced plans for FCVs, including Toyota, Hyundai, Honda, BMW, Daimler, Ford, GM, and VW Group.

Introductory FCV Pricing: Initially, most FCVs are being leased rather than sold. A typical scenario is the new Hyundai Tuscan, which is currently being offered via a three-year closed end lease at $499/month after a $4,000 signing deposit (including incentives). The Toyota Mirai is priced at nearly identical levels. Both include free fueling for three years. The purchase pricing for the Mirai has been set at $58,325; before incentives. However, Toyota projects that about 90% of Mirai customers will choose the $499-per-month lease with approximately $3700 due at signing as of mid-2015. The current Mirai package deal includes roadside assistance, three years of vehicle maintenance, eight years or 100,000 miles of warranty coverage for fuel-cell components, as well as the complimentary fuel for three years. Still unanswered are questions regarding longer-term maintenance and replacement costs for the fuel-cell powertrain and supporting hardware, and how much hydrogen will cost in future years.

FCV Technology and Cost Outlook: Hydrogen fuel cell vehicles have already met the 2015 performance goals set by the U.S. Department of Energy (DOE) for fuel economy and range (see the table below). However, further development is ongoing to reduce costs and enhance performance and durability on key component technologies such as the core proton exchange membrane (PEM) fuel cell technology, hydrogen storage on vehicles, and technologies for renewable and low-carbon hydrogen production. Given the pace of previous advances in H2 technologies, it is anticipated that FCVs will meet the additional DOE goals outlined below, and significantly enhance the performance of FCV products.

Department of Energy Performance Goals for Fuel Cell Vehicles

Goals	2013 Status	DOE Goals
Fuel Cell In-Use Durability (hours)	2500 (on-road) 4000 (in lab)	5000
Vehicle range (miles/tank)	280-400	300
Fuel Economy (miles/kg H2)	72	60
Fuel Cell Efficiency	53-58%	60%
Fuel Cell System Cost[7]($/kW) in large scale mass production	$55	$40 (2020 goal) $30 (long term goal)
H2 Storage Cost ($/kWh)	$15-23	$10-$15 (NRC 2009) $2-$4 (USDOE)

Source: S. Satyapal, United States Department of Energy, presentation 2013.

The projected mass-produced cost of FCV fuel cell systems has dropped more than 50% since 2006. However, the actual costs to manufacture FCVs in the early years of deployment are likely to continue exceeding the selling price, depending on internal accounting for the costs of development and production ramp-up. This is typical for many new vehicle technologies, including conventional hybrids and EVs. However, manufacturers have made an effort to price FCVs within range of an equivalent conventional vehicle after incentives, and these pricing policies are likely to continue while mass market volumes ramp up.

Most studies project that future mass-produced fuel cell cars will be somewhat more expensive than an advanced gasoline car (reflecting the light-weighting and other strategies that OEMs must pursue to meet federal fuel mileage standards). For example, in a 2008 National Academies study, mass-produced, mature technology FCVs were estimated to have a retail price equivalent (RPE) $3,600 to $6,000 higher than a comparable gasoline internal combustion engine vehicle. (Retail Price Equivalent reflects actual production costs, whereas showroom pricing may vary if manufacturers choose to subsidize the price to build market awareness and volume for a new technology.) Similar numbers were estimated by MIT, UC Davis, the National Renewable Energy Laboratory, Argonne National Laboratory, and the Electric Power Research Institute.

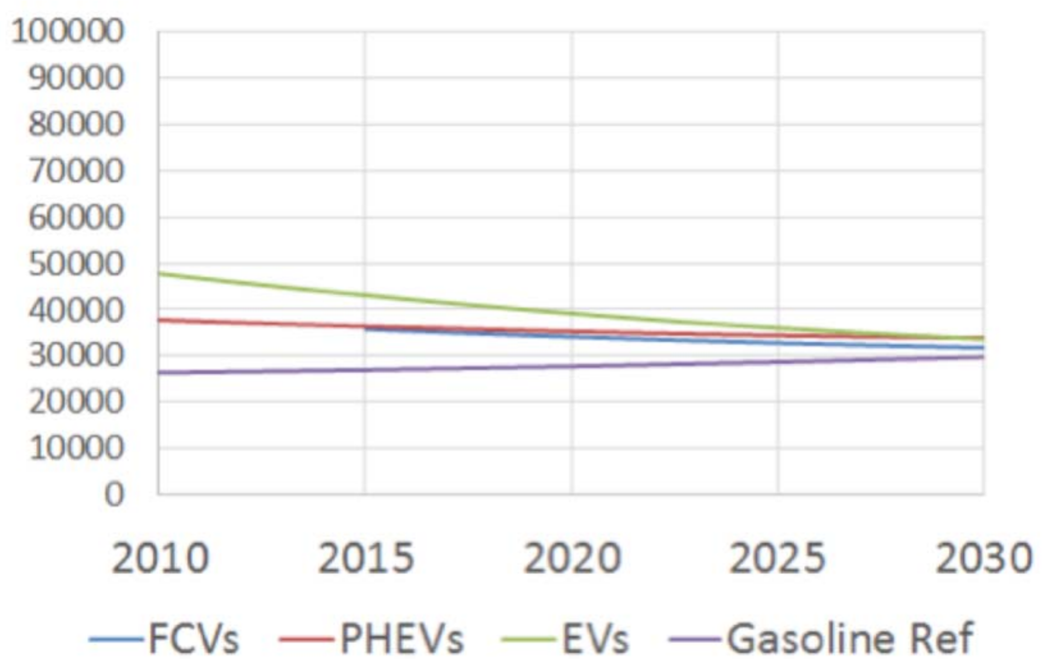
3.20. Future Pricing of FCVs vs. EVs and Conventional Vehicles

Of course, FCVs and EVs are not the only advanced vehicles that will be in the market in coming years. Conventional gasoline-powered vehicles will also be incorporating higher-cost new technologies to meet stringent mileage and emissions standards. Plug-in hybrid technologies will proliferate across all model lines. Among others, VW and BMW have indicated that PHEVs will likely be offered across all model types, and most other automakers will be forced in this direction to comply with U.S. and European fuel economy and environmental regulations.

In 2013, a new National Research Council report provided updated estimates for future vehicles that will incorporate advanced light-weighting and efficiency strategies. The reference gasoline car achieves a fuel economy of about 50 mpg by 2030 and 75 mpg by 2050, albeit at higher cost than today's vehicles. As a consequence of these trends, in the 2030 – 2045 timeframe, ***both fuel cell and battery vehicles are projected to have <u>lower</u> retail prices than these advanced gasoline vehicles.*** This finding underscores the importance of building adequate infrastructure for both EVs and FCVs.

The table below illustrates projected pricing for battery electric vehicles (BEVs), plug-in hybrid vehicles (PHEVs) and hydrogen fuel cell vehicles (FCVs) between 2010 and 2030, as compared to a highly efficient gasoline internal combustion engine vehicle (NRC 2013). A "base case" projection shows cost parity in 2045, while the more optimistic projection suggests 2030 for all three vehicle types. However, this study was criticized by many EV advocates and independent analysts as exhibiting an overly optimistic assessment of future FCV pricing and an overly pessimistic assessment of EV pricing and performance. As of 2015, the NRC model is showing some of these alleged flaws -- insofar as the NRC projected a 100 mile BEV in 2015 would be priced almost $10K higher than FCVs, whereas actual pricing in 2015 is in the mid $30K range for 100 mile BEVs vs. the mid $50K range for equivalent FCEVs. Likewise, in the NRC projection, PHEVs were expected to be at price parity with FCEVs in 2015, whereas in fact a Chevy Volt PHEV is ~$20K less than a comparable FCEV. That said, the NRC report gives insight into the strongly pro-hydrogen orientation of many federal and state policy makers.

Retail Price Equivalent Projections for FCVs, EVs, PHEVs, & Gasoline Cars



Assumptions: All cars will be at mass production levels. The BEV is assumed to have a 100 mile range. The PHEV is assumed to have a 30 mile all electric range.

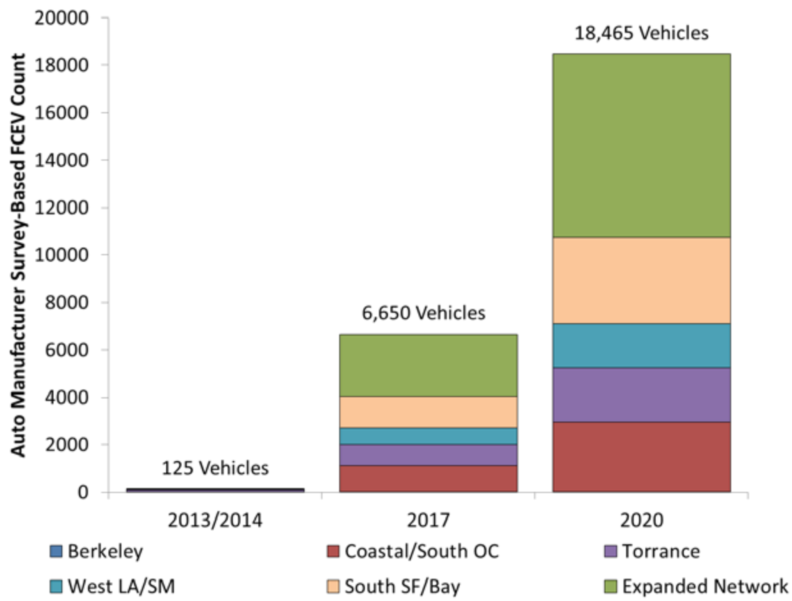
Source: *NextSTEPS White Paper: The Hydrogen Transition,* ITS, UC Davis, July 2014, p. 13.

3.21. California Fuel Cell Vehicle Sales Projections

Given the novelty of FCV technology, and the nascent state of fueling infrastructure, California sales estimates have been low for the 2015-2020 period, and difficult to assess thereafter. For example, Toyota expects only about 200 early adopters in the first year of sales (2015-2016), ramping up to approximately 3000 total on the roads by the end of 2017. While a variety of automakers have announced that they will be ready to produce thousands or even tens of thousands of vehicles beginning over the next few years *if demand warrants,* none have publicly projected how many cars will produced or where they will be deployed.

One of the most recent public estimates for regional FCV introduction was developed based on a 2014 OEM survey conducted by the California Air Resources Board (see table below). The Air Board distributed mandatory surveys to 16 auto manufacturers requesting information on planned deployment of FCVs in the five geographic "clusters" used by CARB and CEC to plan FCV infrastructure. As noted earlier, these clusters include the San Francisco Bay Area, Sacramento Area, Los Angeles/Orange County/Ventura, San Diego, and "Other" (encompassing the rest of California). Auto OEMs forecast a rapid acceleration in the number of vehicles coming to California beginning in 2015 and sustaining growth at least to 2020 (the last year included in the survey). According to the OEMs, by 2017 the state's fleet is expected to grow to more than 6,600 vehicles and, by 2020, to nearly 18,500 vehicles. For the Central Coast and South Orange County areas, the vehicle projections are approximately 1,000 FCVs in 2017, and ~3,000 by 2020.

Current and Projected Cumulative FCV Deployment in California



Source: California EPA, California Air Resources Board, *Annual Evaluation of Fuel Cell Electric Vehicle Deployment and Hydrogen Fuel Station Network Development*, June 2014, p. 4.

Because there is very little sales history for FCVs, estimates of future sales in general, and sales beyond 2020 in particular, are exceedingly difficult to project. Many of the goals set forth by both manufacturers and policy makers may be considered aspirational. For example, the California Zero Emission Vehicle (ZEV) regulation initially suggested that 50,000 FCVs may be on California roads by 2017-8. Given the slow deployment of fueling infrastructure, this is likely to prove highly optimistic. That said, the CARB ZEV credit system will help sustain the ongoing *production* of at least at trickle of "compliance car" FCVs in the face of *potentially* persistent low demand – as these credits provide manufacturers with a substantial economic incentive for manufacturing H2 vehicles. Additionally, it is expected that CARB will continue to provide consumers with a larger incremental state rebate for H2 vehicles ($5000 for FCVs vs. $2500 for EVs) to further incentivize sales through the 2023 period authorized by Assembly Bill 8.[8]

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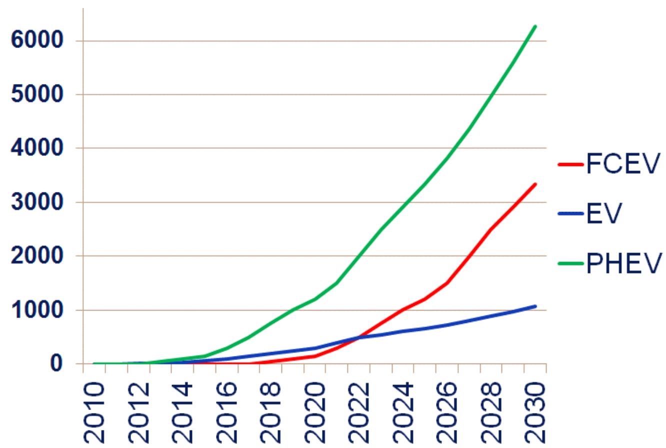
[8] The California Vehicle Rebate Program (CVRP) process is essentially the same for both EVs and FCVs, and is administered by the Center for Sustainable Energy on behalf of the state. The rebate application of the Honda Clarity (one of the initial FCVs for sale in California) is shown on this site: https://energycenter.org/clean-vehicle-rebate-project/requirements/919

3.22. Nationwide FCV Sales Projections

At the national level, the National Research Council data on price parity for FCVs in turn informed a UC Davis Institute of Transportation Studies scenario illustrated below, which shows modest penetration by 2020, and a substantial uptake -- to approximately 300,000 new car sales per year nationally by 2030 vs. 700,000/year for Electric Vehicles, including both BEVs (indicated as EVs below) and PHEVs.

Projected National FCV vs. Electric Vehicle Annual Sales (2010 – 2030)



New Car Sales are in 1000s Per Year

Source: UC Davis Institute for Transportation Studies - (Ogden, Fulton and Sperling, 2014), p. 15.

For both EVs and FCVs, many analysts look at the conventional hybrid vehicle market as an illustrative case for new vehicle technology adoption. In the case of regular hybrids (technically known as Hybrid Electric Vehicles or HEVs), annual sales grew very slowly in the early years, reaching the 500,000/year threshold after 14 years. In the case of EVs (counting BEVs plus PHEVs), it is likely that at current adoption rate growth, EVs will likely achieve this level in just ten years or less. Given the many variables in FCV adoption, the federal DOE has also produced a variety of different scenarios for FCVs in the 2015 – 2025 period. Two out of the three scenarios show a gradually progressive upslope after 2017, toward 500,000 by 2020 and 700,000 by 2025. The final more aspirational scenario, suggesting 2.5M in annual sales by 2025, would likely require significant price reductions, large-scale infrastructure roll-out, new incentives, and potentially a significant increase in gasoline prices to enhance the relative economies of hydrogen operation.

Alternative Scenarios for National FCV Sales Growth (U.S. Department of Energy)

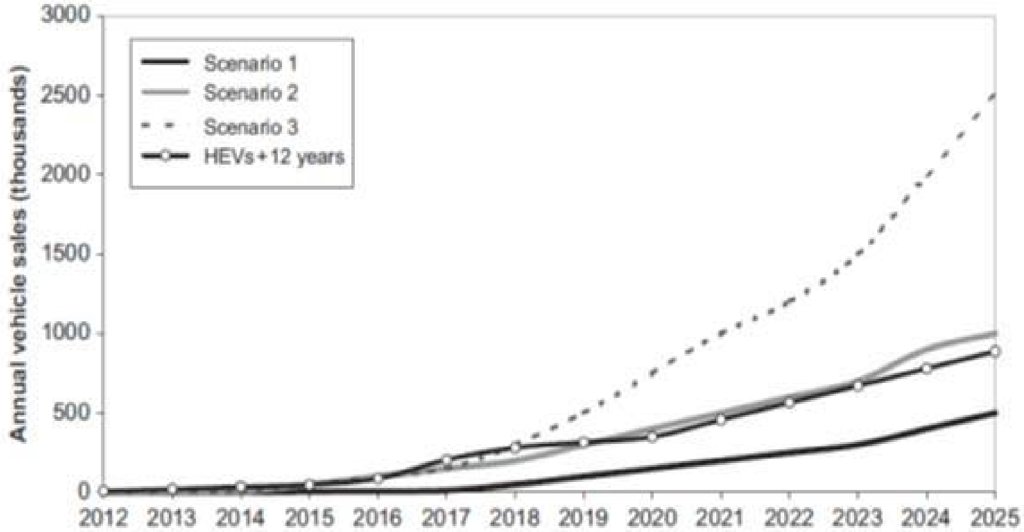


Figure 15.3. Three USDOE Scenarios for H_2 FCV market penetration (Gronich, 2006), and historical market penetration rates for gasoline hybrid vehicles displaced by 12 years.

Source: Greene, Leiby and Bowman 2007, as shown in NRC 2008, cited in UC Davis Institute for Transportation Studies - (Ogden, Fulton and Sperling, 2014), p. 21.

Implications of FCV Sales Projections for Regional FCV Readiness and Market Development: As with the introduction of any new technology, consumer acceptance and future price/performance characteristics are exceeding difficult to predict with accuracy. Despite the uncertainties involved, state policy makers have already chosen a pro-active stance in building the market for FCVs by providing a combination of generous incentives and a significant investment in H2 station rollout. This will enable California consumers to “vote with their feet” with regard to the FCV value proposition – and provide further signals to both automakers and policy makers regarding the outlook for further investment in the FCV ecosystem in the 2020 – 2035 timeframe. For local policy-makers that wish to support FCV adoption, the two most important opportunities are: 1) To work with FCV fueling station developers and the California Fuel Cell Partnership to ensure that projected FCV station siting proceeds without undue delays; and 2) To assess whether FCVs can meet local fleet needs not otherwise achievable by plug-in vehicles or sustainable biofuels. One of the most promising near-term opportunities for FCV deployment in fleets is in the public transit segment, as the first generation of hydrogen buses have been demonstrated in revenue service for several years (including at AC Transit in the Bay Area). Fuel cell buses and available incentives are described in further detail below.

3.23. Fuel Cell Buses and Procurement Incentives

Several companies are conducting hydrogen fuel cell bus trials. These include Daimler AG, Thor Industries (the largest maker of buses in the U.S.) based on UTC Power fuel cell technology, Toyota, Ford (based on the E-350 shuttle bus platform), and others. In California, buses are currently being operated in ongoing revenue testing and revenue service by SunLine Transit Agency in the Coachella Valley and AC Transit in Alameda and Contra Costa Counties. While capital costs are currently higher than diesel or electric, the zero tailpipe emissions, fast refueling, and flexible fuel supply chain hold promise for FCV transit applications. Additionally, future hydrogen drayage trucks for port applications may help reduce port emissions, along with the battery electric drayage trucks now in operation.

As hydrogen fuel cell buses become available commercially, they will be eligible for the California Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP). This program was established in 2007 as part of the California Alternative and Renewable Fuel, Vehicle Technology, Clean Air, and Carbon Reduction Act of 2007 (AB 118). AB 118 in turn created the Air Quality Improvement Program (AQIP), a voluntary incentive program administered by the Air Resources Board to fund clean vehicle and equipment projects, research, and workforce training. HVIP funding helps to buy down the high incremental cost of advanced clean vehicles while production volumes are still low. Both public and private fleets are eligible for the incentives. See the HVIP "For Fleets" page for additional details.

The HVIP offsets about half of the incremental additional cost of eligible vehicles using a purchase voucher, and thus far has enabled procurement of ~1,700 clean vehicles. The HVIP base vouchers normally range from $8,000 to $45,000 on a first-come, first-served basis for the purchase of each eligible new truck or bus. However, with the program's additional funding, the first three vehicles purchased can receive vouchers of as much as $65,000 per vehicle. And electric transit buses currently receive a voucher of $95,000. The complete rules and conditions of the program are available in the Year 4 HVIP Implementation Manual.

3.24. Environmental Characteristics of Hydrogen Fuel Supplies in California

The environmental characteristics of hydrogen fuels depend on the well-to-wheels carbon emissions associated with the full hydrogen fuel supply chain, including production, delivery, and refueling. As noted earlier, hydrogen is similar to electricity in that it is an energy *carrier,* and can be produced from diverse primary energy resources. Just as electricity on the power grid is a mix of generation sources, a number of diverse hydrogen feedstocks and production methods are represented in California's hydrogen fuel supply chain. Therefore, to assess the environmental attributes of hydrogen fuel, it is important to consider the source, supply, and carbon intensity of hydrogen fuel stocks compared to other alternative fuel sources -- including gasoline, natural gas, electricity, and various biofuels.

In recent years, natural gas prices have been relatively low due to a glut of gas produced from shale formations through hydraulic fracturing, commonly known as fracking. Low natural gas prices have in turn helped support low hydrogen prices, and natural gas is thus considered the "feedstock to beat" in a cost-driven market for hydrogen fuels. However, natural gas fueled hydrogen production does not have significant advantages over regular gasoline from a greenhouse gas (carbon) perspective, although it will provide important local air emissions benefits (notably a significant reduction in particulate matter if it is replacing diesel trucks or buses). To address the limitations of natural gas as the principal H2 fuel feedstock -- and to encourage the integration of cleaner renewable feedstocks in the hydrogen supply chain -- the state of California has advanced these four key strategies.

1. **The 33% renewable hydrogen standards:** The state has mandated that 33% of hydrogen fuel be renewably produced, per Senate Bill (SB) 1505. The 33% standard is based on the energy content of the fuel and can be averaged over multiple stations within the state. The statute also requires that hydrogen fuel blends shall provide a 50% reduction of Nitrous Oxides (NOx) and Reactive Organic Gases (ROG), and a 30% reduction of greenhouse gas on a well-to-wheels basis compared with gasoline, along with zero increase in toxic air contaminants. The regulation applies to state co-funded hydrogen stations currently, and it will apply to <u>all</u> hydrogen stations once a volume of 3.5M kg/year is reached state-wide (equivalent to a statewide FCV fleet of ~10,000 cars.)[9] For purposes of assessing the 33% renewable standard for hydrogen production (as well as electricity) renewable fuels are defined by CARB to include:
   - **Biomass**, which is any organic material not derived from fossil fuels, including agricultural crops, agricultural wastes and residues, waste pallets, crates, dunnage, manufacturing, and construction wood wastes, landscape and right-of-way tree trimmings, mill residues that result from milling lumber, rangeland maintenance residues, sludge derived from organic matter, and wood and wood waste.
   - **Digester gas** - gas from the anaerobic digestion of organic wastes.
   - **Geothermal, landfill gas, municipal solid waste**
   - **Ocean wave, ocean thermal, or tidal current technologies**
   - **Solar Photovoltaic or solar thermal technologies**
   - **Small hydroelectric (30 megawatts or less)**
   - **Wind energy**

[9]Presentation by Gerhard Achtelik, California Air Resources Board, *California Regulation of Renewable Hydrogen and Low-Carbon Technologies,* November 16, 2009, http://energy.gov/sites/prod/files/2014/03/f12/renewable_hydrogen_workshop_nov16_achtelik.pdf

2. **Renewable Portfolio standard for electricity**: The state has also mandated that electricity be produced from 33% renewable sources by 2020. Further, Governor Brown has proposed increasing the RPS to 50% by 2030. Thus, as California's grid becomes less carbon intensive, hydrogen produced by electrolysis will become cleaner (as will EVs driven by the California grid power mix).
3. **The Low Carbon Fuel Standard** benefits lowest-carbon fuel producers with economically advantageous tradable credits. Hydrogen fuel producers are eligible to achieve LCFS credits if the hydrogen fuel meets LCFS standards for carbon content.
4. **Preferential Support of Renewable Hydrogen Fueling Infrastructure:** The state is preferentially supporting the development of renewable hydrogen projects vs. non-renewable production in an effort to increase the available supply and reduce the cost of renewable hydrogen.

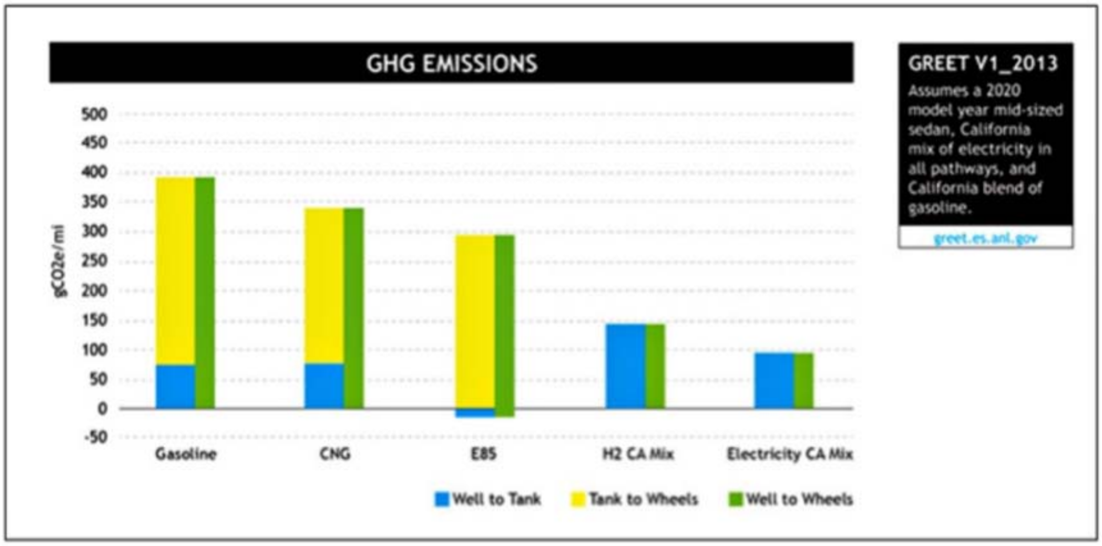
Given the strategies described above, the hydrogen fuel supply chain in California will likely become lower carbon over time, although fuel costs may increase as the proportion of renewable supply increases.

3.25. Assessing the Environmental Attributes of Hydrogen Fuels on a Life Cycle Basis

The methodology used by the California Energy Commission to assess hydrogen fuel attributes is based on the GREET assessment model, which stands for *Greenhouse gases, Regulated Emissions, and Energy Use in Transportation.* GREET is the authoritative model developed by the Argonne National Laboratory to assess the energy and emission impacts of fuels for the full fuel cycle from well to wheels (or "seed to wheels" in the case of biofuels), as well as (via a separate but related protocol) to assess the vehicle's use cycle from manufacturing through material recovery and vehicle disposal. ***The GREET model demonstrates that the current "California mix" of hydrogen in a Fuel Cell Vehicle reduces GHG by slightly more than half compared to a current average ICE.***

As noted above, the California H2 fuel mix includes at least 33% renewable sources. However, it should be noted that this is a statewide average. In local practice, the carbon intensity of hydrogen (as well as electricity) varies by territory, season, and other factors. As illustrated in the chart below by the California Fuel Cell Partnership, ***the California average mix of hydrogen produces a total environmental impact of 150 grams of CO2 equivalent (CO2e) per mile (Co2e/ml) on a well-to-wheels basis. By contrast, the well to wheels impact of gasoline is nearly 400 grams of CO2e per mile, while electricity is 100 grams of CO2e per mile,*** given the California average grid mix as of 2013.

It is important to note that the carbon impact of both EVs and FCVs powered by hydrogen produced through electrolysis will be declining significantly in time as the California grid power mix becomes lower carbon. However, the relative well-to-wheels advantage of EVs will remain due to higher efficiencies in the EV powertrain, and avoided inefficiencies resulting from producing hydrogen fuel from electricity (vs. using electricity directly via on-board battery storage and delivery to the electric motor.)



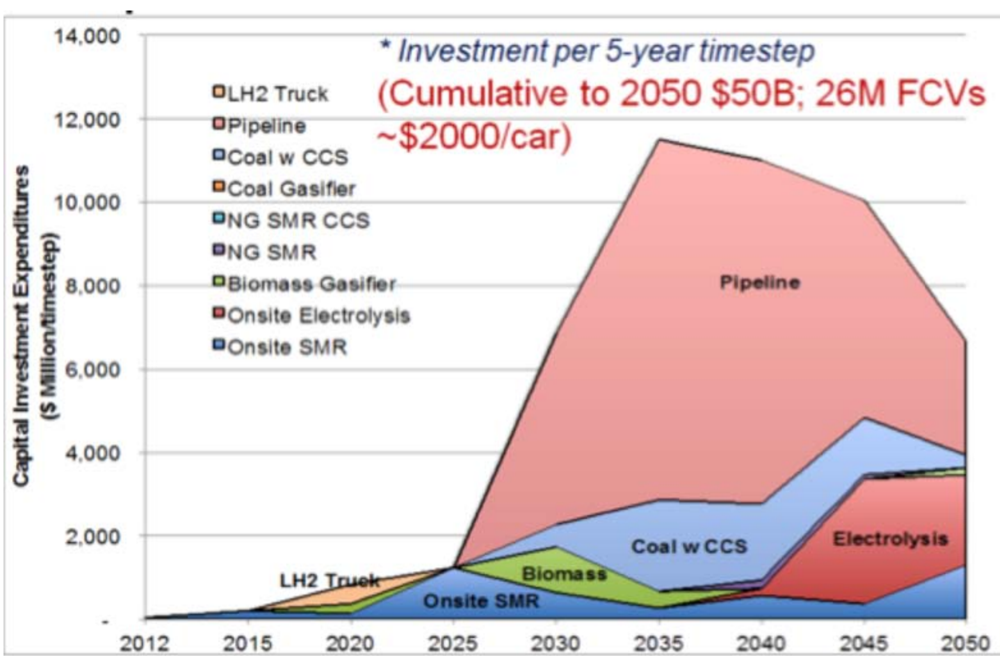
Source: California Fuel Cell Partnership

The relative environmental impact of hydrogen fuel will also be subject to future changes in both actual feedstock carbon intensity and potentially in the measurement methodologies used to assess key feedstocks. On the environmentally positive scale, the electricity used to manufacture hydrogen will steadily be reduced in carbon intensity, making some H2 feedstocks cleaner. On the environmentally negative scale, the assessment of well-to-wheels C02e intensity of natural gas is likely to be adjusted upward (toward higher carbon intensity) based on emerging research that suggests that methane leakage in the fuel supply chain may be much higher than previously assumed (potentially in the range of 3% leakage rather than slightly above 1.3%, which was the previous EPA estimate.) These refinements in the understanding of well-to-wheels impacts of natural gas could degrade the absolute and *relative* rated environmental performance of both FCVs and Natural Gas Vehicles (NGVs) vs. EVs. A comprehensive review of the issue of methane leakage in the natural gas supply chain is underway by the Environmental Protection Agency (EPA) and is expected to be completed in the 2016-17 timeframe.

3.26. The Transition to Green Hydrogen

To realize the full climate benefits of hydrogen and fuel cells, hydrogen must be produced via low carbon production pathways. However, each low-carbon pathway faces challenges. Cost is the major issue for hydrogen produced via electrolysis fueled by solar or wind energy, or biomass gasification. In theory, hydrogen produced by fossil fuels with CO_2 sequestration could produce very low emissions, but decades of research have yet to produce cost-efficient methods of sequestration of coal or natural gas emissions at scale. The UC Davis Institute for Transportation Studies (Chris Yang and Joan Ogden) analyzed alternative strategies for achieving a near zero carbon H2 fuel supply system in California by 2050 and produced a scenario that envisioned future breakthroughs in carbon capture and sequestration (CCS), along with biomass derived hydrogen, and hydrogen produced with renewable electricity. Of course, the existence of *cost-efficient* CCS in the future must be considered speculative. The scenario without CCS demonstrates that either *emissions* will rise (due to continued use of fossil resources without CCS) or *costs* will rise due to reliance on more expensive renewables. According to the UC Davis projections illustrate below, to develop a sufficiently large, low-carbon H2 infrastructure to meet the 80% carbon reduction in the transportation sector called for under AB 32 will require a $50 billion dollar capital investment.

Strategic Pathways and Costs for California's Transition to Green Hydrogen



Acronyms: NG SMR CCS = Natural gas powered steam methane reforming of hydrogen with Carbon Capture and Storage. (Steam methane reforming is the most common method of producing hydrogen fuel.) **LH2** – Liquid hydrogen fuel. **Source:** *NextSTEPS White Paper: The Hydrogen Transition*, ITS, UC Davis, July 2014, p. 33.

In the UC Davis "base case" scenario, hydrogen is made primarily from distributed Steam Methane Reformation (the most common method in use today) in the first several years of H2 station operations, through 2020. As demand grows in the 2020 to 2030 timeframe, medium-scale biomass gasification systems are also deployed. Beyond 2030, large scale fossil fuels with CCS (in this case coal) is envisioned to provide H2 at low cost and low emissions, *if such technologies are available and effective*. Also envisioned in 2045 to 2050 is the emergence of larger-scale distributed renewable electrolysis to ensure the 33% renewable hydrogen mandate is met. In this scenario, average H2 costs decline from over \$10/kg in 2012 to \$4.20/kg H2 in 2050. Average H2 carbon intensity, declines from an efficiency-adjusted value of 4350 gCO2/kgH2 to 1630 gCO2/kgH2 in 2050 – which represents an ***85% reduction from current gasoline carbon intensity on a well-to-wheels basis,*** taking into account higher FCV efficiency. The UC Davis analysis suggests that the development of a low-carbon hydrogen supply pathway could become economically competitive with gasoline on a cost-per-mile basis with just 50,000 FCVs in a region with 100 stations, at an initial capital investment of \$100-200 million.

3.27. Best Practices in Local Readiness for Hydrogen Fueling Station Development

Overview of Local Readiness Roles and Activities: Auto makers, policy makers, and the general public are well aware that convenient and ubiquitous refueling is essential to the success of any new Alternative Fuel Vehicle, whether they be EVs, Fuel Cell Vehicles, Natural Gas Vehicles, or biofuel-powered. Regional agencies, counties, and municipalities have an important role to play in scaling up the AFV fueling infrastructure in general -- and hydrogen stations in particular – by:

- Participating in public/private consortia to obtain grant funding for stations
- Assisting in the siting and permitting process
- Ensuring that planning, permitting, and emergency responders receive appropriate training in the many facets of the FCV transition.

Of course, the widespread availability of FCV stations is only part of the overall market deployment challenge. Vehicle manufacturers and consumers will ultimately determine whether adoption levels are sufficient to enable station operators to sustain and expand a retail H2 fueling infrastructure beyond the early years of state subsidy. As discussed earlier, overall station placement across the state is being guided by the collaborative efforts of the California Fuel Cell Partnership, the California Energy Commission, FCV manufacturers, and fueling providers. The first stages of the siting process begin with the targeting of localities for stations based on the statewide market analysis. Specifically, the automakers, Fuel Cell Partnership, and the CEC have assessed the coverage needed to enable intra-regional and (ultimately) inter-regional driving between the identified early-adopter market "clusters." This mapping process is balanced with the expected capacity utilization that will be required for each station to achieve breakeven operations. Thus, the over-arching strategy for early station deployment is to create a network that meets the needs of early adopters, while ensuring that operators are able to build a business case for selling hydrogen over the long term. This may require that market actors build fewer stations initially to support higher utilization rates and an earlier breakeven point.

Local vs. State Station Development Roles: Broadly speaking, there are two levels of approach to FCV station development – the first is "top down" and involves pro-active outreach by state-level FCV stakeholders to local Authorities Having Jurisdiction (AHJs). State level actors include fueling station operators, the Fuel Cell Partnership, FCV manufacturers, the Energy Commission, and GoBiz, the state's economic development organization now assisting with the siting process. The second approach is "bottom up" and involves potential public, private, and NGO sector allies forming local partnerships to accelerate the establishment of FCV infrastructure in a particular city or region. Such initiatives may or may not require state grant support in the longer-term, although in the early years of market development most FCV stations will require both state funding and matching private investment.

In the context of the Central Coast, both "top-down" and "bottom-up" processes are already in motion. As noted earlier, First Element Fuels is expected to open a station in Santa Barbara by the end of 2015, and other stations are on the 100 station "drawing board" for opening in the 2015-2020 timeframe, per the state's ZEV Action Plan and the Fuel Cell Partnership siting strategy. To advance Central Coast hydrogen readiness and fueling infrastructure in particular, the County of Santa Barbara was awarded a planning grant from the Energy Commission, which provides resources to develop guidelines and plans to site potential hydrogen fueling stations, and to educate local planning staff and policy-makers on FCV related issues. This planning process will extend from mid-2015 through 2017, and result in a comprehensive FCV infrastructure plan for the region.

Although much of the action in FCV readiness occurs at the state and regional level, there are a number of critically important roles to be played by municipalities, notably in the area of FCV station site planning, permitting, zoning, and safety. Local leaders can begin the H2 readiness process by considering these opportunities for advancing FCV readiness, and packaging those elements that are aligned with local priorities into a municipal AFV or FCV readiness action plan.

Summary of Potential Local Government Actions to Support Hydrogen Readiness	
FCV Site Identification	1. **Determine if your locality is in or near a designated FCV cluster**, connector route, or destination areas (see the Fuel Cell Partnership website at www.calfcp.org for information). 2. **Reach out to companies with grants for fuel station installation** to coordinate on future siting, permitting, and construction issues. 3. **Participate in the Central Coast AFV Coordinating Council** to maximize local opportunities to access grant funds and expertise on FCV deployment. (The local contact for the AFV Council is the County of Santa Barbara Planning Department, which is helping coordinate H2 site development activities in the region.) 4. **If no sites have been identified, assess available locations** by determining if any existing gasoline or natural gas station has a vacant area of at least 20 by 40 feet, which could house an FCV installation.
H2 Station Zoning	5. **Determine which zoning classifications, if any, should provide explicit permission for hydrogen stations**, based on the current land use mix 6. **Consider including hydrogen fueling as an option for obtaining a density bonus** when negotiating with developers who want to build more densely on a site than the zoning code normally allow
Hydrogen Fueling Station Permitting	7. **Document existing municipal permitting and inspection processes for gasoline or compressed natural gas (CNG) stations** and for completing the inspection process, including contact information for key staff. 8. **Create an expedited permitting process for hydrogen stations**, which could include pre-permit meetings and negative CEQA declarations where feasible and appropriate. 9. **Create instruction sheets to guide installers and inspectors** through local requirements for hydrogen stations. 10. **Provide a pre-submittal review** to address issues at the proposed site that the applicant is not aware of or that were not assessed in the draft evaluation. 11. **Communicate plans to the public**: Station developers and key partners (such as FCV automakers and the California Fuel Cell Partnership) can prepare high-level presentations about FCVs and fueling, safety, and emergency response. Plan for intensive and ongoing outreach to the public—including local elected officials, businesses, and residents.

Summary of Potential Local Government Actions to Support Hydrogen Readiness	
Training for Public Agency Staff	12. **Participate in training on hydrogen vehicle and fueling safety, codes, and standards --** utilizing best practice resources such as the U.S. DOE online training: *Introduction to Hydrogen for Code Officials;* resources available at *H2BestPractices.org;* the *Regulations, Codes and Standards Template for California Hydrogen Dispensing Stations;* and other resources at the California Fuel Cell Partnership website.
FCV Integration in Planning	13. **Assess potential of Fuel Cell Vehicles to meet GHG reduction, air emissions, green fleet, ZEV adoption, or other sustainability goals** -- taking into account the most authoritative research on GHG and air quality impacts of hydrogen vehicles. 14. **Integrate FCVs in local plans** addressing climate action, air quality, AFV readiness, transportation, and fleet operations. 15. **Integrate the principle of ZEV readiness in the General Plan.** At a minimum, including ZEV readiness as a high-level policy objective can be added in just once sentence in the circulation element of a General Plan – stating that the community intends to work toward ZEV readiness. See the state's *Office of Planning and Research General Plan Guidelines Update* for more information about incorporating ZEVs into general plans, available at www.opr.ca.gov.

Planning Resource: *H2 Readiness: Best Practices Guide for Hydrogen Stations in Early Adopter Communities: Part of the ZEV Action Plan: A Roadmap Toward 1.5 Million Zero Emission Vehicles on California Roadways by 2025;* April 2014, p. 34.

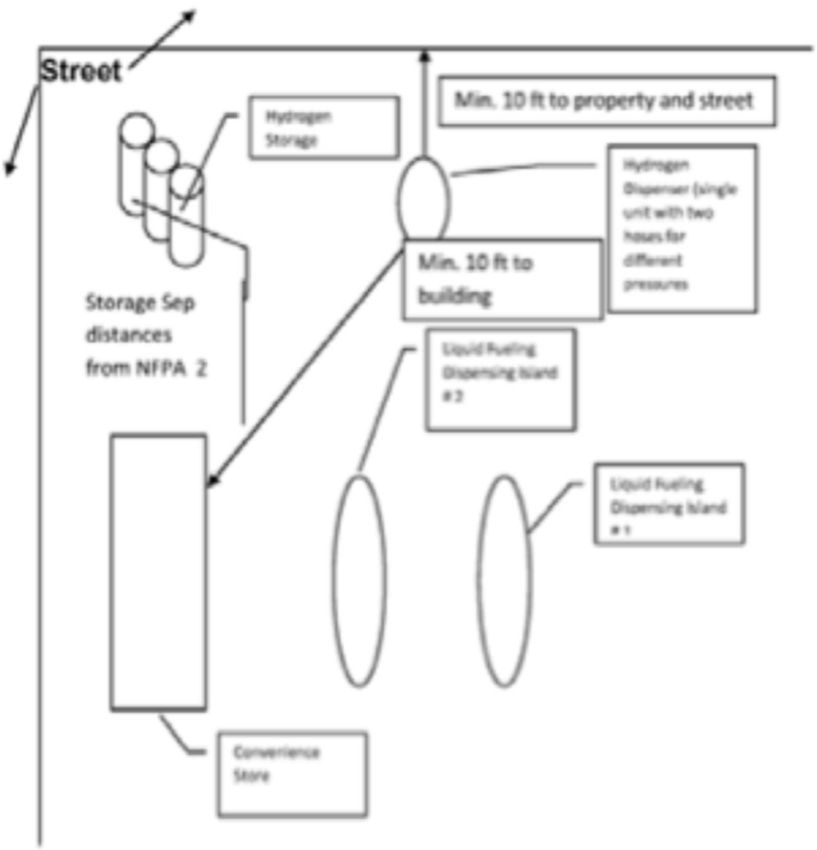
3.28. Hydrogen Station Construction and Zoning

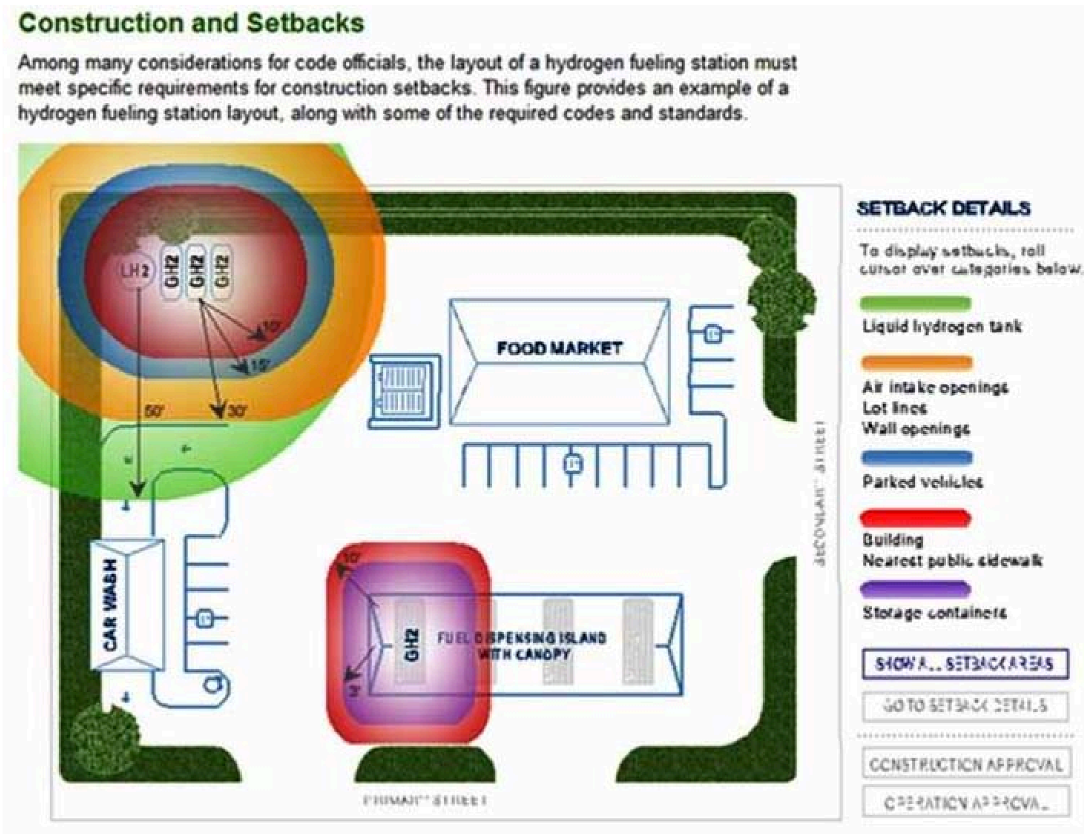
As noted above, H2 fueling equipment is most often co-located with existing gasoline or CNG fueling stations. From a safety perspective, H2 dispensers can physically be placed under an existing fueling station canopy, but some station brands do not allow other fuels to be under the brand canopy. At some stations, H2 dispensers are on the same island as other dispensers. At other stations the H2 dispenser is on its own island either under the canopy, just outside, or on a separate section of property. Since local jurisdictions are responsible for writing or adopting their own zoning codes, rules governing the specific layout of hydrogen stations may differ from one jurisdiction to another. A typical station map featuring locally specific setbacks and layout decisions and a setback diagram are indicated below. In the single-line drawing below, the scenario illustrated is that of an integrated gasoline and hydrogen station that does not have on-site fuel production, and includes a convenience store and two "liquid fuel dispensing islands" as well as one hydrogen-only dispensing island. Note that the distances separating the hydrogen fuel storage canisters from other station elements are per National Fire Protection Association (NFPA) code.

Hydrogen Station Installation Showing Protective Bollard

Source: *H2 Readiness: Best Practices for Hydrogen Stations in Early Adopter Communities,* p. 11.

Hydrogen Station Elements and Typical Setbacks





Source: *H2 Readiness: Best Practices for Hydrogen Stations in Early Adopter Communities,* p. 50.

3.29. Hydrogen Station Permitting and Signage

Hydrogen station development and permitting typically involves these seven stages:

1. Preliminary project scoping
2. Station design
3. Approval process
4. Station/dispenser construction
5. Station/dispenser startup (Commissioning)
6. Station/dispenser operation
7. Station/dispenser maintenance

The required permits typically address all of these stages – from project scoping and design through operations and maintenance, as noted below in this generic example.

Range of Permits Potentially Required for Hydrogen Station Development		
Permit	**Agency**	**Permit/Permit Scope**
Construction	Building Department	▪ Permit to Construct General/ ▪ Address safety construction issues
Drainage	Engineering Department	▪ Permit to Construct Drainage/ ▪ Modification to sewer drainage
Site grading	Engineering Department	▪ Permit to Construct Grading/ ▪ Modification to site elevation
Electrical	Building/Electrical Department	▪ Electrical Permit ▪ Modification to electrical service
Demolition	Building Department	▪ Construction Permit/Demolish structures required for dispenser construction
Food services	Health Department	▪ Food sales
Air emission impacts	Air Quality Management District	▪ Air Quality Permit or No impact declaration
Fire safety	Fire Department Plans Review Office	▪ Fire Safety Permit/General fire code compliance
Approvals Required for Hydrogen Station Construction and Operation		
Approval	**Agency**	**Approval Scope**
California Environmental Quality Act (CEQA)	Local Agency Having Jurisdiction (typically a city or county)	▪ CEQA approval or finding of no significant impact
Zoning	Local zoning board	▪ Zoning approval allowing construction and operation at specified location
California Accidental Release Prevention Program (CAL–ARP)	Local administering agency (for example county health or fire department) and U.S. EPA	▪ Approved submission or finding of non-applicability -- requires an evaluation of the impact of the release of regulated materials and a plan in the event of release

The administrative process for reviewing and approving projects varies by jurisdiction, but a typical process involves:

- Pre-submittal review and feedback (optional but highly recommended)
- Review and feedback to applicant

- Formal submission of application
- Public meeting (on an as needed basis)
- Adjustments in the permit application (as needed) based on public input
- Review of modified application and feedback to application
- Resubmittal of modified application
- Issuance of permit
- Project construction
- Site inspection to determine that project built as shown in final design plans
- Periodic inspections to determine ongoing compliance

Of the steps above, the pre-submittal review and consultation with other jurisdictions on their permitting process are particularly important. The pre-submittal review provides an opportunity to avert potential issues that may delay the permitting process or lead to application denial, such as right-of-way issues, or other requirements the applicant had not evaluated in the draft application. Consultation with other local jurisdictions that have already permitted hydrogen stations can alert local officials to issues, work-arounds, and document templates that can be invaluable in developing and managing an efficient and streamlined process.

Permit Template for Hydrogen Dispenser Added to an Existing Fueling Station
[**Source:** *H2 Readiness: Best Practices for Hydrogen Stations in Early Adopter Communities,* p. 43.]

For this template a single dispenser is added to an existing fueling station. In all California jurisdictions, the California Fire Code is the enforced fire code. The addition of a single dispenser will trigger construction requirements. The dispenser will require at least the following elements:

- A dispensing platform
- Vehicle crash protection
- Electrical service
- Hydrogen storage or generation equipment or both for dispenser that has hydrogen generating and storage capability
- Lighting
- Compressors to compress the hydrogen to vehicle storage pressure
- Dispenser with fueling hose and nozzle
- Piping from the gaseous hydrogen storage system to the dispenser
- Fire protection system
- Maintenance system
- Unique construction requirements such as handicapped parking requirements

Additional permit templates are available at www.nrel.gov/docs/fy13osti/56223.pdf

Sample Permit

Jurisdiction of _______________, California
Building/ Fire Permit For Hydrogen Dispensing Installation

Section 1: Basic Identifying Information

Compliance with the following permit will allow the construction and operation of a hydrogen dispensing installation in the __________ jurisdiction. This permit addresses the following situations: 1) The addition of a hydrogen dispensing and storage system to an existing fueling station; 2) Other station elements TBD

This permit contains a general reference to the California Fire and Building Codes or equivalent codes used in the jurisdiction. All work and installed equipment will comply with the requirements of XXXX code used in the jurisdiction. The jurisdiction maintains the authority/responsibility to conduct any inspections deemed necessary to protect public safety.

Section 2: Code Requirements

[This section identifies code requirements (see listing below of specific relevant fire/safety codes) and addresses specific elements of station safety:

- Approval/listing and labeling requirements
- Piping code compliance
- Storage vessel stamps/approval]

Issue	Sample Permit Requirements
Siting	Do storage and dispenser systems meet separation distance requirements?
Mechanical	Is equipment listed or approved? Valves, Pressure Relief Devices (PRDs), Piping, Containers, Hoses, Nozzles
Electrical	Is equipment proximate to dispenser classified?
Maintenance	Have maintenance requirements been defined in the permit application? Is documentation required?
Emergency response	Are E-stops accessible? Do they have a plan? Are personnel trained? Is communication with the fire department and other emergency responders clearly defined?
Sensors	Do sensors detect releases or upset conditions? Is the information from sensors conveyed to the process equipment, operators, and fire department?

Section 3: Standard Certification Statement

By signing the certification statement the applicant agrees to comply with the standard permit conditions and other applicable requirements. This consent would give the jurisdiction the option of allowing the applicant to proceed with installation and operation of the dispensing equipment.

Example

I hereby certify that the electrical work described on this permit application shall be/ has been installed in compliance with the conditions in this permit, NFPA 70, National Electric Code, and the Fire Code currently adopted and enforced within the jurisdiction of installation. By agreeing to the above requirements, the licensee or owner shall be permitted to construct and operate the hydrogen station.

Signature of Owner ______________________________ *Date* __________________

Section 4: Jurisdiction Checklist

Below is a sample checklist the jurisdiction could develop to track key information on the application. A few of the many items that could be tracked include:

1. Unique requirements in the jurisdiction such as seismic requirements
2. Summary of California Risk Management Plan (RMP) analysis if subject to RMP
3. Summary of California Environmental Quality Act Compliance (CEQA) analysis

Section 5: Schematic (optional)

A schematic drawing should show the arrangement of the equipment in conformance with relevant Fire Code and other codes and standards (see below).

Relevant California Fire Code Citations (2012 edition) are available at http://cafcp.org/sites/files/H2-Best-Practices_Final-Single-Page.pdf, pp. 44-48. The relevant citations (using the International Fire Code numbering system) include: General Requirements (2309.3.1.1.), Dspensing platform (2309.4.1.), Vehicle crash protection and fueling area (2309.5.1.), Electrical Service (2309.2.3.), Lighting (must meet NEC requirements), Hydrogen storage or generation equipment or both for dispenser that has H2 generating and storage capability (2309.2.0 – 2309.2.3 and 2309.3.1.3 – 2309.3.1.4), Compressors to compress the hydrogen to vehicle storage pressure (2309.2.0 – 2309..2.2.), Dispenser with fueling hose nad nozzle (2309.2.1 – 2309.2.2), Piping from the gaseous hydrogen storage system (shall be in accord with ASME B31.12 hydrogen pipelines and piping), and Sections 704.1.2 through 704.1.2.5.1, Chapter 27 of the International Fire Code and ASME B31.3), Fire protection system (2309.3.1.5.2. and 2309.3.1.5.3. and 2309.3.1.5.4. addressing emergency discharge and shutdown control), Maintenance system (2309.3.1.2.1.), Ignition control (2309.3.1.2.2 – 2309.3.1.2.4., Emergency shutoff

(2309.5.0 – 2309.5.3.1.) Unique construction requirements – Canopy tops (2309.3.1.5.1.-2309.3.1.5.5, Chapters 53 and 58 and the International Fuel Gas Code), Construction of canopies (2309.3.1.5.1.), Signage (2309.3.1.5.5), Canopy separation (2309.3.2.)

Hydrogen Fueling Stations and the California Environmental Quality Act: The California Environmental Quality Act (CEQA) applies to projects undertaken by state and local agencies or a private entity for which some discretionary approval is required. Installing a hydrogen station generally fits the definition of a project under CEQA. Local governments have taken a range of actions under CEQA to install hydrogen fueling stations, including filing categorical exemption or preparing a negative declaration. According to the Governor's Office of Planning and Research, most of the recently built hydrogen stations have used categorical exemptions. Commonly filed exemptions for hydrogen stations are:

- 15301 (Class 1) for Existing Facilities
- 15303 (Class 3) for Small Structures

It is recommended that agencies enforcing the CEQA statue refer to exemptions granted by other authorities having jurisdiction. An up-to-date map of currently opened hydrogen fueling stations is available at www.cfcp.org to determine which localities have issued permits and filed CEQA documentation.

Hydrogen Fueling Station Signage: As in the case of Electric Vehicles, signage is an important "force multiplier" to drive enhanced consumer awareness and confidence in the availability of fueling stations. Accordingly, local authorities and station operators are strongly encouraged to deploy signage in the most expansive way feasible in the early stages of commercial station deployment. Signs should ~~conform~~ to the Caltrans standards for ZEV signage, including the FCV sign protocol which was issued in its Traffic Operations Policy Directive 13-01 released in March 2013 (www.dot.ca.gov/hq/traffops/signtech/signdel/policy/13-01.pdf). The directive incorporates new ZEV-related signs and pavement markings into the California Manual on Uniform Traffic Control Devices (MUTCD). State law and federal regulations require signs, markings and signals placed on California's public roadways to comply with the requirements of the MUTCD. Also, signs installed on private roadways and parking must be consistent with the MUTCD to be legally enforceable. Specifically, the MUTCD defines the allowable hydrogen sign illustrated below and indicates (in Section 21.03 of the General Service Signs for Expressways and Freeways, Paragraph 41, Subpart 13) it states: "Where hydrogen (HYD) fuel is available, the Hydrogen (G66-22G(CA)) symbol sign and Hydrogen (G66-22H(CA)) supplemental plaque may be used within 3 miles of a State highway and be available to the public at least 16 hours a day, in addition to the other appropriate signs."

In addition, Guidance 34 indicates that "To avoid misleading the road user, those services that are more than 0.5 mile from the access point on the major route to the service, should have a Distance with Arrow (G66-21A(CA)) plaque installed below the service sign." Given the importance of signage to raise consumer awareness, local authorities could consider placing hydrogen station signs on all major public thoroughfares in a substantial radius of the facility and on nearby freeways (with Caltrans concurrence). The cost of such installations could potentially be provided in whole or in part by the station developers and relevant funding agencies.

The California Approved Hydrogen Fueling Sign

Fueling Technology Codes, Standards, and Certification: A variety of organizations have developed codes and standards that address H2 distribution, storage, and dispensing. These include the National Fire Protection Association (www.nfpa.org), and the International Code Council (www.iccsafe.org). Nationally recognized testing laboratories are also beginning to publish design and performance standards for hydrogen station components. However, these are emerging only gradually during the early commercialization stage of FCVs. For the latest information, local officials are encouraged to consult the National Renewable Energy Laboratory website, which provides continuously updated information about evolving codes and standards that can assist in H2 station design, construction, and regulatory approval. See www.nrel.gov for the most up-to-date information.

3.30. Hydrogen Safety and Training for First Responders

Hydrogen has been produced in significant quantities for many decades – for use in oil refineries, as an industrial chemical, and for a variety of transportation applications from forklifts to space rockets. Consequently, methods to safely produce, store, transport and use hydrogen have been well developed – such that hydrogen is generally considered to be no more or less dangerous than other flammable fuels. Like gasoline and natural gas, hydrogen is flammable and can behave dangerously under specific conditions, but some of its properties provide safety benefits compared to liquid fuels such as gasoline. Because hydrogen is a lighter-than-air gas that diffuses quickly, it is difficult to concentrate the fuel enough to make it catch fire, let alone explode. To further reduce the chance of accidents, hydrogen stations are mandated to implement the following safety systems:

- **If required flame detectors or gas sensors detect a fire or leak, safety measures turn on automatically**, such as sealing the storage tanks, stopping hydrogen flow or—in the case of an extreme fire—safely venting the hydrogen.
- **Strategically placed emergency stops will manually shut down hydrogen equipment**.
- **Retaining walls, equipment setbacks and bolsters** are designed into the site plan to maximize safety.
- **Above ground fuel storage is required** for ease of inspection and maintenance. (Note that codes and standards organizations are looking at below-ground storage, but this change is not likely for some years).

Other Safety-Related Attributes of Hydrogen: Hydrogen also has a variety of natural properties that provide some relative safety benefits in comparison to gasoline or natural gas.

- **Hydrogen flames have low radiant heat**: When hydrogen does ignite, it burns with an invisible or near-invisible flame and produces heat and water. Because a hydrogen fire radiates significantly less heat compared to a hydrocarbon fire, the flame is more easily contained and the risk of secondary fires is usually lower.
- **The energy required to ignite hydrogen (0.02 megajoule) is low compared to gasoline and natural gas.** Further, it is more difficult to reach a combustible mix of hydrogen and oxygen in the air than with other fuels.
- **Hydrogen is non-toxic and non-poisonous**: It will not contaminate groundwater, because it is a gas under normal atmospheric conditions, nor will a release of hydrogen directly contribute to atmospheric pollution. Hydrogen does not create harmful fumes, and does not have the drips and spills associated with liquid fuels.

- **Hydrogen has a low risk of asphyxiation**: While any gas can cause asphyxiation hydrogen's buoyancy and diffusivity make it unlikely to be confined where asphyxiation might occur.

To minimize risks associated with hydrogen fuel, it is critical that first responders gain training in the unique challenges associated with both FCVs and hydrogen fueling stations. Rather than summarize key elements of the training, which could result in a limited understanding of risks and mitigation strategies, we recommend that emergency responders consult ***The Emergency Response Guide to Alternative Fuel Vehicles***, available at:
http://osfm.fire.ca.gov/training/pdf/alternativefuelvehicles/Altfuelintroduction.pdf
This comprehensive manual prepares emergency medical, law enforcement, and fire service personnel for an emergency response involving FCVs and the full spectrum of alternative fuel vehicles. Other hydrogen-specific resources are listed below:

- **Best Practices for Hydrogen Stations** (California Governor's Office of Planning and Research): http://cafcp.org/sites/files/H2-Best-Practices_Final-Single-Page.pdf
- **The National Hydrogen and Fuel Cell Emergency Response Training Resource** (a collaboration of the California Fuel Cell Partnership and Pacific Northwest National Laboratory): https://h2tools.org/fr/nt
- **California Fire Code Text**: www.osfm.fire.ca.gov/
- **California Risk Management Plan regulations**: www.calarp.com/CalARP%20Regs.pdf
- **Governor's ZEV Executive Order:** gov.ca.gov/news.php?id=17472
- **ZEV Action Plan:** www.opr.ca.gov/docs/Governors_Office_ZEV_Action_Plan_(02-13).pdf
- **ZEV Guidebook:** www.opr.ca.gov/docs/ZEV_Guidebook.pdf

3.31. Recommended Regional and Local Actions to Support Hydrogen Vehicle Readiness

Hydrogen fuel vehicles have overcome significant technical and economic obstacles to provide a potentially viable alternative fuel and vehicle choice for California consumers and fleet operators. To fully develop the potential of the hydrogen vehicle ecosystem, however, auto manufacturers, fuel producers, and state policy makers must achieve these challenge goals:

1. **Product manufacturing costs and retail pricing must achieve parity** with both ICEs and other EVs
2. **Fueling infrastructure must become ubiquitous**
3. **The hydrogen fuel supply chain must continuously improve its "well-to-wheels" emissions while remaining economically competitive** with gasoline -- by developing cost-efficient renewable and low-carbon feedstocks and production methods at scale

4. **The FCV product range must diversify** to fully leverage hydrogen's refueling advantages over EVs – notably in the medium and heavy-duty segments
5. **State policy-makers must maintain support for both vehicle incentives and fueling infrastructure** to bridge the "chasm of death" between early adopter and mass markets.

While these challenges are significant, the California Governor's Office, the California Air Resources Board, the California Energy Commission, and their supporters in the state legislature have reaffirmed their steadfast support of the hydrogen vehicle market for nearly two decades – most recently reaffirmed by the passage of AB 8 and the commitment to build out the initial 100+ hydrogen fueling station network over the 2015 - 2023 period. Further, there are a host of technological advances in both fuel cell vehicles and fueling infrastructure that promise to lower costs and improve the environmental attributes of hydrogen over time. While the energy efficiency of EVs (and thus the potential well-to-wheel emissions profile) will always be superior to hydrogen (even accounting for 100% renewable energy inputs for both vehicle types), there is a legitimate policy case for continued public development and support of the hydrogen vehicle infrastructure and ecosystem, especially given its advantage in fueling convenience – and its potential for replacing diesel powered heavy-duty trucks and transit buses.

As of 2015-16, California has begun establishing the necessary "virtuous circle" of policies and programs to enable a viable Fuel Cell Vehicle market – including both vehicle incentives and fueling infrastructure investments and operating subsidies. California's station funding program is establishing the necessary "cluster" and "corridor" fueling network to provide assurance to drivers and automakers that they will be able to refuel FCVs as they travel within and between major population centers throughout the state. Soon, auto manufacturers must respond in kind by committing to increased development and promotion of FCV models so that station builders will reach breakeven operations and a sustainable ROI for their stations.

As in the case of the Electric Vehicle ecosystem, the most important role of local governments, regional agencies, public and private fleet operators, and relevant NGOs, are:

1. **To pro-actively assist interested fueling station developers** to move expeditiously through the planning, permitting, and construction process
2. **To participate in training on FCV infrastructure and vehicles** from a station planning, fleet operations, and safety/emergency response perspective
3. **To partner with the Central Coast AFV Coordinating Council and other agencies to access available funds** for fueling stations, vehicle incentives, and H2 related planning, outreach and education.

H2 Readiness Tasks Currently Underway at the Regional Level: Several key hydrogen readiness tasks are already underway at a regional level. Most importantly, as noted above, a comprehensive regional hydrogen plan for the Central Coast is being developed under the auspices of the County of Santa Barbara Planning Department, which will go into much more depth on specific fuel station siting issues than is possible in this higher-level AFV Readiness Plan. Through that intensive planning process, additional training of local stakeholders in code and permit issues will also be addressed. In addition, the broader AFV Readiness initiative in the Central Coast, of which this AFV Readiness Plan itself is just one component part, will be actively building stakeholder awareness and knowledge across the AFV spectrum, including the hydrogen Fuel Cell Vehicle ecosystem. The key tasks that are central to both FCV readiness and the broader AFV work include the development of pro-active consumer and fleet outreach via local sponsorship of multiple Green Car Shows (Recommendation 3.1), and AFV Training seminars (Recommendation 3.2.) described further in the chart of Recommended Actions below. Additional recommendations for local government action (not yet underway in most Central Coast jurisdictions) are indicated below.

H2 Readiness Tasks Recommended for Local Government Action: In addition to the regional actions noted above, recommended local government FCV readiness activities involve three domains:

- **Assessment and potential integration of FCVs into public fleets** (Recommendations 2.1. - 2.2)
- **Integration of FCVs and fueling infrastructure into General Plans, Climate Action Plans, and other sustainability-related plans** (Recommendation 2.6.1)
- **Assessment of local hydrogen fueling infrastructure needs & siting options** (Recommendation 2.6.2) as appropriate relative to the California Fuel Cell Partnership map of planned station locations;
- **Participation in available training on hydrogen fuel vehicle and infrastructure planning and safety issues** (Recommendation 2.6.3).

Recommended Regional and Local Actions to Support Hydrogen Vehicle Readiness		
Domain	**Recommendation**	**Lead**
2.6. Fuel Cell Vehicles and Infrastructure	**2.6.1. Assess potential of Fuel Cell Vehicles (FCVs) to meet local GHG reduction, cost, and sustainability goals** -- taking into account the most authoritative research on GHG and air quality impacts and integration of FCV readiness into General Plans, Climate Plans, and other sustainability related plans as appropriate.	**Planning Departments** **Fleet Departments**
	2.6.2. Assess local hydrogen fueling infrastructure needs & siting options in cooperation with the AFV Council and the California Fuel Cell Partnership (where relevant based on planned station locations)	**Planning Departments**
	2.6.3. Participate in local government staff training on hydrogen vehicle and fueling safety, code, and standards utilizing best practices such as: a) the DOE online training: *Introduction to Hydrogen for Code Officials*; b) *H2BestPractices.org;* c) the *Regulations, Codes and Standards Template for California Hydrogen Dispensing Stations;* and, d) CA Fuel Cell Partnership resources.	**Planning Departments with AFV Coordinating Council and CA Fuel Cell Partnership**
3.1. Consumer Outreach and Education	**3.1.1. Produce ongoing Green Car Shows and "Ride and Drive" events to introduce consumers to the full spectrum of AFV types.**	**Central Coast AFV Coordinating Council** **Community Environmental Council**
3.2. Education of Key Decision-Makers and Stakeholders	**3.2.1. Develop AFV training workshops targeting fleet operators, first responders, planners, and decision-makers**. Seminars will introduce key stakeholders to the most recent authoritative information on the full spectrum of AFVs, fueling infrastructure, incentives, and their economic and environmental benefits and operating characteristics.	**Central Coast AFV Coordinating Council**

3.32. Information Resources on Hydrogen Fueling Stations, Funding, and Local Readiness: The following organizations and resources can be helpful in preparing for the arrival of hydrogen vehicles and fueling infrastructure.

Focus	Organization	Website
▪ California H2 information, resources, training	California Fuel Cell Partnership	www.cafcp.org
▪ H2 station developers, business connections, & education	California Hydrogen Business Council	www.californiahydrogen.org
▪ H2 buses, medium and heavy duty vehicles, and stations	CALSTART	www.calstart.org
	Center for Transportation and the Environment	www.cte.tv
▪ AFV and H2 workforce development	Rio Hondo College	www.riohondo.edu
▪ Regional AFV information, training, resources	Clean Cities Coordinators	www1.eere.energy.gov/cleancities/coalitions.html

Funding Resources for Fuel Cell Vehicle Readiness

The California Fuel Cell Partnership - http://cafcp.org

The California Governor's Office of Policy and Research – see the 2013 ZEV Action Plan and companion documents at– http://opr.ca.gov/docs

California Energy Commission – http://www.energy.ca.gov/contracts/transportation.html

Sign up for Energy Commission mailing lists at http://www.energy.ca.gov/listservers/index.html

California Air Resources Board – http://www.arb.ca.gov/ba/fininfo.htm

Air Quality Improvement Program – http://www.arb.ca.gov/msprog/aqip/aqip.htm

DriveClean – http://www.driveclean.ca.gov/Calculate_Savings/Incentives.php

FundingWizard – http://www.coolcalifornia.org/funding-wizard-home

Alternative Fuels Data Center – http://www.afdc.energy.gov/laws/

Adopt a Charger – http://adoptacharger.org/

Community Development Block Grant – http://portal.hud.gov/hudportal/HUD?src=/program_offices/comm_planning/communitydevelopment/programs

Plug-In Electric Vehicle Collaborative Resource Center – http://www.pevcollaborative.org/sites/all/themes/pev/files/PEV_Incentives_12.pdf

Employee Corporate Incentives – http://www.hybridcars.com/corporate-incentives.html

Alternative Fuel Vehicle Refueling Property Credit – http://www.irs.gov/pub/irs-pdf/f8911.pdf

Clean Vehicle Rebate Project – http://www.arb.ca.gov/msprog/aqip/cvrp.htm

California Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project – http://www. californiahvip.org/docs/HVIP_Year%203_Implementation%20Manual_2012-11-14.pdf

Enhanced Fleet Modernization Program – http://www.arb.ca.gov/msprog/aqip/efmp.htm

Carl Moyer Program: On-Road Heavy-Duty Voucher Incentive Program – http://www. arb.ca.gov/msprog/moyer/guidelines/2011gl/2011cmp_offvip_4_28_11.pdf

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3.33. Glossary of Frequently Used Hydrogen-Related Terms

Fuel Cell: A device that uses hydrogen and oxygen to create electricity through an electrochemical process

Fuel Cell Stack: Individual fuel cells connected in series (or stacked) to increase electrical current

Fuel Cell Electric Vehicle (FCEV): A vehicle that uses electricity produced by an onboard fuel cell (typically powered by hydrogen) to run motors located near the vehicle's wheels

Fuel Processor: Device used to extract the hydrogen from fuels, such as natural gas, propane, gasoline, methanol and ethanol, for use in fuel cells

Liquefied Hydrogen (LH2): Hydrogen can exist in a liquid state, but only at extremely cold temperatures, and typically has to be stored at -253°C (-423°F)

Proton Exchange Membrane (PEM) Fuel Cell: A fuel cell that uses a solid catalyst-coated membrane, similar in consistency to thick plastic wrap, to allow positively charged ions to pass through it, but block electrons

Reformer: Device used to extract the hydrogen from fuels, such as natural gas, propane, gasoline, methanol and ethanol, for use in fuel cells

Reforming: A chemical process that reacts hydrogen-containing fuels in the presence of steam, oxygen or both into a hydrogen-rich gas stream

CHAPTER 4: Biofuel Vehicles and Infrastructure

4.1. Biofuel Types and Definitions

As the name suggests, biofuels are derived from biological materials, as opposed to fossil fuel feedstocks. Several types of biofuels are being produced from a wide range of biomass materials and through a variety of conversion processes or pathways. The primary biofuels that are commercially produced today are ethanol, made from sugars and starches, and biodiesel, produced from animal fats or vegetable oils. Biofuels are further divided into two categories – either "first generation" or "advanced" biofuels. First generation biofuels include starch-based ethanol as well as oil crop-based biodiesel. Corn, wheat, sugar, soybean, and palm oil are the commonly used first-generation feedstocks. These biofuels typically reduce carbon intensity by 5%-30% vs. a gasoline baseline. Production of these biofuels is now at a large commercial scale nationally, as first-generation biofuels are blended into existing fossil-fuel based gasoline, and are supported by a variety of federal tax incentives and investment policies.

Many first generation biofuels are widely considered to be environmental sub-optimum insofar as they may displace food production and have a higher carbon intensity and a lower "energy return on energy invested" (EROEI) than more advanced biofuels. In 2014, corn grown for biofuel production in the U.S. exceeded corn grown for human and animal consumption for the first time in history, leading to widespread concern that the "feeding" of automobiles was increasing food insecurity on a global basis. Many food systems analysts have warned that the trend toward fossil-fuel intensive first generation biofuel production is raising food prices beyond the reach of many of the world's poorest populations, and that the energy return on energy invested in first-generation biofuels is unfavorable compared to many other forms of fuel production.

Advanced biofuels – also called second or third generation biofuels – include biofuels produced from non-corn starch, sugar, or cellulosic biomass. These feedstocks have more favorable environmental profiles insofar as they do not necessarily displace other agricultural crops, and can be grown on lower-quality land with reduced fossil fuel inputs such as nitrogen fertilizer. As a matter of EPA definition, advanced biofuels reduce carbon intensity by 50% or more vs. the gasoline baseline.[1] (Specific carbon intensities of various feedstocks are noted later in this chapter). Feedstocks for advanced biofuels include agricultural waste, perennial grasses, farmed woody biomass that can be derived from bamboo or other trees, waste oils, algae, and post-recycled waste.

Biofuels are used primarily to fuel vehicles, but can also fuel engines or fuel cells to generate electricity. Biofuels can be deployed as "drop-in" substitutes or blended with fossil-fueled gasoline and diesel to power light duty and heavy duty vehicles, marine transport, railroads, aviation, and free-standing diesel electric generators for irrigation pumping. The uses of

[1] http://www.c2es.org/technology/overview/biofuels

biofuels (and the percentage of biofuels used in blended formulations with fossil fuels) is constantly expanding as manufacturers design and test their engines for increasing biofuel content.

4.2. The Importance of Biofuels in Decarbonizing Transportation and Achieving GHG Goals: Global, national, and state-level climate and energy analyses have concluded that low carbon biofuels will be essential to reduce greenhouse gases to the levels needed to mitigate the worst impacts of global warming. Biofuels are particularly essential to decarbonize those transportation sectors which are most dependent on fossil fuels, and the most costly and technically challenging to electrify -- notably long-haul trucking, aviation, rail, and marine transport. For many of these applications, batteries are currently too heavy to support the needed travel distances and hydrogen suffers from low energy density and costly pathways to scaled low-carbon production. Given these constraints, the International Energy Agency (IEA, 2012) projects that approximately 25 percent of global transportation energy in 2050, or nearly 250 billion gallons of gasoline equivalent (GGE), must come from advanced, low carbon biofuels if the world is to limit global warming to a two-degree Celsius increase -- the current goal of international climate policy.

4.3. Federal Biofuels Policy Regarding First Generation and Advanced Biofuels: Recognizing the importance of biofuels in the decarbonization of transportation, in 2007, the U.S. Congress passed the Energy Independence and Security Act (EISA), which created robust goals for boosting renewable fuel production and use. The federal policy path created new economic supports for expanded corn ethanol production, to be followed by a transition to cellulosic or algal materials that (once fully implemented) will not compete directly with food supplies. At the center of the EISA legislation is the Renewable Fuel Standard (RFS), which established a mandate for the production of 15 billion gallons of corn ethanol by 2015, and a gradually phased-in target for cellulosic fuels reaching 16 billion gallons per year by 2022, plus an additional one billion gallons of biodiesel to be produced from algae, waste oils, and oil seed crops. Altogether, the Renewable Fuel Standard has mandated 36 billion gallons of renewable fuel to be blended into transportation fuels nationwide by 2022 in four broad categories: cellulosic, biomass-based diesel, advanced biofuel, and total renewable fuels.

Corn ethanol was expected to enable cellulosic and algal biofuels to leapfrog forward by putting in place a flexible production and distribution infrastructure that could handle diverse feedstocks with superior GHG and sustainability characteristics. However, the jump from demonstration to commercial stage has proven much more difficult than expected for cellulosic and algal biofuel companies. In 2013, the production of starch and oil-crop-based fuels topped 14 billion gallons while less than one *million gallons* of cellulosic biofuels were produced. The original nationally mandated level of cellulosic biofuels for 2013 had been one *billion* gallons. To date, even smaller volumes of algae-based fuels have been produced. The EPA's original target ranges for each fuel category are shown below for 2014.

4.4. National Renewable Fuel Volumes and Renewable Fuel Standards (2014)

Category	Range of Volume*	Proposed Volume*	Required Percent of Fuels
Cellulosic Biofuel	8-30 million gallons	17 million gallons	0.01 percent
Biomass-Based Diesel	1.28 billion gallons	1.28 billion gallons	1.16 percent
Advanced Biofuel	2.0-2.51 billion gallons	2.20 billion gallons	1.33 percent
Total Renewable	15.00-15.52 billion	15.21 billion	9.20 percent

Source: U.S. EPA website. *All volume is reported in ethanol-equivalent gallons, except for biomass-based diesel, which is in native gallons.

Since 2007, many of the real-world impacts of federal biofuel policies have been considered problematic from both an environmental and economic perspective, primarily with respect to corn ethanol and certain imported biofuels, notably sugarcane and palm oil based fuels from Brazil and Southeast Asia. Corn ethanol production has been very energy-intensive (Farrell et al., 2006), consumed large amounts of land, raised food prices (Fresco, 2009), and indirectly increased greenhouse gas emissions by diverting land to corn production (Fargione et al., 2008; Searchinger et al., 2008). To satisfy both American and European biofuel mandates, there has been substantial clearing of Amazonian lands in Brazil and rainforests in Southeast Asia to enable the development of palm oil based biofuel crops. Most disappointingly, the development of low-carbon advanced biofuels has lagged far behind expectations. Informed by these unintended consequences and shortfalls in federal biofuels policy, California policies have been designed to spur ecologically sustainable fuel pathway development within the state.

4.5. California Biofuels Policy and Investments - Production and Use Goals: At approximately the same time as President George W. Bush first proposed a major federal biofuels policy initiative, the administration of Governor Schwarzenegger developed the *Bioenergy Action Plan for California*, released in July 2006. This Action Plan established for the first time a set of specific biofuels use targets in California: 0.93 million gasoline gallon equivalents (GGE) in 2010, 1.6 billion GGE in 2020, and 2 billion GGE in 2050. In addition, in-state production goals were established to ensure that California's economy would reap the benefits of the new mandates. These goals called for a minimum of 20 percent of biofuels production within California by 2010, 40 percent by 2020, and 75 percent by 2050. In-state production potential was estimated to be substantial because California produces approximately 80 million dry tons of biomass from the state's farms, dairies, forests, and landfills. Using waste materials from the agricultural, forestry, and urban waste streams could advance many environmental goals at once, including reduced air emissions, landfill, and wildfire risk, among other benefits. As a whole, biofuels have been expected to provide large GHG emission reductions (up to 75 percent compared to gasoline) because carbon dioxide emissions from the burning of biofuels are recycled through plant photosynthesis in the growth of biofuel feedstocks.

As part of the 2007 state *BioEnergy Action Plan,* the state articulated a variety of additional policy goals and measures to achieve them. Highlights of the Action Plan include the following measures, which are now well-advanced:

General Biofuels – Immediate and Mid-Term Actions

1. **Undertake a multimedia evaluation** of the effects on air quality, water quality, and waste disposal requirements.
2. **Encourage California businesses to develop fuel production technologies and produce low-carbon biofuels from in-state feedstocks**.
3. **Verify the performance and environmental attributes of advanced gasoline biofuel** blending components for compliance with the Low Carbon Fuel Standard (LCFS) by 2020.
4. **Improve and expand terminal storage of fuel and transport logistics** for biofuels production.

Ethanol – Immediate Actions

1. **Develop 30-60 ethanol production plants** in California using imported corn feedstocks initially, but transitioning to production from agricultural, forestry, and urban wastes; producing biomethane and biogas; using purpose-grown crops such as sugar cane.
2. **Complete a cellulosic ethanol proof-of-concept production plant**.
3. **Facilitate automaker certification of Flexible Fuel Vehicles** (FFVs) to meet California air emission standards.
4. **Facilitate automaker commitments to produce FFVs** to enable FFVs to comprise a sizeable portion of a total of 750,000 alternative fuel vehicles added per year over five years.
5. **Expand installation of higher blends of ethanol (E-85) pumps in 2,000 stations** over the next 10 years based on geographic distribution of FFVs within the state.
6. **Conduct consumer education and outreach programs to highlight FFV and biofuel attributes** and identify locations for alternative fueling stations.

Ethanol – Mid-Term Actions

1. **Ease transition of ethanol production facilities in California from imported corn feedstocks to low-carbon California biomass feedstocks.**

Renewable Diesel and Biodiesel Immediate Actions

1. **Develop renewable diesel and biodiesel production plants** in California to displace 1 billion gallons of diesel over 10 years.
2. **Establish a California fuel producer's tax credit or subsidy** to complement the existing federal fuel producers' credit.
3. **Continue and expand ongoing R&D to optimize favorable fuel**

characteristics, performance, fuel quality, and environmental impacts, such as nitrogen oxide emissions of higher blend renewable/biodiesel in ratios between 5 to 20 percent.

4. **Facilitate development of "sustainability standards" for renewable diesel and biodiesel** feedstocks (canola oil, palm oil, soy oil, waste grease, and other sources).
5. **Research and develop ways to resolve cold weather performance for higher level renewable/biodiesel blends** in engines.

SOURCE: ***California Alternative Fuels Investment Plan, 2007, CEC and CARB.*** CEC-600-2007-011-CMF, pp. 23-25.

4.6. California Blending Requirements: For more than a decade, gasoline sold in California has been blended with 5.7 percent biofuel on average. In June 2007, ARB revised its reformulated gasoline regulations to enable up to 10 percent ethanol to be blended with gasoline. Increasing California ethanol/biofuels use beyond the 10% level will require widespread use of Flexible Fuel Vehicles (FFVs), which are designed to operate on formulations containing up to 85 percent ethanol blended with fossil fuel based gasoline -- known as E-85. The development of advanced biofuels could also allow system-wide blends beyond 10 percent as a "drop-in" gasoline substitute without requiring use of purpose-built FFVs. Advanced biofuels are defined to have a minimum of a 50 percent reduction in carbon intensity over gasoline and diesel, so even modestly increased blend levels in California's fuel supply could help California meet the state's Low Carbon Fuel Standard (LCFS) targets.

4.7. E85 Fuels and Flexible Fuel Vehicle (FFV) Characteristics and Deployment: Ethanol, or ethyl alcohol, is a clear, colorless liquid that is chemically the same alcohol as found in alcoholic beverages. Ethanol use has a number of functional advantages over gasoline, in addition to reduced carbon intensity (with the specific reduction level dependent on feedstock types). Thanks primarily to favorable incentives and tax treatment, ethanol can be cheaper at the pump than regular gasoline. E85 typically increases horsepower and octane (rated at 105 octane), and thus reduces engine knocking and pinging. It also reduces fuel injection system build up. However, consumers who use E85 in their FFVs will experience between 23 and 28 percent lower fuel economy compared to gasoline that contains only 10 percent ethanol. This means that a retail station owner typically needs to price E85 at more than 23 percent lower than gasoline to entice consumers to alter their existing purchase habits.[2]

Flexible Fueled Vehicles are defined as vehicles that are warrantied to run on either regular gasoline or on E-85 (or another intermediate blend, such as E-20). The size and substantial market penetration of FFVs may be the best-kept secret in American transportation. E85 fuel has been in the marketplace for nearly two decades, but sales were modest until 2013, when Renewable Fuel Standard requirements and favorable blending economics spurred

[2] http://www.ecy.wa.gov/climatechange/cleanfuels/PacificCoastRegionLCF_Jan2015.pdf

substantial sales growth. There are now approximately 3,250 retail stations offering E85 today in the U.S. -- ***although only about 100 E85 stations in California.*** As of 2014, approximately 25% of new vehicles sold in the U.S. were FFVs capable of operating on E85. This includes approximately half of new models produced by Ford, Chrysler and General Motors, as well as select models made by Volkswagen, Land Rover, Jaguar, Toyota, Mercedes-Benz, Bentley and Audi. On a cumulative basis, nearly one of out every ten cars on the road nationally is an FFV. However, many consumers are completely unaware of whether they are already driving an FFV, and may never have fueled their car with E85.

To determine if a particular car is an FFV, check the fuel door, look for an exterior FFV badge or a yellow gas cap, or consult the owner's manual. The Renewable Fuels Association also maintains a comprehensive listing of FFVs at their website at: http://ethanolrfa.3cdn.net/c1cbb67143f6ec4358_97m6buo45.pdf According to the most recent data available from the US Energy Information Administration (Annual Energy Outlook 2013), there were nearly 13 million flex fuel cars on the road nationwide as of 2013, ***and over 400,000 FFVs in California.*** (http://www.eia.gov/tools/faqs/faq.cfm?id=93&t=4) FFVs cost around $100 more per vehicle to manufacture compared to a non-FFV of the same model (Reuters, 2010; Hess, 2007). Through 2016, automakers receive additional credits from selling FFVs to comply with the EPA's greenhouse gas standards. Despite the slightly higher cost of manufacture, this incentive has effectively driven substantially increased production and sales of FFVs in recent years.

4.8. Flex Fuel Vehicles vs. Regular Gasoline Vehicles: FFVs differ from regular gasoline vehicles insofar as they contain a fuel sensor that detects the ethanol/gasoline ratio. In addition, the fuel tank, fuel lines, fuel injectors, computer system, and anti-siphon device have been modified to enable use with E85, including use of a stainless steel fuel tank and Teflon-lined fuel hoses. The use of E85 in gasoline-only vehicles is not recommended as it may cause damage due to the incompatibility of ethanol with regular parts in gasoline-only engines. Despite the rapidly growing availability of FFVs, drivers of Flex Fueled Vehicles in the U.S. have consumed relatively little E85, choosing instead to power their vehicles with regular gasoline (or technically speaking with the E-5 or E-10 blends that are now generally deployed nationwide in compliance with the federal Renewable Fuel Standard). ***In recent years, only 1-3% of the fuel consumed by FFVs has been E85,*** as noted in the table below. The low consumption of E-85 is due in part to limited distribution, but also to the fact that many FFV owners are not aware that they drive a FFV, Another key contributing factor to under-consumption of E-85 is that the fuel is much less energy dense, resulting in a reduction in fuel economy of more than 20% on average vs. standard gasoline.

FFV Deployment and E85 Fuel Consumption in the U.S. in 2011-2013 (EIA, 2014)			
	2011	2012	2013
Flexible Fuel Vehicles (millions)	9.94	11.38	12.82
E85 (million gallons)	25.4	132.0	175.8
% of FFV miles driven on E85	0.6%	2.5%	3.0%

Location of E85 Retailers and Pricing of E85 Fuel: There are approximately 3,250 retail stations offering E85 today in the U.S. today. A comprehensive listing of E85 retailers is available at the DOE's Alternative Fuel Station Locator at http://www.afdc.energy.gov/locator/stations/. At this website, the user can specify the kind of fuel wanted, enter an address, and the locator will map out the closest stations that sell that fuel. Drivers using a Garmin or TomTom GPS device can also use the Renewable Fuel Association's Points of Interest (POI) E85 Fuel Locator application to identify nearby stations. A Flex Fuel Station Locator can also be downloaded from the Apple App Store or the Android Marketplace. Information on E85 pricing can be found at www.chooseethanol.com. A recent search (July 2015) found prices as low as $1.90 in Iowa and as high as $3.49 in California, with average pricing in the $2.50 range nationally and somewhat higher in California. Within California, there are only 98 E85 fueling stations listed at the California station located at the e85.com website (http://www.e85vehicles.com/e85-stations/e85-california.html).

4.9. Projections for Increased Ethanol Use and E85 Fueling Station Deployment: The revised federal Renewable Fuel Standard (RFS2) mandate establishes a maximum volume of federally incentivized corn ethanol production -- and mandates specific volumes of lower-carbon biofuels that meet the technical specifications for EPA designation as an "advanced biofuel" – which requires a minimum 50% reduction in carbon intensity vs. petroleum based fuels. These RFS volume mandates apply to all petroleum fuel producers nationwide. The California Energy Commission projects that the federal Renewable Fuel Standard combined with the state's Low Carbon Fuel Standard spur the production and sale of 2.7 billion to 3 billion gallons of ethanol by 2030. Reaching these levels of E85 consumption is of course contingent upon the number of FFVs on the road, adequate E85 fueling stations and fuel supplies, and the willingness of California FFV drivers to actually purchase E85 fuels if available.

To realize the 2030 RFS2 forecast, the consulting firm ICF International estimates that the installation of between 1,300 and 13,000 new E85 dispensers will be required by 2022, depending on total consumer demand and dispenser throughput.[3] The estimated average cost per E85 dispensing unit, including installation and permitting of tank, dispenser, and other components is approximately $330,000, based on recent grant award data from the California

[3] http://www.ecy.wa.gov/climatechange/cleanfuels/PacificCoastRegionLCF_Jan2015.pdf

Energy Commission. However, California retail gas station owners and operators have no obligations under the RFS2 regulations or the LCFS to actually offer E85 for sale -- and little or no financial incentive to make an investment of this size for new E85 infrastructure. Expanded E85 fueling is challenging not only because of the up-front capital outlay, but also because owners face significant difficulty in setting the retail price of E85 low enough relative to regular gasoline (with its superior energy density and MPG) to attract customers while still making a profit. In specific terms, the ethanol price has not been consistently less than the 20% discount relative to gasoline that is required to compensate drivers for the decreased fuel economy of E-85.

To spur broader access to E-85, the Energy Commission has plans to fund over 100 new E-85 locations by 2016. In addition, the Energy Commission has invested $6 million in recent years to encourage California ethanol producers to leverage their efforts in new and retrofitted production technologies, feedstocks, and facilities through the California Ethanol Producer Incentive Program, known as CEPIP. This program has provided targeted production incentives to reduce the carbon intensity of ethanol and to promote cellulosic feedstock use. Despite these efforts, economic conditions have slowed expansion of in-state ethanol production, and CEC investment strategies in ethanol are being reassessed.

4.10. Flex Fuel Vehicle Sales Projections: Despite limited success in boosting E-85 consumption, the outlook for Flex Fuel Vehicle deployment is robust in both the automobile and light truck segments (including pickups and SUVs). The strong sales projections below reflect the reality that there is no substantial price premium on FFVs compared to regular gas vehicles, and consumers have no reason to "opt out" of vehicle models that come with FFV capability as standard equipment across the model line. The International Council for Clean Transportation projects that 2020 sales of FFVs will be 3% for cars and 15% for light trucks at the "low" case, and as high as 13% for cars and 52% for light trucks in the "high" case.

Flex Fuel Vehicle Sales Growth Projections (percentage of annual sales)				
CASE	**VEHICLE TYPE**	**2010**	**2020**	**2030**
Low	Cars	3%	3%	3%
	Light trucks	15%	15%	15%
Low-med	Cars	3%	5%	5%
	Light trucks	15%	18%	18%
Medium	Cars	3%	6%	6%
	Light trucks	15%	22%	22%
Med-high	Cars	3%	7%	7%
	Light trucks	15%	26%	29%
High	Cars	3%	13%	15%
	Light trucks	15%	52%	58%

SOURCE: ***Potential low-carbon fuel supply to the Pacific Coast region of North America,***

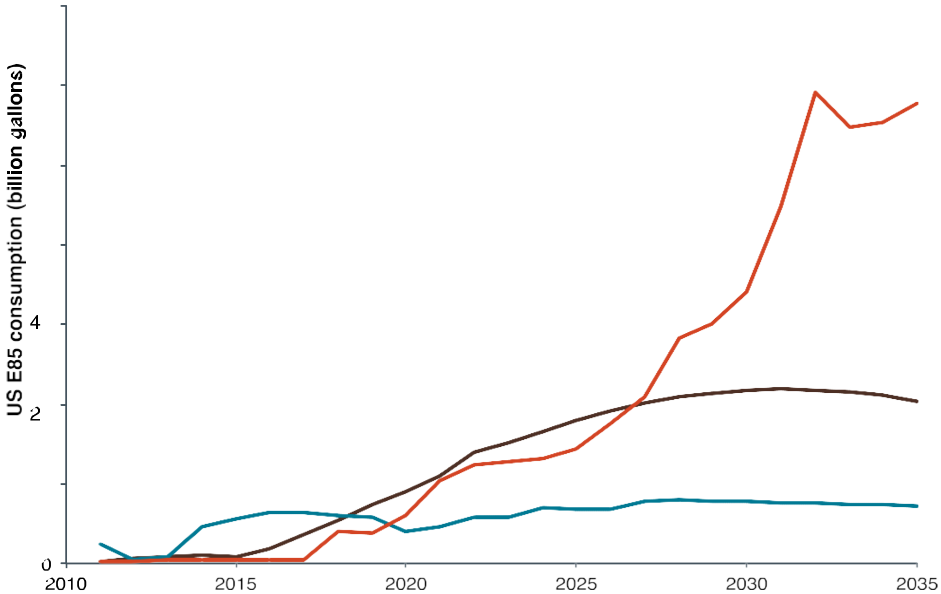
The International Council on Clean Transportation. Washington, D.C., Malins, C., Lutsey, N., Galarza, S., Shao, Z., Searle, S., Chudziak, C., & van den Berg, M. (2015).

As discussed above, the volume of ethanol actually consumed by FFV's does not exist in a linear relationship to the number of FFVs deployed. Currently, FFVs in the U.S. only use E85 for 1% of total miles traveled on average. However, this fraction is expected to rise in the future, according to recent estimates below by the International Council on Clean Transportation.

Projected Share of Vehicle Miles Traveled on E85 by Flex-fuel Vehicles			
CASE	**2010**	**2020**	**2030**
Low	1%	4%	8%
Low - Medium	1%	6%	12%
Medium	1%	7%	14%
Medium - High	1%	9%	18%
High	1%	15%	30%

SOURCE: ***Potential low-carbon fuel supply to the Pacific Coast region of North America,***
The International Council on Clean Transportation. P. 84

4.11. National E85 Fuel Consumption Projections: The U.S. Energy Information Agency (EIA) *Outlook 2014* forecasts growing consumption of E85 to 2020 and 2030, but not to a level that would enable the original RFS targets to be met. Interestingly, EIA has dramatically changed its forecast of E85 consumption in its 2012, 2013, and 2014 Annual Energy Outlooks (see below) and does not discuss the reasons behind these changes. It is worth noting that EIA forecasts are frequently far off the mark, as it is exceedingly difficult to predict future oil or agricultural price behavior. Oil is subject to numerous political, technical, and macroeconomic factors, and agricultural crops are (in addition to these factors) subject to the vagaries of weather, longer-term climate change, consumer demand, and government price supports and other policies.



Projected E85 consumption in the U.S. from 2011-2040 according to EIA's Annual Energy Outlooks published in 2012, 2013, and 2014.

4.12. The Federal Renewable Fuel Standard (RFS) Mandates and Ethanol Consumption Growth: As noted earlier, the federal Renewable Fuel Standard originally required 7.5 billion gallons of renewable fuel to be blended into gasoline by 2012. Under the follow-on Energy Independence and Security Act (EISA) of 2007, the revised RFS program (RFS2) expanded the volume of renewable fuel required to be blended into transportation fuel from 9 billion gallons in 2008 to 36 billion gallons by 2022. It also set forth additional requirements for biodiesel and renewable biodiesel (discussed in depth in Section 4.37 of this chapter).

According to the EPA, U.S. non-petroleum fuel production is projected to grow from 1.09 million barrels per day in 2011 to just under 2 million barrels per day in 2040 (an oil barrel is 42 US gallons), or 30.66 billion gallons per year. In 2011, ethanol production was nearly 14 billion gallons per year (just over 10 percent of total gasoline consumption). In compliance with the RFS2, the EPA established an interim mandate for biodiesel at 1.28 billion gallons per year by 2013. In addition to the biodiesel mandate, the EPA has required that production of advanced biofuels (meaning all fuels with at least a 50 percent emissions reduction from gasoline), will increase from 2 billion gallons to 2.75 billion gallons in 2013.

Total U.S. Renewable Fuel Requirements, 2011 – 2013 (billion gallons unless noted)			
Fuel Type	**2011**	**2012**	**2013**
Cellulosic biofuel	6.6 million	10.45 million	14 million
Biodiesel	0.8 billion	1 billion	1.28 billion

Advanced biofuel	1.35 billion	2 billion	2.75 billion
Total Renewable fuel (Including Ethanol)	13.95 billion	15.2 billion	16.55 billion

Source: *EPA (2013) http://www.epa.gov/otaq/fuels/renewablefuels/regulations.htm*
Note: Volumes are ethanol-equivalent, except for biodiesel which is actual volume.

4.13. Potential to Expand E85 and Biofuel Production in California: Although take-up of E85 has been slow, CARB and the California Energy Commission remain committed to both Flex Fuel Vehicles and the broader biofuels opportunity -- for the simple reason that the potential for GHG reduction is so large. With biofuels defined as gasoline substitutes, diesel substitutes, and biomethane, the biofuels sector as a whole represents the largest existing stock of alternative fuel in California's transportation sector. Of the roughly 28.4 million vehicles on California's roads, more than 96 percent rely on gasoline or diesel for fuel. If low-carbon biofuels were to become available in the right quantity and price, they could directly displace the roughly 13 billion gallons of conventional gasoline and 3.3 billion gallons of diesel used per year in California – thereby reducing both GHG emissions and petroleum dependence. For this reason, the CEC continues to invest heavily in companies and communities with the potential to develop economically competitive biofuels from renewable and low-carbon feedstocks.

4.14. Ethanol Production and Use in California: Currently, ethanol is used primarily as a fuel additive with gasoline in concentrations of either 10 percent (E10) or 85 percent (E85). However, the vast majority of ethanol is consumed in the E10 blend, which is broadly distributed in alignment with the federal Renewable Fuel Standard. To give a sense for the difference in scale between deployment of E-10 (the standard fuel type), and E-85, approximately 1 million FFVs registered in California used just 6.6 million gallons of E85 in 2013, versus 1 billion gallons of ethanol used in the blending of B-10!

Virtually all of the ethanol currently used in California is imported from out of state. ICF and other sources project that near-term ethanol supplies will continue to be produced from imported Midwest corn, while in-state production will feature both waste stream sources and purpose-grown energy crops, such as switchgrasses and sugar cane grown in the Imperial Valley. Maximizing in-state production of ethanol has been a policy goal of the state for the last decade – with biomass residues from agricultural, forestry, and urban sources heavily favored for ethanol production, given the large volume of California's untapped biomass resource. Currently, the state is estimated to have the capacity to produce nearly 220 million gallons of ethanol per year, using primarily corn or sorghum as a feedstock. There are four major in-state ethanol plants operational, but according to the CEC, several have experienced lengthy idling periods in the past because of the unattractive producer price and weak demand for ethanol.

4.15. California's Low Carbon Fuel Standard (LCFS) and the Shift to Lower Carbon Ethanol: Total in-state ethanol consumption has not substantially changed since 2011; however, production has steadily shifted to lower-carbon-intensity ethanol feedstocks. Like other biofuels, ethanol is eligible for Low Carbon Fuel Credits. The number of credits provided to ethanol has increased almost 40 percent in 2013 vs. 2012 because of the shift to lower-carbon production (with LCFS credits being distributed in proportion to carbon intensity.) However, ethanol as a share of all LCFS credits fell from about 73 percent in 2012 to about 53 percent in 2013 due in large part to increasing production of renewable diesel and biodiesel. It is anticipated that ethanol will continue its trend toward lower carbon intensity thanks to a combination of LCFS credits and advances in low-carbon biofuel production capacity.

4.16. Prospects for E15 Ethanol Blend Utilization and Feedstock Diversification: In a recent comprehensive study on alternative fuels in the Pacific Coast region, ICF Consulting assumed that ethanol would continue to be blended into gasoline at a rate of 10 percent by volume, consistent with today's reformulated gasoline requirements. However, ICF anticipates that an E15 blend will also be introduced soon and be consumed in meaningful quantities in the 2017-2018 timeframe as a result of policy drivers such as the state LCFS and the federal RFS2. The chart below indicates the diversity of feedstocks that California and out of state suppliers can drawn on to boost their production of lower-carbon ethanol, in alignment with LCFS goals.

Overview of Ethanol Feedstocks

Corn, Conventional (Midwest): Corn from conventional processes is typically sourced from the Midwest and has been the most common feedstock for ethanol consumed in California. Nearly 1.5 billion gallons of corn ethanol are consumed in California today as an oxygenator in reformulated gasoline.

Corn (California-produced): California currently has seven ethanol production facilities with a combined nameplate production capacity of more than 250 million gallons. However, actual production capacity is close to 200 million gallons annually. ICF estimates that there is potential for actual production capacity to ~220 million gallons.

Corn, low carbon intensity: There is potential to lower the carbon intensity of corn ethanol, with a potential lower limit of 73 g/MJ (per ICF estimates). A variety of lower carbon pathways have been reviewed and approved by CARB.

Sugarcane: Most sugarcane ethanol is produced in Brazil and shipped via tanker to the United States. The ethanol arrives in California either via port or rail after landing in Texas. An estimated 90 million gallons comes to California, out of 500 million gallons of sugarcane ethanol imported in 2012.

Cellulosic: Cellulosic ethanol is produced from wood, grasses, or other lingocelluosic materials. Cellulosic ethanol production capacity in California will be increasing in coming years to reduce the carbon intensity of ethanol and create a more sustainable feedstock strategy that does not compete with food supplies.

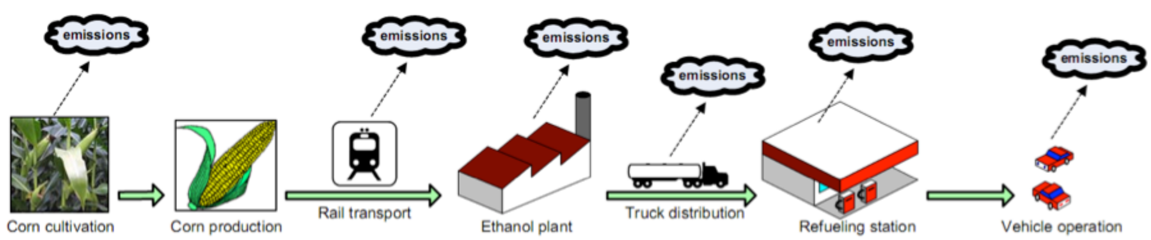
4.17. Estimating GHG Impacts and Carbon Intensity Values for Biofuels: If grown in a sustainable manner, biomass (in and of itself) is considered a carbon-neutral energy source –

meaning that the greenhouse gas emissions (tracked in the form of CO_2 equivalent or CO_2e), released from converting biomass to energy are equivalent to the amount of CO_2e absorbed by the plants during their growing cycles. Sustainable biomass sources refer to those that limit land use change, avoid pollution, prioritize waste materials, and regrow quickly without substantial energy and chemical inputs. Without actions to ensure ecological sustainability, however, an increase in dedicated biofuel crops can result in undesirable land use impacts, unfavorable energy return on energy invested (EROEI) and increased pesticide use. Additionally, fossil fuel used in biomass harvesting, transporting, and processing has an effect on total emissions, and must be considered in a full life-cycle analysis.

It is challenging to design scientifically-based, equitable methodologies for estimating lifecycle greenhouse gas emissions for both petroleum- and bio-based fuels. In practice, not all greenhouse gas emissions can be included in a fuel's greenhouse gas footprint. To address this challenge, the Argonne National Laboratory has developed a full life-cycle model called GREET (Greenhouse gases, Regulated Emissions, and Energy use in Transportation). It enables researchers to evaluate various vehicle and fuel combinations on a full fuel-cycle and a full vehicle-cycle basis. The first version of GREET was released in 1996. Since then, Argonne has continued to update and expand the model. The most recent GREET versions are the GREET 1/ 2014 version for fuel-cycle analysis and GREET 2/ 2014 version for vehicle-cycle analysis. GREET is provided as a public domain, multidimensional spreadsheet model in Microsoft Excel, and is available free of charge at https://greet.es.anl.gov.

With GREET or any other model, some emissions are directly measurable, including tailpipe CO_2, while others must be estimated, such as indirect land use change occurring because of displaced food crops from increased biomass crops. In the case of biofuels, the following diagram of the lifecycle pathway of corn ethanol indicates the complexity of the measurement process.

Diagram of Lifecycle Emissions Pathway, Corn Ethanol



Source: Delucchi, M., *A Lifecycle Emissions Model (LEM): Lifecycle Emissions from Transportation Fuels, Motor Vehicles, Transportation Modes, Electricity Use, Heating and Cooking Fuels, and Materials,* http://www.its.ucdavis.edu/publications/2003/UCD-ITS-RR-03-17X.pdf

The table below illustrates the carbon intensity values used for fuels that substitute for gasoline. Unless otherwise noted, carbon intensity values were taken directly from CARB's look-up tables, which use the GREET methodology, depicting carbon intensity in grams of CO_2e per megajoule.

Carbon Intensity Values for Fuels that Substitute for Gasoline	
Fuel / Feedstock	**Carbon Intensity (gCO2e/MJ)**
Ethanol, conventional	95.66
Ethanol, CA corn	80.70; decreasing to 70.70 in 2016
Ethanol, Low CI Corn	73.21
Ethanol, Sugarcane	73.40; decreasing to 67.38 by 2020
Ethanol, Cellulosic	21.30 [a]
Renewable Gasoline	25.00 [b]
Compressed natural gas	68.00
Biogas, landfill	11.56
Electricity, marginal [c]	30.80; decreasing to 26.32 by 2020
Hydrogen [d]	39.42

SOURCE: *California's Low Carbon Fuel Standard: Compliance Outlook for 2020,* June 2013, ICF International. pp. 11-12. [a]The average of CARB pathways for ethanol from farmed trees and forest ways. [b]Estimated carbon intensity based on stakeholder consultation. [c]Includes the energy economy ratio (EER) of 3.4 for electric vehicles. [d]Includes the EER of 2.5 for fuel cell vehicles

4.18. Projected Growth in Ethanol Production by Feedstock Type: Ethanol consumption growth in California in the 2015-2020 period is projected to be relatively limited, although biofuel growth in general through the 2050 period must become highly robust to meet CARB goals. The ICF biofuels study projected future growth of ethanol from corn (of various types), sugarcane, and cellulosic feedstocks. The table below indicates the volumes (in million gallons) of ethanol broken down by feedstock.

Ethanol Volumes by Feedstock Type (in millions of gallons)								
Feedstock	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Corn, Conventional	264	0	0	0	0	0	0	0
California Corn	215	220	220	220	220	220	220	220
Low Carbon Intensity (CI) Corn	780	884	699	526	408	311	214	87
Sugarcane	120	240	360	480	500	500	500	500
Cellulosic	5	41	100	150	246	328	406	511
Total	1,384	1,385	1,379	1,376	1,374	1,359	1,340	1,318
% Ethanol in Gasoline	**10%**	**10%**	**10%**	**10%**	**10%**	**10%**	**10%**	**10%**

SOURCE: *California's Low Carbon Fuel Standard: Compliance Outlook for 2020,* June 2013, ICF International. p. 18.

4.19. Introduction to Diesel Fuels, Vehicles, and Emissions Trends: The production and use of diesel fuels and vehicles has an enormous impact on California's air quality, public health, and economic security. Nearly all semi-trucks, delivery vehicles, buses, trains, ships, boats and barges, farm, construction and military vehicles and equipment utilize diesel engines. Diesel fuel accounts for about 16% of total refined petroleum products consumed in the U.S. and a similar percentage in California. On-highway motor vehicles use about 75% of this total, with the rest consumed by "off-highway" construction, farming equipment, military, railroad equipment, and marine transport.[4]

Diesel engines emit a complex mixture of air pollutants, composed of gaseous and solid material. The visible emissions in diesel exhaust are known as particulate matter or PM. ***Diesel-powered vehicles account for about 4 percent of California motor vehicles, but produce nearly 60 percent of directly emitted Particulate Matter (PM).*** Two thirds of the PM is emitted from off-road diesel equipment, typically construction equipment and agricultural pumps and generators. The prevalence of off-road diesel applications further underscores the need for electrification (including use of off-grid solar and storage for pumping operations) and use of cleaner renewable diesel fuels in these key segments.

Diesel Health Impacts and Emissions Trends: In 1998, California identified diesel exhaust particulate matter (PM) as a toxic air contaminant based on its potential to cause cancer, premature death, and other health problems. Those most vulnerable include children and the elderly. According to the California Air Resources Board, diesel PM contributes each year to approximately 2,000 premature deaths, with an uncertainty range of 1,500 to 2,400. In addition, diesel soot causes visibility reduction and is a potent global warmer. According to CARB and the Union of Concerned Scientists, Diesel trucks produce 9% of the greenhouse gases emitted from all sources statewide. Diesel vehicles produce more than double the PM and NOx of the 20 million vehicle Light Duty fleet. Just one heavy duty diesel truck with a pre-2010 engine produces the emissions impact of 150 regular light-duty vehicles. Unfortunately, growth in diesel emissions is substantial, increasing by 77% from 1990 – 2013, a growth rate three times greater than LDVs in that period. Further, the CEC predicts a 42% increase in use of diesel by 2030, while the federal Department of Energy predicts transport GHGs from freight trucks will grow from 17% in 2007 to 20% in 2030.[5]

As a result of these serious adverse public health impacts, both CARB and the EPA have implemented a new cleaner diesel fuel program, which significantly reduces sulfur content, creating immediate health benefits, and enabling engine manufacturers to begin using advanced emissions control systems that reduce harmful emissions. The EPA diesel program regulations can be accessed at http://www.epa.gov/otaq/fuels/dieselfuels/ and are located in 40 CFR Part 80 subpart I. A 15 parts per million (ppm) sulfur specification, known as Ultra Low

[4] California Energy Commission, *Energy Almanac,* July 2015, http://energyalmanac.ca.gov/transportation/diesel.html

[5] **Source: UCS/ CARB**, "California: Diesel Trucks, Air Pollution and Public Health," http://www.ucsusa.org/clean-vehicles/california-and-western-states/diesel-trucks-air-pollution.html#.V0cIXGOeyAY

Sulfur Diesel (ULSD), was phased in for highway diesel fuel by 2010. Diesel engines equipped with advanced emission control devices (generally, 2007 and later model year engines and vehicles) must use ULSD fuel. Exhaust emissions from these engines will thereby decrease by more than 90%.

CARB has implemented a companion risk reduction plan that includes the ULSD standard of 15 ppm as well as use of catalyzed particulate filters, NOx after-treatment, and other advanced emission control technologies, both for new and for retrofitted existing engines. The major sources of diesel PM are the 1,250,000 diesel-fueled engines and vehicles in use in California. This includes trucks and buses, large off-road equipment such as bulldozers and tractors, engines used in portable equipment such as cranes, refrigerating units on trucks, and stationary engines used to generate power or pump water. In the aggregate, these diesel engines release over 25,000 tons per year of particulate matter into California's air -- with two-thirds of these emissions coming from off-road equipment.

4.20. CARB Diesel Regulations and GHG Impacts: In 2002, California adopted Assembly Bill 1493 to control emissions from motor vehicles. The regulation was developed by the ARB in 2004, and became effective from January 1, 2006. The standards are being phased-in over the period of 2009 to 2016, as shown in the table below. The GHG standards are incorporated into the California low emission vehicle (LEV) legislation. There are two fleet average GHG requirements: (1) for passenger car/light-duty truck 1 (PC/LDT1) category, which includes all passenger cars and light-duty trucks below 3,750 lbs equivalent test weight (ETW); and (2) for light-duty truck 2 (LDT2) category, including light trucks between 3,751 lbs ETW and 8,500 lbs gross vehicle weight (GVW). In addition, medium-duty passenger vehicles (MDPVs) from 8,500 to 10,000 lbs GVW are included in the LDT2 category for GHG emission standards.

California Diesel Fleet Average GHG Emission Standards

Time Frame	Year	GHG Standard, g CO_2/mi (g CO_2/km)		CAFE Equivalent, mpg (l/100 km)	
		PC/LDT1	LDT2	PC/LDT1	LDT2
Near Term	2009	323 (201)	439 (274)	27.6 (8.52)	20.3 (11.59)
	2010	301 (188)	420 (262)	29.6 (7.95)	21.2 (11.10)
	2011	267 (166)	390 (243)	33.3 (7.06)	22.8 (10.32)
	2012	233 (145)	361 (225)	38.2 (6.16)	24.7 (9.52)
Medium Term	2013	227 (142)	355 (221)	39.2 (6.00)	25.1 (9.37)
	2014	222 (138)	350 (218)	40.1 (5.87)	25.4 (9.26)
	2015	213 (133)	341 (213)	41.8 (5.63)	26.1 (9.01)
	2016	205 (128)	332 (207)	43.4 (5.42)	26.8 (8.78)

SOURCE: California ARB, in California Cars: Diesel Emissions, at https://www.dieselnet.com/standards/us/ca_ghg.php

In addition to these fuel standards, CARB has initiated a comprehensive set of emissions strategies to address diesel particulate matter, air toxics, and GHG emissions from trucks over a multi-decadal time scale. Key milestones in this regulatory effort include the following:

- **2002 – 2010 --** Per the passage of Assembly Bill (AB) 1493 in 2002, CARB and the EPA introduced Ultra Low Sulfur Diesel (ULSD) requirements beginning in 2010. The use of ULSD, in combination with advanced diesel engines (required since 2007), will help to decrease diesel emissions by 90%+ compared to earlier (pre 2010) diesel engine performance.
- **2004** -- CARB passes 5-minute idling regulation for heavy-duty (HD) diesels
- **2008** – requirement issued for all HD trucks & buses to have a 2010 year diesel engine or equivalent by 2023 – with intermediary regulatory requirements beginning in 2011 (in tandem with the lower carbon fuel requirements identified above.) Key technologies applied to the diesel engine to meet these mandates include diesel particle filters (DPFs), which remove most PM, and selective catalytic reduction (SCR), which removes most nitrogen oxides (NOx).
- **2017 –** all ~1M CA trucks & buses must have Diesel Particulate Filter (DPF)
- **2031 -** Federal ozone standards require a 90% reduction in NOx by 2031.

Local Air Quality Impact of Diesel Regulations: Due to the long lead times for phasing in some of these standards and technologies, local public health advocates have questioned when conditions on the ground in the most impacted neighborhoods would be evident. In the greater San Francisco Bay Area, a study by the Lawrence Berkeley National Laboratory (LBNL) and the Bay Area Air Quality Management District (BAAQMD) sought to answer that question with reference to the most concentrated source of diesel emissions in Northern California -- the Port of Oakland and surrounding East Bay communities along the I 80 and I 580 corridors. Over the 2009 - 2013 period, researchers found that the percent of trucks with diesel particulate filters (DPFs) increased from 2 to 99 percent; the median engine age fell from 11 to 6 years, and the emissions factor decreased by 76% for black carbon & 53% for Nox. Additional improvements are expected over the coming years as the 2023 requirement comes online requiring the retirement of all pre-2010 engines.

4.21. Biofuels and the Federal Ozone Standard Challenge: California has made substantial progress in reducing emissions from all mobile sources, with many vehicles sold today being over 90 percent cleaner than those sold just a decade ago. However, despite this progress, these vehicles and equipment remain major contributors to statewide emissions of oxides of nitrogen (NOx), GHG, and diesel particulate matter (diesel PM). Compared to today's levels, a 90 percent reduction in NOx emissions by 2031 will be necessary to achieve compliance with current federal ozone standards, in addition to the 80 percent reduction in GHG emissions by 2050 required to meet AB 32 targets. These targets will require dramatic increases in the supply and availability of clean diesel. The many strategies and methods for producing cleaner diesel -- and the growing availability of vehicles capable of running on higher blends of biodiesel -- are reviewed below.

4.22. Clean Light-Duty Diesel Use Characteristics, Models, and Availability: Light-duty diesel vehicles, including autos, pick-ups, and SUVs, have historically suffered in consumer perception from association with the soot and smells of heavy-duty diesel trucks and buses. But the performance and sales of light-duty diesel vehicles are changing dramatically. There are now a total of 7.4 million diesel cars and SUVs on U.S. roads, out of a total vehicle pool of roughly 250 million, an increase of 47.6% since 2010, compared to an overall market rise of just 6.4% during the same period. Data provided by IHS Automotive to the Diesel Technology Forum showed that some of the highest year-over-year increases since 2010 have come from California.[6]

A key milestone in the recent renaissance of diesel LDVs was reached in 2006, when Mercedes introduced its BlueTEC clean diesel technology for the E-Class sedan. The core of this technology is an injected liquid solution known as AdBlue that reduces smog-causing nitrogen oxide to nitrogen and water vapor. BlueTEC's introduction coincided with the rollout of the ultralow-sulfur diesel fuel requirement in California, giving diesel a "green halo" that it had not had previously. Another milestone was reached at the 2008 Los Angeles Auto Show, where the 2009 Volkswagen Jetta TDI was named Green Car of the Year with an estimated 41 miles per gallon EPA performance on the highway and compliance with emissions standards in all 50 states.

As of 2015, diesel offerings are proliferating not only from Mercedes and VW, but also from BMW, Jeep, Mazda, Porsche, and even Chevrolet – which has promoted the diesel version of the strong-selling Cruze as a "clean turbo diesel sedan," with an EPA highway rating of 46 mpg. Notable models now available in diesel variants include the Audi A3 and Q5, BMW 328, 535, X3 and X5 series, the VW Toureg SUV, VW Golf, Jetta, Passat, and Beetle, the Mercedes E250, the Porsche Cayenne, Jeep Cherokee and Dodge Ram 1500. Altogether, there are estimated to be 47 new clean diesel car, light-duty truck, and SUV models available now or launching in the 2015 model year, with forecasts of 62 light-duty diesel models available throughout North America by 2017. The 2016 offerings will include the Audi A4, Jaguar XE, Mazda 6, Jeep Wrangler, Porsche Macan, Range Rover Sport, Nissan Titan, and several others.

Nationwide, diesels make up only about 3 percent of the passenger vehicle market, but this percentage is expected to grow in the next few years. Currently, light-duty diesel vehicles are approximately $2,000 to $5,000 more expensive than the equivalent conventional vehicle, but resale value is typically proportionately higher. Further, diesel engines have a reputation for very long life, which supports strong resale values. Additional benefits of diesel use include enhanced fuel economy (20% to 40% improvement), and greater power availability for towing and heavier vehicles. Diesel fuel pricing is variable, but in general has been close to that of regular gasoline, sometimes slightly higher or lower. The availability of diesel vehicles and their clean fuel capabilities are outlined in the chart below. Dates indicated below indicate when the OEM first approved B20 or higher biodiesel blends.

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[6] "*Texas And California Lead The Country In Diesel Vehicles,"* The Association for Convenience and Fuel Retailing, http://www.nacsonline.com/news/daily/pages/nd0331155.aspx#.VcjIgngf9p8

Diesel Cars, Trucks, and Low-Carbon Biodiesel Fuel Capabilities		
OEMs	**OEMs Supporting B20**	**OEMs Supporting B5**
Case IH (2007)	**Arctic Cat** (2006)	**Audi** * (Allowngi up to B20 in IL and MN in 2009---2015 models)
Deutz AG (2012)	**Buhler** (2007)	**BMW**
Fairbanks Morse	**Caterpillar** (All model years)	**Hustler Turf Equipment**
New Holland (2007)	**Fiat Chrysler (FCA)** – **Ram** (2007) & **Jeep** (2013)	**Mercedes Benz** * (For blends over B5, see MB
	Cummins (2002)	**Mitsubishi Fuso** *
	Daimler Trucks --- Including: (2012)	**PACCAR* --- Including:**
	--- Detroit Diesel * (Series 60 engines only; other models approved	**--- Kenworth** (Allow up to B20 in models with
	Freightliner / Custom Chassis (with Cummins engines)	**--- Peterbilt** (Allow up to B20 in models with
	Thomas Built Buses	**Volkswagen** * allowing up to B20 in IL and MN in 2009-2015 models)
	Western Star (w/ Cummins engines)	
	Ferris (2011)	*** = Actively Researching B20**
	Ford (2011)	
	GMC & Chevrolet (2011 all; SEO available since 2007)	
	HDT USA Motorcycles (2008)	
	Hino Trucks (2011)	**Biodiesel Position Not Yet Announced**
	Navistar --- International / MaxxForce (2007)	**JCB**
	IC Bus (2007)	**Jaguar / Land Rover**
	Isuzu Commercial Trucks (2011)	**Mahindra**
	John Deere (2004)	**Mazda**
	Kubota (2006)	**Porsche**
	Mack (EPA 2007 & EPA 2010 models)	**Nissan**
	Monaco RV (2007)	**Toyota**
	Perkins (2008)	
	Tomcar (2008)	
	Toro (2008; SEO kits for <2008)	
	Volvo Trucks (EPA 2010 models)	
	Workhorse (2007)	
	Yanmar (2011)	

SOURCE: http://biodiesel.org/docs/default-source/ffs-engine_manufacturers/oem-support-summary.pdf?sfvrsn=16

All major OEMs producing diesel vehicles for the U.S. market support at least B5 and lower blends, and nearly 80% of those manufacturers now support B20 or higher biodiesel blends in at least some of their equipment, including nearly 90% of the medium & heavy duty truck OEMs. The biodiesel component of the fuel must meet the approved standard for pure biodiesel, known as ASTM D6751, and the B20 blends must meet ASTM D7467 specifications. For a complete listing of OEM position statements on biodiesel, visit: www.biodiesel.org/using---biodiesel/oem---information.

4.23. Clean Diesel Market Outlook: Many industry analysts predict that diesel vehicles will make up to 10 to 15 percent of the U.S. light-duty market by the year 2025, up from just over 3 percent in 2014.[7] With diesels delivering up to 40 percent better real-world fuel economy than gasoline counterparts, automakers are turning to diesel platforms to help them meet the new U.S. Corporate Average Fuel Economy (CAFE) standards, which mandate a fleet average of 54.5 MPG by 2025. In the Medium- and Heavy-Duty truck, bus, and RV markets, there are 27 brands with over 115 different diesel models. While numerous companies are working on both electric and hydrogen product offerings in the MDV/HDV space, it could be as much as a decade before many of these are ready for mass production with pricing that is competitive with current diesel offerings. Therefore, the short to medium term outlook for diesel in all segments – light, medium, and heavy-duty, is quite strong.

4.24. State Funding for Biofuel Vehicles via the Carl Moyer Program: Operating since 1998, the Carl Moyer state grant program provides about $60 million annually in incentives to both private companies and public agencies to purchase cleaner-than-required engines, equipment, and emission reduction technologies. The program operates as a partnership between CARB and California's 35 local air pollution control and air quality management districts, and is funded by tire fees and vehicle registration fees. Projects that reduce emissions from heavy-duty on-road and off-road equipment qualify for Moyer grants.

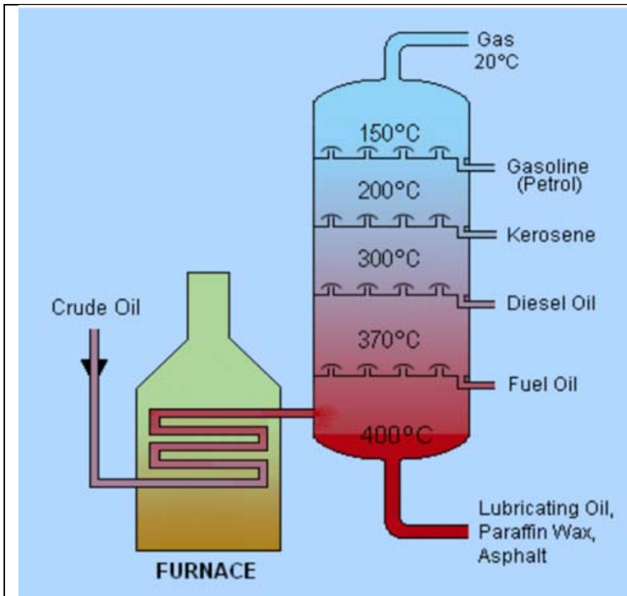
Eligible engines can include on-road trucks over 14,000 lbs. gross vehicle weight (GVW), off-road equipment such as construction and farm equipment, marine vessels, locomotives, stationary agricultural equipment, forklifts, light-duty vehicles, airport ground support equipment, lawn and garden equipment, and emergency vehicles. The program pays up to 85 percent of the cost to repower engines and up to 100 percent to purchase an ARB-verified retrofit device. Maximum grant amounts vary for purchase of new vehicles and equipment. Moyer Program grants are based on the "incremental cost" of the equipment and emission benefits. The Santa Barbara, Ventura, and San Luis Obispo Air Pollution Control Districts can assist organizations in determining funding eligibility. More information on eligible source categories can be found on ARB's Carl Moyer Program website at *http://www.arb.ca.gov/msprog/moyer/moyer.htm,* along with links to local Air District program contacts.

4.25. Diesel and Biodiesel Fueling Infrastructure: The current diesel fuel infrastructure (including refineries, pipelines, terminals, and service stations) covers the entire state and country and operates at very large scale. There are approximately 160,000 service stations and

[7] *The Diesel Technology Forum, Clean Diesel Resources, July 2015. http://www.dieselforum.org/resources/clean-diesel-vehicles-currently-available-in-the-u-s-*

5,000 truck stops in the United States, which supply ~380 million gallons of gasoline per day (blended with ethanol) and ~140 million gallons of diesel per day (blended with biodiesel). Diesel biofuels are attractive as an alternative fuels strategy in large part because they can use of this large-scale existing infrastructure. There are no substantial technical hurdles for retrofitting existing service stations to dispense ethanol blends above 10%, although there would be some cost factors involved in developing new tanks and pumps for biodiesel and renewable diesel. The principal issue in expanding biodiesel infrastructure is expanding the feedstock production from among the viable candidates described below.

4.26. Diesel vs. Biodiesel Production and Feedstocks: To identify the differences between biodiesel and renewable diesel, it is important to first define petrodiesel, more commonly known simply as "diesel fuel" or "diesel." Diesel fuel is a petroleum distillate produced from the fractional distillation of crude oil between 200C (392F) and 350C (662F).



As illustrated in the diagram at the left, the fractions at the top of the fractionating column have lower boiling points than the fractions at the bottom. The heavy bottom fractions are often cracked into lighter, more useful products. All of the fractions are processed further in other refining machinery.

SOURCE: What's the Difference between Biodiesel and Renewable (Green) Diesel, by Jesse Jin Yoon ***for Advanced Biofuels USA***

http://advancedbiofuelsusa.info/wp-content/uploads/2011/03/11-0307-Biodiesel-vs-Renewable_Final-_3_-JJY-formatting-FINAL.pdf

4.27. Biodiesel and Renewable Diesel Characteristics and Standards: Biodiesel is produced using what is known as a transesterification process, whereby vegetable oils or animal fats react catalytically with methanol or ethanol (or another alcohol type). Through transesterification, the glycerin in the feedstocks is separated from the fat or vegetable oil. The process leaves behind two products -- methyl esters (the chemical name for biodiesel) and glycerin -- which is considered a valuable byproduct that is usually sold to be used in soaps and other products. Biodiesel is defined under the standard of ASTM D6751 as "a fuel comprised of mono-alkyl esters of long-chain fatty acids derived from vegetable oils or animal fats." Biodiesel is also referred to as FAME (fatty acid methyl ester) or RME (rape seed methyl ester) in Europe. Unlike renewable diesel, biodiesel is not a "drop-in" replacement for petrodiesel. Biodiesel users must be aware of the key differences that can affect the operation of diesel engines.

Some of biodiesel's properties can present benefits over traditional petrodiesel. The use of biodiesel can reduce net CO2 emissions, reduced hydrocarbon (HC) and carbon (CO) emissions, and lower visible smoke. Biodiesel also has a higher cetane number, contains no aromatics, and is non toxic and biodegradable. Lastly, biodiesel has low sulfur content and improves lubricity. On the other hand, biodiesel may not be compatible with certain metals causing corrosion -- including zinc, copper-based alloys, tin, and lead. Biodiesel can also cause certain elastomers and seals to swell or harden. Biodiesel can also increase NOx emissions, especially at higher blend levels. This is especially critical to consider when using biodiesel in newer vehicles equipped with certified emission control technologies for the more stringent 2007 NOx emission standards. Biodiesel can also negatively impact low- temperature operability due to its higher cloud point and pour point properties. Biodiesel compatible additives may need to be utilized to address these low-temperature issues. Other additives may need to be utilized to address the poorer thermal and oxidative stability of biodiesel. Lastly, biodiesel has lower energy content than petrodiesel. Although this lower value may not be noticeable at blend levels of B2 or B5, users of high blend levels or B100 may notice a drop in power output as well as fuel efficiency.

Over the past few years, manufacturers have been working to support the use of biodiesel in their engines and equipment. As noted in the chart above indicating vehicle availability and fuel type, some OEMs permit the use of biodiesel at blends of B2, B5 and even B20 in their engines. Some are still assessing the possibility of use at higher blend levels, and have not yet taken a position. Of course, for blending at any level, it is critical to know that the original biodiesel blending stock (B100) meets the industry quality standard, known as ASTM D6751, EN 14214 or equivalent specification. For this reason, biodiesel users are strongly encouraged to purchase biodiesel blends from sources that have been fully accredited and quality-tested by the National Biodiesel Board. This accreditation is indicated by the designations: *BQ-9000 Certified Marketer* and *BQ-9000 Accredited Producer*.[8] ***Please note that it is critical to consult your vehicle and engine manufacturer before switching to biodiesel***. Some brands, such as John Deere, utilize multiple engine manufacturers, and therefore it is important to confirm which engine type you are using and check directly with the engine manufacturer as appropriate.

4.28. Summary of Biodiesel Benefits and Limitations: The California Energy Commission has provided the following useful summary of the benefits and limitations of biodiesel:

[8] BQ-9000® is a voluntary program for the accreditation of producers and marketers of biodiesel fuel. The program combines adherence to the ASTM standard for biodiesel, ASTM D6751, and a quality systems program that includes storage, sampling, testing, blending, shipping, distribution, and fuel management practices. BQ-9000® helps companies improve fuel testing and quality control. To receive accreditation, companies must pass a rigorous review and inspection of their quality control processes by an independent auditor.

Benefits

- Biodiesel can be blended up to 5% of the total volume in conventional diesel without costly conversions.
- It is lower in harmful emissions than traditional diesel engines -- reducing carbon dioxide emissions by approximately 50%-88% depending upon the feedstock used.
- Biodiesel energy crops can be grown on marginal lands.

Limitations

- Dependent on feedstock, biodiesel may have a higher cost than conventional diesel.
- Biodiesel fuels have special handling, storage and use requirements.
- The fuel can cause problems with vehicle and engine durability and can solidify in cold weather.
- The higher NOx emissions from biodiesel must be offset by other environmental benefits.
- Soy-based biodiesel has a very modest GHG reduction.

4.29. National Scale-Up of Biodiesel Production: With just over a decade of commercial-scale production, biodiesel production has increased from about 25 million gallons in the early 2000s to about 1.7 billion gallons of advanced biofuel in 2014. This represents a small but growing component of the annual U.S. on-road diesel market of about 35 billion to 40 billion gallons. Consistent with projected feedstock availability, the industry has established a goal of producing about 10 percent of the diesel transportation market by 2022. There are currently about 200 biodiesel plants across the country with registered capacity to produce some 3 billion gallons of fuel. However, a crucial factor in the further expansion of biodiesel production infrastructure is diversifying feedstocks to include more cellulosic sources, reliable sources of fats and oils, and next-generation feedstocks such as algae and camelina. Opportunities for expanding biodiesel and renewable diesel production in California will be explored below.

4.30. Renewable Diesel Characteristics and Use: Renewable Diesel (RD) is chemically the same as petrodiesel, but it is made of recently living biomass. Sometimes called "green diesel" or "second generation diesel," renewable diesel utilizes biological sources that are chemically not esters and thus distinct from biodiesel. (Esters are a class of organic compounds that react with water to produce alcohols and organic or inorganic acids.) Renewable diesel meets ASTM D975 specifications for diesel fuel quality, and is considered chemically and operationally nearly identical to petrodiesel, with the principal distinction being that the organic material used in RD production is (like most biodiesel feedstocks) made of recently living organic material, as opposed to the fossilized organics used in petro-diesel. RD has also been defined in a technically specific manner by the Department of Energy, the Internal Revenue Service, and the EPA to enable producers to participate in the formal RFS program and the Renewable Identification Numbers (RIN) system.

While renewable diesel can be made from the same feedstocks as biodiesel, RD has been hydrocracked and refined in a manner similar to petroleum diesel, and utilizes hydrotreating, thermal conversion, and Biomass-to-Liquid processes. Renewable diesel blends follow the same nomenclature as biodiesel. For example, renewable diesel in its pure form is designated R100 while a blend comprised of 20% renewable diesel and 80% petrodiesel is called R20. Because renewable diesel is chemically the same as petrodiesel, it can be mixed with petrodiesel in any proportion -- although users may need to add an additive to address lubricity issues. RD has also most recent been marketed as a "drop in" replacement for diesel by refiners such as Neste, which has created an "R99" product known as NexBTL, and Valero, which has created its own version of RD through their Diamond Green division.

4.31. Carbon Intensity and Emissions of Petrodiesel, Biodiesel, and Renewable Diesel: From an end use standpoint, the key difference between renewable diesel and biodiesel is its usability as a "drop in" replacement. While there is no mandate for blending biodiesel with conventional diesel (as there is with ethanol and gasoline), a blend of up to 5 percent biodiesel can be used without special modifications to the vehicle. Blends of 20 percent biodiesel and higher (B20) are also common; however, these may not be compatible with retail infrastructure and may interfere with vehicle warranty provisions. Both renewable diesel and biodiesel have very low carbon intensities, which will be discussed in detail later in this document, as the calculation of carbon intensity varies depending on the many feedstock options that exist for both fuels. The chart below indicates other key technical differences between the three major types of diesel.

Properties	Petrodiesel	Biodiesel	Renewable Diesel
Cetane#	40-55	50-65	75-90
Energy Density, MJ/kg	43	38	44
Density, g/ml	0.83-0.85	0.88	0.78
Energy Content, BTU/gal	129 K	118 K	123 K
Sulfur	<10 ppm	<5 ppm	<10 ppm
NOx Emission	Baseline	+10	-10 to 0
Cloud Point, C	-5	20	-10
Oxidative Stability	Baseline	Poor	Excellent
Cold Flow Properties	Baseline	Poor	Excellent
Lubricity	Baseline	Excellent	Similar

SOURCE: *What's the Difference between Biodiesel and Renewable (Green) Diesel* by Jesse Jin Yoon *for Advanced Biofuels USA*

Within the biodiesel fuel type itself, emissions factors vary according to the blend. The federal EPA has surveyed a large body of biodiesel emissions studies and averaged the health effects testing results with other major studies. The results are seen in the table below.

4.32. Biodiesel Emissions vs. Conventional Diesel Without Advanced Emissions Controls		
Emission Type	**B100**	**B20**
Regulated Emissions		
Total Unburned Hydrocarbons	-67%	-20%
Carbon Monoxide	-48%	-12%
Particulate Matter	-47%	-12%
NOx	+10%	+0% 1
Non-Regulated Emissions		
Sulfates	-100%	-20% 2
PAH (Polycyclic Aromatic Hydrocarbons) 3	-80%	-13%
nPAH (nitrated PAH's)4	-90%	-50% 5
Ozone potential of speciated HC	-50%	-10%
Lifecycle CO2 Emissions 6	-76%	-15%

SOURCE: "A Comprehensive Analysis of Biodiesel Impacts on Exhaust Emissions," US EPA, 2001. www.epa.gov/otaq/models/analysis/biodsl/p02001.pdf

1 Eur. J. Lipid Sci. Technol. 2009 "Effect of biodiesel blends on North American heavy-duty diesel engine emissions." 2 Estimated from B100 result. 3 Average reduction across all compounds measured. 4 Average reduction across all compounds measured. 5 2-nitroflourine results were within test method variability. 6 Univ. of Idaho/USDA "Reassessment of Life Cycle GHG Emissions for Soybean Biodiesel."

4.33. Summary of Pollution Reduction and Health Impacts of Biodiesel: Based on EPA testing, the emissions and health impacts of (B100) biodiesel can be summarized as follows:

- **The ozone (smog) forming potential of biodiesel is less than diesel fuel**. The ozone forming potential of biodiesel hydrocarbon emissions is 50 percent less than that measured for diesel fuel.
- **Sulfur emissions are essentially eliminated with pure biodiesel**. The exhaust emissions of sulfur oxides and sulfates (major components of acid rain) from biodiesel are highly reduced when compared to diesel.
- **Criteria pollutants are reduced with biodiesel use**. Tests show the use of biodiesel in diesel engines without advanced emissions controls results in substantial reductions of unburned hydrocarbons, carbon monoxide, and particulate matter. Emissions of nitrogen oxides stay the same or are slightly increased.
- **Carbon Monoxide** -- The exhaust emissions of carbon monoxide (a poisonous gas) from biodiesel are on average 48 percent lower than carbon monoxide emissions from diesel.
- **Particulate Matter** -- Breathing particulate has been shown to be a human health hazard. The exhaust emissions of particulate matter from biodiesel are about 47 percent lower than overall particulate matter emissions from diesel.

- **Hydrocarbons** -- The exhaust emissions of total hydrocarbons (a contributing factor in the localized formation of smog and ozone) are on average 67 percent lower for biodiesel than diesel fuel.
- **Nitrogen Oxides** -- NOx emissions from biodiesel can increase or decrease depending on the engine family and testing procedures. NOx emissions (a contributing factor in the localized formation of smog and ozone) from pure (100%) biodiesel increase on average by 10 percent. However, the 2009 data review showed there is no statistical evidence that the average NOx emissions from US EPA approved diesel fuel and B20 are different.
- **Lifecycle CO2** – *Lifecycle CO2 emissions are 76-86 percent lower compared to 2005 baseline petroleum in a well-to-wheels lifecycle analysis*. This methodology was used by the US EPA to set thresholds in the Renewable Fuel Standard and includes penalties for indirect land use change. More recently, the University of Idaho and USDA used the same methodology and updated the numbers to reflect more recent data.
- **Biodiesel reduces the health risks associated with petroleum diesel**. Biodiesel emissions show decreased levels of polycyclic aromatic hydrocarbons (PAH) and nitrated polycyclic aromatic hydrocarbons (nPAH), which have been identified as potential cancer causing compounds. In Health Effects testing, PAH compounds were reduced by 75 to 85 percent, with the exception of benzo(a)anthracene, which was reduced by roughly 50 percent. Targeted nPAH compounds were also reduced dramatically with biodiesel, with 2-nitrofluorene and 1-nitropyrene reduced by 90 percent, and the rest of the nPAH compounds reduced to only trace levels.

SOURCE: U.S. EPA data cited by the National Biodiesel Board, www.biodiesel.org.

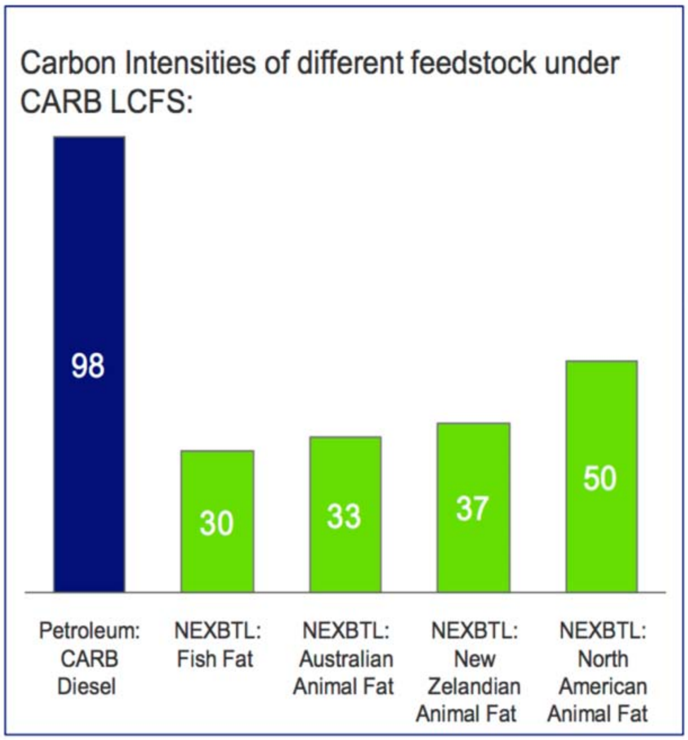
4.34. Renewable Diesel and Biodiesel Feedstocks, Production, and Use in California: Renewable diesel is the most common diesel substitute used in California, recently supplanting biodiesel. Volume is currently about 95 million Gallons (vs. nearly 3 billion gallons of regular diesel.) The majority of this increase is accounted for by overseas imports; however, additional in-state renewable diesel producers are expected to come on-line soon. As noted above, the "drop in" replacement capability of RD means that it can be used effectively in all types of diesel applications, including light, medium, and heavy duty vehicles, nearly all marine applications and some aviation applications, with a Los Angeles to San Francisco flight soon to begin by United Airlines using a combination of RD and petroleum diesel, known as BioJet.

Renewable Diesel Emissions Profile: The overall GHG profile of RD varies according to feedstock sourcing. The carbon intensity (CI) value of the current dominant product in terms of volume and market share -- the Neste RD99 blend – is in the 30 - 33 range (with the reference petroleum gasoline being measured at 100.) The overall profile is as follows:

- **~80% lifecycle reduction in GHG vs. fossil diesel** (depending on RD feedstock)
- **PM is 33% lower**

- **Nitrogen oxides (NOx) = 9% lower**
- **Hydrocarbons (HC) = 30% lower**
- **Carbon monoxide (CO) = 24% lower**

Source: Neste RD product description on website, based on CARB-certified CI values. https://www.neste.com/na/en/customers/products/renewable-products/nexbtl-renewable-dieselS



SOURCE: CARB CI certification values, presentation at Local Gov't Commission by Neste, Golden Gate Petroleum, and NextGen. **http://www.lgc.org/wordpress/wp-content/uploads/2015/10/Renewable-Diesel_Neste-Flyer-with-Golden-Gate-Petroleum.pdf**

CARB-approved CI Analysis for Neste RD: In the following carbon intensity analysis performed by CARB, the relative carbon inputs of different stages in the fuel supply chain are indicated. Note that figures for both "well to tank" (WTT) and "tank to wheels" (TTW) are provided separately so as not to conflate the vehicle combustion efficiency with the fuel supply pathway. Note that in the case of renewable biofuels, "well to tank" is better represented as "source-to-tank" -- since these are not fossil fuels, and the products are sourced from either newly grown or recently living organic matter.

Carbon Intensity of Renewable Diesel Sourced from Tallow

	Carbon Intensity in gCO_2e/MJ
Tallow Production (By rendering)	16.06
Tallow Transport	3.95
Renewable Diesel Production	10.63
Renewable Diesel Transport and Distribution	5.79
Total WTT	36.43
Total TTW	0.78
Propane Rich Off-Gas Credit	-3.75
Total WTW	**33.46**

Source: CARB – Neste, ***NExBTLRenewable Diesel Singapore Plant , Tallow Pathway Description,,*** ***http://www.arb.ca.gov/fuels/lcfs/2a2b/apps/neste-aus-rpt-031513.pdf***

To put the potential of Renewable Diesel in perspective, below is a table of CARB GHG values for various alternative fuels.

FUEL	GHG REDUCED	PETROLEUM REDUCED
Biodiesel (B20)	**10-13%**	**15-17%**
Renewable Diesel (RD99)	**70-90%**	**99%**
Hybrid Electric	**25%**	**25%**
Plug-in Hybrid	**48%**	**60%**
Battery Electric	**72%**	**99.8%**
H2 Electrolysis	**26%**	**99.7%**
H2 Natural Gas	**54%**	**99.7%**
Biodiesel (B20)	**10-13%**	**15-17%**
Midwest Corn E85	**1-28%**	**70%-73%**
California Corn E85	**36%**	**70%-73%**
Cellulose E85	**60-72%**	**73-75%**
CNG LDV	**20-30%**	**4-13%**

Source: CARB 2013 LCFS look-up tables.

Renewable Diesel Production Capacity Growth: In part because of increased demand in California and other jurisdictions with strong carbon reduction goals, Renewable Diesel capacity is ramping up quickly. Currently, there are ten plants worldwide producing RD, with four additional projects in development. Given the high capital requirements for new plants (typically in excess of $200M per facility), there are a total of just four RD producers as of 2016, including Neste – the world's largest, and Italy's ENI, US-based Diamond Green

Diesel (a subsidiary of Valero), and Swedish refiner Preem. With growing biofuel demand and the search for higher quality renewable fuels, the outlook is for continued growth of several hundred million gallons of capacity per year, as in the 2011-2014 period.[9]

- 2011: 300M gallons
- 2012: 700M gallons
- 2013: 900M gallons
- 2014: 1.2 billion gallons

Renewable Diesel Use in Public Agency Fleets: Renewable Diesel has only recently been available in quantity in California, and public and private fleets began integrating use of this fuel in the 2015-16 period. On December 15, 2015, the City of San Francisco announced its transition to 100% RD for all 1,966 city vehicles previously relying on petroleum diesel. Following an RFP process, the city selected Golden Gate Petroleum as its supplier. Golden Gate Petroleum in turn is supplying a combination of the Neste "RD 99" product with the trade name NEXTBTL. This product is blended with a comparable product from Diamond Green, and is being distributed to 53 city-run fueling facilities.

The carbon intensity value of the Neste product is 31, while the Diamond Green product is closer to 15, depending on specific feedstocks at a given point in time. Golden Gate Petroleum is currently the largest RD distributor in the Western US. Other municipal users of the product include the cities of Walnut Creek, Oakland, and the California Department of General Services. Within the private sector, the product is being used by Google (for its gBus employee commuter fleet), and UPS. RD distribution is becoming more robust, as Propel Fuels recently began carrying RD at many of its stations throughout the state.

Given the challenges of sustainable sourcing for these fuels, San Francisco elected to define a carbon intensity requirement in its specification, rather than to indicate which feedstocks would be used. The CI level established was required to be at or below 60% less than the current ultra-low sulfur diesel CI. It was the view of the City that neither palm oil nor food feedstocks such as corn would be included given this CI level, since these feedstocks typically have higher CI values given the petroleum inputs to palm oil and corn production. At this time, some "technical corn oil" is used in the Neste product, utilizing waste distillers' grain, while there is no palm oil coming into California from Neste (although Neste does use palm oil in products shipped to other regions.)

Fleet managers have responded positively to Renewable Diesel which, in contrast to biodiesel, does not require any special handling or pose any operational challenges. According to Richard Battersby, Oakland fleet director and the chair of the East Bay Clean Cities Coalition: "At first, renewable diesel seemed like a 'too good to be true' cost-neutral way to achieve our goals. But renewable diesel gives you the ability to convert your entire

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[9] Tina Caparella, "Global Renewable Diesel Use Triples," *Render, 12/15*, http://www.rendermagazine.com/articles/2015-issues/december-2015/biofuels/

diesel-powered fleet to alternative fuel overnight. The most common reaction I've experienced is disbelief that there is a cleaner burning direct diesel fuel substitute that is made from renewable sources, doesn't require any additional expense for the fuel itself, and does not require equipment and infrastructure modifications." The City of Oakland is now using Nexgen renewable diesel supplied by Golden Gate Petroleum to power the 250+ diesel vehicles in its fleet, at price parity with petroleum diesel.

Biodiesel Production Capacity in California: California has seven biodiesel production facilities, with a combined production capacity of 59 million gallons per year, accounting for 35 percent of LCFS credits from a combined total of about 174 million gallons of low carbon fuel in 2013. Though the Energy Commission has funded upstream biodiesel infrastructure projects, the LCFS regulation has encouraged the regulated fuel distributors to integrate larger shares of biodiesel into their upstream infrastructure without special state incentives. Several major oil terminals throughout the state have either converted or begun converting existing infrastructure to accommodate biodiesel blending. Given that private investment is supporting large-scale biodiesel blending, the Energy Commission is not currently proposing additional funding for diesel substitutes infrastructure. The table below projects the likely volume of future California biodiesel production by feedstock.

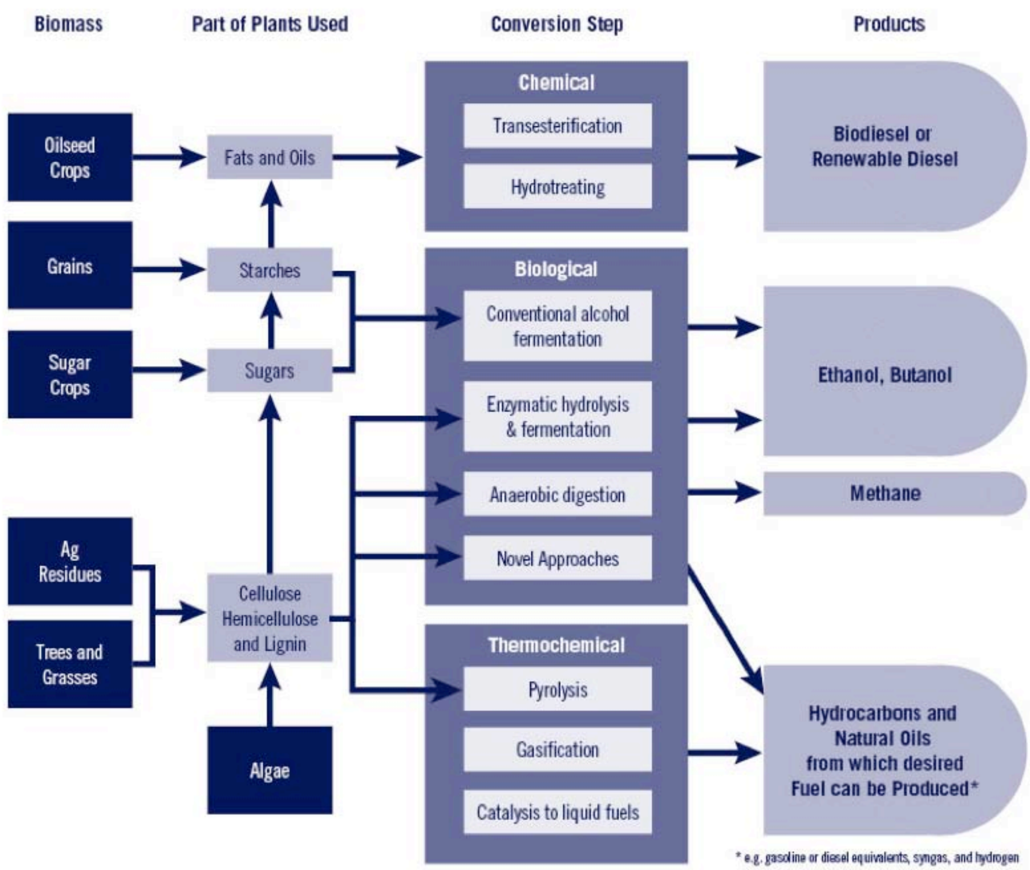
Biodiesel Consumption Through 2020 (million gallons)								
Feedstock	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Soy Oil	3	5	8	11	14	16	19	23
Waste Grease	19	29	48	51	51	51	51	51
Corn Oil	19	29	48	67	86	95	112	189
Canola Oil	3	5	8	27	49	59	80	62
Total Biodiesel	**45**	**68**	**113**	**157**	**200**	**221**	**262**	**325**
Biodiesel Blend (%)	1%	2%	4%	5%	7%	8%	10%	12%

SOURCE: *California's Low Carbon Fuel Standard: Compliance Outlook for 2020,* June 2013, ICF International. p. 18.

As noted above, both renewable diesel and biodiesel fuels can be produced from a broad range of feedstock options, including animal waste, soy beans, vegetable oils, wood wastes, animal fats, and protein. The U.S. Navy and Marine Corps use B20 in their non-tactical diesel vehicles and account for approximately one-third to one-half of all biodiesel purchases in California. The military has robust goals for increased use of both biofuel and electric vehicles. Given this increasing use, and the increasing number of diesel LDVs in the marketplace, increasing biofuel production is a key strategy for California to reduce net CO_2e emissions. An additional driver for increased production is the federal Renewable Fuel Standard mandate of 15 billion gallons for 2015 – which is likely to be filled largely by corn ethanol in 2015. However, an expanding target for cellulosic fuels -- reaching 16 billion gallons in 2022 – will further boost all biofuels, especially given additional one billion gallon mandate for biodiesel from algae, waste oils, and oil seed crops. The expectation was that corn ethanol would create conditions for cellulosic (and algal) biofuels to leapfrog forward, but that jump has proven difficult. Legislated cellulosic targets were lowered for 2010-2013 due to lack of commercial production—less than one million of cellulosic biofuels were produced in 2013—but future targets remain in place. Golden Gate Petroleum is currently working with consultants and investors to develop a potential $200M+ biofuel production facility in the state, but the project is still in early development phase and prospects for completion are not yet firm.

Current and Emerging Biofuel Pathways: The diverse biofuel feedstocks currently in use or under development differ significantly in the types of lands on which they can be grown, yields per acre, and the fuels into which they are processed. The table below indicates the various biomass types, plant elements, conversion steps, and products that can be produced among the diversity of biofuel pathways available -- and the current and emerging pathways for these diverse feedstocks.

Figure 2: Current and Emerging Biofuel Pathways



Source: Peña and Sheehan, 2007.

Source: Pena, N., *Biofuels for Transportation: A Climate Perspective, 2008. http://www.c2es.org/publications/biofuels-transportation-climate-perspective .*

The dominant methods of biofuel production in use at this time convert simple sugars, starches, or oils to produce biofuels. For example, the fermentation of cornstarch (from the corn kernel), sugar beets, or sugarcane produces ethanol, and the transesterification of oils (e.g., soybean or palm oil) produces biodiesel. Of the feedstocks in use today, sugar beets, sugarcane, and palm oil yield the highest amount of fuel per acre on a gasoline gallon-equivalent basis. However, these feedstocks are also very energy intensive to grow, compete with fuel supplies, and have other sustainability issues (they are typically water intensive, fossil-fuel intensive, and pesticide intensive.) In principle, the vast majority of available plant material for biofuels is in the form of cellulose, hemicellulose, and lignin (not food crops), which would significantly lower the resources needed to grow biofuel feedstocks.[10] Furthermore, once the cellulose is extracted from the plant to produce the biofuel, the remaining lignin can be used as a fuel to power the biofuel conversion process. Lignin yields energy when burned and further limits the fossil fuel inputs required to produce the biofuel. Researchers are also looking at different sources for oils that can be converted into biodiesel. However, early federal subsidies for biofuel production and existing agricultural subsidies have favored corn and other sugar and starch-based biofuels, and technology for biofuel production with these feedstocks is more advanced.

California policy makers are seeking to advance more sustainable approaches with a targeted investment approach that emphasizes cellulosic sources, wastes, algae, and crops that can be grown on marginal lands (such as jatropha), further described below.

- **Cellulosic feedstocks** include perennial grasses (e.g., switchgrass and Miscanthus) or short rotation woody crops, which can be converted to ethanol or other biofuels.
- **Industrial waste** includes agricultural wastes such as manure and other processing wastes that are high in protein and fats; these can be converted to oils and then to biodiesel. Other waste biomass includes wood residues from the forest industry and agricultural residues from corn farming; the cellulose in these materials can be converted into ethanol.
- **Algae** can produce oil that can be converted to a number of different biofuels. Additional opportunities are in microalgae (microscopic algae) that can create biomass even more efficiently than terrestrial plants. Algae based biofuel research has been ongoing for many years, but is not yet economic at large commercial scales.
- **Jatropha**, a species able to grow on barren, marginal land, especially in many parts of Asia. Jatropha oil is extracted from the seeds of the plant and can be used to produce biodiesel.

Following harvesting or collection, all forms of biomass must be converted to sugar or other feedstock through the following processes:

- **Pretreatment** processes remove the protective sheath of lignin and hemicellulose to allow for further enzyme hydrolysis of the cellulose biomass to glucose or simple sugar.

[10] Cellulose is complex carbohydrate and the main structural component of plants. Hemicellulose is similar to cellulose and found in plant cell walls. Cellulose and hemicelluloses account for 25 to 50 percent of plant material. Lignin is a polymer that provides rigidity to plants cell walls and is second largest component of plant biomass.

- **Conditioning and enzymatic hydrolysis** is a process that lowers the acidity of the material so that enzymes and organisms can thrive. The pH is adjusted and the toxicity of the material is lowered.
- **Microorganisms**: The feedstock must then be fermented using microorganisms developed through metabolic engineering techniques. Researchers are currently developing microorganisms that can more effectively ferment all the sugars in biomass – improving ethanol and expanding feedstock options.

All of the feedstocks identified above have the ability to reduce greenhouse gas emissions significantly relative to conventional gasoline and diesel fuel. Because they are not food-based and are often processing wastes from other industries, they also have the added benefit of limiting "competition" between transportation fuel uses and food crops. To ensure that the use of sustainable feedstocks is significantly expanded, the California Energy Commission has invested in expanding research, development, and commercial deployment of production facilities associated with promising biofuel pathways.

4.36. State Investments in Biofuel Production Facilities: State investments in biofuel infrastructure are focused on options with the lowest carbon intensities. Biofuels derived from waste-based feedstocks typically represent the lowest carbon intensities among all biofuels and often among all alternative fuels. The table below illustrates recent commercial-scale projects by fuel type that either received or are proposed to receive CEC funding.

GHG Emission Reduction Estimates for Commercial-Scale CEC-Funded Projects

Fuel Type	Pathway Description*	Average GHG Emission Reduction	# of Projects	Range of Annual Capacity for Individual Projects (DGE or GGE)	Total Annual Capacity Increase
Biomethane	Food, green, yard, and mixed municipal waste	110%	6	570,000 – 2,870,000	9.8 Million DGE Per Year
Diesel Substitutes	Waste oils (various)	81%*	9	4,600,000 – 7,500,000	53.2 Million DGE Per Year
Gasoline Substitutes	Grain sorghum	31%	3	2,600,000 – 3,000,000	9.6 Million GGE Per Year

Source: California Energy Commission. *Note that several diesel substitute production projects will use a mixture of waste-based oils and conventional vegetable oils (for example, canola or soy).

The CEC is also investing in pre-commercial biofuel production demonstrations aimed at demonstrating very low carbon technology pathways – including both diesel and gasoline substitutes, such as cellulosic ethanol and drop-in renewable gasoline that are still in the developmental phase. The following chart illustrates the GHG reduction potential of some of these emerging technologies which have been awarded CEC grants in the most recent

Alternative Fuel Investment Plan solicitations.

CEC Funded Pre-commercial Low-Carbon Biofuel Projects (2014)				
Fuel Type	**Pathway Description**	**Estimated GHG Reduction**	**# of Projects**	**Annual Capacity for Individual Projects Diesel or Gasoline Equivalent**
Biomethane	Wastewater	88%	1	160,000
Diesel Substitutes	Algae	66%-122%	2	1,200 – 5,000
Diesel Substitutes	Green Waste	66%	1	365,000
Gasoline Substitutes	Woodchips and Switchgrass	76%	1	21,000
Gasoline Substitutes	Sugar Beets	82%	1	215,000

Source: California Energy Commission.

Other state programs also provide support and incentives to biofuel producers. The California Department of Resources Recycling and Recovery (CalRecycle) receives cap-and- trade revenue funds to administer grant and loan programs, some of which may be used to support waste-based bio-methane production. Also, the LCFS and RFS requirements can support biofuel producers by creating markets for carbon credits and renewable fuels.

4.37. Federal Biodiesel Tax Incentives: A federal biodiesel tax credit has been an important support in keeping prices for biodiesel and renewable diesel competitive with petrodiesel. This credit allows blenders of biodiesel and renewable diesel to claim a credit of $1 per gallon against their U.S. federal tax liability. The tax credit has expired four times since 2009 and then subsequently been reinstated retroactively three times. There is a clear correlation between the tax incentive and increased biodiesel production, which has grown from about 100 million gallons in 2005, when the tax incentive was first implemented, to almost 1.8 billion gallons in 2013. The biodiesel credit expired at the end of 2014, but a bill to retroactively reinstate the credit for 2015 (which would be a windfall for blenders), was passed out of a Senate finance committee in July 2015, and was enacted at the end of 2015. The reinstated credit also includes a controversial amendment that would shift the biodiesel tax credit upstream to producers rather than blenders and retailers. This provision takes effect on Jan. 1, 2016. The credit will remain at the blender level for 2015 retroactive to Jan. 1. An economic analysis of the complex impacts of shifting the credit upstream is provided by the *Farm Doc Daily* website at http://farmdocdaily.illinois.edu/2015/08/implications-of-changing-biodiesel-tax-credit.html.

In addition to the structural changes to the biodiesel tax credit, the package includes a 30 percent investment tax credit for alternative fuel pumps, a provision that enables small business to deduct certain property expenses from their taxes known as Section 179 expensing, as well as bonus depreciation provisions. Recent information and relevant documents on the tax credit are available at the National Biodiesel Board website http://biodiesel.org/policy/fueling-action-center

4.38. The Federal Renewable Fuel Standard and EPA Biodiesel Targets: As noted earlier, the Renewable Fuel Standard (RFS) program established renewable fuel volume production and blending mandates, initially known as RFS1. Under the Energy Independence and Security Act (EISA) of 2007, the RFS program was updated (now called RFS2) and set these new policies in motion:

- The Renewable Fuel Standard was expanded to include diesel, in addition to gasoline
- The volume of renewable fuel required to be blended into transportation fuel was increased from 9 billion gallons in 2008 to 36 billion gallons by 2022
- EISA established new categories of renewable fuel, and set separate volume requirements for each one, including biomass based (renewable) diesel and biodiesel (now classified as an Advanced Biofuel.)

EISA also required EPA to apply lifecycle greenhouse gas performance threshold standards to ensure that each category of renewable fuel emits fewer greenhouse gases than the petroleum fuel it replaces. For the purposes of implementing the RFS, EPA's lifecycle analysis includes emissions related to:

- Feedstock production & transportation
- Fuel production & distribution
- Use of the finished fuel

As required by the Clean Air Act (CAA), EPA's analysis also includes significant indirect emissions such as:

- Emissions from land use changes
- Agricultural sector impacts
- Co-products from biofuel production

The sum of all of these lifecycle emissions for each renewable fuel pathway are then compared to the direct emissions from the baseline petroleum fuel it displaces. The results of these analyses are used to determine if the fuel pathways meet the GHG reduction thresholds required by the Clean Air Act.

When the RFS was passed into law, Congress decided to treat biodiesel differently than other fuels. Rather than setting year-by-year targets through 2022, as it did for other types of renewable fuels, lawmakers decreed only that EPA must mandate at least 1 billion gallons a year of biodiesel by 2012. After that, they left the decision up to the agency whether and by how much to increase the annual target. EPA has set targets for conventional ethanol and advanced biofuel -- including biodiesel -- for the years 2014, 2015 and 2016. It also will set the 2017 mandate for biodiesel. Some biofuel producers have come out in opposition to the EPA’s targets, suggesting that it reflects the reluctance of oil refiners to include more biofuels in their product.

For biomass-based diesel made from soybean oil, animal fats and used cooking grease, the EPA requires refiners to use 1.7 billion gallons of biodiesel in 2015 and 1.8 billion gallons in 2016. In 2017, the proposal would set the biodiesel mandate at 1.9 billion gallons. The targets represent a substantial increase from the agency's original proposal for 2014, which EPA withdrew after objections from biofuel stakeholders. That proposal would have kept the biodiesel target level at 1.28 billion gallons for both 2014 and 2015.

According to the National Biodiesel Board, which is the foremost trade association for the biodiesel industry, more than 50 biodiesel facilities have either idled or gone bankrupt since 2012 as a result of a lack of robust RFS targets and Congress allowing the industry's $1-a-gallon tax credit to expire periodically. (Retroactive reinstatement, which has occurred on numerous times, does not support stable pricing or market confidence in the same way that a permanent credit can do). Under the RFS program, the biodiesel mandate is contained in the larger mandate for advanced biofuel use. After enough of the fuel is produced to satisfy the biodiesel mandate, it can compete in the broader advanced biofuel mandate. There, biodiesel's toughest competition has come from imported sugarcane ethanol from Brazil, which EPA also considers an advanced biofuel. The long-term outlook for stabilizing federal biofuel tax credits and production mandates looks uncertain, as the current Congress tends to legislate in favor of the petroleum industry, such that biofuel and renewable energy tax credits are subject to annual cancellation or retroactive reinstatement, whereas petroleum industry credits and incentives are permanent or of long duration.

4.39 Renewable Volume Obligations (RVOs) and Renewable Identification Numbers (RINs): To increase the amount of biofuels in gasoline, the Renewable Fuel Standard (RFS) also created a program of Renewable Identification Numbers (RINs) and Renewable Volume Obligations (RVOs). RVOs are the targets for each refiner or importer of petroleum-based gasoline or diesel fuel, while RINs allow for flexibility in how each of them may choose to comply. The volumes for the four RFS targets (cellulosic, biodiesel, advanced, and total) are assigned to the obligated parties—refiners and importers of gasoline and diesel fuels—by means of Renewable Volume Obligation (RVO) percentages. The RVOs are calculated by dividing each RFS target by the total estimated supply of nonrenewable gasoline and diesel fuel in each year. There are four separate RVOs that represent the four different RFS targets. For 2013, the four RVO targets (adding up to a total of approximately 12% of the renewable plus nonrenewable total of 100%) were:

- cellulosic biofuels, 0.008%
- ethanol equivalent for biomass-based diesel, 1.12%
- advanced biofuels, 1.6%
- total renewable fuels, 9.63%

The RVOs are applied to each obligated party's actual supply of gasoline and diesel fuel to determine its specific renewable fuel obligation for that calendar year. Obligated parties must cover their RVOs by surrendering Renewable Identification Numbers (RINs) within 60 days after the end of each calendar year. Each RIN is a 38-character alphanumeric code assigned to each gallon of renewable fuel that is produced in or imported into the United States. RINs are valid for the year in which they are generated. However, up to 20% of a year's mandate can be met with RINs generated in the previous year. When renewable fuels are blended into gasoline and diesel fuel or sold to consumers in neat form (typically 100% biofuel), the RIN representing the renewable attribute of the fuel becomes separated from the physical biofuel and can be used for either compliance purposes or traded (similar to the status of Renewable Energy Credits or RECs in the solar and wind industry). Separated RINs have a market value attached to them and provide flexibility for obligated parties in meeting their RVOs. Obligated parties have the option to either acquire RINs by purchasing and blending physical quantities of biofuels, or by purchasing already separated RINs and submitting them to the EPA for compliance.

The value of RINs provides an economic incentive to use renewable fuels. If RIN prices increase, blenders are encouraged to blend greater volumes of biofuels, based on their abilities to sell both the blended fuel and the separated RIN. If a biofuel is already economical to blend up to or above the level required by the RFS program, such as ethanol was from 2006 through much of 2012, one would expect the RIN price to be close to zero. When the biofuel is more costly than nonrenewable fuels but is needed to meet RFS standards or must be blended in greater volumes to be economic, the RIN value should increase to a point at which firms will increase biofuel blending.

The flexibility to trade RIN credits was requested by the petroleum industry so they would have the option of using an actual gallon of biofuel or "over-complying" in a certain market and applying that "extra credit" to another area of the country. As for the marketability of the RINs, if for example an obligated party is required to use 1,000 gallons and used 1,200 then the first thousand RINs are "retired" as they are turned in to demonstrate compliance. The remaining 200 credits are available to be traded, sold, or held for another time. Biofuel stakeholders have long complained that oil companies have elected to meet their RFS requirement by purchasing RINs (which have escalated in price from ten cents to nearly $1/gallon), rather than by blending ethanol at volumes above 10% and marketing blends such as E85 more broadly. Congress intended that ethanol and other biofuels would gradually be integrated into the US gasoline pool, and anticipated that E85 and other ethanol/biofuel blends would be scaled up through market-based mechanisms such as the RIN. However, with the oil industry willing to forego profit to prevent increased biofuel market share, many analysts consider that the RIN mechanism has failed in its original purpose. Now, the federal government's primary policy mechanism has been the mandatory minimum production requirement enacted through the RFS, which operates in a manner similar to California's biofuel mandate.

For more information on the RIN program, see the US Energy Information Agency website fact sheet at http://www.eia.gov/todayinenergy/detail.cfm?id=11511.

4.40. Biofuels and California's Low Carbon Fuel Standard: California's Low Carbon Fuel Standard (LCFS) sets targets for reductions in greenhouse gas intensity for the entire transportation fuel pool, not only biofuels. The LCFS specifies the average carbon intensity for transportation fuels, typically for a given year, expressed as a percent reduction from a baseline.

Based on Executive Order S-1-07 (issued on January 18, 2007), CARB has set a goal of reducing the carbon intensity of passenger fuels statewide by a minimum of 10 percent by 2020. For more information on how the standard is set, see the Low Carbon Fuel Standard Map created by the consulting firm, C2ES. For the LCFS, the greenhouse gas intensity of a fuel is calculated on a lifecycle basis, which includes the emissions from production or extraction, processing, and combustion of the fuel. This policy allows manufacturers to produce and retailers to purchase the mix of fuels that most cost-effectively meets the standard. LCFS credits are tradable to enable cost-efficient compliance (similar in that respect to Cap and Trade credits, RINs, or the Zero Electric Vehicle mandate programs).

4.41. Federal Research and Development Funds for Advanced Biofuels Production: Biofuel feedstock and production process technology is still in its infancy compared to many other clean technologies. To achieve very low carbon intensities, further R & D is needed. In addition to the California Energy Commission support described earlier, the federal EPA Bioenergy Program for Advanced Biofuels, authorized under the 2009 Farm Bill, Section 9005, provides payments to eligible producers that expand production of advanced biofuels from sources other than corn starch. Incentives are intended to diversify the source of biofuel production as well as increase overall output.[11] Additional support is available through the joint DOE and Department of Agriculture Biomass Research and Development Initiative for advanced biofuels. The Department of Transportation also carries out biofuel research in its Bio-based Transportation Research Program in an effort to promote innovation in transportation infrastructure.

4.42. Biofuel Vehicle and Fueling Infrastructure Deployment on the Central Coast: According to current DMV data, residents of the Central Coast had registered a total of 2,459,015 cars and trucks as of the beginning of 2015, of which approximately 7.7%, or 189,000, are Flex Fuel vehicles, divided between autos and trucks as noted in the table below.

Conventional and Flex Fueled Vehicles in the Central Coast (2014)

County	Auto	Truck	Total Vehicles	Flex Fuel Vehicles*
Ventura	565,405	134,239	829,329	63,775
Santa Barbara	263,924	77,107	442,735	34,046
San Luis Obispo	178,811	64,125	1,186,951	91,277
TOTAL	1,008,140	275,471	2,459,015	189,098

Source: California Department of Motor Vehicles

*County data is extrapolated based on the statewide ratio of Flex Fuel to conventional vehicles of 1 to 13.

[11] EPA, *Program for Advanced Biofuels*, http://www.epa.gov/agstar/tools/funding/incentive/USbioenergyprogramforadvancedbiofuels.html

Unfortunately, there is not definitive data on the percentage of VMT in the region that is powered by E85, biodiesel, or renewable diesel. What is clear to date is that the key gating issue for growth of biofuel and E85 VMT is: 1) available fueling supply infrastructure and; 2) consumer awareness of the benefits of E85 vs. conventional gasoline, as well as the benefits of biodiesel at the higher blend rates. When viewed in historic context, the expansion of E85 stations has been a success. In the late 1990s, no E85 refueling stations existed; today there are 118 E85 fueling facilities in California. Of these facilities, 63 are public or retail facilities and 55 are private fleet facilities. The following chart shows the public, private, and north/south breakdown of the stations.

Statewide Distribution of E85 Fueling Stations			
	Northern California	**Southern California**	**Total**
Public/Retail	41	22	63
Private/Fleet	35	20	55
Total	76	42	118

Unfortunately, the biodiesel and E85 stations are unevenly distributed across the state, with major metro areas and areas of intensive agriculture getting a much larger number of stations than either the Central Coast or the Monterey Bay areas. The table below indicates public E85 and biodiesel stations in the tri-county Central Coast area.

Central Coast E85 and Biodiesel Fueling Stations				
County	**Company**	**Address**	**Contact Info**	**Fuel**
San Luis Obispo	**Pearson Fuels**	6305 Morro Rd Atascadero, CA 93422	http://www.pearsonfuels.com/stations/atascadero/ 805-466-6042	**E85**
	J.B. Dewar	75 Prado Road San Luis Obispo, CA 93401	805-543-0180	**B99** **B20**
Ventura	**Pearson Fuels**	6417 Ventura Blvd. Ventura, CA 93003	http://www.pearsonfuels.com/stations/ventura/ 805-288-5477	**E85** **B20**

Expanding the number of E85 retailers has been challenging for many reasons. First, while tanks and pumps at existing gasoline fueling stations can be modified to sell E85, the ROI on such modifications is extremely limited. With a gallon of E85 having approximately 23% to 28% less energy than a gallon of gasoline, studies have shown that drivers of flex-fuel vehicles are aware of this energy density/MPG reduction and will purchase E85 only if it is priced proportionally lower than gasoline. Further, with the price of gasoline fluctuating significantly in recent years, the relative value of E85 has also fluctuated widely. This in turn has led to a lack of consistent demand for E85, which makes it difficult for retailers to justify the capital investment to sell E85.

Both E85 and biodiesel are subject to the classic "chicken and egg" dilemma characteristic of so many alternative fuels. The lack of fueling infrastructure causes consumers not to purchase the alternative vehicle (or causes them not to fuel with an optional alternative fuel such as E85 or B100), while the lack of demand for the fuel causes prospective fueling providers not to make the needed investments to address consumer anxiety about fuel availability.

Despite these challenges, however, a number of biofuel projects have moved forward in recent years on the Central Coast, with support from the state, private investors, and the regional Air Quality Management Districts. One of the most important of the biofuel infrastructure investments is the Bio-refinery in Port Hueneme, summarized in this case study developed by the U.S. EPA.

- **Bio-refinery in Port Hueneme:** Biodico, a biofuels research and development company, was tasked by the U.S. Navy in 2002 to design, develop, and deploy modular biofuel and bioenergy systems that can use a variety of feedstocks and produce renewable on-demand primary heat and power. Since then, Biodico has built a sustainable bi-refinery at Naval Base Ventura County that will provide 10 million gallons per year of biodiesel production capacity and will supply biodiesel and bioenergy at competitive prices. Developing the 10 million gallon per year facility costs approximately $12.5 million from inception to completion. A CEC grant was provided to open this facility, which will in part focus on how new non-food crops can produce biodiesel. This work will be conducted in cooperation with Dr. Stephen Kaffka, Director of the California Biomass Collaborative at the University of California Davis, and John Diener, president of Red Rock Ranch. The CEC grant will also help make Biodico production facilities energy self-sufficient. The goal is to use sustainable resources to produce all of the plant's heat and power needs -- becoming the first biodiesel production facility to become totally self-sustainable.

4.43. Recommendations for Biofuel Vehicle and Fueling Infrastructure and Deployment: Biodiesel and renewable diesel offer substantial GHG reductions and other air emissions benefits that are particularly important for cleaning up the medium and heavy-duty vehicle truck segments. Given the dangerous impact of diesel emissions on public health, it is vital that local and regional stakeholders cooperate with the state and private industry to accelerate the Central Coast's transition to cleaner-running diesel vehicles. In addition to the biodiesel/renewable diesel opportunity, Central Coast leaders have an opportunity to encourage more gasoline retailers to carry E85, and to "walk the talk" of clean fuels by ensuring that both public and private fleets maximize use of these sustainable biofuels.

Of course, many of the challenges of expanding biofuels use must be addressed by ongoing (and in some cases, increased) efforts by the auto industry, fuel suppliers, and state and federal agencies. To be clear on the relative scope for local and regional action, we briefly review these state and federal level initiatives, and the additional efforts can be expected to help drive the biofuels transition.

Key National Market Drivers for Renewable and Biodiesel Vehicles

1. **Light-duty diesel manufacturing costs and retail pricing must trend toward parity** with ICEs in order to reduce the up-front price disadvantage that is one reason for the modest (though rapidly improving) performance of diesel vehicles in the LDV segment
2. **Additional product diversity is needed to attract more buyers to the clean diesel and Flex Fuel Vehicle market**
3. **Fueling infrastructure incentives and grant support must be further enhanced** to assist fuel retailers with the one-time capital expense of expanding tanks, pumps, and other infrastructure needed to accommodate multiple fuel types
4. **Research and development must continue into sustainable feedstocks** that do not compete with food supplies, that have a strong energy return on energy invested (EROEI), and have the lowest possible carbon intensity as well as other air emissions reductions
5. **Automakers and the state of California need to strongly encourage the use of B20 as a "drop-in" fuel** for existing diesel engines, based on an accelerated program of testing and standardization of vehicle capabilities.

Given the challenges facing expanded biofuel deployment, it is noteworthy that there has been very strong growth in both light-duty diesel and Flex Fuel Vehicles. Together, these are now approaching 10% of new vehicle sales (and over 7% of cumulative sales) in California. With vehicle sales relatively strong, it is clear that the most important next steps for the biofuels ecosystem as a whole are: 1) expanding the fueling outlets for E85 and biodiesel; and 2) expanding the low-carbon production and distribution pathways for ethanol, biodiesel, and renewable diesel. Clearly, the existing infrastructure of just three public biodiesel and E85 stations in the tri-county region is inadequate. To increase the number of available biofuel outlets in the Central Coast, local governments and regional agencies will need to join with private station operators to take the following steps.

Key Steps to Drive Accelerated Renewable Diesel and Biodiesel Market Development

1. **Secure commitments from distributors** to carry renewable diesel and biodiesel in publicly accessible stations
2. **Enhance outreach and education to fleet managers** to drive greater adoption of renewable diesel and biodiesel supplies
3. **Develop competitive grants to the California Energy Commission** for expanded biofuel infrastructure development
4. **Enable biofuel station developers to move expeditiously through planning,** permitting, and construction processes

5. **Commit to increasing the number of Flex Fuel vehicles in fleets** (where electric options are not available), and the use of E85

Biofuel Readiness Tasks Currently Underway at the Regional Level: Several key biofuel readiness tasks are already underway at a regional level. Through the Central Coast Alternative Fuels Project, local stakeholders will receive training in biofuels-related code and permit issues will be addressed. In addition, the AFV Readiness Task Force is building stakeholder awareness and knowledge across the AFV spectrum, including biofuel vehicles and fueling infrastructure. The key tasks that are central to both FCV readiness and the broader AFV work include the development of pro-active consumer and fleet outreach via local sponsorship of multiple Green Car Shows (Recommendation 3.1), and AFV Training seminars (Recommendation 3.2.) Additional recommendations for local government action (not yet underway in most Central Coast jurisdictions) are indicated below.

2.5. Biofuel Vehicles & Infrastructure	**2.5.1. Assess potential of biofuel vehicles to meet local GHG reduction, cost, and sustainability goals** -- taking into account the most recent and authoritative research on GHG and air quality impacts and integration of biofuel vehicle readiness into General Plans, Climate Action Plans, and other sustainability related plans as appropriate **2.5.2. Determine need for additional local biofuels production**, distribution, and fueling infrastructure to meet planned biofuel fleet needs as demand increases **2.5.3. Partner with other cities and the AFV Readiness Council to outreach to potential biofuel/biodiesel fuel infrastructure developers** and operators to develop potential fueling sites (if applicable)	**Planning Departments** **Fleet Departments**

To help local stakeholders take the steps outlined above, the following resources are highly recommended.

4.44. Biofuel Resources

- **Federal Laws and Incentives for Biodiesel,** U.S. Department of Energy, http://www.afdc.energy.gov/laws/laws/US/tech/3251.
- **Federal Laws and Incentives for Ethanol**, http://www.afdc.energy.gov/laws/laws/US/tech/3252.
- **Advanced Biofuels Market – Overview of market segments and companies,** https://www.e2.org/ext/doc/E2AdvancedBiofuelMarketReport2014.pdf
- **EPA Biofuel Case Studies in CA**: http://www.epa.gov/region9/waste/biodiesel/california.html
- **California Biodiesel Economic Growth**: https://www.e2.org/ext/doc/E2_Fueling%20Growth_2013.pdf
- **Biodiesel Value Chain Report**: https://www.e2.org/ext/doc/CaliforniaBiodieselValueChainReport.pdf
- **BQ-9000 Website** *(for a list of accredited producers),* National Biodiesel Board.
- **Biodiesel Handling and Use Guidelines, National Biodiesel Board**
- **Warranties and OEM Statements, National Biodiesel Board**
- **Fuel Quality and Performance Troubleshooting Guide, National Biodiesel Board**

Biodiesel Companies

- **Biodico** – Production Technology
- **Agron Bio Energy** (formerly NorthStar Biofuels) - Feedstock
- **Yokayo Biofuels** - Collector
- **Crimson Renewable Energy**, LP - Production
- **Imperial Western Products** - Blending
- **Propel Fuels** - Retail and Distribution

4.45. Biodiesel Terms and Definitions

- **Ash** – Ash is a measure of the amount of metals contained in the fuel. Ash forming materials may be present in three forms: (i) abrasive solids, (ii) soluble metallic soaps, and (iii) residual biodiesel catalyst. Abrasive solids and biodiesel catalyst materials result in wear of fuel system and internal engine components exposed to fuel after injection. Metallic soaps can contribute to deposits in the fuel system. All ash forming compounds can contribute to the accumulation of materials on diesel particulate filters, requiring filter maintenance.
- **Cetane Number** – Cetane number is a measure of the fuel's ignition and combustion quality characteristics. Biodiesel blend stock typically has a higher minimum cetane level than that of petroleum diesel. Fuels with low cetane numbers will cause hard starting, rough operation, noise and increased smoke opacity. The level specified is consistent with EMA's requested increase in the minimum cetane number for petroleum diesel fuel.
- **Cloud Point** – Cloud point is a test used to characterize the low temperature operability of diesel fuel. It defines the temperature at which a cloud or haze appears in the fuel under prescribed test conditions. The cloud point for biodiesel blends is generally higher than it is for petroleum diesel fuel. To avoid component precipitation in vehicle fuel tanks and blockage of fuel filters, the traditional blending practices for a given ambient temperature should be modified prior to blending with biodiesel. Alternative low temperature operability test methods such as Cold Filter Plugging Point (CFPP) and Low Temperature Flow Test may be agreed to between the supplier and the purchaser of the fuel.
- **Copper Strip Corrosion** – The copper strip corrosion test indicates potential compatibility problems with fuel system components made of copper alloys such as brass and bronze. The limit specified is the same as that for petroleum diesel fuel.
- **Flash Point** – The flash point temperature is the minimum temperature at which the fuel will ignite (flash) on application of an ignition source under specified conditions. Flash point varies inversely with the fuel's volatility. Flash point minimum temperatures are required for proper safety and handling of fuels. Note that the biodiesel component must meet a flash point criteria, prior to blending, for the purpose of assuring that the biodiesel component does not contain methanol. It is not possible, however, to rely on the flash point of the blend for the same purpose inasmuch as the flash point of the petroleum component is much lower.

- **Kinematics Viscosity** – Kinematics viscosity affects injector lubrication and fuel atomization. Biodiesel fuel blends generally have improved lubricity; however, their higher viscosity levels tend to form larger droplets on injection that cause poor combustion and increased exhaust smoke. The limits established provide an acceptable level of fuel system performance for D1 and D2 fuel blends.
- **Lubricity** – Lubricity is a measure of the fuel' s ability to provide adequate lubrication of the components of the fuel system, including fuel pumps and injectors. The precision required in the manufacturing of these components and the significant influence of abnormal wear require that they be adequately protected from scuffing, scratching, wearing, etc. that may affect their fuel delivery characteristics. The level specified is consistent with that recommended by suppliers of fuel injection equipment for modern diesel engines.
- **Physical Distillation** – Distillation provides a measure of the temperature range over which a fuel volatizes or turns to a vapor. D1 typically has a greater volatility than D2; however, the inclusion of biodiesel at B20 blend levels results in comparable T90 temperature characteristics. V olatility directly affects the engine' s ability to operate as intended. Biodiesel does not have a traditional petroleum distillation characteristic; however, the addition of biodiesel to petroleum diesel in a blend can result in an increase in T90 distillation temperature. Higher volatility, as represented by a lower T90 temperature, generally provides better engine performance, while lower volatility generally provides better fuel economy. The T90 temperature specified has been evaluated for engine performance with biodiesel blends, up to B20, where the petroleum diesel fuel utilized in the blend met the requirements of ASTM D975.
- **Rams bottom Carbon Residue** – The Rams bottom Carbon residue test is intended to provide some indication of the extent of carbon residue that results from the combustion of a fuel. The limit specified is the same as that for petroleum diesel fuel.
- **Sulfur** – Sulfur levels in fuel are regulated by various governmental agencies to assure compatibility with emission standard requirements. In the United States there are currently three sulfur grades: S5000, S500, and S15, for both D1 and D2 petroleum diesel fuel. Biodiesel blends may not exceed the applicable maximum sulfur levels as defined for petroleum diesel.
- **Water and Sediment** – Fuel should be clear in appearance and free of water and sediment. The presence of these materials generally indicates poor fuel handling practices. Water and sediment can shorten filter life or plug fuel filters, which can lead to engine fuel starvation. In addition, water can promote fuel corrosion and microbial growth. The level of water specified is within the solubility level of water in fuel and, as such, does not represent free water. Limits are established to allow measured results to be compared to a maximum level acceptable for proper engine operation.

Chapter 5: Natural Gas Vehicles and Infrastructure

5.1. Introduction to Natural Gas Vehicles (NGVs) and Fueling: Petroleum-based fuels have long dominated U.S. transportation, with oil accounting for approximately 93 percent of domestic transportation fuel consumption. Within the transportation industry, medium and heavy duty vehicles alone account for approximately 22 percent of all oil use, and a significantly higher proportion of harmful emissions. The search for petroleum substitutes has also gained new urgency due to the need to reduce foreign oil dependence and mitigate the risk of supply disruption, and to reduce economic exposure to the price volatility of the oil market.

Thanks to its relatively low price, abundant supply, and potential for emissions reduction, natural gas is receiving significant attention as an alternative fuel -- especially for medium and heavy duty vehicles. While electricity shows great promise for displacing oil in the light-duty vehicle sector, until battery energy density significantly increases, heavier duty trucks pose special challenges for electrification. Moreover, the development of expanded biomethane fuel pathways – a very low-carbon substitute for natural gas – holds promise for reducing the carbon intensity of natural gas and mitigating fugitive methane leakage from landfills. For all these reasons, natural gas merits serious consideration as a viable alternative fuel and vehicle technology option.

Natural gas has been notably inexpensive and abundant on the domestic U.S. market in recent years thanks to the recent boom in hydraulic fracturing (“fracking”). In terms of its environmental performance, natural gas can significantly reduce tailpipe emissions of some criteria pollutants (especially particulate matter) as much as 90% below that of conventional petroleum diesel. In addition, some analyses have suggested that natural gas <u>could</u> reduce greenhouse gas emissions (which are chemically distinct from criteria pollutants) compared petroleum sources, depending on a variety of factors -- including the methane leakage rate in the natural gas fuel supply chain, the relative efficiency of new natural gas engine technologies, and the relative performance of emerging clean diesel technologies. However, many estimates of natural gas carbon impacts are currently undergoing revision, raising questions about the performance of natural gas vs. petroleum from a climate perspective.

In light of the many complex issues particular to NGVs, this chapter of the *Alternative Fuel Readiness Plan* will address these questions:

- What are likely trends in natural gas pricing, vehicle availability, and vehicle performance in the 2016-2025 period?
- What are key best practices in natural gas fleet management and fueling infrastructure development?
- What are the most recent estimates and trends in NGV emissions from a “well to tank” perspective? (Note that due to the complexity of this discussion, some of the relevant material is covered in Appendix 1 to this report.)

5.2. Natural Gas Vehicle Types, Applications, and Deployment Trends: There are three principal types of NGVs currently deployed in the United States. These include:

- **Dedicated NGVs** – operating on 100 percent natural gas, either in the form of Compressed Natural Gas (CNG) or Liquefied Natural Gas (LNG).
- **Bi-Fuel NGVs** – operating on either gasoline or natural gas (the bi-fuel vehicle type has two completely separate fuel systems).
- **Dual-Fuel NGVs** – NGVs that operate on natural gas but use diesel fuel for pilot ignition assistance. This design is primarily used in heavy-duty vehicles.

Despite the recent abundance of low-cost domestic natural gas supplies, the United States is one of the last industrialized countries to embrace natural gas as a transportation fuel. Worldwide, there are more than 15.2 million natural gas vehicles – but according to NGV America, there are just over 120,000 NGVs of all types on U.S. roads today, as noted in the chart below, which includes all NGV fueling system configurations. Nearly all the deployed NGVs in the U.S. are fueled with Compressed Natural Gas (CNG) rather than Liquefied Natural Gas (LNG), in part because the predominantly truck-based LNG distribution system is more expensive than pipeline-based CNG distribution, and there are few LNG equipped vehicles currently available on the marketplace.

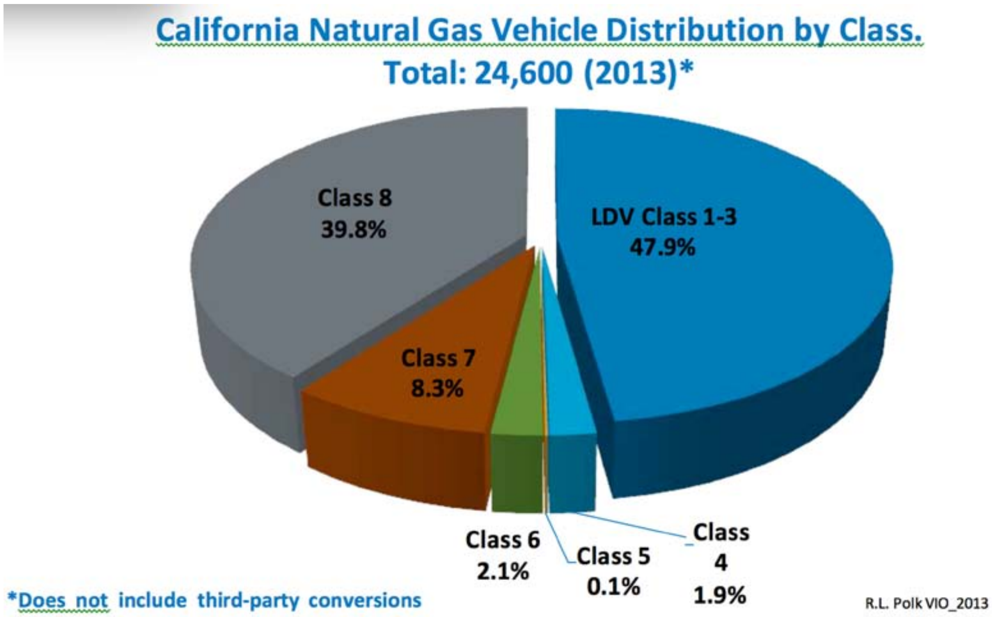
Natural Gas Vehicle Registrations in the United States

Year	Compressed Natural Gas (CNG)	Liquefied Natural Gas (LNG)
1992	23,191	90
1997	68,571	813
2002	120,839	2,708
2007	114,391	2,781
*2010	115,863	3,354

*last year data available

Source: U.S. Energy Information Administration: http://www.eia.gov/renewable/

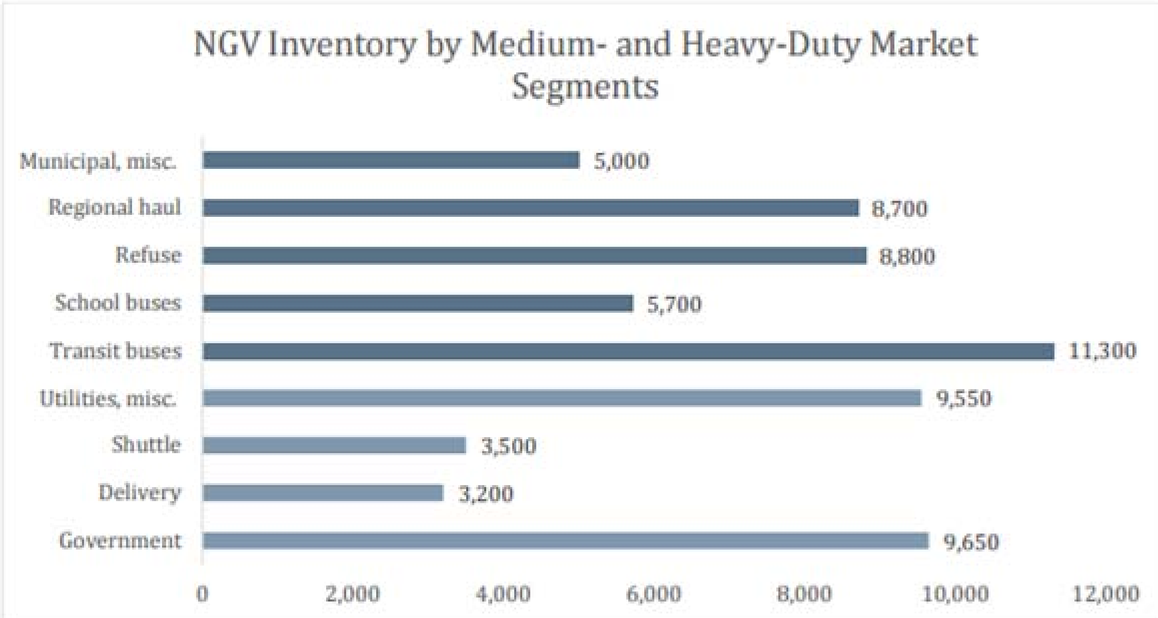
Natural Gas Vehicles in California: As of 2015, approximately 13,500 Class 3-8 trucks utilizing natural gas are registered with the California Department of Motor Vehicles, along with nearly 20,000 CNG-fueled light-duty vehicles.



Diversity of NGV Applications: CNG and LNG vehicles can be deployed to meet diverse transportation needs, from light duty sedans to specialty trucks, buses, and off-road vehicles, as shown in the chart below.

Application	CNG	LNG
Light duty vehicles	X	
Transit buses	x	x
Refuse trucks	x	x
School buses	x	
Industrial equipment ie., forklifts	x	
Agricultural equipment ie., water pumpers	x	
Marine vessels	x	x
Shuttle buses and vans	x	
Railroad Cars	x	x
Long-haul trucks		X
Local delivery vehicles	x	

Distribution of Medium- and Heavy-Duty NGVs in the U.S. By Application: As shown in the chart below, medium- and heavy-duty NGVs are used predominantly in transit buses, utilities, refuse, regional hauling, and municipal/government applications, with shuttle, school bus, and delivery applications representing smaller segments.



Source: 2014 NGV Production and Sales Report, NGV America

5.3. CNG Vehicle Economic Attributes: Compressed natural gas (CNG) was initially introduced as a transportation fuel during World War II, when gasoline was in short supply. However, NGVs were not generally commercially available until the 1980s, when they were introduced primarily as a technology to reduce criteria air pollutants – especially nitrogen oxides (NOx) and particulate matter (PM) – and to take advantage of the price differential between natural gas and diesel. NGVs still enjoy substantial advantages in meeting criteria emission standards compared to conventional diesel, but the gap will narrow significantly as clean diesel vehicle regulations tighten in 2017 and beyond. (Emissions differences are discussed in detail in Appendix 1.)

For most fleet managers, cost is a primary concern when choosing between natural gas vs. diesel vehicles. However, relative fuel costs can fluctuate significantly. NGVs over the 2010-2014 period offered a differential savings of as much as 30% to 50% lower fuel cost than diesel, as well as lower maintenance and repair costs. However, crude oil prices in 2015 reached an 11 year low, which doubled the payback period for US natural gas vehicles compared to diesel -- from about one year and eight months in mid-2014 to approximately three to four years currently.[1] As of late 2015, the fuel price spread between diesel and CNG is less than $1 per gallon-equivalent of fuel at the retail level.

Current retail prices for CNG generally range from $2-$2.50 per gasoline gallon equivalent (GGE) within California and may be lower for private fleets. Diesel fuel prices have been quite volatile in recent years, varying from $2.50 to $3.50 or more. Although many analysts

[1] http://ngvtoday.org/2015/02/04/growth-in-north-american-ngv-sales-projected-for-coming-decade/

expected crude oil prices to rise, they have remained near historic lows as of early 2016. Natural gas commodity prices are also expected to rise over time (along with diesel), even as CNG is expected to remain cheaper at the pump than diesel or gasoline. The likely differential between diesel and natural gas is, unfortunately, extremely difficult to predict as so many unpredictable variables are at work.

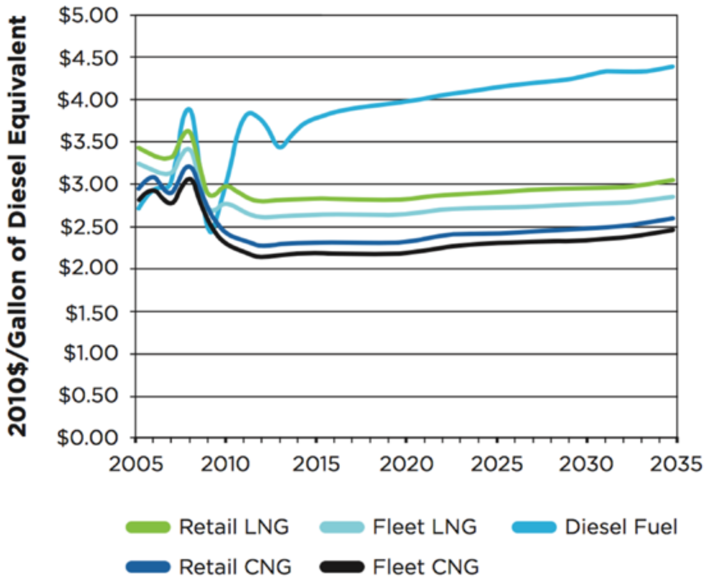
A key ongoing challenge to NGV market growth in the heavy-duty arena is that large fleet operators typically replace their vehicles every three to four years, leaving a relatively short time to amortize the higher initial cost of NGV vehicles and gain the longer-term benefit from their lower fuel costs. For example, diesel prices in April 2014, before the oil price slump, were nearly $4.00 per gallon, while natural gas was $1.81 per diesel gallon equivalent (DGE) – after taking into account the 15% lower fuel economy for the natural gas engine. The spread between oil and gas prices meant the cost for fuel and diesel exhaust fluid (DEF) for a Class 8 heavy duty truck running 100,000 miles a year was around $58,063, while it amounted to $30,420 for the same mileage with natural gas. Opting for natural gas at that time of higher oil prices would have produced savings of $27,643 per year. Considering that Class 8 natural gas trucks cost about $43,640 more to purchase and maintenance costs are higher, it would have taken about one year and eight months to pay back the difference between a natural gas engine truck and a diesel engine truck.

Taking a diesel price of $2.78 a gallon, which is towards the lower end of the price range seen in mid-2015, the diesel cost per year for 100,000 miles is only $40,608. This puts the fuel price difference between a diesel and natural gas vehicle at around $10,188 per year, with a payback period of between four and five years. This is outside the typical three-year replacement cycle for new Class 8 vehicles, and well beyond the ~18 month payback timeframe sought by many fleet operators.

Another factor limiting natural-gas-powered sales is the arrival on the market of new, more efficient diesel engines. The first phase of a federally mandated 6% improvement in fuel economy by 2017 took effect in 2015, pushing heavy-duty truck mileage closer to 7 miles per gallon from about 6.5 mpg. Continuous improvements in diesel fuel efficiency are expected in the foreseeable future, which could further reduce the overall economic advantage of NGV fueling.

5.4. Future Natural Gas Pricing and Supply Scenarios: Recent increases in both oil and natural gas supplies in the U.S. and globally have occurred due to the fracking boom. The consequent price decreases have also narrowed the spread between diesel and natural gas. Future demand increases for natural gas are likely in the utility sector as more coal plants are phased out. As always with fuel price predictions, however, there is no way to foresee all the potential economic and political factors that could effect prices. A Middle Eastern conflict that impacts oil transport through the Straits of Hormuz, for example, could dramatically increase oil prices virtually overnight. Therefore, it is prudent to look at a variety of pricing scenarios for natural gas.

According to a meta-analysis of recent industry studies by the Clean Skies Foundation – a research institute focused on the adoption of clean fuels and energy efficiency – the "high case" for NGV adoption anticipates that the transportation share of total natural gas demand increases from just 0.2 percent in 2013 to 2.3 percent in 2025. By 2025, the high case estimate is that approximately 2.4 million NGVs will be on U.S. roads, of which 480,000 are heavy duty trucks. These vehicles would consume about 711 Bcf (billion cubic feet) of gas annually by 2025 and displace over 180 million barrels of oil. The analysis concludes that the price rises attributable to this level of incremental NGV demand is at most $0.25/Mcf (million cubic feet) by 2025. As illustrated in the chart below, this translates to a continuing substantial price advantage for natural gas versus petroleum fuels.



Natural Gas Fuel Price History & Outlook: 2005 - 2035

SOURCE: *EIA Annual Energy Outlook 2012 Heavy Duty Vehicle Reference Case: Transportation Fuel Prices*. http://www.cleanskies.org/wp-content/uploads/2013/04/driving-natural-gas-report.pdf

Incremental NGV vs. Diesel Purchase and Operating Costs: The incremental upfront costs for natural gas engines in the truck segment vary significantly by engine size and supplier -- but typically are in the low thousands for lighter-duty vehicles and $40,000 or more for heavy-duty Class 8 vehicles due to the cost of high-pressure tanks. As a result, natural gas engines are most economical in vehicle applications where fuel costs constitute a higher share of overall vehicle costs, and are especially attractive for heavy-duty trucks that travel tens of thousands of miles per year. The key variables in the cost efficiency equation are fuel and maintenance costs, annual mileage, and the ownership period of the vehicle. Once the incremental cost difference is paid off, the truck owner can benefit from significant savings in fuel costs over the useful life of the NGV truck and engine, which is comparable to diesel vehicles.

On the diesel side, initial purchase costs may increase faster than NGVs in future years, because technologies have grown much more complex due to requirements for the use of selective catalytic reduction (SCR) and other technologies that increase operating costs. As always, consumers and fleet managers must assess product offerings carefully in light of individual use cases and the availability and cost of relevant fueling infrastructure in order to arrive at a rational decision regarding NGV vs. diesel or other alternative fuel vehicle adoption. Please note that more detailed data on fuel, refueling infrastructure, and vehicle cost will be addressed later in this chapter, along with links to online tools that can assist with Total Cost of Ownership (TCO) calculations and vehicle comparisons.

5.5. Nationwide Natural Gas Vehicle Sales: Navigant Research is projecting that sales of medium-duty (MD) and heavy-duty (HD) NGVs in North America, including trucks and buses, will show a Compounded Annual Growth Rate (CAGR) of 3.2 percent between 2014 and 2024, with 18,195 units being sold in 2014, increasing to 23,283 annually in 2024. By contrast, for light-duty (LD) vehicles, Navigant projects a CAGR of 6.1 percent between 2014 and 2024, with sales of natural gas cars growing at a CAGR of 4.7 percent and sales of natural gas Light Duty trucks, mainly pickups and vans (including both dedicated and bi-fuel vehicles), growing at a CAGR of 6.3 percent. The projections are contained in Navigant's report: *Natural Gas Passenger Cars, Light Duty Trucks and Vans, Medium/Heavy Duty Trucks and Buses, and Commercial Vehicles: Global Market Analysis and* Forecasts.

Navigant Research NGV Sales Projections for North America			
	2015	2024	CAGR
Light Duty Cars	4,949	7,279	4.7
Light Duty Trucks	29,400	48,972	6.3
MD & HD Trucks & Buses	18,195	23,283	3.2

Source: *Natural Gas Passenger Cars, Light Duty Trucks and Vans, Medium/Heavy Duty Trucks and Buses, and Commercial Vehicles: Global Market Analysis and Forecasts*, Navigant.[2]

These numbers remain a tiny fraction of overall new vehicle sales in the United States, which topped 17 million new vehicle sales in 2015. Between 2013 and 2014, light-duty natural gas vehicles in the US experienced a sharp sales decline, in part due to the lower differential between natural gas and gasoline prices, while growth was strongest in the heavy-duty segment. However, overall unit volume was down more than 6% across all NGV segments.

Corporate Sustainability Goals Driving Some Natural Gas Sales: Despite the ongoing challenges facing the NGV market in the U.S., a number of high-profile fleets remain committed

[2] http://ngvtoday.org/2015/02/04/growth-in-north-american-ngv-sales-projected-for-coming-decade/

to Natural Gas Vehicles. United Parcel Service in 2015 ordered approximately 300 NG-powered heavy-duty trucks, adding to a fleet of 700 NG Class 8 tractors purchased in 2014. The trucks operate primarily in West Coast and Southern corridors with sufficient natural gas stations, some of which were financed with UPS assistance. By 2016, about 2% of UPS's 100,000 vehicles world-wide will be powered by natural gas.

In addition, Wal-Mart, Lowes, Office Depot, and Procter & Gamble are among a growing number of companies requesting that their trucking suppliers use alternative fuel vehicles to comply with corporate policies to reduce CO2 emissions and criteria pollution caused by diesel fuel. For AT&T's global fleet of more than 70,300 vehicles, the company announced plans in 2009 to invest up to $565 million as part of a long-term strategy to deploy approximately 15,100 alternative-fuel vehicles through 2018. This includes a goal to replace up to 8,000 service vehicles with CNG vehicles. The company opened a private CNG refueling station in Los Angeles last year and is working with the Department of Energy, local and regional Clean Cities coalitions, and industry stakeholders to encourage the development of publicly available refueling facilities throughout California.[3]

Despite some high-profile successes, CNG purchases are dwarfed by the sheer number of new diesel-powered trucks being sold. North American sales of diesel-powered trucks are forecast to rise 17% to 281,620 in 2015. Two years ago, many forecasters expected as much as 20% of the heavy-duty trucks sold annually in North America by the end of the decade would be natural-gas powered, whereas the percentage of current sales remain in the single digit range.[4]

5.6. Available Natural Gas Vehicles: Major automakers have been selling dedicated light-duty natural gas vehicles in Europe, South America, and elsewhere for years, but American market availability has been limited due to lack of demand. In the U.S., only a handful of light duty vehicles have been available, predominantly larger pickups and vans. In the light-duty sedan segment, the Chevrolet Impala and the Honda Civic GX have been the only offerings recently, but Honda will end production of the CNG Honda Civic with the 2016 model year. For the 2014-15 model years, the chart on the next page indicates the CNG light-duty vehicles available for purchase from OEMs.

[3] http://www.automotive-fleet.com/article/story/2012/04/great-fleets-share-best-practices.aspx

[4] http://ngvtoday.org/2015/02/04/growth-in-north-american-ngv-sales-projected-for-coming-decade/

2015 Light Duty Natural Gas Vehicles, Including Pick-Ups and Vans

Natural Gas Vehicle Model	Vehicle Type	Engine Size	Starting MSRP
Chevrolet Silverado 2500/3500 HD	Pickup	6.0L; V8	-
Chevrolet Impala	Sedan	3.6L; V6	$38,210
Chevrolet Express 2500/3500	Van	6.0L; V8	-
Chevrolet Express Cutaway 3500/4500	Van	6.0L; V8	-
Ford Super Duty F-350/450/550*	Chassis Cab	6.2L; V8	$31,400
Ford Super Duty F-350/450/550*	Chassis Cab	6.8L; V10	$31,400
Ford Super Duty F-250/350*	Pickup	6.2L; V8	$31,045
Ford Super Duty F-650*	Chassis Cab	6.8L; V10	$55,595
Ford Transit Connect*	Van/Wagon	2.5L; I4	$22,000
Ford Transit 150/250/350*	Van/Wagon	3.7L; V6	$29,556
Ford E-350/450*	Chassis Cab/ Cutaway	5.4L; V8	-
Ford E-350/450*	Chassis Cab/ Cutaway	6.8L; V10	-
GMC Savana 2500/3500	Van	6.0L; V8	-
GMC Savana Cutaway 3500/4500	Van	6.0L; V8	-
GMC Sierra 2500/3500 HD	Pickup	6.0L; V8	-
Honda Civic	Sedan	1.8L; I4	$26,640
Ram 2500	Pickup	5.7L; V8	-

Source: 2015 Clean Cities Vehicle Buyer's Guide, p. 15
http://www.afdc.energy.gov/uploads/publication/2015_vehicle_buyers_guide.pdf

For the most current information on available vehicles, it is recommended to consult the current *Clean Cities Vehicle Buyer's Guide* provided at the federal Alternative Fuel Data Center, as well as manufacturer websites for local dealer information.

Medium and Heavy Duty Vehicles: There are a number of OEM certified natural gas engine models being used in a various medium and heavy-duty vehicle models. The engines listed below can be installed by certified conversion companies known as Qualified Vehicle Modifiers or QVMs.[5] These programs are typically very rigorous and quality is high. A QVM qualification regime is described on the Ford Motors website at http://www.fleet.ford.com/showroom/limo-livery-and-funeral/qualified-vehicle-modifiers/, and is typical for major manufacturer QVM relationships.

- Cummins Westport ISL G 8.9L (250 – 320 hp)
- Cummins Westport ISX12 G12L (320 – 400 hp)
- Ford Motor Company 2.0L L-4
- Ford Motor Company 5.4L V-8
- Ford Motor Company 6.8L V-10
- General Motors 3.0L
- General Motors 6.0L V-8
- BAF Technologies 6.8

Source: *2015 Clean Cities Buyer's Guide* http://www.afdc.energy.gov/uploads/publication/2015_vehicle_buyers_guide.pdf

5.7. Diesel to Natural Gas Conversion Strategies: Today's primary NGV markets are public transit buses (the largest consumer of natural gas as a transportation fuel), and waste collection and transfer vehicles (the fastest growing market segment). Many airports and other government fleets have also adopted natural gas. Private fleets typically adopt natural gas primarily for service vehicles that return to base daily. Although there are a relatively small number of natural gas engine models, these are typically installed into a wide variety of vehicle body types by vehicle manufacturers and retrofit providers. For example, the same Cummins natural gas engine may be used in a refuse truck, a bus, or a street sweeper.

There are numerous aftermarket engine conversion kits which are certified by the California Air Resources Board and available for a wide range of vehicle platforms and classes. Most conversion kits allow for bi-fueling (CNG/gasoline) or even tri-fueling (CNG/gasoline/E85) capability. As with new OEM vehicles, payback periods vary but can be less than two years, depending on annual miles traveled, current fuel price differentials, and retrofit costs.

Retrofit options are expanding -- thanks in part to state and federal investment in R&D. Medium and heavy duty engine manufacturers such as Cummins Westport, Volvo, and Navistar have received California Energy Commission funds to develop new natural gas engines which are being integrated into a number of heavier duty vehicle chassis, such as Peterbilt and Kenworth. Product offerings in the heavy-duty segment are expected to increase in future years based on stronger emissions requirements for diesel (which will increase their

[5] http://www.baaqmd.gov/~/media/Files/Strategic%20Incentives/Alt%20Fuels/CNG%20and%20LNG%20Best%20Practices%209-30-14%20FINAL.ashx?la=en

relative purchase price vs. CNG) -- and the return of larger fuel price differentials between diesel and natural gas.

Qualified system retrofitters (QSRs), also referred to as upfitters or installers, can economically and reliably convert many light- and medium-duty vehicles for natural gas operation. To be certified as a QSR, manufacturers must provide a comprehensive training program and detailed documentation to their own technicians as well as to QSR technicians to ensure that equipment and components are installed properly, and the QSR must obtain the relevant emissions certifications and tampering exemptions.

Typically, certified installers will only perform a CNG conversion on new or nearly new vehicles. Also, CNG conversion kits must meet or exceed the same emissions standards that apply to the original vehicle or engine according to stringent Environmental Protection Agency (EPA) and/or California Air Resources Board (CARB) requirements. For this and other reasons, it is important that conversions be performed by reputable QSRs. The trade association, NGV America, offers information on light-, medium-, and heavy-duty NGVs and engines available directly from OEMs or via conversion systems certified by the EPA or CARB. They also provide manufacturer and QSR contact information at http://www.ngvamerica.org/vehicles/vehicle-availability/.

NGV Manufacturers and Retrofit Providers

Heavy-Duty Vocational OEMs

- Mack
- Peterbilt
- Crane Carrier
- Autocar Truck
- ALF Condor
- Elgin
- Johnston
- Schwarze
- Tymco
- Capacity
- Ottawa

Heavy-Duty Bus OEMs

- Thomas Built Bus
- Blue Bird Bus
- Optima/NABI
- El Dorado
- New Flyer
- Motor Coach Ind.
- Gillig
- DesignLine

Light-Duty OEMs

- American Honda
- General Motors
- Ram Trucks
- Ford

Light-Duty/Medium-Duty Retrofits

- Altech-Eco
- Landi Renzo USA/Baytech
- IMPCO Automotive
- Westport/BAF Technologies
- Crazy Diamond Performance
- NGV Motori USA
- M-Tech Solutions
- STAG
- NatGasCar
- AGA Systems
- Greenkraft
- PowerFuel Conversions
- World CNG
- Zavoli

Heavy-Duty Truck OEMs

- Freightliner Truck
- Volvo
- International
- Kenworth
- Peterbilt
- Mack

Heavy-Duty Retrofit/Repowers

- American Power Group
- Clean Air Power
- Fyda Energy Solutions
- NGV Motori
- Omnitek Engineering
- Diesel 2 Gas

Source: NGV America Website http://www.ngvamerica.org/vehicles/vehicle-availability/

5.8. Liquefied Natural Gas (LNG) Vehicles: Liquefied natural gas (LNG) is the liquefied form of natural gas, produced by cooling natural gas to temperatures below -260° F. As a fuel source, it is both cleaner burning and more economical than traditional petroleum fuels, including diesel. The energy content of a given amount of natural gas remains the same regardless of whether it is in the liquid (LNG) or gaseous (CNG) state. However, LNG has higher energy density than CNG and thus offers significant potential in NGV market segments where long driving range is required. However, the potential for LNG vehicles has not yet been fully realized due to the high initial cost and limited distribution of LNG infrastructure and vehicles. Because LNG must be stored at extremely low temperatures, large insulated tanks are required to maintain these temperatures in stationary fuel storage and in vehicles. This makes LNG most appropriate for heavy-duty vehicles, which can accommodate the volume needed for LNG storage. LNG also requires fairly consistent vehicle use as the fuel slowly heats from the tank's warmer surroundings, which can lead to tank venting and loss of fuel. Typical LNG fuel tank hold times are about one week if the vehicle is not driven, although venting will not occur if the vehicle is driven every few days.

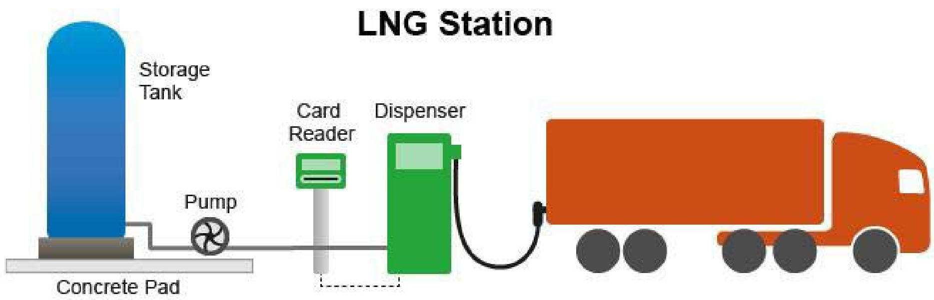
Outlook for LNG: Liquefied Natural Gas or LNG as a vehicle fuel has the potential to be successful in select vehicle market segments based upon favorable economics and strong government support for expanded infrastructure. As noted, the most promising markets are long-haul heavy-duty trucking, as well as transit and refuse vehicles, and marine and railroad applications. Currently there are fewer than 4,000 LNG vehicles nationwide and fewer than 200 LNG stations. To support expansion of LNG, an integrated network of public access stations and LNG infrastructure across the country will be needed.

LNG Feedstocks and Fueling Infrastructure: Feedgas for LNG may come from the natural gas wellhead, from pipelines, or from sources of renewable natural gas (landfills or anaerobic digestors). Like CNG, LNG has a wide range of environmental profiles depending on the source of gas (fossil vs. biogas or other sources.) Successful LNG infrastructure implementation will need to minimize the three main cost components of the LNG supply chain: feedgas cost, liquefaction and upgrade cost, and transportation cost. Feedgas cost is largely determined by market forces, although government support for biogas will be important to create scale in the sustainable gas segment. Liquefaction may be performed at one of a wide variety of facilities, but distribution of LNG is primarily performed by tanker trucks that deliver the fuel from the liquefaction facility to the vehicle fueling station. As with other alternative fuels, sustainable LNG fueling system development will require careful selection of station locations and capacities and widespread use of standardized designs, while targeting the most promising market segments for LNG penetration. LNG stations that dispense LCNG (CNG produced from LNG) have the benefit of supporting both natural gas fuel types. With strategic expansion of an LNG infrastructure network in specific regions, successful penetration of the LNG Class 8 truck market could achieve attractive economics and much larger market uptake.

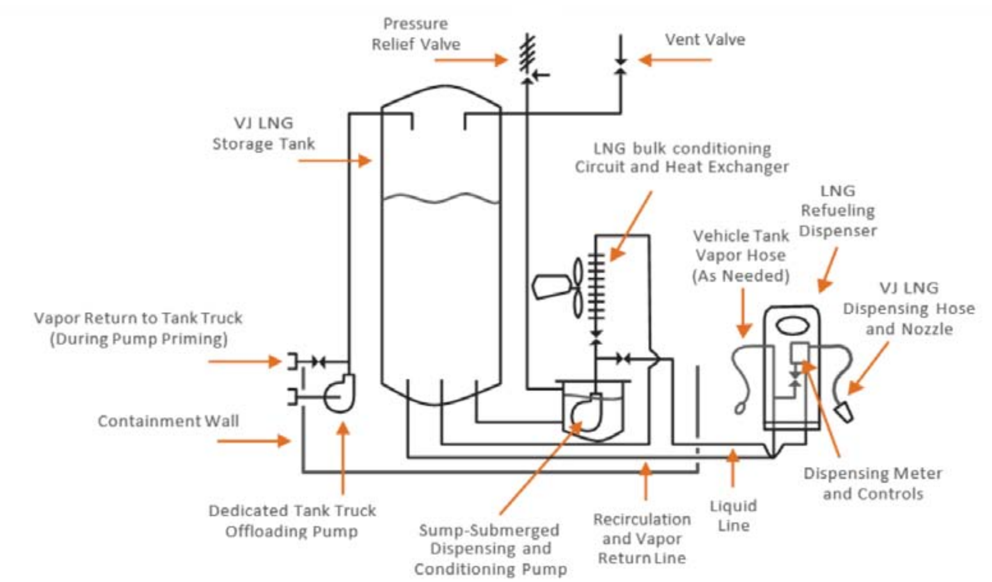
LNG Station Design: LNG fueling stations generally receive their LNG supply from a liquefaction plant via tanker truck specially designed to distribute cryogenic fuels. At the fueling site, LNG is offloaded into the facility's storage system. In most LNG stations, the fuel passes through a pump to an ambient air vaporizer that serves as a heat exchanger whereby the temperature of the LNG is increased. The pressure increases at these temperatures, but the fuel remains a liquid. This process is called conditioning. After conditioning, LNG is stored in large cryogenic vessels that can be configured horizontally or vertically, and are typically found in capacities of 15,000 or 30,000 gallons. When needed, LNG is dispensed as a liquid into cryogenic tanks onboard the vehicle. LNG fueling is similar to CNG fast fueling in terms of time and convenience, except that users are advised to use gloves to protect against the cold, and they should receive an orientation to cryogenic fuel handling.

LNG stations are very costly as they must address unique design and functionality requirements, including tank truck off loading, fuel conditioning, cryogenic fluid storage and processing, vapor management and venting minimization, codes and standards compliance, and special metering and dispensing needs. Cost efficiencies are being developed through new technology that produces LNG at warmer temperatures, which could reduce component costs in the system. LNG station designers, some of whom are also cryogenic equipment manufacturers, have developed standardized station designs. However, most stations installed to date have been custom designed to accommodate particular site requirements. Further progress toward installing LNG stations at truck stops and building more "greenfield" stations will enable increased use of standardized designs. A simplified view of an LNG station is provided below, followed by a more complex technical diagram.

Simplified LNG Station View



Typical LNG Station Design Schematic



Source: NGV America website, http://www.ngvamerica.org/stations/lnglcng/

Operational LNG Station

Source: U.S. Department of Energy, Alternative Fuels Data Center

LNG Fuel Tax Parity: One key barrier to broader use of LNG powered trucks was removed in 2015 when the U.S. Congress passed legislation requiring that liquefied natural gas be taxed on a diesel gallon equivalent (DGE) basis, putting it on an equal footing, energy-wise, with diesel. Until the new change, fleets operating LNG-powered trucks were effectively taxed for their fuel at a rate 70% higher than that of diesel fuel because the tax was based on volume rather than energy content. The new taxation approach brings LNG into parity with diesel, reducing the excise tax on LNG from approximately 41.3 cents per Diesel Gallon Equivalent (DGE) to 24.3 cents per DGE. A natural gas truck traveling 100,000 miles per year at 5 miles per DGE typically consumes about 20,000 DGE per year. Prior to the passage of the new law, the LNG truck would have a highway fuel tax bill of approximately $8,262. With this change, the LNG truck will now pay ~$4,860 a year in fuel taxes, a savings of $3,402 per year.[6]

5.9. CARB Natural Gas Vehicle Grants, Incentives, and Rebates: The California Energy Commission has provided funding for natural gas truck deployment projects, as well a buy-down incentive that historically provided subsidies for both natural gas and propane vehicles. However, propane incentives were ended after the 2014-15 investment plan year, due to uncertainty about their emissions benefits combined with limited vehicle availability. Available incentives for medium and heavy-duty vehicles are temporarily exhausted under the NGV Incentive Project (NGVIP), but may be reinstated later in 2016. Given the very limited number of natural gas light duty OEM vehicles available for sale in the U.S. (only the Chevy Impala will remain in 2016), the focus of the CEC rebate program will likely remain on medium- and heavy-duty vehicles. These are defined as vehicles with a gross vehicle weight rating (GVWR) above 10,000 lbs. While these vehicles classes account for only 936,000 out of California's 28.4 million total vehicles, or 3%, because of their lower efficiency and higher vehicle miles travelled (VMT) per year, they are responsible for 30% of on-road GHG emissions.[7]

From 2009 to mid-2015, the CEC has subsidized the deployment of a total of 1,361 natural gas vehicles, summarized in the table below. These include large one-time awards under the American Recovery and Reinvestment Act of 2009, as well as two solicitations (PON-10-604 and PON-11-603) that offered first-come, first-served buy-down incentives for both natural gas cars and trucks. The most recent buy-down incentive solicitation (PON-13-610) has further refined incentive levels based on the fuel displacement for each Gross Vehicle Weight (GVW) class per CEC dollar.

As noted above, as of late 2015, funds have been exhausted under this first-come, first-served solicitation. However, CEC maintains a wait list, as it is possible that some vehicle reservations may not actually be utilized if an applicant does not follow through on their purchase, thus releasing the incentive for the next eligible applicant. In addition to the PON-13-610 funding,

[6] "LNG Tax Fix Passed by US Congress," *Fleets and Fuels,* July 2015, http://www.fleetsandfuels.com/fuels/ngvs/2015/07/lng-tax-fix-passed-by-u-s-congress/?utm_source=Fleets-Fuels+August+5%2C+2015&utm_campaign=fleetsfuelsnewsbrief&utm_medium=email

[7] *2015-16 Investment Plan Update for the Alternative and Renewable Fuel and Vehicle Technology Program,* California Energy Commission, May 2015, p. 52.

the Energy Commission is developing an agreement with UC Irvine to provide an incentive directly to vehicle purchasers using additional available funds from previous investment plans. Details on any program extensions are likely to be announced in 2016, and additional funding to reopen the program could be allocated later in the year or in 2017.

CEC Funding for Natural Gas Vehicle Deployment (2009-2015)			
Funding Agreement or Solicitation	**Vehicle Type**	**# of Vehicles**	**Funding (in millions)**
San Bernardino Associated Governments (ARV-09-001)	Heavy-duty trucks	202	$9.3
South Coast Air Quality Management District (ARV-09-002)	Heavy-duty drayage trucks	120	$5.1
Buydown Incentives PON-10-604 and PON-11-603 *(Reflects all approved incentives)*	Up to 8,500 GVW	245	$0.7
	8,501-14,000 GVW	137	$1.1
	14,001-26,000 GVW	211	$4.2
	26,001 GVW and up	446	$12.9
Buydown Incentives PON-13-610 (In Progress) *(Reflects approved reservations only, not claimed or approved incentives)*	Up to 8,500 GVW	1,616	$1.6
	8,501-16,000 GVW	628	$3.8
	16,001-26,000 GVW	314	$1.9
	26,001-33,000 GVW	0	$0
	33,001 GVW and up	551	$13.8
UC Irvine Agreement (Pending)	TBD	TBD	$10.2
Total		**4,470 (+ TBD)**	**$64.6**

Source: California Energy Commission, 2015-16 Investment Plan.

Requirements Under the CEC Natural Gas Vehicle Incentive Project (NGVIP): As articulated in its 2015-16 Investment Plan for the Alternative and Renewable Fuel and Vehicle Technology Program (ARFVTP), the CEC's long-term goal for its natural gas incentive program is "to increase consumer familiarity and supplier production to a point where various natural gas vehicle types can grow in the market without further subsidy." With this goal still some distance in the future, the Commission allocated $10 million for FY 2015-2016 to support ongoing NGV deployment via the Natural Gas Vehicle Incentive Project (NGVIP). Prior to this funding being exhausted, incentives were available through the NGVIP exclusively for vehicles meeting all of the following requirements. (It is expected that in the event that NGVIP is re-funded, these criteria will continue to apply.)

- Vehicles must be new, on-road natural gas light-, medium-, or heavy-duty vehicles.
- Vehicles must be purchased on or after August 7, 2015.
- Vehicles must meet all emission requirements of the California Air Resources Board (ARB).
- Vehicles must be registered and operated on natural gas in California (at least 90 percent of the time) for at least 3 years.
- Vehicles must be fully warranted. "Fully warranted" means that all vehicle components, including the natural gas fuel system, are covered exclusively by the Original Equipment Manufacturer (OEM) or covered under separate warranties by the OEM and the fuel system upfitter that together provide warranty for the complete vehicle.
- Eligible vehicles must have engines prepped for natural gas.
- Transit buses are not eligible for incentives under the NGVIP.
- The individual incentive amounts by gross vehicle weight (GVW) are as follows:

Natural Gas Vehicle Incentives

GVW (lbs)	Incentive Amount
Up to 8,500	$1,000
8,501 – 16,000	$6,000
16,001 – 26,000	$11,000
26,001 – 33,000	$20,000
33,001 & greater	$25,000

A single Applicant is eligible for up to a maximum of 30 incentives. This cap may be modified or removed during the term of the NGVIP by the CEC. For the purposes of this limit, a single Applicant is defined as any single individual or business entity including all subsidiaries. Once an Applicant exceeds this maximum incentive cap, the Energy Commission and the NGVIP Administrator reserve the right to reject incentive reimbursement requests associated with Applicants exceeding the cap. More information is available at: https://ngvip.its.uci.edu/docs/ngvip-application-manual-2015-08-03-rev2.pdf

CEC Support for Medium- and Heavy-Duty Vehicle Technology Demonstrations and Scale-Up: In addition to the standard vehicle rebates and NGVIP program described above, the CEC has provided support for natural gas vehicles within its broader *alternative fuel medium- and heavy-duty vehicle technology demonstration and scale-up program.* This is a competitive, project-based program available by application only – not a standardized rebate program. Since the program's inception, the Energy Commission has provided $58.7 million for the broad portfolio of various AFV projects described below, including $8.3M for four natural gas truck demonstration projects (totaling five demonstration vehicles) shown in blue below.

Medium- and Heavy-Duty Truck Demonstration Projects Supported by the CEC (all AFV fuel types)			
Vehicle/Technology Type	**# of Projects**	**# of Units**	**CEC Funding (in millions)**
Medium-Duty Hybrids, PHEVs and BEVs	8	164	$15.8
Heavy-Duty Hybrids, PHEVs and BEVs	6	14	$11.3
Electric Buses	4	17	$6.3
Natural Gas Trucks	**4**	**5**	**$8.3**
Fuel Cell Trucks and Buses	3	6	$4.5
Vehicle-to-Grid	3	TBD	$5.3
Off-Road Hybrids	2	2	$4.5
E85 Hybrids	1	1	$2.7
TOTAL	**31**	**209+**	**$58.7**

Source: California Energy Commission, *2015-16 Investment Plan.*

Among the natural gas truck projects identified above, the Energy Commission partnered with the South Coast Air Quality Management District to support development and demonstration of a Cummins Westport natural gas engine with NOx emission levels that are 90 percent lower than 2010 engine emission certification standards. Support for these technology demonstration programs are typically developed via partnerships of OEMs, technology providers, Air Quality Management Districts, CalSTART and other industry groups, research labs, or universities. Such projects are typically focused on new technology development and demonstration rather than scaled deployment in fleet settings.

Additional Fuel Incentives for CNG – Local Tax Exemption and SoCalGas Discounts: CNG (as well as electricity) that local agencies or operators use to operate public transit services is exempt from applicable user taxes that a county normally imposes. (See the California Revenue and Taxation Code 7284.3) The Southern California Gas Company (SoCalGas) also offers natural gas at discounted rates to customers fueling NGVs. Known as Schedule G-NGVR, the Natural Gas Service for Home Refueling of Motor Vehicles is available to residential customers only. Commercial customers can utilize the rate known as G-NGV, Natural Gas Service for Motor Vehicles. For more information, see the SoCalGas NGVs website.

5.10. Propane Fuels and Vehicles: Propane, also known as liquid petroleum gas (LPG), is produced as a byproduct of natural gas processing and crude oil refining. Most widely used in rural areas for heating homes and powering farm and industrial equipment, less than 3% of propane produced in the U.S. is currently used in vehicles. However, propane is the most commonly used alternative motor fuel in the world, and its price has historically been lower and more stable than gasoline. Local pricing can vary widely depending on supply and demand. Propane's energy content is approximately 25% less than gasoline. However, due to its lower cost, propane still remains an attractive choice for fleet operators. As of early 2016, California propane prices varied from $1.60 to $2.80, with most prices closer to $2.00/gallon. At lower prices, cost savings can quickly offset increased purchase price.

Propane-fueled vehicles produce about 10% fewer greenhouse gas emissions than equivalent conventional vehicles. Propane is available at more than 2,600 stations throughout the country, and ~1,500 stations in California, according to the California Energy Commission.[8] The CEC allocated several million dollars for a vehicle purchase incentive program aimed at encouraging propane vehicle usage in California. However, the funding for this program has been exhausted and the CEC has no plans to reinstate support due to concerns about propane's environmental attributes relative to other alternative fuel options.

Propane vehicle options from OEMs are quite limited, as indicated in the chart below. However, engines and fueling systems are widely available for upgrading heavy-duty vehicles such as school buses, shuttle buses, and street sweepers.

Propane Vehicle Model	Vehicle Type	Engine Size	Starting MSRP
Chevrolet Express Cutaway 3500/4500	Van	6.0L; V8	-
GMC Savana Cutaway 3500/4500	Van	6.0L; V8	-
Ford Super Duty F-350/450/550*	Chassis Cab	6.2L; V8	$31,400
Ford Super Duty F-350/450/550*	Chassis Cab	6.8L; V10	$31,400
Ford Super Duty F-250/350*	Pickup	6.2L; V8	$31,045
Ford Super Duty F-650*	Chassis Cab	6.8L; V10	$55,595
Ford Transit Connect*	Van/Wagon	2.5L; I4	$22,000
Ford Transit 150/250/350*	Van/Wagon	3.7L; V6	$29,556
Ford E-350/450*	Chassis Cab/ Cutaway	5.4L; V8	-
Ford E-350/450*	Chassis Cab/ Cutaway	6.8L; V10	-

** Ford offers a "prep package" for this vehicle. An approved qualified vehicle modifier (QVM) can convert the vehicle to run on propane for delivery through select Ford dealerships, without impacting OEM warranties or service agreements.*

Source: 2015 Clean Cities Vehicle Guide, p. 11.

[8] California Energy Commission, Drive Clean website, http://www.energy.ca.gov/drive/technology/propane.html

Converting Vehicles to Propane: According to the U.S. Department of Energy (DOE) *Clean Cities Vehicle Guide*, a variety of options are available to convert a vehicle to propane with minimal impact on horsepower, towing capacity, or factory warranty – if the conversion is performed by an authorized technician. All conversions must meet emissions and safety standards instituted by EPA, the National Highway Traffic Safety Administration, CARB, and relevant state agencies. Many new and used conventional light-duty vehicles can be converted to run on propane (or CNG) for a cost of about $4,000 to $12,000 per vehicle. The table below lists conversion companies that offer certified CNG or propane conversion systems. The lists of systems certified by EPA and/or the California Air Resources Board (CARB) are updated regularly. Visit EPA's "Alternative Fuel Conversion" page (epa.gov/otaq/consumer/fuels/altfuels/altfuels.htm) and CARB's page on Certification of Alternative Fuel Retrofit Systems at arb.ca.gov/msprog/aftermkt/altfuel/altfuel.Htm for the most current lists of certified systems for vehicles of all model years. Additional information on vehicle conversions is available at the federal Alternative Fuel Data Center at afdc.energy.gov/vehicles/conversions.html.

2014–2015 EPA-Certified Light-Duty Clean Alternative Fuel Conversions

Conversion Fuel System	Original Equipment Manufacturer (OEM)	Conversion Fuel System Manufacturer
Dedicated CNG	Ford Motor Company	Altech-Eco Corporation BAF Technologies IMPCO Automotive, Inc Landi Renzo USA Corporation World CNG
	General Motors	BAF Technologies IMPCO Automotive, Inc The CNG Store, LLC (dba Auto Gas America)
	Chrysler Group, LLC	NatGasCar, LLC
Bi-Fuel CNG/Gasoline	Ford Motor Company	AC Spółka Akcyjna (dba Stag Autogas Systems) Altech-Eco Corporation BAF Technologies CNG Interstate of Oklahoma, LLC Landi Renzo USA Corporation M-Tech Solutions, Inc NatGasCar, LLC PowerFuel CNG Conversions, LLC Westport Power, Inc
	General Motors	AGA Systems, LLC IMPCO Automotive, Inc NatGasCar, LLC The CNG Store, LLC (dba Auto Gas America)
	Chrysler Group, LLC	NatGasCar, LLC
Dedicated Propane	Ford Motor Company	Icom North America, LLC Roush Industries, Inc.
Bi-Fuel Propane/Gasoline	Ford Motor Company	Blossman Services, Inc Icom North America, LLC IMPCO Automotive, Inc
	General Motors	Icom North America, LLC IMPCO Technologies, Inc.

Source: EPA Certified Clean Alternative Fuel Conversion Systems (Excel)
epa.gov/otaq/consumer/fuels/altfuels/altfuels.htm#4
CARB Alternative Fuel Retrofit Systems Certified By The Air Resources Board (Pdf)
arb.ca.gov/msprog/aftermkt/altfuel/altfuel.htm

5.11. Natural Gas and NGV Fueling Infrastructure Attributes and Requirements: Natural gas is primarily composed of methane (88 to 93 percent) but it also contains a number of other components in smaller quantities, including ethane, propane, butane, and inert gases. In its natural state, natural gas is noncorrosive, colorless, and odorless. Natural gas is also an asphyxiant and, in sufficient quantities, can cause suffocation. Natural gas may also contain water (measured in millions of parts per cubic foot) and foreign material such as scale from transportation pipelines. Since both of these materials could harm engines, dessicant dryers that remove moisture are typically standard equipment in CNG fueling stations. Filters may also be added to remove other impurities.

Natural gas is highly combustible at low levels of concentration (4 to 16 percent of volume) and burns with a blue flame. Because it is lighter than air, whenever there is a release of gas it quickly dissipates into the air. Based on the National Fire Protection Act Section 49, Appendix B (NFPA), natural gas is classified as extremely hazardous for flammability, slightly hazardous for health, and non-hazardous in terms of reactivity. The amount of an explosive gas in a given volume of air is measured by the Lower Explosion Limit (LEL) and the Upper Explosion Limit. For natural gas the lower explosion limit is 5% by volume and the upper limit is 15% by volume. To avoid concentration of natural gas above safe levels, venting and pressure relief devices are required, as well as methane gas detection systems. As an additional safety measure, a substance known as mercaptan is added as an odorant in the gas utility transmission pipeline so that leaks can be detected. The mercaptan creates the distinctive "rotten egg" odor associated with a gas leak. Facilities where natural gas is being used (including vehicle maintenance and repair facilities) must meet stringent building code standards for explosion proofing, fire proofing, and air circulation.

Natural gas does not liquefy under pressure alone, but any releases of pressurized gases are quite loud and can be very dangerous. For example, a pressurized hose that has a gas release can whip around and cause bodily injury or property damage. Natural gas-fueled explosions and flames <u>cannot</u> be fought effectively with water, but must be extinguished with carbon dioxide, dry chemicals, or halo carbon. (More information on natural gas safety procedures and training are provided later in this chapter.)

Natural Gas Fuel Distribution: Natural gas is transported from the well to the gas utility in underground transmission pipelines that flow at 150 to 450 pounds per square inch gauge (psig). At the distribution level the pressure is reduced to 15 to 45 psig. The gas dispensed to customers is measured by the local utility using a Meter Set Assembly or MSA which serves as the meter and cash register for the utility. An emergency gas supply shutoff is also installed at the MSA in case of an earthquake or other catastrophic event. To determine whether the existing distribution system will support a new natural gas station, a prospective station developer must assess the inlet pressure at the point of connection to the distribution system.

Home Natural Gas Fueling: Home natural gas pressure is very low and is measured in "inches on the water column" which is less than one pound per square inch. This pressure level is adequate for cooking and heating or cooling and can also be used for a consumer-level vehicle refueling appliance. Devices such as the BRC or Honda "Phil" home refueling product provide an overnight fueling solution. Commercial stations require much higher inlet pressures—typically a minimum 14.5 pounds per square inch. Pounds per square inch is also known as a "bar."

How Natural Gas Moves from Pipeline to Vehicle: Natural gas moves through multiple steps in preparation and delivery from the pipeline to the inlet on a CNG vehicle. As described in the *CNG Infrastructure Guide* developed by the American Gas Association,[9] from a fueling infrastructure perspective, the process begins at the gas utility connection to the CNG station site. The gas is metered at this connection, and then the following steps are typically required to make the gas "vehicle ready".

Inlet Gas: The municipal "inlet" gas connection will require sufficient flow rate and pressure for the designed application. Many CNG infrastructure applications can use the standard low pressure available in municipal gas lines, but it is important to know the pressure available at the line and if the envisioned application will require a larger line or more pressure. It is recommended that potential station owners/operators check with the local utility and/or gas supplier to determine the "guaranteed" minimum inlet pressure available at your selected location.

Gas Quality: The quality of inlet gas primarily concerns moisture content, and scale or other foreign matter that may be contained in the inlet line. Moisture content in natural gas is measured in millions of parts per cubic foot. Inlet gas with high moisture content will require "drying" in order to make it serviceable for fueling vehicles, and dryers are standard equipment in most fueling applications. Further, a filter may occasionally be necessary if there is a quantity of pipe scale or foreign matter in the gas line. Filters come standard on many models of compressors.

Gas Compression: Dried and filtered inlet gas is compressed by one or more compressors and often stored in tanks, or delivered directly to a fuel dispenser. This pressurized gas is now "Compressed Natural Gas" ready for vehicle fueling.

Priority Distribution: Moving the CNG from the compressor to storage tanks or directly to the vehicle requires directed control, and this function is supplied by a computerized "priority panel." Priority panels direct the flow of CNG from the compressor to on-site storage tanks. Sequential panels direct the flow of CNG from the compressor or tanks to fuel dispenser units and/or vehicles. Based on the pressure measured in the vehicle tank, the priority panel switches between the low, medium, and high pressure tanks to ensure a complete fill.

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[9] *CNG Infrastructure Guide,* America's Natural Gas Alliance and the American Gas Association, pp. 5-6. https://www.aga.org/sites/default/files/sites/default/files/media/cng_infrastructure_guide.pdf

Gas Storage: Fast fill CNG applications will require pressurized gas to be stored in high pressure tanks to accommodate more vehicles fueling faster. CNG storage tanks often come in cascades of up to three tanks in a "bank" or in spheres. Cascade banks are most often maintained at three different pressure levels (high, medium, low) to accommodate faster vehicle refueling, and ensure a proper fill. Natural gas storage tanks are required by law to be installed above ground.

Dispensing CNG: CNG dispensers come in many different sizes, shapes, and varieties. However, they all conform to either a fast fill or a time fill configuration and are available in different hose configurations and with different flow rates and methods of metering. Time fill units typically dispense fuel through a fixed pressure regulator. When the fuel flow reaches a minimum rate, the fuel flow is shut off. Fast fill units measure the pressure in the tank, then a small amount of precisely measured fuel is dispensed into the tank and the pressure rise is measured. From these figures, the volume of the tank is calculated and the tank is filled rapidly to this level. When the tank is full the flow is shut off. Many dispensers come with temperature compensators that ensure a complete fill in cold environments.

CNG Fueling Station Storage and Filling Technologies: CNG stations are distinct from gasoline and diesel stations insofar as they include unique components such as gas dryers and high pressure storage systems that must conform to relevant codes and standards. As noted above, gas may be dispensed directly ("direct fill") from the compressor to the vehicle through a fueling hose (known as buffer storage) or stored in large high pressure vessels (known as cascade storage). Direct fill is a better choice for stations with a relatively steady flow of vehicles, whereas the cascade storage approach is more suitable for stations with sharp peaks in demand. Storage vessels for cascade storage are typically sold in banks of three vessels -- each of which typically hold a total of 30,000 standard cubic feet (scf) each or approximately 240 gasoline gallons equivalent (gge). A three vessel bank consists of high, medium and low pressure vessels as well as the computerized priority panel that directs gas from the appropriate bank to the dispenser hose. Since gas moves in response to unequal pressure, the higher pressure gas in the storage vessels will move to fill the lower pressure vehicle tank. Buffer storage consists of smaller tanks that provide fuel for a very short period (less than a minute) while the compressor ramps up.

Natural Gas Compression and Vehicle Filling Strategies: Natural gas vehicle tanks are generally filled at 3600 psi, but ambient temperature, as well as the heat of compression and pumping, may cause natural gas to expand, reducing the pressure in the vehicle tank below 3600 psi. As a result, the vehicle may not fill completely. In order to rectify this situation, the gas may be initially compressed to as much as 5500 psi to compensate for heat-related expansion. An algorithm controls this process -- known as temperature compensation -- so that vehicles receive a complete fill.

Liquefied Natural Gas: Liquefied natural gas (LNG) is methane that is chilled to -270 degrees Fahrenheit. The cold temperatures cause other impurities in the gas to drop out -- creating a fuel that is approximately 97 percent methane -- resulting in higher energy density. LNG is stored, transported, and dispensed as a liquid.[10] This higher energy density makes LNG a potential fuel of choice for long distance vehicles, such as heavy-duty Class 8 tractor trailers. To date, however, LNG has had extremely limited uptake in the United States, with just ~3300 vehicles registered as of 2010, vs. ~113,000 CNG vehicles.

LNG in the U.S. has been produced in large centralized plants and then trucked long distances to fueling stations where it must be stored at very cold temperatures and used within a few days to avoid evaporation. The use of long distance trucking to deliver LNG reduces the emissions benefits of the fuel and can lead to weather-related delivery problems. New developments are making various sizes of on-site liquefaction plants more practical, although these products are in the early stages of market introduction. LNG is also more difficult to odorize than CNG and must be odorized on site as a safety precaution. Because of the complex technology and cost hurdles facing the LNG distribution system, projected growth in the LNG-fueled vehicle segment is expected to be very limited over the 2015-2025 period. (Additional information on LNG vehicles and use cases is provided later in this chapter.)

Renewable Natural Gas and BioMethane: Conventional natural gas is not considered to be a renewable fuel. However, biomethane or renewable natural gas can be produced from organic material found in dairies, landfills, and wastewater treatment facilities, leading to GHG emission reductions of up to 85% compared to conventional natural gas. (Further discussion of biomethane production opportunities is provided later in this chapter.)

The Natural Gas Fueling Experience: Refueling of Natural Gas Vehicles can be easier and safer than with gasoline or diesel – it takes about the same amount of time, but liquid spills and stains do not occur as CNG fuel is in a gaseous state. In the case of bi-fuel cars (shown below), the CNG fuel inlet may be paired with the liquid fuel inlet, while in dedicated CNG vehicles, there is no option for liquid fueling.

OEM bi-fuel cars often have the natural gas fuel inlet paired with the liquid fuel inlet.
Source: NGV Global website. http://www.iangv.org/refuelling_ngvs/

The fueling process differs only slightly for CNG, LNG, or a blend of hydrogen and CNG

[10] Due to its cryogenic state, LNG easily evaporates -- and it can also be gasified to create what is known as L/CNG (LNG that has been converted back to CNG for fueling of CNG vehicles). However, the extra cost of transporting LNG in tanker trucks makes conversion of LNG to CNG economically inefficient compared to the direct use of CNG distributed by existing gas pipelines.

(HCNG). In all cases, the refueling nozzle clicks onto the receptacle on the vehicle and the user is ready to fill. When the cylinder is full, the dispenser automatically shuts off and the user is ready to disconnect again. With LNG, it is usually necessary to wear gloves due to the extreme cold temperatures of the fuel (the user does not come into contact with the fuel but the equipment usually conducts the cold). Options for refueling include public station, depot based and home refueling. The principal difference between each option is the volume and speed at which the fuel is dispensed and the means of paying for the fuel.

Public Refueling: Public CNG stations operate much like gasoline or diesel stations. The driver pulls up at a dispenser, switches the engine off and then connects the nozzle to the receptacle. However, some nozzles have an isolator fitted, which prevents the engine from being switched on while connected to the dispenser. In some converted vehicles, the refueling receptacle may be located under the hood or in the trunk. In most OEM vehicles, the receptacle is located where the gasoline or diesel inlet is. Refueling usually takes the same amount of time as a gasoline or diesel vehicle, though if demand is particularly high, a resulting pressure drop may slightly extend the time to refuel. Public CNG refueling stations are usually supplied either by piped natural gas, or by trucks known as "tube trailers." A station supplied by a tube trailer is part of what is known as a "mother-daughter" system, in which the fuel is compressed at the mother station and delivered via tube trailer to the daughter station. Mother-daughter systems are typically used when piped natural gas is not available.

Depot Based Refueling: A depot based CNG station usually serves a limited fleet, though facilities are often shared with fleets or private vehicle owners that are not related to the depot. Depot based refueling may deploy either a "fast-fill" or a "time-fill" (aka slow-fill) system. A fast-fill CNG system will refuel a vehicle in approximately five minutes or less. A time-fill system fills the vehicle over a period of hours, often overnight, depending on the specific system pressure level and vehicle tank size. Time-fill systems are usually used for vehicles that have regular extended periods of non-operation – such as refuse and utility trucks, courier vans, private vehicles, school buses, and other fixed route vehicles.

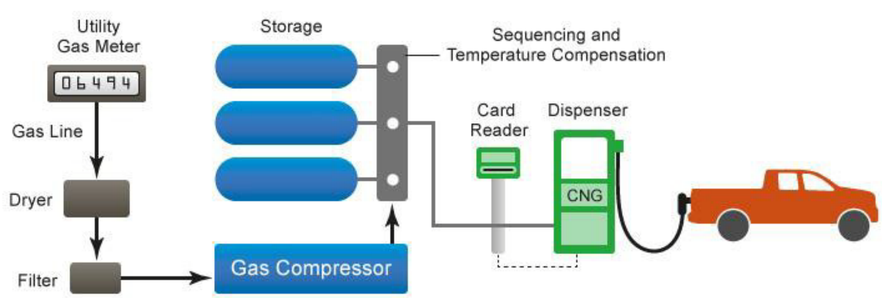
A private Time-Fill (aka slow-fill) refueling depot can fill multiple vehicles concurrently via single posts with multiple dispensers. **Source:** NGV Global.

CNG Station Configurations: In total, there are four predominant configurations of CNG stations:

- Cascade Fast-Fill
- Buffer Fast-Fill
- Time-Fill
- Combination-Fill, which combines two of the three configurations

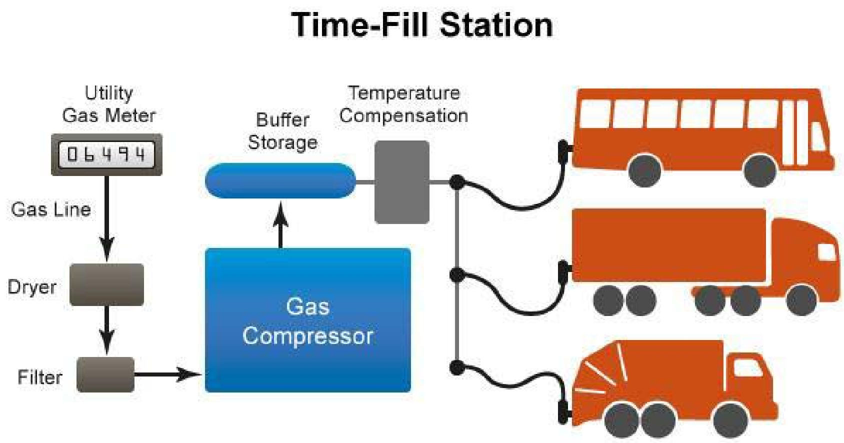
As noted above, fast-fill stations typically refuel vehicles in approximately the same time as a gasoline station unless concurrent demand is unusually high. By contrast, Time-Fill (aka slow-fill) stations refuel vehicles in a matter of hours – typically overnight. The advantage of Time-Fill is significantly reduced upfront system cost to establish a fuel depot (cost variations are detailed below). Cascade Fast-Fill stations primarily fill from storage tanks and are typically used for retail applications or vehicles that require refueling at varying times. Unlike gas stations which keep thousands of gallons in underground storage, CNG stations often have three-packs of above ground storage vessels in which 240 to 300 gallons of compressed gas are stored after delivery from a pipeline or truck (in those locations where pipeline infrastructure is not available). Vehicles are filled either from the storage vessels or directly from the compressor, depending on the compressor equipment manufacturer. Typically, the compressor will refill the storage during off-peak periods while there are no vehicles fueling. Larger fleets and most public CNG stations utilize the cascade fast-fill configuration below.

Fast-Fill Station



Source: U.S. Department of Energy, Alternative Fuels Data Center, http://www.afdc.energy.gov/

Time-Fill vs. Fast-Fill Station Configurations: Most Time-Fill stations use Single Hose Fueling Posts as in the diagram below. As needs change, Time-Fill stations can be modified to become Fast-Fill stations with the addition of a small amount of storage and Fast-Fill dispensing equipment. Time-fill stations are considerably simpler in construction, and include just the components illustrated below.



5.12. Natural Gas Fueling Infrastructure Cost Factors: The cost associated with constructing a CNG refueling station can vary significant based on land costs, size, and application and ranges from $675,000 to $1,000,000 or more (not counting land), depending on capacity and throughput. The table below provides estimates of equipment and installation costs for one Time-Fill and two Fast-Fill stations, and illustrates several scenarios for the number and type of vehicles that can be refueled at the station. Since land costs vary widely, they are excluded. It is recommended that Fast-Fill stations incorporate redundancies in their design, therefore the table also shows a Fast-Fill station with two compressors. It is important to note that the costs associated with combination-fill stations will incorporate the costs of both fast and time-fill stations.

	Fast Fill Station I	Fast Fill Station II	Time Fill Station
	Natural gas dryer, one 300 scfm compressor, 3 ASME vessel high-pressure storage systems, 1 two-hose fast-fill dispenser (no redundancy)	Natural gas dryer, two 300 scfm compressors, 3 ASME vessel high-pressure storage systems, 1 two-hose fast-fill dispenser (with redundancy)	Natural gas dryer, one 300 scfm compressor, 20 two-hose, time-fill dispensers (no redundancy)
Component Cost	$500,000	$650,000	$375,000
Installation Cost*	$300,000	$350,000	$300,000
Total Cost	$800,000	$1,000,000	$675,000
Vehicle Fueling Scenarios	15 light-duty/15GGE consecutively fueling in a 1-hour peak period or Randomly arriving light-duty/10 GGE or 10 heavy-duty/20 DGE consecutively fueling in a 1-hour peak period or Randomly arriving heavy-duty/DGE	15 light-duty/15 GGE consecutively fueling in a 1-hour peak period or Randomly arriving light-duty/10 GGE or 10 heavy-duty/20 DGE consecutively fueling in a 1-hour peak period or Randomly arriving heavy-duty/10 DGE	40 vehicles/38 GGE in a 10-hour period or 40 vehicles/33 DGE in each vehicle in a 10-hour period

Source: American Gas Association *CNG Infrastructure Guide.* https://www.aga.org/sites/default/files/sites/default/files/media/cng_infrastructure_guide.pdf

Cost Breakout for Components: The following cost ranges are representative of recent low and high costs of constructing a CNG fueling station and are suggested as a general guideline. Each specific site will have its unique requirements and associated costs. Note that internal project management costs and land costs are not included.

Component	Estimated Costs, $
Gas Supply Line	20,000 - 150,000
Compressor Package	200,000 - 400,000
Noise Abatement	0 - 40,000
Gas Dryer	50,000 - 80,000
Storage (3 or 6 ASME)	100,000 - 200,000
Dispenser (1 or 2 00M-hose)	60,000 - 120,000
Card Reader Interface	20000- 30,000
Engineering	25,000- 75,000
Construction	300,000 — 600,000
Contingencies	10 — 150,000
Estimated Total (Excludes, land	**805,000 – 1,845,000**

Source: American Gas Association *CNG Infrastructure Guide.*

Cost Components of Fuel: The cost of fuel includes multiple components, of which the natural gas itself is just one element. Note that there is no profit margin built into this calculation, thus reflecting a private depot price, not a public commercial station price.

Natural Gas Fuel Pricing Elements	low	high
Natural gas (gallon)	$ 0.64	$ 0.91
Gas Commodity	$ 0.52	
Transportation to local distribution companies (LDCs) via interstate pipelines to LDC's "city gate"	$ 0.04	$ 0.04
Local gas company service fee to transport gas to customer meter		
State/local receipts/use taxes and/or special assessments		
Electricity for compression	$ 0.09	$ 0.30
Maintenance/repair	$ 0.15	$ 0.30
Capital Amortization	$ 0.35	$ 0.50
Federal motor fuels excise tax	$ 0.18	$ 0.18
State motor fuel excise tax	$ 0.08	$ 0.30
Taxable fuel sales	$ -	$ 0.10
Total	$ 2.05	$ 2.63
Notes: assumes no grants or other buydowns of equipment cost and no profit margin.		

5.13. Best Practices in Planning, Permitting, and Development of NGV Fueling Stations

CNG fueling station designs vary widely and are constructed in a variety of form factors, with minimal standardization. To determine necessary capacity and flow rates, CNG station designers must consider a particular fleet application and/or local consumer demand, as well as technical factors related to the existing pressure in the pipeline gas distribution system (if any) at a particular location. Additional CNG station siting factors include proximity to fleet vehicles or concentrations of private CNG vehicles, and local zoning and permitting requirements. Note that the guidance for CNG stations is substantially similar to the guidance for hydrogen station development -- as it draws on the Governor's Office of Planning and Research protocols for H2 station development.[11] These guidelines also reflect information in the *CNG Infrastructure Guide* produced by the American Natural Gas Association and the California Statewide Alternative Fuel and Fleets Project guidance document: *Permitting CNG and LNG Stations: Best Practices Guide for Host Sites and Local Permitting Authorities* prepared by Clean Fuel Connection, Inc.

All guidance documents agree: it is critical to start the permitting process early—at least nine months before the anticipated construction date! Prior to beginning the permitting and construction process, station developers are advised to take all relevant steps to ensure that the project is feasible -- and to select equipment and installation vendors based on a bidding process that will surface available options and price ranges. Once selected, the equipment vendor and installation contractor will help address permitting, construction/installation, and start up/commissioning processes.

Step A. Start the permitting and vendor/installer selection process early: Prior to beginning the permitting and construction process, project developers will likely want to ensure that the project is feasible. Developers are advised to select experienced equipment and installation vendors that can in turn help assess and demonstrate feasibility -- and trouble-shoot permitting processes. Most developers or owners will establish a bidding process to assess available options and prices. Once selected, the equipment vendor and installation contractor will help navigate permitting and installation and other start up processes.

Step B. Set up an initial meeting between the end user applicant and the Planning or Community Development Department: The agenda should include these items:

- Zoning classification of proposed station to determine if it is a permitted use
- Any approvals required to allow the station as a permitted use – e.g. a general plan amendment, variance, or a conditional use permit
- Based on the zoning regulations, determine what setbacks are required from the property line
- Define any special clearances required for explosion proofing

[11] California Governor's Office of Planning and Research, *H2 Readiness: Best Practices for Hydrogen Stations in Early Adopter Communities,* April 2014. http://cafcp.org/sites/files/H2-Best-Practices_Final-Single-Page.pdf

- Define the level of environmental review, if any, required under the California Environmental Quality Act (CEQA)
- Identify any noise or odor issues based on the neighboring properties. Note that the CNG station noise standard is 85 dBa (OSHA limit without hearing protection); and this can be reduced to 70 dBa at the property line with enclosures or a noise reduction package
- Review the scope of CNG station project
- Identify any additional traffic or circulation issues created by the station

- Define approval processes and timelines. Approvals for construction permits will typically be required from these departments:
    - Planning
    - Building and Safety
    - Public Works
    - Fire Department
    - Traffic
    - Landscaping, architectural, or design review
- Identify the number of sets of plans and calculations to be submitted
- Identify fee schedules
- Confirm that the end-user has contacted the local gas utility to obtain inlet pressure and any other utility requirements for natural gas delivery to the site
- Consider visiting similar sites or meet with the local gas utility representative for an orientation. (A list of resources for additional information is at the end of this guide)
- Once it is determined that the project is feasible and there are no major obstacles such as zoning restrictions, the prospective station owner can proceed to permitting (see below)

Step C. Prepare and submit permitting package to the City; place equipment order: In addition to any specific local requirements, the package should include:

- Single Line electrical diagram
- Civil Drawings and Specifications stamped by a Registered Engineer:
- A plot plan showing the surrounding area and streets as well as the placement of the station on the property
- Foundations and Structures
- Mechanical Drawings and Specifications stamped by a Registered Engineer:
- Piping and Instrumentation Diagram (P&ID) including piping, tubing, vessels and mechanical equipment
- Electrical Drawings and Specifications
- Electrical distribution system, panel schedules, grounding and load calculations
- Safety sign package
- Grading Plan

- Preliminary schedule
- Submittal of the permit package will be followed by a series of reviews by various city departments (Fire, Building and Planning or Community Development) with possible comments and corrections at each step until a set of plans is approved by the city.

Step D. Construction, inspection, and Commissioning

- Conduct interim inspections during construction process in accordance with all relevant CNG standards documents (See below for list of relevant standards)
- Complete final electrical hookups and utility work
- Install utility metering

Step E. Final inspection by local jurisdiction and signoff

Typical Project Schedule: The following CNG station project management spreadsheet provides an overview of key tasks and development timeframes.

CNG PROJECT DESIGN SCHEDULE

															AS OF:			
#	Project Division	Project Description / Notes	Completion Date	% Complete	$K Estimate	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	Find and Settle Land for Station			0	$0.00													
2	Assess Gas Availability			0	$0.00													
3	Determine Line Pressure			0	$0.00													
4	Assess Tariffs or Delivered Price			0	$0.00													
5	Select CNG Equipment Vendor			0	$0.00													
6	Select Project Engineer			0	$0.00													
7	Order CNG Equipment			0	$0.00													
8	Finalize Initial Design Documents			0	$0.00													
9	Complete Local Permit Process			0	$0.00													
10	Sign Gas Delivery Agreement			0	$0.00													
11	Get Permission to Tap Line			0	$0.00													
12	Obtain Right-of-Way for Pipeline			0	$0.00													
13	Finalize Site Design/Specifications			0	$0.00													
14	Select Construction Manager/Contractors			0	$0.00													
15	Construct CNG Filling Station			0	$0.00													
16	Lay Pipeline to CNG Station			0	$0.00													
17	Deliver CNG Equipment			0	$0.00													
18	Tap Main / Transmission Line			0	$0.00													
19	Schedule Gas Delivery Volumes			0	$0.00													
20	Install Meter & Take Delivery of Gas			0	$0.00													
21	Complete Landscaping & Site Details			0	$0.00													
22	Sign Agreement with Fuel Mgt. System			0	$0.00													
23	Complete Automation and Start-Up			0	$0.00													

Source: *CNG Infrastructure Guide,* America's Natural Gas Alliance and the American Gas Association. p. 44

NGV Station Siting, Zoning, and Permitting: Land is a significant cost component in building a CNG station in a "greenfield" scenario. Requirements for land begin at approximately 1⁄2 acre of property for a light duty station, and increase with larger applications. If civil design work is needed for new construction, a geotechnical site evaluation will likely be required. This evaluation will provide critical soil composition information necessary for concrete foundations and electrical grounding systems. Considerations must be given to road access (public or private) and utility connections. Easy access to major trunk highways is desirable. Where land costs are prohibitive for a new stand-alone station, many developers seek out partnerships with a convenience store. Many existing gas stations will not have sufficient land available for the necessary storage and equipment associated with a CNG station.

Local building codes and regulations are also of critical importance. Since CNG and LNG are relatively new fuels, they may not be specifically called out in zoning regulations. CNG and LNG stations are usually permitted wherever gasoline fueling stations are allowed, typically in industrial and commercial zones. However, based on National Fire Protection Association codes and standards (NFPA 52), CNG stations have specific requirements due to the nature of the fuel, including:

- Setback of 15 feet from a residential property line
- Class I Division I rating for all components within a 5 foot radius of the compressor or dispenser

In some cases, residential fueling is permitted. The City of Chino has even taken the step of requiring new home construction to include plumbing for a possible home natural gas fueling appliance. If a fueling station is <u>not</u> a permitted use at the desired location, the site owner can appeal to the local Planning Commission for a variance. Of course, this will add time and cost to the approval process.

In addition to zoning regulations, local governments may have their own municipal codes that impact construction of a CNG station, including:

- City Fire Codes
- Local Building Ordinances
- Local Noise/Lighting/Traffic ordinances
- Any local requirements that are more restrictive than the national codes

Prospective station owners should familiarize themselves with local design and construction requirements to avoid costly delays.

Utility Service: An adequate natural gas supply accessible to the proposed CNG station location is critical. CNG station developers should contact the local gas distribution company early in the site selection process. An inadequate gas supply and pressure or excessive distance to the gas supply could make the station infeasible. In addition, high capacity electrical service will be required at most CNG fueling installations to run the equipment necessary to prepare, store, and dispense CNG to waiting vehicles. Contact the local utility provider to confirm adequate power is available or can be provided.

Station Design and Capacity: The following key parameters must be assessed by the station developer and key consultants and contractors to specify the station equipment and operating parameters:

- **Inlet pressure**: the pounds per square inch (psi) available at the utility meter
- **Flow**: the amount of compressed natural gas that can be dispensed over time (as measured by standard cubic feet per minute or scfm). The flow can also be communicated in gasoline gallon equivalent (gge) units per minute. Approximately 125 scfm equals one gasoline gallon equivalent and 135 scfm equals one diesel gallon equivalent – with the number varying slightly depending on the definition of standard conditions. Note that gas composition also varies slightly from location to location, thus the amount of energy (BTU) in each gasoline gallon equivalent of natural gas will also vary. Using BTUs as the unit of measure (rather than cubic feet) eliminates this discrepancy.
- **Duty cycle**: the specifics of the individual application will determine what kind of CNG compressor is needed. Smaller compressors produce anywhere from a fraction of a gge per hour to about 2 gge per minute. On the other end of the spectrum, high horsepower compressors can produce as much as 12 to 15 gasoline gallons per minute or more.

5.14. NGV Fueling Station Safety and Code Guidelines: As noted in the step-by-step guidance above, it is extremely important to contact the local Fire Marshall and Building Inspector to gain their guidance through the permitting process – and to ensure the station is designed and constructed in accordance with all applicable local, state, and federal laws, rules, regulations, codes and standards.

Given the flammable nature of CNG and LNG, safety is of paramount concern. Stations need to meet all applicable federal, state, and local codes and requirements. However, all codes are subject to interpretation by local authorities having jurisdiction (AHJs) who make the ultimate decision on compliance. The primary code governing compressed natural gas and liquefied natural gas stations is issued by the National Fire Protection Association (designated NFPA 52), and is described as follows.

NFPA 52 provisions cover the design, installation, operation, and maintenance of CNG and LNG fuel
systems on all vehicle types--plus their respective compression, storage, and dispensing systems.
Most jurisdictions have adopted this code, although some may be using older versions.
Additional relevant codes are included in the chart below:

Code Organization	Key Function
ANSI American National	Facilitates development of codes and standards that govern the use of CNG and manufacturing of CNG fueling components, including nozzles, receptacles, dispensers, hoses, breakaway devices, valves, and related components

Standards Institute	
ASME American Society of Mechanical Engineers	Boiler and Pressure Vessel Code Section 8 of the ANSI/ASME B31.3 Chemical Plant and Conventional Fuel Refining Piping Code regulates high-pressure CNG storage vessels and piping. Section 8 is the manufacturing standard for pressure vessels in CNG station, while section B31.3 establishes specifications for piping throughout the station. Key code elements include: ▪ Section 523. Design and Construction of CNG Tanks ▪ Section 524 Design and Construction of Compressed Natural Gas Cylinders ▪ Section 530 Approval of Devices ▪ Section 531 Location of Storage tanks and Regulating Equipment ▪ Section 532 Installation of Above Ground Storage Tanks ▪ Section 536 Piping Standards ▪ Section 541 Safety Relief Valves
ASNT American Society for Nondestructive Testing	Tests CNG station components for safety.
NEMA National Electrical Manufacturers' Association	Establishes standards for electrical component manufacturing.
NFPA National Fire Protection Association	NFPA 52, NFPA 70, and NFPA 30A codes and standards regulate the use of natural gas as a vehicle fuel, including stations and vehicles; defines the boundaries of the hazardous areas inside the fueling station; and governs the use of multiple fuels in one location.
NFPA 70/NEC	Defines the electrical classification of the hazardous areas within a CNG station
OSHA Federal and State	Regulates occupational safety and health in the work environment CAL-OSHA Title 8 Article 7 Unfired Pressure Vessel Code for safety for pressure Vessels (CNG storage containers)
SAE - Society of Automotive Engineers	SAE J1616 establishes recommended practices for fuel quality and water content
UBC Uniform Building Code (local jurisdiction)	Regulates structures that contain CNG fueling equipment. ▪ Seismic Zone 4—for footings, founding and soil for dryer, compressor and storage vessels ▪ UBC must meet wind requirements up to 70 miles per hour for dryer, compressor and storage vessels
UFC - Uniform Fire Code	Some localities use this code; often contains NFPA 52 within it

UPC - Uniform Plumbing Code	Governs the plumbing components of CNG stations
NIST National Institute for Standards & Testing	Establishes the unit of measurement for custody transfer of CNG from the retailer to the customer
UL Underwriters Lab	Tests components and publishes lists regarding compliance

Source: *Permitting CNG and LNG Stations: Best Practices Guide for Host Sites and Local Permitting Authorities.* Prepared by Clean Fuel Connection, Inc.

CNG Station Certification by a National Recognized Test Laboratory: In the process of permitting and approving CNG stations, local building officials will need to consult a Nationally Recognized Test Laboratory (NRTL). Although the most widely recognized NRTL is Underwriters' Laboratory (UL), there are at least a dozen NRTLs that may be accepted by local jurisdictions. CNG stations are not UL listed as a comprehensive unit, rather the individual electrical components are UL listed. This reflects the reality that CNG stations are individually designed according to specific customer applications and site conditions, such that no two stations are exactly alike. Responsibility for CNG component testing and certification is distributed per the table above, such that no one agency is equipped to certify all natural gas equipment components. Some local jurisdictions will require field certification of installed systems. In this case an approved test lab will visit the site to confirm that all components and their assembly meet the applicant listing standards. Other agencies accept written reports of testing and listing of components by independent laboratories.

5.15. Overview of Nationwide Natural Gas Fueling Infrastructure: There are approximately 1,300 public and private CNG stations located in the United States -- vs. over 120,000 retail gas stations. According to the California Natural Gas Vehicle Coalition (whose data is cited by the California Energy Commission), California leads the United States in the number of CNG and LNG fueling stations, with more than 500 combined (public or private) CNG stations and roughly 45 LNG stations.[12] According to the U.S. DOE's Alternative Fuel Data Center, of this total, there are about 140 public CNG stations and 14 public LNG stations in the state. Consumers in most areas can also purchase a slow-fill system for at-home, overnight fueling, although no data is readily available on slow-fill residential deployment. Nationally, approximately half of all CNG stations are for private fleet use. Thus, the ratio of CNG to gasoline stations on a national basis is approximately 1 CNG station to every 100 retail gasoline stations -- counting both public and private stations, or 1 to every 200 counting just public stations.

During the early 1990s the country's CNG refueling infrastructure experienced a period of

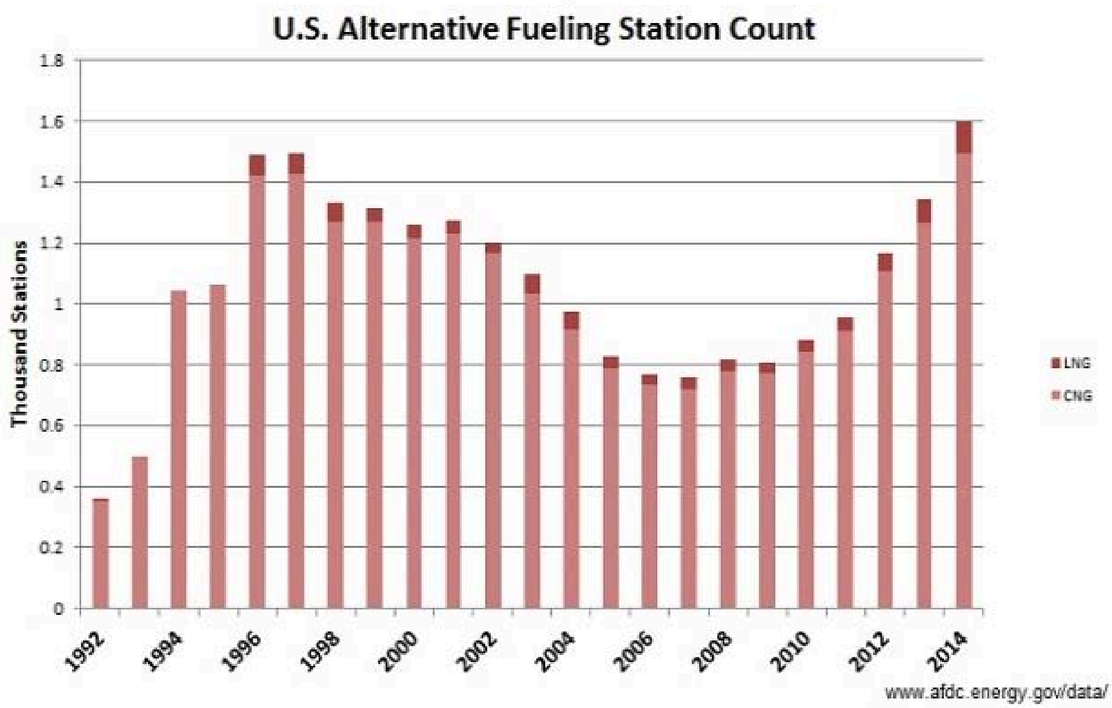
[12] *2015-16 Investment Plan Update for the Alternative and Renewable Fuel and Vehicle Technology Program,* California Energy Commission, May 2015, p. 49. http://www.energy.ca.gov/2014publications/CEC-600-2014-009/CEC-600-2014-009-CMF.pdf

growth, largely driven by the alternative fuel vehicle mandates of the Energy Policy Act, which also boosted biofuel production, as discussed in Chapter 4 of this Plan. Following a peak in 1997, national CNG refueling infrastructure declined for approximately a decade, while trending upwards again since 2006. CNG stations are also in the early stages of development in Canada, which currently reports 56 stations with public access. To fuel the projected moderate NGV sales growth, the energy consulting firm Navigant expects there will be about 2,100 to 2,200 NGV fueling stations open in the U.S. and Canada combined in 2024, up from about 1,500 today. Globally, sales of NGVs are projected to grow from 2.3 million units annually in 2014 to 3.9 million units in 2024, which should bring additional models to North America.[13]

National NGV Strategy: The first major national strategy to boost natural gas use in the transportation sector was developed by an industry-led effort known as the NGV Coalition -- which published the first *Natural Gas Vehicle (NGV) Industrial Strategy* in 1995. This coalition helped increase the demand for natural gas in the transportation sector by focusing on increasing awareness and adoption of NGVs by transit agencies, delivery and refuse services, and other medium- and heavy-duty truck fleets with high fuel usage. Between 1997 and 2009, annual demand for natural gas fuels grew by threefold to 3.2 billion cubic feet, or 27.7 million gasoline gallon equivalent (GGE). The NGV Strategy document estimates that the U.S. will require between 12,000 and 24,000 CNG stations -- equivalent to 10 to 20 percent of traditional liquid fuel outlets -- to make CNG competitive in terms of public access for all vehicle segments.

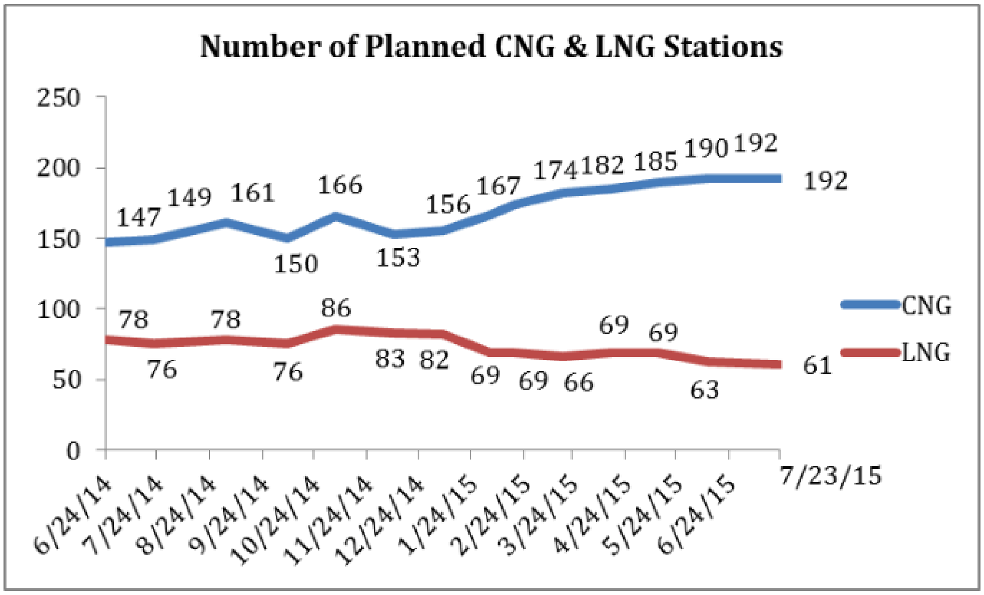
Growth in NGV Stations: Recent growth in CNG and LNG fueling stations has been somewhat uneven, with a dip between 1998 and 2008, but an overall upward trend is ongoing since 2009, illustrated in the chart below.

[13] http://ngvtoday.org/2015/02/04/growth-in-north-american-ngv-sales-projected-for-coming-decade/



Source: US Department of Energy, Alternative Fuels Data Center (AFDC). http://analysis.fc-gi.com/natural-gas-vehicles/cng-vehicle-rise-spurs-filling-station-projects

5.16. California Natural Gas Fueling Infrastructure: As in the case of other Alternative Fuel Vehicles (AFVs), the overall NGV deployment outlook is clouded in part by the "chicken or egg" dilemma that inadequate fueling infrastructure is limiting consumer confidence in NGVs, while the limited quantity of NGV sales limits the economic inventive for fuel suppliers to provide more retail fueling outlets. In the California context, the chart below from the DOE Alternative Fuel Data Center reports that there are 192 CNG stations and 61 LNG stations in the planning phase in California. The AFDC data does not break out planned stations by whether they will be public or private access. However, if national averages hold, approximately 50% of these could be publicly accessible. Planned stations are stations that have been either: 1) publicly announced; 2) are in permitting; or 3) are under construction. The list also includes stations where installation of fueling infrastructure has been completed but the stations have yet to begin dispensing fuel. Note that in the case of LNG stations, installation of fueling infrastructure has been completed at many of the LNG stations reported as planned in the AFDC database, but these stations have not yet begun dispensing LNG pending sufficient demand from customers to justify opening.



Source: *NGV Today*, July 2015. http://ngvtoday.org/2015/07/23/number-of-planned-cng-and-lng-stations-8/

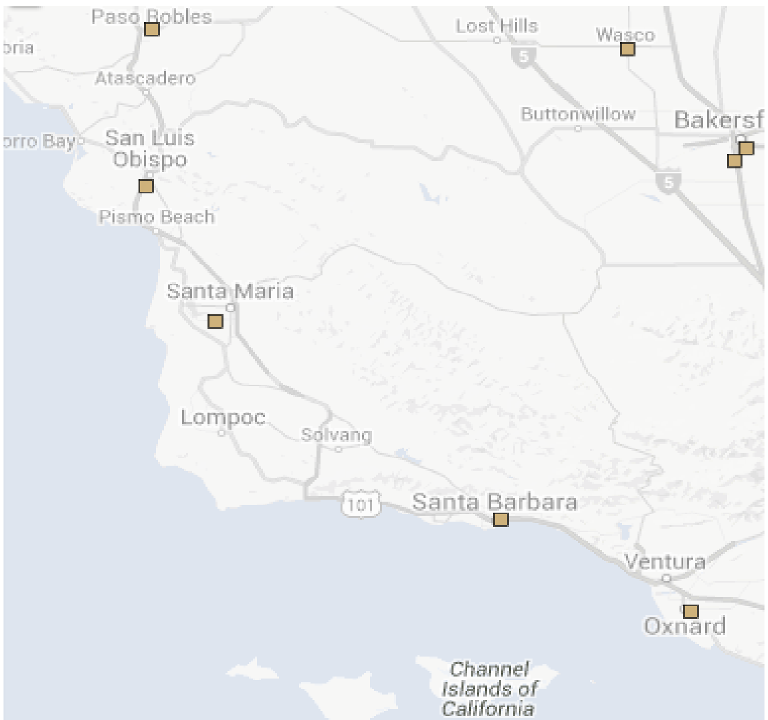
5.17. Central Coast and Monterey Bay Area Natural Gas Fueling Infrastructure: CNG fueling infrastructure in the Central Coast and Monterey regions is relatively modest compared to either the Bay Area and the South Coast, where there is a much larger concentration of CNG fleet vehicles, particularly in public agencies. Monterey County has two CNG stations, on in Santa Cruz, the other in Salinas (per the map below). There are no Liquefied Natural Gas stations in either county, and there is one Liquefied Petroleum Gas (Propane) station in the Royal Oaks area of Santa Cruz County.

CNG Stations in the Monterey Bay Area

Source: Alternative Fuel Data Center Fuel Locator
website. http://www.afdc.energy.gov/locator/stations

Central Coast CNG Stations: The Central Coast currently has six CNG Stations in operation according to the DOE AFDC website (see map below), located in Paso Robles, Santa Maria, San Luis Obispo, Santa Barbara, Oxnard, and Thousand Oaks.

CNG Stations in the Central Coast



Source: Alternative Fuel Data Center Fuel Locator
website. http://www.afdc.energy.gov/locator/stations
There are eight Liquefied Petroleum Gas (Propane) fueling locations in the Central Coast, with several for private fleet use only (including the U-Haul centers in Santa Barbara, Ventura, and Oxnard.) LPG locations are in Paso Robles, San Luis Obispo, Santa Maria (two locations), Santa Barbara, Ventura, Oxnard, and Santa Paula.

5.18. California Energy Commission Support for NGV Fueling Infrastructure: As noted above, the CEC has provided support for both natural gas vehicle purchases as well as natural gas fueling infrastructure. However, the $5 million in support for natural gas fueling infrastructure in 2015-16 is modest when compared to vehicle incentives and CEC support for AFV fueling infrastructure for hydrogen and electric vehicles, and biofuels. The chart below indicates relative CEC investments in AFV infrastructure.

CEC FY 2015-2016 Funding for Alternative Fuel Infrastructure		
Electric Charging	**$17 Million**	**Increased from $15 million in FY 2014-2015**
Hydrogen Fueling	**$20 Million**	**No funding allocation change relative to FY 2014-2015**
Natural Gas Fueling	**$5 Million**	**Increased from $1.5 million in FY 2014-2015 to target disadvantaged communities and applications (such as school buses and municipal fleets) where ZEVs are not yet as available or practical.**
TOTAL	**$42 Million**	

Notably, the emphasis on vehicles rather than fueling infrastructure has been supported by many natural gas stakeholder organizations, which believe that increased vehicle deployment is the better strategy to drive overall NGV ecosystem growth vs. a dominant emphasis on expanded fueling. Within recent fueling infrastructure solicitations, the CEC has prioritized public agencies and school districts in particular. These agencies are strong candidates for NGV adoption due to their fleet vehicle duty cycles, but they often do not have access to the capital for fueling infrastructure investment.

In the most recent solicitation for proposals, CEC infrastructure funding applicants were permitted to request up to $300,000 for stations dispensing CNG and $600,000 for stations dispensing LNG (due to the higher costs of such stations). As these numbers indicate, the CEC is willing to provide substantial portion of development costs depending on the existing station infrastructure, compressor size, storage size, and dispensing capabilities. According to CEC data, total costs for these projects ranged from $500,000 for smaller CNG-only stations to several million dollars for large combined LNG-CNG fueling stations.

Since the beginning of AB 118 program funding, the Energy Commission has provided a total of $17.5 million for 62 natural gas fueling stations, many of which have been awarded to public entities. In the most recent solicitation (PON-12-605), of the 18 successful applicants, 6 were school districts, 5 were municipalities, and 4 were municipal solid waste entities. This emphasis on public entities has been re-affirmed for the 2015-16 Investment Plan.

CEC Natural Gas Fueling Infrastructure Awards (PON-12-605)		
Applicant Type	**Projects Awarded Among Qualifying Proposals**	**CEC Funding (in millions)**
School District	6 out of 6	$1.8
Municipality	4 out of 4	$1.2
Fuel Vendor	2 out of 2	$0.4
Municipal Solid Waste	5 out of 7	$2.0
Utility	1 out of 3	$0.3
Transit	0 out of 1	-
Towing	0 out of 1	-
Air District/Joint Power Authority	0 out of 2	-
TOTAL	**18 out of 26**	**$5.7**

Source: California Energy Commission, 2015-16 Investment Plan

The Energy Commission has also supported projects to improve the cost-effectiveness and efficiency of CNG fueling stations. In 2014, the Commission released its Public Interest Energy Research Natural Gas program solicitation PON-14-502, which offered awards of up to $400,000 for enhancing station performance. More information is available at http://www.energy.ca.gov/contracts/PON-14-502/.

A range of additional strategies for enhancing both vehicle and fueling system performance and environmental attributes are described in the Commission's *Natural Gas Vehicle Research Roadmap* – which describes the strategic research, development, demonstration, and deployment actions needed to enhance the viability of the NGV market in California. In addition to supporting fueling infrastructure technology, the CEC also seeks to promote increased production of biomethane to achieve a lower carbon intensity for natural gas fuels, and to promote other advanced vehicle technologies (such as low-NOx engines or hybrid-drive technology) to further lower emissions. Support for biomethane development is derived from a different program budget within the CEC and will be discussed in more detail in the natural gas fuel production pathways section of this report.

CEC Priorities for Future Development and Deployment of Enhanced Natural Gas Technology: Key priorities identified in the CEC's *Natural Gas Vehicle Research Roadmap* include the following:

- **Enhanced R&D for advanced natural gas engines** across a broader range of engine sizes, suitable for more applications. The results of research investments to date have yielded natural gas engines on the market that compete well with diesel engines in the heavy-duty sector. Additional funding is needed to broaden the selection of engine sizes.

- **Increased support for field demonstration** with fleets to accelerate market penetration and to better understand fleet decision-making.
- **Low-NOx Engines:** California faces challenging requirements for reducing criteria air pollutants by 2023 and 2032. Further development of low-NOx engines, both for NGVs and conventional vehicles, is needed to achieve these goals where zero-emission technologies are not feasible.

Future solicitations are likely to provide NGV stakeholders with opportunities to address these priorities through collaborative development and deployment projects that bring together industry partners, public agencies, fleets, and research institutions.

5.19. The Policy Basis for Natural Gas Vehicle Ecosystem Development in California: Natural gas vehicle and fuel promotion in California has been supported at the policy level by several key elements of state legislation and executive orders, some of which apply to other alternative fuels as well. Assembly Bill (AB) 1007 (Pavley, Chapter 371, Statutes of 2005) directs the California Energy Commission and the California Air Resources Board to "develop and adopt a state plan to increase the use of alternative transportation fuels" -- which are defined to include natural gas. In parallel to AB 1007, the Low-Carbon Fuel Standard (LCFS) -- initiated under Executive Order S-1-07 -- calls for a reduction of at least 10% in the carbon intensity of California's transportation fuels by 2020. AB 118 (Núñez) established the Alternative and Renewable Fuel and Vehicle Technology Program to provide the necessary resources to implement the State Alternative Fuels Plan. AB 118 specifically requires that alternative vehicle and fuel technology deployment and commercialization should emphasize support for fuels that "lead to sustainable feedstocks." The policy analysis and debate about definitions of feedstock sustainability in relationship to CNG and diesel (and other fuel pathways) are ongoing and will influence funding going forward.

In 2013, in response to the growing supply and demand for natural gas, the California Legislature passed Assembly Bill 1257 (Bocanegra, Statutes of 2013, Chapter 749), also referred to as the Natural Gas Act. This law tasks the Energy Commission with developing a report to "identify strategies to maximize the benefits obtained from natural gas, including biomethane. . . helping the state realize the environmental costs and benefits afforded by natural gas." The first of these reports was released in October 2015 and will be updated every four years thereafter. The report reaffirms current state policy on Natural Gas Vehicles, citing opportunities for improved criteria pollutants but limited opportunity for GHG benefits with fossil based Natural Gas. However, the report draws attention to emerging opportunities for increasing biomethane production, and cites the need for additional research to:

- Support the ARB's Low-Carbon Fuel Standard Intensity Value
- Expand natural gas and biomethane fueling infrastructure

- Understand methane leakage from infrastructure
- Develop and demonstrate functionality of large NG engines
- Better quantify the impacts of NGV's on the environment.

The CEC 2016-17 Investment Plan describes a potential "compliance scenario" for achieving the 2020 goal of reducing GHG emissions by 10 percent – which would involve a substantial increase in the production of biomethane – as well as a substantial increase in the sale of NGVs (or retrofitted natural gas engines). The compliance scenario would require increasing the utilization of natural gas in transportation to 600 million - 1,200 million Diesel Gallons Equivalent (DGE), with 250 million - 500 million DGE of this coming from biomethane. By contrast, current demand for natural gas in the transportation sector is closer to 100 million DGE per year. [14]

However, the natural gas strategy of the California Air Resource Board and the CEC may be modified based on revised data developed in the transition from the air emissions analysis model known as CA-GREET 1.8b, to CA-GREET 2.0 – which has established new carbon intensity values for both natural gas and other fuel types. (CA-GREET is the acronym for *California Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation.* This model was originally developed by the Argonne National Laboratories, and provides a standard reference for carbon intensity across the full "well to wheels" fuel cycle.) The ongoing shifts in scientific understanding and regulatory agency determinations of Natural Gas environmental impacts are discussed in depth in Appendix 1.

5.20. Overview of Natural Gas Emissions and GHG Impacts: Significant analysis is ongoing by government agencies and other scientific authorities on the environmental attributes of natural gas as a transportation fuel. These assessments are typically developed as part of broader analyses of the entire natural gas fuel supply chain – and in a context in which other fuel pathways are likewise assessed on a well-to-wheels basis. For California stakeholders, the most important model for understanding emissions impacts across all fuel types is CA-GREET model, which was formally adopted in its version 2 form by CARB in September 2015. Known as CA-GREET 2.0 – this model provides the Carbon Intensity (CI) values used to establish requirements and credit values under the Low Carbon Fuel Standard (LCFS), and guides California policy makers in establishing transportation, energy, and climate regulations, programs, and funding.

It should be emphasized that the CA-GREET assessments of carbon intensity are by no means static. As illustrated in the table below, significant variations in assessments of fuel impacts are evident between the CA-GREET 1.8b model and CA-GREET 2.0. These changes may continue and even accelerate in future years based on the results of important research and policy actions in two key areas:

[14] *2015-16 Investment Plan Update for the Alternative and Renewable Fuel and Vehicle Technology Program,* CEC, May 2015, p. 57.

- **ongoing assessment of the methane leakage rate** across the natural gas fuel supply chain (and the impact of ongoing efforts to reduce leakage rates
- **the timeframe used for analysis of the Global Warming Potential of methane impacts**, which vary in intensity across the decay period of methane in the atmosphere.

The timeframe used for analysis of global warming impact – typically either 20 years or 100 years – has a very strong impact on assessments of fossil-based natural gas, and thus can strongly influence the policy actions deemed appropriate relative to natural gas fuel and vehicle development. A brief overview of current information on methane leakage rates and Global Warming Potential will follow the GREET chart below. Additional information on this key issue is provided in Appendix 1 to inform policy makers and the public on new scientific findings and assessment trends that are likely to impact future policy choices relative to natural gas.

Low-Carbon Fuel Standard Carbon Intensity Values per the CA-GREET Model[15]		
Fuel Source	**CA-GREET 1.8b** [96] (Grams CO2-equivalent per megajoule, adjusted to baseline- fuel equivalent using EER)	**CA-GREET 2.0** (Grams CO2-equivalent per megajoule, adjusted to baseline- fuel equivalent using EER)
Ultra-Low-Sulfur Diesel	98	102
California Reformulated Gasoline	99	98
North American Natural Gas (CNG)	76	87
North American Natural Gas (LNG)	80	94
Landfill Gas (CNG)	13	20
WWTP Sludge (CNG)	15	9 or 34
Biomethane Derived From High- Solids Anaerobic Digestion of Food and Green Wastes (CNG)	-14	-25

[15] CARB notes in its *2015 AB 1251 Final Report* that this table is intended to illustrate the expected ordinal ranking of various fuel CIs. Under the adopted LCFS regulation (adopted September 25, 2015, and pending approval), alternative fuel providers will submit data specific to each operation and supply chain to determine their actual CI, which may vary slightly depending on the fuel pathway.

Source: California ARB. Note that the units in the table are adjusted to megajoule (MJ) of baseline fuel, by dividing the alternative fuel CI by its Energy Economy Ratio (EER). The EER for diesel and gasoline is 1. The EER for CNG and LNG used in a spark ignition engine is 0.9. See the CA-GREET website of CARB at http://www.arb.ca.gov/fuels/lcfs/ca-greet/ca-greet.htm

Summary of the Impact of Methane Leakage Rates on Climate Impact Assessment of Natural Gas: Fossil fuel based natural gas is comprised of approximately 87% methane, with some variations depending on the source. And methane is a highly potent greenhouse gas. However, a key factor in determining the overall climate impact of methane, in terms of its rated Carbon Intensity (CI) value, is not only to measure natural gas use, but also to determine the methane leakage rates in the entire natural gas fuel supply chain that should properly be assigned to Natural Gas from an assessment perspective. This supply chain includes pre-production, production, processing, and delivery. All stakeholders agree that some methane leakage occurs throughout the system, and that data limitations on methane leakage is a cause for caution regarding current models for assessing the Carbon Intensity (CI) of natural gas, and thus its role in the global warming crisis. Accordingly, the EPA's officially defined leakage rate (and thus the Carbon Intensity value of Natural Gas) is now undergoing potentially significant revision by the EPA and other scientific researchers and institutions.

The currently utilized methane emissions values used in the GREET model are obtained directly from the US Environmental Protection Agency's (EPA) Greenhouse Gas Inventory (GHGI), which provide a national average methane leakage across the fuel supply chain. However, many scientists and research institutions have strongly critiqued the EPA method. This has led to a new initiative within EPA to reassess the existing methodology behind the leakage rate calculation -- and to recommend new policies to mitigate methane leakage. In brief, criticisms of the current methane leakage assessment methodology include these factors:

- Data on leakage rates is derived entirely from voluntary participants in the EPA's GasStar compliance program. Independent assessment by the Environmental Defense Fund and others demonstrate that these market actors have better records on methane leakage than others excluded from the inventory. Only six firms (out of 30 in the voluntary program and hundreds in the marketplace) actually allowed EPA onsite to make validated measurements.
- Data on methane leaks from three million abandoned oil and gas wells is not included in the EPA analysis.
- Data from vehicle and refueling station leakage are also absent in the EPA inventory.
- An authoritative meta-analysis of 20 years of studies published in *Science* in February 2014 indicates that the real leakage rate is closer to 3% - nearly triple the EPA estimate. This significantly shifts methane calculations to be substantially less favorable to substituting natural gas for petroleum diesel.[16]

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[16]A.R. Brandt, et. al, METHANE LEAKS FROM NORTH AMERICAN NATURAL GAS SYSTEMS; Science 14 February 2014: Vol. 343 no. 6172 pp. 733-735 http://www.sciencemag.org/content/343/6172/733.summary?sid=aa20376c-626b-42af-9f93-2475e7990ac4

Given the possibility of a doubling or tripling of the scientifically validated methane leakage rate, and its impact on natural gas utilization, policy makers, industry stakeholders, and citizens should be aware of the underlying issues driving this re-assessment. In addition to the methane leakage rate controversy, there is an equally important debate about the appropriate timeframe that should be used to assess the global warming potential (GWP) of methane.

The Importance of Assessment Timeframes for Determining Methane's Impact on Global Warming: A 100 year analytic timeframe has customarily been used in many analytic models to assess the Global Warming Potential (GWP) of methane and other greenhouse gases, and this 100 year timeframe is likewise used for the GREET analysis. However, many scientists and policy makers make a compelling case that methane and other GHGs should be evaluated for their impact within *a 20 year timeframe* rather than the currently used 100 year timeframe. This is due to the catalytic role that methane is expected to play in the imminent triggering of climatic "tipping points" within the twenty year 2015-2035 timeframe.

While methane accounts for only 14 percent of emissions worldwide as measured by volume, methane traps far more heat molecule for molecule than carbon dioxide. Specifically, the latest Global Warming Potential data accepted by the UN Intergovernmental Panel on Climate Change (UNIPCC) indicates that any methane molecule released today is more than 100 times more heat-trapping than a molecule of carbon dioxide when assessed on a five year basis, approximately 86 times more potent than carbon dioxide when "amortized" over a 20 year timeframe, and 34 times more potent in the 100 year timeframe.

To this date, EPA and CARB have used the 100 year Global Warming Potential timeframe for their analysis of natural gas impacts, but the 20 year timeframe for methane yields significantly different values for natural gas related climate impacts compared with other fuels. There are compelling reasons for paying more attention to climate impacts in the near-term, according to many scientists and research institutions (notably including James Hansen, the former Chief NASA Climate Scientist, who is credited with bringing global warming dangers to the attention of policy-makers in the 1980's.) The reason is the rapidly accumulating evidence -- presented by the UN Intergovernmental Panel on Climate Change and other authoritative agencies -- that the earth is in critical danger of entering the runaway stage of climate change within the next twenty years, leading to 5 degrees centigrade or more of warming this century. This level of warming would radically destabilize and degrade the natural systems on which human life depends -- leading to such impacts as greater than six feet of sea level rise this century, accelerated release of sub-Arctic methane, extreme droughts and storms, and food insecurity.[17] As a result of this emerging science regarding the near-term dangers of exceeding climatic

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and Mark Golden, "America's Natural Gas System is Leaky and in Need of a Fix," in *Stanford Report,* Feb. 2014, http://news.stanford.edu/news/2014/february/methane-leaky-gas-021314.html

[17]Numerous studies address the possibility that key tipping points in climate change are imminent or already reached, with important policy consequences for assessing global warming potential timeframes. A representative overview of this literature is the September 2013 report by David Spratt entitled "*Is Climate Change Already Dangerous?*" available at http://www.climatecodered.org/p/is-climate-change-already-dangerous.html

"tipping points," and the disproportionate role of methane in climate destabilization, there is a strong rationale to shift from a 100 year to 20 year timeframes as the dominant unit of analysis for the Global Warming Potential of all GHGs, including methane.

To facilitate a broader policy assessment that includes both 20-year and 100-year impacts, Appendix 1 of this document includes additional information on Global Warming Potential timeframes and methane leakage rates – and the impact of emerging data on policy choices for natural gas applications. This appendix has been informed in part by an important new report from the UC Davis Institute for Transportation Studies - Sustainable Transportation Energy Pathways Program (NextSTEPS). This UC Davis report includes further meta-analysis of the methane issue that triggered the recent EPA and CARB re-assessment of Greenhouse Gas Inventory factors and the CA-GREET model, respectively. Entitled "The Carbon Intensity of NGV C8 Trucks," this report was released in March 2015 by Professor Rosa Dominguez-Faus, Ph.D., who has produced other authoritative reports on natural gas and alternative fuel choices for state agencies.

In addition to providing more detail on GWP and methane, the UC Davis Report (along with other materials in Appendix 1) discusses the development of an appropriate risk management approach for evaluating air emissions and climate impacts consistent with other risk management norms in the public sector, as used in infrastructure planning, for example. Policy makers and interested citizens are encouraged to make use of these resources in the Appendix to fully understand natural gas transportation options in the broader context of the climate crisis and related risk management imperatives.

5.21. Outlook for Emissions Performance of NGVs and New CARB Mitigation Measures: Emerging data and statements from the Californai ARB suggest that natural gas vehicles powered by fossil fuels (as opposed to biomethane) may not have a clear advantage from a climate perspective. However, they can reduce criteria pollution emissions relative to existing diesel vehicles. That said, the relative virtues of natural gas and diesel are not at all static, as both NGV and diesel technology (as well as relevant low-carbon biofuel pathways for both vehicle types) are evolving very rapidly. Stricter regulatory standards are also pushing both NGVs and diesel manufacturers toward significant reductions in harmful emissions. In December 2013, for example, the ARB adopted an optional reduced NOx emission standard for heavy-duty vehicles that incentivizes engine manufacturers to further reduce emissions. Such standards include NOx levels that are 50, 75, and 90 percent lower than the current 0.20 grams per brake horsepower-hour emission standard. This voluntary standard may help position natural gas engines as a primary initial technology for meeting the more aggressive 75 percent and 90 percent NOx reduction targets expected to be deployed in the future.

Depending on the ability of natural gas engine manufacturers to demonstrate such reductions, and the commercial availability of products in relevant applications, the CEC indicates that emerging NGV technology could support scaled deployment of natural gas trucks in the 2016-17 timeframe and beyond. Scaled deployment of very low-carbon NGV trucks could in turn mitigate criteria air pollutants in areas most impacted by current diesel technologies. While there are not yet vehicles currently available commercially at scale with these emissions attributes (as of early 2016), an announced near-zero NOx natural gas engine produced by Cummins Westport features substantially reduced methane emissions, as well as reduced criteria pollutants. As profiled below, this engine could greatly strengthen the case for natural gas as a competitor to diesel relative to both economic and environmental criteria.

Emerging Natural Gas Engines With Near-Zero NOx and Reduced Methane: In its Integrated Energy Policy Report, the CEC indicated that "in September 2015, Cummins Westport Innovations [CWI] certified its first near-zero engines for buses, waste haulers, and medium-duty trucks. This engine will reduce oxides of nitrogen (NOx) emissions by more than 90 percent from the current standard and will play an important role in improving air quality for Californians."[18]

This unusually prominent announcement by the CEC highlights the fact that this engine is the first mid-range engine in North America to receive emission certifications from both the EPA and CARB that meet the 0.02 g/bhp-hr (grams per brake-horsepower per hour) Near Zero NOx Emissions standards for medium-duty truck, urban bus, school bus, and refuse applications. The exhaust emissions of this engine, known as the ***Cummins Westport ISL G NZ,*** will be 90% lower than the current EPA NOx limit of 0.2 g/bhp-hr and also meet the 2017 EPA greenhouse gas emission requirements. The *ISL G NZ* engine meets the ARB certification well in advance of the 2023 California Near Zero NOx schedule. ARB has defined the certified Near Zero emission level as equivalent to a 100% battery truck using electricity from a modern combined cycle natural gas power plant (although a battery-electric truck using the greener power from California's grid mix will in turn be superior to even this relatively clean NGV.)

In addition to the 90% reduction in NOx, the ISL G NZ engine utilizes Closed Crankcase Ventilation (CCV) to reduce engine related methane emissions by 70%. Further, these near-zero carbon natural gas engines do not require active after-treatment such as a Diesel Particulate Filter (DPF) or Selective Catalytic Reduction (SCR). Support for the development of the Cummins Westport engine was provided jointly by the South Coast Air Quality Management District (SCAQMD), SoCalGas and the CEC. Production of the ISL G NZ is expected to begin in April 2016. The engine will be made available as a "first fit" engine with transit and refuse OEMs, and as an engine replacement for existing ISL G vehicles. Performance and efficiency will match the current ISL G, with engine ratings from 250-320 horsepower, and 660-1,000 lb-ft torque available. Maintenance procedures, service intervals, and warranty terms are the same as the current ISL G.[19] It is highly recommended that fleet managers become further acquainted with this engine technology to determine if it can play a

[18] *AB 1251 Natural Gas Act Report: Strategies to Maximize the Benefits Obtained from NaturalGas as an Energy Source,* California Energy Commission, p. 4.

[19] *"ISL G Near Zero Natural Gas Engine Certified to Near Zero - First MidRange engine in North America to reduce NOx emissions by 90% from EPA 2010~",* Cummins Westport Inc. Press Release -- October 5, 2015, http://www.cumminswestport.com/press-releases/2015/isl-g-near-zero-natural-gas-engine-certified-to-near-zero

role in reducing emissions and enhancing operating economies in local fleets.

5.22. The CARB Sustainable Freight Strategy: The California Air Resources Board has indicated that achieving the state's 80% carbon reduction goals will require a dramatic transformation across the transportation system in California, and that developing both zero-emission and near-zero emission vehicles and cleaner fuel pathways in the medium and heavy-duty vehicle segment will be essential. The ARB has laid out their preliminary approach in a planning document known as the *Sustainable Freight Strategy* -- with a goal of dramatically reducing emissions across the state's goods movement system, including truck, rail, and marine components. Many of the elements of this strategy, now beginning the early deployment stage at CARB, target increased utilization of natural gas vehicles and cleaner (biomethane) pathways as well as new emissions reduction strategies for diesel trucking. The range of measures is described below, with *NGV relevant state policy measures* highlighted in blue, and *measures with potential for regional action* highlighted in green.

CARB Sustainable Freight Initiatives – NGV relevant actions highlighted in blue		
Actions	**Policy Developm ent**	**Policy Implementat ion**
Trucks Action 1: Develop and propose strategies to ensure durability and in-use performance. Such strategies may include: ▪ Reduced exhaust opacity limits for PM filter-equipped trucks. ▪ New certification and warranty requirements for low in-use emissions. ▪ Strengthen existing emission warranty information reporting and enable corrective action based on high warranty repair rates. ▪ Clarification on the State's authority to inspect heavy-duty warranty repair facilities to ensure proper emission warranty repairs are being conducted.	2015 - 2017	2017+
Trucks Action 2: ***Develop and propose increasing flexibility for manufacturers to certify advanced innovative truck engine and vehicle systems in heavy-duty applications. Enables accelerated introduction of new technologies to market.***	2015	2016
Trucks Action 3: ***Develop and propose new, stringent California Phase 2 GHG requirements to reduce emissions from trucks and trailers, and provide fuel savings.***	2016-2017	2018+
Trucks Action 4: ***Petition U.S. EPA to develop lower NOx standards for new heavy-duty truck engines for rulemaking in 2018.***	2015	--

Trucks Action 5: (if U.S. EPA does not complete Trucks Action 4): ***Develop and propose California specific standards for new heavy-duty truck engines to provide benefits above national standards.***	2018	2023+
All sectors/freight hubs: Collect data (such as facility location, equipment, activity, and proximity to sensitive receptors) from seaports, airports, railyards, warehouse and distribution centers, truck stops, etc. to identify and support proposal of facility-based approach and/or sector-specific actions to reduce emissions and health risk, as well as efficiency improvements.	2015	2015-2016
Delivery Vans/Small Trucks: Develop proposal to accelerate penetration of zero emission trucks in last mile freight delivery applications, with potential incentive support.	2017	2020
Large Spark-Ignition Equipment (forklifts, etc): ***Develop proposal to establish purchase requirements to support broad scale deployment of zero emissions equipment.***	2016-2018	2020
Transit Buses: Develop proposal to deploy commercially available zero emission buses in transit, and other applications, beginning with incentives for pilot programs and expanding purchase requirements, as appropriate, to further support market development of zero emission technologies in the heavy-duty sector with potential incentive support.	2016	2018
Airport Shuttles: Develop proposal to deploy zero emission airport shuttles to further support market development of zero emission technologies in the heavy-duty sector, with potential incentive support.	2017-2018	2020
Transport Refrigeration Units: Develop and propose a regulatory requirement to prohibit the use of fossil-fueled transport refrigeration units for cold storage in phases, with incentive support for infrastructure.	2016	2020+
Incentive programs: ***Develop modifications to existing incentive programs to increase the emphasis on and support for zero and near-zero equipment used in freight operations, including introduction of truck engines certified to optional low-NOx standards.***	2015-2016	2016-2020

5.23. Opportunities for Coordinated Regional Action on NGV and EV Goods Movement: Most of the actions listed in the CARB Sustainable Freight Strategy require state policy intervention or new state investments. However, the proposal to develop "facility-based approaches" to low-emissions and zero-emissions freight movement suggests the potential for local cities, counties, air quality districts, and freight industry stakeholders to take action at the local and regional level. The development of an appropriately constituted regional *Sustainable Freight Working Group* will help prepare for and attract anticipated state investment in planning and implementing the CARB vision for low-carbon goods movement.

Through the Sustainable Freight Working Group, local and regional public agencies and freight stakeholders would cooperate first to obtain essential planning funds, and then to collaboratively develop a systematic approach to implement low-emissions goods movement strategies. These strategies would likely include (but not be limited to), development of freight handling facilities in support of low-carbon inter-regional travel, as well as "green last mail" delivery strategies. Together, these and other complementary initiatives could maximize the use of near-zero carbon CNG or lower-carbon LNG Class 8 vehicles for long-distance, heavy-duty trucking, as well as zero-emissions Medium-duty Battery-Electric Trucks (BETs) for "last mile" delivery routes (typically within the 100 mile range of current Medium Duty e-trucks). These strategies would likely also engage stakeholders in:

- Green fleet procurement strategies
- Mapping and deployment of NGV and electric fueling infrastructure for trucks
- Innovative strategies for centralizing "green last mile" delivery to reduce congestion.

Both the Monterey Bay Area and the South Coast region (via the Gateway Cities COG, among other stakeholders) provided preliminary concept proposals to CARB in April 2015 to initiate planning efforts to develop low-emissions freight depots in regions adjacent to the Central Coast.[20] The proposal from the Association of Monterey Bay Area Governments (AMBAG) for the Salinas Valley Intermodal Freight Implementation Plan and the Freight Enterprise Zone Guidelines Project . Likewise, the Gateway Cities COG/Los Angeles Transportation Authority (Metro) proposal for a Los Angeles/Gateway Freight Technology Program has many elements that are relevant to the Central Coast. In addition, there are many additional projects underway via the the Port of Los Angeles, CalSTART, and other stakeholders to lower emissions on the I-710 corridor between the Port of Long Beach and downtown Los Angeles. An analysis of these efforts as they relate to low- and zero-emissions trucks is provided in the *I-710 Project Zero-Emission Truck Commercialization Study Final Report*[21] -- a 2013 CalSTART report to the Gateway Cities COG. This document also provides useful background on the projected timelines for deployment and integration of emerging zero-emissions freight vehicles and systems that could also be deployed on the Central Coast.

In the Central Coast and Monterey Bay context, a series of integrated truck transfer or inter-modal (rail/truck or rail/truck/marine) facilities could provide natural gas and electric refueling infrastructure and trans-shipment facilities to enable cargo in the region to be delivered via lower-emissions CNG and electric trucks -- and potentially via increased rail utilization. An

[20] See the "Sustainable Freight Pilot Project Ideas" website at the California Air Resources Board at http://www.arb.ca.gov/gmp/sfti/pilotprojectsub.htm. Relevant projects include the Salinas Valley

[21] *I-710 Project Zero-Emission Truck Commercialization Study Final Report* for the Gateway Cities Council of Governments and the Los Angeles County Metropolitan Transportation Authority, CalSTART, 2013. http://www.calstart.org/Libraries/I-710_Project/I-710_Project_Zero-Emission_Truck_Commercialization_Study_Final_Report.sflb.ashx

initial effort of this kind in the Central Coast region could create a continuous low-emissions sustainable freight corridor from San Jose to the Port of Long Beach through cooperation with AMBAG and the Southern California Association of Governments (SCAG), relevant Air Districts and regional/local transportation authorities, and industry and non-governmental stakeholders.

It is anticipated that CARB will create a competitive RFP process to fund sustainable freight planning and implementation proposals in 2016-17. To prepare for such a process, one of the Recommended Actions arising from the current Central Coast AFV Readiness planning process is to invite key stakeholders to consider development of funding for a Central Coast (or combined Central Coast/Monterey) sustainable goods movement plan. Additional discussion of the potential for a regional sustainable freight initiative is found in the Recommended Actions section at the end of this Chapter.

5.24. Potential for Biomethane Development to Reduce NGV Emissions Impacts: According to the most recent CARB scoping plan for meeting AB 32 goals, natural gas from traditional fossil fuel sources cannot represent a significant share of energy use by 2050 if the state is to meet its long-term GHG targets (80% below 1990 levels by 2050.) By 2050, traditional uses of oil and natural gas, including transportation fuels, water and space heating, and industrial boilers and process heating, will need to be mostly, if not fully, decarbonized. However, decarbonized gaseous fuels could have a longer-term future in California *if biomethane production can be scaled up.*

Biomethane possesses the lowest carbon intensity values established by the Low Carbon Fuel Standard (LCFS) on a "source-to-tank" basis (also called "well-to-tank".) Note that the source-to-tank methodology does NOT include combustion impacts from fuel burning in the vehicle, typically known as "well-to-wheels." (Well-to-wheels impacts can differ based on vehicle and engine type, whereas source-to-tank data enables valid comparisons among fuel pathways prior to utilization in the vehicle.) On a source-to-tank basis, biomethane from anaerobic digestion of food and green waste can achieve a negative CO2e rating, due to avoided methane emission from organic matter compared to emissions impacts when disposed of in landfills. The following table from the latest "Tier 2" CARB Low Carbon Fuel Standard Regulatory Order, provides comparative data on natural gas vs. other fuel sources.[22]

[22]*Low-Carbon Fuel Standard Final Regulatory Order 2015,* Table 6: Tier 2 Lookup Table for Gasoline and Diesel and Fuels that Substitute for Gasoline and Diesel, California Air Resources Board, p. 67. http://www.arb.ca.gov/regact/2015/lcfs2015/lcfsfinalregorder.pdf

Carbon Intensities of Natural Gas vs. Other Fuels on a "Source to Tank" Basis					
Fuel	Pathway Identifier	Pathway Description	Carbon Intensity (gCO_2 e/MJ)		
			Direct Emissions	Land Use / Indirect Effect	Total
CARBOB *	CBOB001	CARBOB - based on the average crude oil supplied to California refineries and average refinery efficiencies	99.78	0	99.78
Diesel*	ULSD001	ULSD - based on the average crude oil supplied to California refineries and average California refinery efficiencies	102.01	0	102.01
Com-pressed Natural Gas	CNG005	Biomethane produced from the high-solids (greater than 15 percent total solids) anaerobic digestion of food & green wastes; compressed in CA	-22.93	0	-22.93
	CNG020	Biomethane produced from the mesophillic anaerobic digestion of wastewater sludge at a California publicly owned treatment works; on- site, high speed vehicle fueling or injection of fuel into a pipeline for off-site fueling; export to the grid of surplus cogenerated electricity.	7.75	0	7.75
	CNG021	Biomethane produced from anaerobic digestion of wastewater sludge at a California treatment works for on-site, high speed vehicle fueling or injection of fuel into a pipeline for off-site fueling.	30.92	0	30.92
Electricity	ELC002	California grid electricity	105.16	0	105.16
Hydrogen	HYGN001	Compressed H_2 from central reforming of NG (includes liquefaction and re-gasification steps)	151.01	0	151.01
	HYGN002	Liquid H_2 from central reforming of NG	143.51	0	143.51
	HYGN003	Compressed H_2 from central reforming of NG (no liquefaction and re-gasification steps)	105.65	0	105.65
	HYGN004	Compressed H_2 via on-site NG reforming	105.13	0	105.13
	HYGN005	Compressed H_2 from on-site reforming with renewable feedstocks	88.33	0	88.33

Source: California Air Resources Board, *Low-Carbon Fuel Standard Final Regulatory Order 2015,* Table 6: Tier 2 Lookup Table for Gasoline and Diesel and Fuels that Substitute for Gasoline and Diesel, p. 67, http://www.arb.ca.gov/regact/2015/lcfs2015/lcfsfinalregorder.pdf

*CARBOB designates the standard unit of measure for California "standard" gasoline: the California Reformulated Gasoline Blendstocks for Oxygenate Blending. The numbers above are adjusted by Energy Efficiency Ratio (EER) for gasoline (CARBOB) or diesel (ULSD) substitute.

State policy makers are now assessing the longer-term potential for utilizing biomethane as a principal form of decarbonized pipeline gas (along with biogas, hydrogen, and renewable synthetic gas) -- which could in turn be distributed through existing pipeline networks. A study released in 2015 by the environmental consulting firm Energy + Environmental Economics (E3), *Decarbonizing Pipeline Gas to Help Meet California's 2050 Greenhouse Gas Reduction Goal,* examines the potential for growth of decarbonized pipeline gas fuels. The term "decarbonized gas" refers to gaseous fuels with a net-zero, or very low, GHG impact -- including biogas, hydrogen, and renewable synthetic gases produced with low GHG emissions. "Pipeline gas" refers to any gaseous fuel transported through natural gas distribution pipelines.

The E3 study assesses two alternative technology scenarios for meeting the state's goal of reducing GHG to 80 percent below 1990 levels by 2050. In the *electrification scenario,* all energy end uses, to the extent feasible, are electrified and powered by renewable electricity. In the *mixed scenario,* both electricity and decarbonized gas play key roles by 2050. Both scenarios meet California's 2020 and 2050 GHG goals, accounting for constraints on energy resources, conversion efficiency, delivery systems, and end-use technology adoption. By contrast, a reference scenario reflects limited adoption of alternative fuels in both transportation and electricity supply beyond the present (2015) base case, and clearly does not meet the 2050 GHG target.

Scenario	Source of residential, commercial, industrial energy end uses	Source of transportation fuels	Source of electricity supply	Source and amount of decarbonized pipeline gas[3]
Electrification	Mostly electric	Mostly electric LDVs, mostly hydrogen fuel cell HDVs	Renewable energy, some natural gas with CCS	Small amount of biogas
Mixed	Decarbonized gas for existing gas market share of end uses	Electric LDVs, Decarbonized gas in HDVs	Renewable energy, some natural gas with CCS	Large amount of biogas, smaller amounts of SNG, hydrogen, natural gas
Reference	Natural gas	Gasoline, diesel	Mostly natural gas	None

Source: *Decarbonizing Pipeline Gas to Help Meet California's 2050 Greenhouse Gas Reduction Goal,* Energy + Environmental Economics (E3). https://ethree.com/documents/E3_Decarbonizing_Pipeline_01-27-2015.pdf

The study concludes that: 1) a technology pathway for decarbonized gas could meet the state's GHG reduction goals and may be easier to implement in some sectors (notably heavy-duty trucking) than a high electrification strategy; and 2) the total costs of the decarbonized gas and electrification pathways are comparable. The study also indicates that decarbonized gases can complement a low-carbon electrification strategy by.

- **Addressing sectors that are difficult to electrify**, such as process heating, heavy duty vehicles, cooking, and existing space and water heating.
- **Providing gas using electricity when renewables are generating power**, and then storing the gas in the pipeline distribution network until it is needed
- **Enabling continued use of the state's existing gas pipeline distribution network**, eliminating the need for new energy delivery infrastructure to meet 2050 GHG targets, such as dedicated hydrogen pipelines or additional electric transmission and distribution capacity.

Of course, there are major hurdles to overcome to bring decarbonized gas into production, distribution, and use at large commercial scale. The E3 study makes it clear that, unlike the electrification pathway, where key technologies are already available, a significant level of new R&D effort would be needed to make decarbonized gas a reality at commercial scale. For example, the low-carbon gas pathway presumes that carbon sequestration in the context of natural gas production can be made economically and technically viable at large scale, but this has not yet been demonstrated. Biomethane pathways, while promising, will also require a much larger infrastructure for efficient (and low-carbon) collection of organic waste, and so forth. To fully develop the state's capacity for low-carbon natural gas production, E3 identifies a need for the following key research, development, and demonstration (RD&D) initiatives.

Priority R&D Needs to Accelerate Low-Carbon Natural Gas Fuel Pathway Development

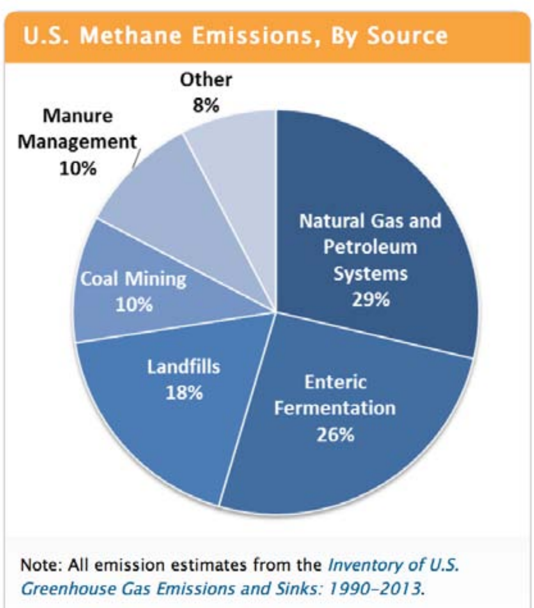
Timeframe of RD&D payoff	RD&D Area	Challenge
Near-term	Energy efficiency	Achieving greater customer adoption and acceptance
	Reduction in methane leakage	Cost-effectively identifying and repairing methane leaks in natural gas mining, processing, and distribution
	Use of anaerobic digestion gas in the pipeline and pilot biomass gasification	Quality control on gas produced via anaerobic digestion for pipeline delivery
Medium-term	Agronomic and supply chain innovation for biomass feedstocks	Competition with liquid fuels, food, fodder, fiber may limit amount of biomass available as a source of decarbonized gas
	Pilot decarbonized SNG technology to improve conversion efficiency and cost	Gasification, electrolysis, and methanation need efficiency improvements, reductions in cost to be competitive; safety, scale, and location challenges must be addressed
	Limits on hydrogen volumes in existing pipelines	Need pipeline and operational changes to accommodate higher volumes
Long-term	Emerging technologies (e.g., P2G, artificial photosynthesis, CO_2 capture from seawater for fuel production)	P2G must be scalable and available as a renewable resource balancing technology; in general, emerging technologies still require innovations in material science

Source: *Decarbonizing Pipeline Gas to Help Meet California's 2050 Greenhouse Gas Reduction Goal*, Energy + Environmental Economics (E3). https://ethree.com/documents/E3_Decarbonizing_Pipeline_01-27-2015.pdf

5.25. Biomethane Development Opportunities on the Central Coast

Background on Biomethane Production: Biomethane is a very low-carbon option (potentially negative carbon) for fueling natural gas vehicles and for other uses such as heating and power generation. Chemically, biomethane and fossil natural gas are very close. Biomethane produced from landfill gas initially consists of 55-65% methane, 30-35% carbon dioxide, and the remaining balance being hydrogen, nitrogen, and various impurities. Its heating value is approximately 600 BTU per cubic foot. By contrast, natural gas contains about 87% methane, with a heating value of approximately 1000 BTU per cubic foot. However, filtering biomethane (known as "scrubbing") removes the carbon dioxide and other impurities, raises BTU, and enables biomethane to be used interchangeably (or as an admixture) with fossil natural gas. Production of biomethane can occur through processing of organic matter in landfills or biogas plants. Both methods utilize anaerobic digestion, which is performed by the anaerobic microbes that thrive in the absence of oxygen. These microbes also produce carbon dioxide along with methane, thus requiring scrubbing.

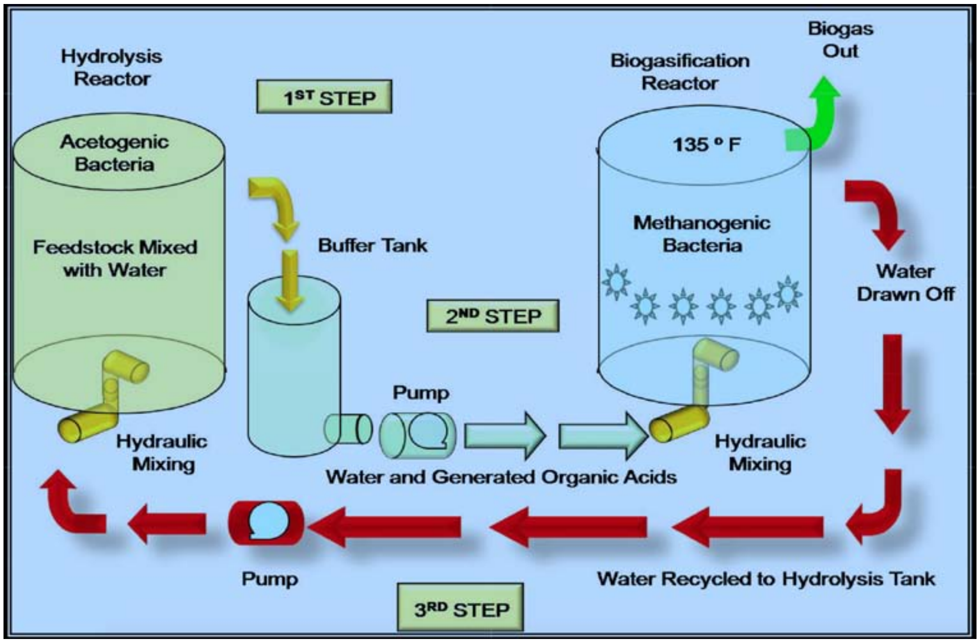
Although biogas plants produce carbon dioxide and other greenhouse gases, they are generally considered to be nearly carbon-neutral (or better) because they can -- depending on collection and processing methods -- reduce the amount of methane and other greenhouse gases that would have been released into the atmosphere if the organic matter was left to decompose naturally. As the chart below indicates, landfills alone are responsible for 18% of methane production in the U.S., and are a *relatively* easy target for reductions (compared to bovine enteric fermentation, for example.) That said, some localities do not view biomethane, heat, or electricity production from landfill gas as the most environmentally beneficial approach to green waste.



The City of San Francisco Department of Environment, for example, has determined that other forms of green waste reuse can be more beneficial. For example, separate collection of fats and oils can be used in biodiesel production while other green waste can be used in developing compost for soil amendments "tuned" for maximum carbon sequestration in agricultural and rangeland applications or urban forestry. Such strategies could in principle provide equal or superior carbon benefit. However, biogas development is greatly superior to unchecked landfill emissions. The basic process of anaerobic digestion is well-understood (see the diagram below), and the economics can be attractive wherever landfill capacity is scarce.

Source: EPA Website: Overview of Greehouse Gases: Methane Emissions, http://www3.epa.gov/climatechange/ghgemissions/gases/ch4.html

Biogas Production Through Anaerobic Digestion



Biogas production through anaerobic digestion works by combining organic waste in a feedstock mixed with water, introducing bacteria to fuel the hydrolysis process, and then removing water, carbon dioxide, and impurities.
Source: California Energy Commission, Presentation by Thomas Damberger, Golden State Energy
http://energy.gov/sites/prod/files/2014/03/f10/renewable_hydrogen_workshop_nov16_damberger.pdf

County of Santa Barbara Tajiguas Resource Recovery Project: The Santa Barbara County Department of Public Works, in collaboration with the cities of Santa Barbara, Goleta, Solvang and Buellton, has been leading a nearly decade-long effort to develop a Resource Recovery Project that will process municipal solid waste currently disposed at the County owned and operated Tajiguas Landfill. This project includes facilities that will extract recyclables mistakenly sent to the landfill and anaerobically digest organic material currently buried at the landfill. The project is planned to convert biogas directly to heat for homes in the area and for electricity sales back to the grid -- rather than to use the biomethane to power vehicles. However, the project is noteworthy for its carbon benefit, its indirect link to transportation (given that the local grid powers electric cars), and as a replicable project that could in the future provide a model for biomethane production to fuel low-carbon NGVs. The project is also purposed to increase recycling rates above 80% and provide a range of other benefits described below.[23]

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[23]County of Santa Barbara Tajiguas Resource Recovery Project website, http://resourcerecoveryproject.com

The Tajiguas Resource Recovery Project is a collaboration of the Santa Barbara County Department of Public Works, and the cities of Santa Barbara, Goleta, Solvang and Buellton.

The lengthy Tajiguas project development period, which began in 2007, has included two feasibility studies, a request for proposals, a proposal review process, and a comprehensive public outreach effort involving over 80 presentations to stakeholders over the past five years. The winner of the RFP process, which attracted four bidders, is a team of entrepreneurs known as Mustang Renewable Power Ventures, based in San Luis Obispo County. The final project design consists of an Anaerobic Digestion Facility (ADF) that will convert all organics recovered from the waste stream into digestate and biogas. The digestate will be aerobically cured into a compost product to be marketed as a soil amendment or used for reclamation projects, while the biogas will be converted at a power plant into electricity used to run the plant and sell back to the grid. According to EPA formula calculations the project will reduce the local GHG impact by 133,382 MTCO2E (Metric Tons Carbon Dioxide Equivalent) a year, equal to removing 26,153 average passenger vehicles on the road annually and generates 1 megawatt (net) of renewable energy/year. This is a formidable project that attests to the potential of biomethane production pathways.

Future Opportunities at UC Santa Barbara: In November 2013, University of California President Janet Napolitano announced a pioneering sustainability effort that commits the entire UC system to achieve carbon neutrality by 2025.[24] The Carbon Neutrality Initiative commits UC to balancing its net greenhouse gas emissions from its buildings and vehicle fleet with renewable forms of energy, as well as reducing emissions through energy efficiency. UC Santa Barbara will have opportunities to engage the Carbon Neutrality Initiative at a variety of levels that <u>could</u> include new projects to develop alternative fuel pathways and deploy additional AFVs and related infrastructure, <u>potentially</u> including NGVs and biomethane pathways, as well as hydrogen and electric vehicles. UCSB has already made substantial commitments to low-carbon transportation and EVs in particular. However, the university could likely harvest additional state grant support by further developing and integrating its alt fuel and renewable energy strategies.

[24] *A Carbon Neutral Future: Representatives from the UC campuses and research labs meet to discuss the UC System's ambitious Carbon Neutrality Initiative,* The UC Santa Barbara Current,
October 27, 2014 http://www.news.ucsb.edu/2014/014468/carbon-neutral-future#sthash.O54AlXW9.dpuf

David Auston, Executive Director of UC Santa Barbara's Institute for Energy Efficiency (IEE) has helped convene workshops and seminars on the UC Carbon Neutrality Initiative to explore strategies to zero out the University's carbon footprint. And Arjun Sarkar, sustainable transportation program manager at UCSB, has developed a number of alt fuel vehicle programs for the campus as well as serving on the Central Coast Alternative Fuel and EV Coordinating Councils. A *Recommended Action* discussed at the close of this Chapter is to convene alternative transportation, renewable energy, and energy efficiency stakeholders to explore upcoming CEC and Electricity Program Electric Charge (EPIC) funding for potential development of alternative fuel pathways and vehicles that could involve low-carbon power sources such as biomethane for NGVs, as well as renewable energy for EVs, and various forms of Vehicle-Grid Integration (VGI).

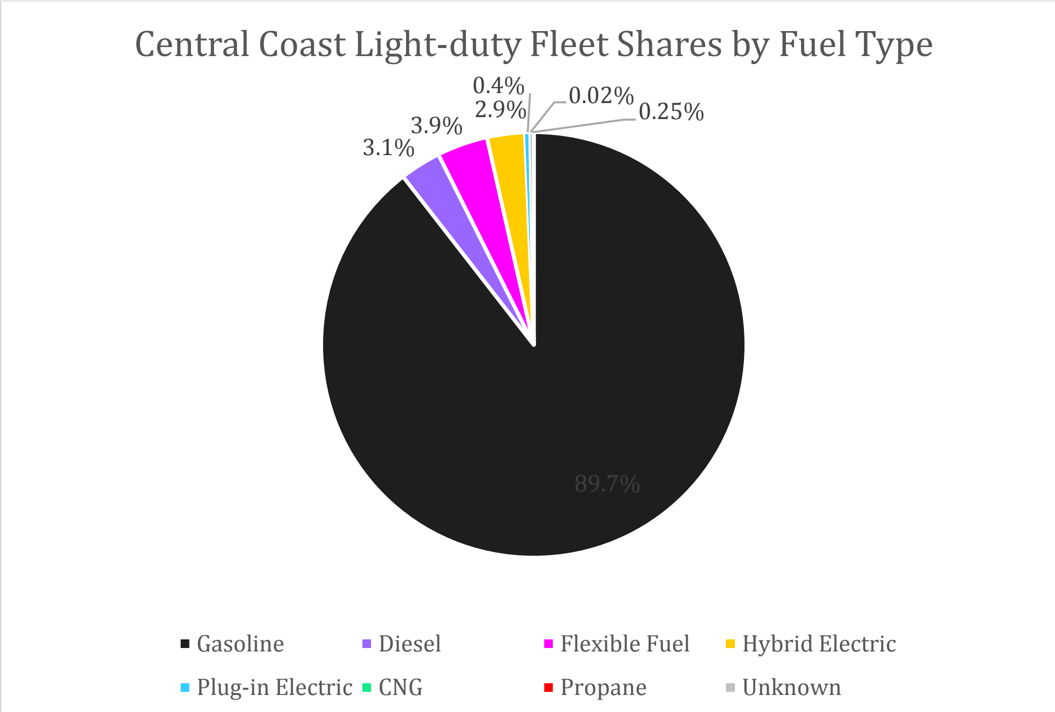
5.26. Central Coast NGV Deployment in the Context of All AFV Types

There are relatively few CNG-fueled light-duty vehicles (LDVs) in the region -- less than 0.1% of the total light-duty fleet. Publically-accessible CNG fueling infrastructure is also limited. There are only seven public CNG fueling locations in the Central Coast region. Propane vehicles account for an even smaller share of LDVs in the region (less than 0.001%). There are 19 publically accessible propane fueling stations in the tri-county area.

2014 Light-duty CNG, Flex Fuel, Hydrogen, and Propane Vehicle Population Estimates

County	CNG	Flex Fuel	Hydrogen	Propane
San Luis Obispo	19	8,507	0	1
Santa Barbara	35	11,685	0	0
Ventura	131	25,521	2	0
Grand Total	**185**	**45,713**	**2**	**1**

Source: NREL/IHS Automotive



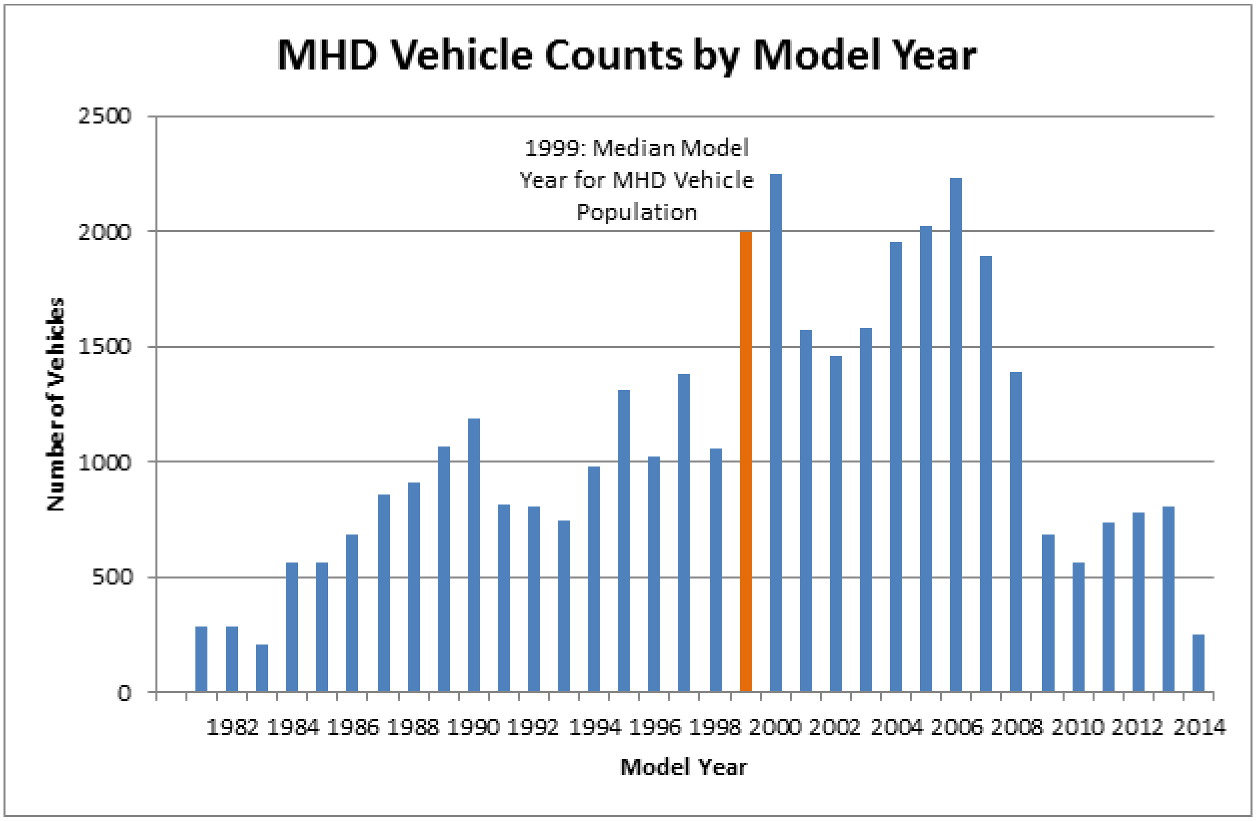
An estimated 66.4% of the medium- and heavy-duty (MHD) vehicles in the Central Coast region were diesels. About 32.6% of all MHD vehicles were powered by gasoline.[25] Relative to these diesel and gasoline MHD vehicles, there are very few CNG, electric & diesel hybrid, flexible fuel, and propane MHD vehicles. Together, these four different alternative fuel classes for MHD vehicles accounted for less than 1% of all MHD vehicles in the region. CNG-fueled vehicles account for the largest number of MHD vehicles powered with alternative fuels.

2014 Medium-and Heavy-duty Vehicle Population Estimates

COUNTY	Diesel	Gasoline	CNG	Electric & Diesel Hybrid	FFV	Propane
San Luis Obispo	5071	2410	37	3	1	9
Santa Barbara	6695	2744	85	3	5	17
Ventura	12664	6858	115	23	13	16
Central Coast Total	**24430**	**12012**	**237**	**29**	**19**	**42**

Source: NREL/IHS Automotive

[25] IHS Automotive Inc. data, National Renewable Energy Laboratory, 2015



Based on our analysis of MHD vehicle data obtained from IHS Automotive, the median model year for the Central Coast population of MHD vehicles is 1999. Approximately 61% of all Central Coast MHD vehicles are greater than 12 years old (i.e. older than model year 2004). Given the turnover rate for MHD vehicles and the higher emissions associated with the operation of these older vehicles, the large share of aging MHD vehicles represents a potential opportunity for increasing the number of clean, alternative fuel vehicles in the Central Coast region and should be a focus for the region moving forward.

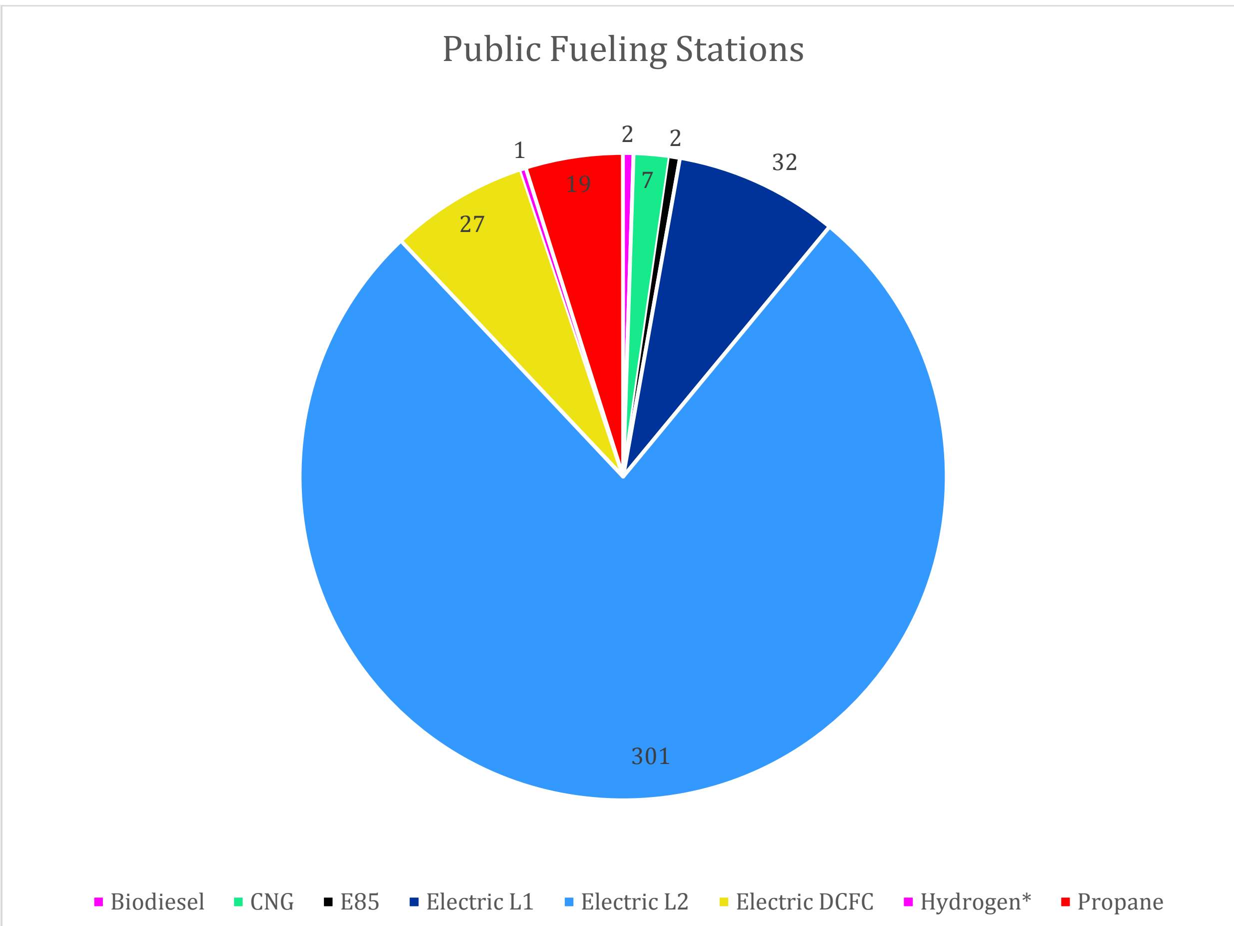
There are 392 publically-accessible alternative fuel stations in the Central Coast region[26]. More than 90% of the publically accessible alternative fueling stations are charging stations for electric vehicles. Despite the small number of propane-fueled vehicles operating in the region, fueling stations for propane are the second most common alternative in the region. This is likely attributable to propane demand for other purposes than transportation. There are few fueling stations (7 total) in the Central Coast region offering CNG. Similarly, only 2 stations offer biodiesel and E85 in the region. The Central Coast region has one planned hydrogen fueling station, which is anticipated to open in May 2016. The hydrogen fueling station is located at 150 South La Cumbre Road, directly adjacent to Highway 101.

[26] U.S. Department of Energy, Alternative Fuels Data Center. Retrieved June 6, 2015 from http://www.afdc.energy.gov/data_download/.

Public Alternative Fuel Stations in Central Coast Region

Region	Biodiesel	CNG	E85	ELEC			Hydrogen*	Propane
				L1	L2	DCFC		
SLO County	1	2	1	2	74	1	0	9
Santa Barbara County	0	3	0	12	106	4	1	4
Ventura County	1	2	1	18	121	22	0	6
Region	**2**	**7**	**2**	**32**	**301**	**27**	**1**	**19**

Source: DoE Alternative Fuels Data Center

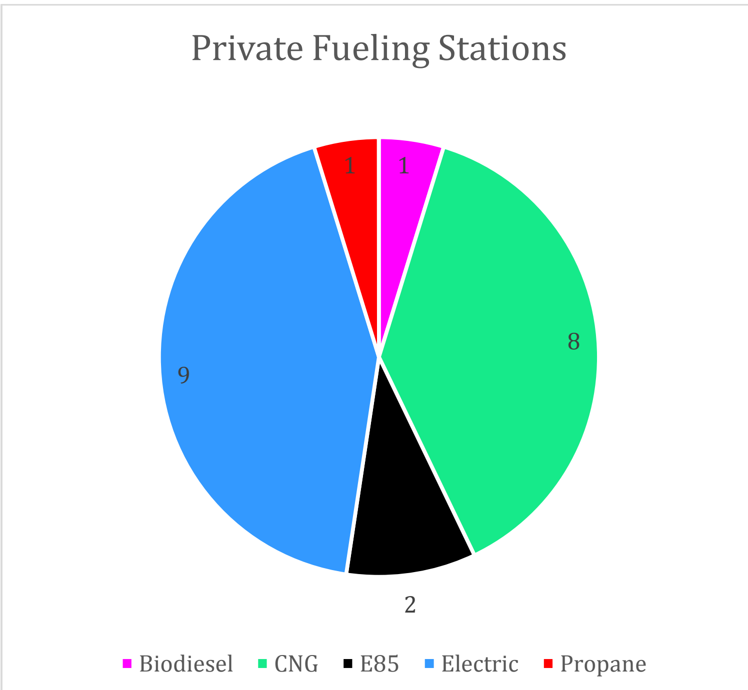


There are 21 private fueling stations in the Central Coast region. Of these, approximately 43% (9 total) provide electricity for private electric vehicle charging, not including residential charging stations. There are 8 private fueling stations offering CNG, which account for 38% of all private fueling stations in the region. There are only two private fueling stations offering E85, one private fueling station offering biodiesel, and one private fueling station offering propane.

Private Alternative Fueling Stations in the Central Coast Region

Region	Biodiesel	CNG	E85	Electric	Propane
SLO County	0	2	0	1	0
Santa Barbara County	1	2	1	1	0
Ventura County	0	4	1	7	1
Region	**1**	**8**	**2**	**9**	**1**

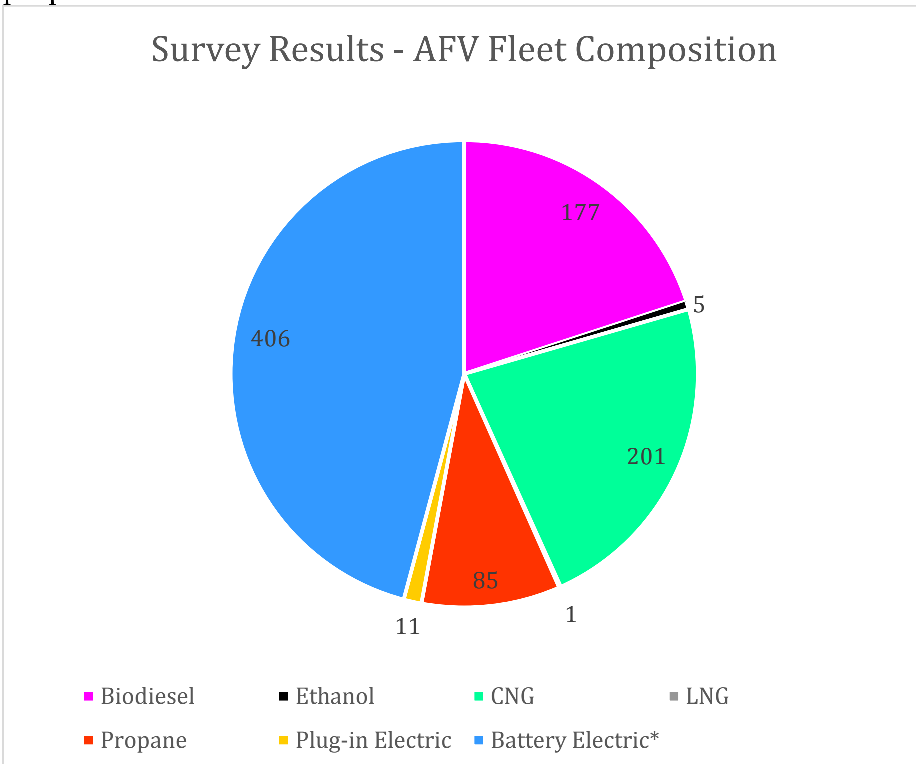
Data Source: DoE Alternative Fuels Data Center



Regional Fleet Operator Survey: A Central Coast Alternative Fuel Vehicles Survey was distributed by the Community Environmental Council of Santa Barbara to fleet operators at 27 local organizations in the counties of Ventura and Santa Barbara from May through August 2015. The survey had a response rate of 51.85%. The total number of vehicles reported by respondents in Ventura and Santa Barbara counties was 7,482. The average fleet size for respondents was 498 vehicles. In addition, the Central Coast Clean Cities Coalition (C5) conducts a comprehensive survey of fleet operators in San Luis Obispo County each year. The Community Environmental Council incorporated data from C5's 2014 Transportation Technology Deployment Report into the Inventory & Assessment survey results[27].

[27] U.S. Department of Energy (2015). "2014 Transportation Technology Deployment Report: Central Coast Clean Cities".

The combined survey results indicate that AFV types are not uniformly distributed across fleets, given the diversity of fleet applications. Biodiesel and LNG vehicles were present in just one fleet. Only two fleets reported LPG vehicles and three fleets reported plug-in hybrid electric vehicles. CNG fleet vehicles were relatively numerous at 201 vehicles, while there were 85 propane vehicles.



Fleet managers estimated the replacement time for each vehicle category. In general, vehicles are replaced between 7 and 11 years after their procurement. The average replacement time varies across vehicle category, per the chart below

Average Vehicle Replacement Time

Vehicle Type	Light-duty passenger cars	Light- and medium-duty trucks	Heavy-duty trucks	Heavy-duty shuttles or buses	Off-road or special purpose vehicles
Average	9.7 years	10.7 years	10.9 years	7.3 years	7.5 years

Surveyed fleet managers estimated that they would procure 891 new vehicles in the 18 to 24 months after the survey. Of these, fleet managers anticipated that 135 (approximately 15%) would be AFVs, per the chart below.

Estimated # of Vehicles Considered for Procurement 18-24 Months from Time of Survey

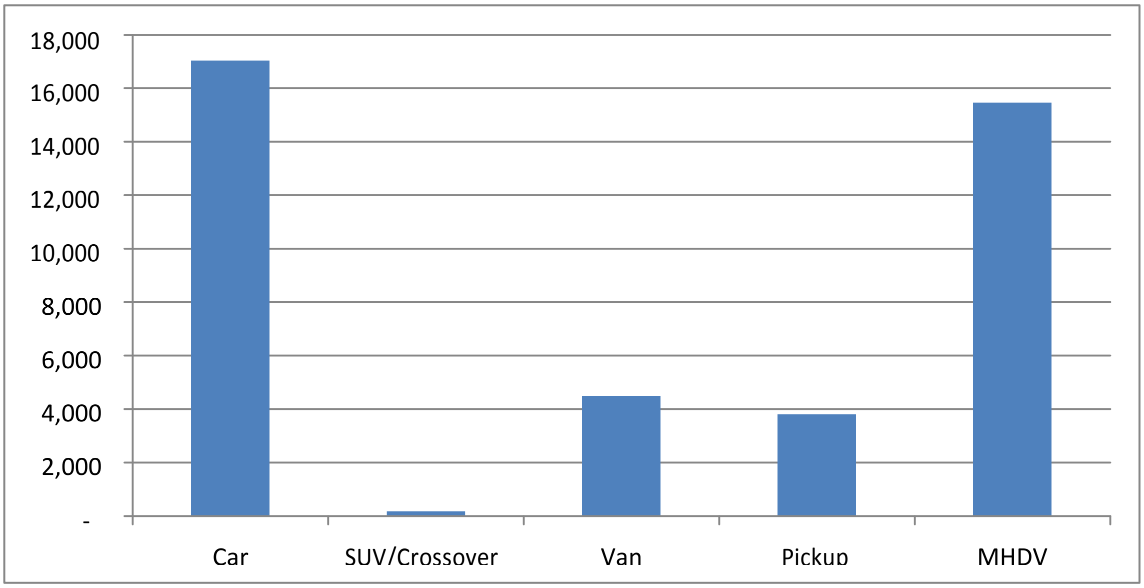
Vehicle Type	Light-duty passenger cars	Light- and medium-duty trucks	Heavy-duty trucks	Heavy-duty shuttles or buses	Off-road or special purpose vehicles	Total
Total Vehicles	265	318	199	22	87	891
Fleet Average	18	21	13	1	6	59

Estimated AFV Procurement 18-24 Months from Time of Survey

Fuel-type	Anticipated AFVs Procured	Percentage of Total Planned Procurement
Biodiesel	**16**	**1.80%**
Ethanol	**10**	**1.12%**
CNG	**18**	**2.02%**
LNG	**0**	**0.00%**
Propane	**0**	**0.00%**
Hydrogen FCEV	**0**	**0.00%**
Hybrid Electric	**54**	**6.06%**
Plug-in Electric	**17**	**1.91%**
Battery Electric	**20**	**2.24%**

Cumulative registrations of NGV vehicles in the Central Coast can be compared against cumulative state registrations of NGVs as of 2013 through the following chart.

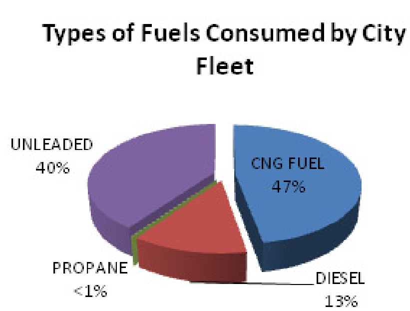
NGV Registrations in California (2013 data)



Source: Energy Commission staff analysis of 2013 Department of Motor Vehicles vehicle registration database, cited in *Strategies to Maximize the Benefits Obtained From Natural Gas as an Energy Source. California Energy Commission.* pp. 41-42.

5.27. Central Coast CNG Fleet Adoption Case Studies: CNG fleet adoption in the Central Coast has been concentrated in public agencies, larger private fleets, and refuse haulers and recycling providers. A variety of mini-case studies are provided below to suggest the range of CNG initiatives undertaken in recent years and to encourage additional assessment of NGV and alt fuel vehicle potential by other regional and local fleet leaders.

City of Thousand Oaks: The City of Thousand Oaks has been a state and regional leader in deploying alternative fuel vehicles across its 200 vehicle fleet. The City has met its initial goal of converting one-third of the fleet to alternative fuels, of which the majority is CNG. Thousand Oaks was the first city in Ventura County to purchase CNG passenger vehicles and buses and the first to operate a public/private CNG fueling facility and electric charging stations. The City now aims to convert 50 percent of its fleet to AFVs. As noted in the chart below, as of 2015, CNG fuel is the largest share of fuels consumed by the City fleet.



The City has focused on CNG as the most viable fuel source due to availability, fuel characteristics, and vehicle type. In 2001, the City of Thousand Oaks opened the first public/private CNG fueling station in Ventura County to make it possible for private companies and citizens to operate CNG vehicles as well. The station is located at 1993 Conejo Blvd. in Newbury Park.[28]

Gold Coast Transit District (GCTD): GCTD provides fixed-route bus and paratransit services in the cities of Ojai, Oxnard, Port Hueneme and Ventura, and in the unincorporated County areas between the cities. GCTD operates a fleet of 54 transit buses using exclusively compressed natural gas (CNG). GCTD operates its own onsite CNG fueling station. The GCTD service area is approximately 91 square miles with a population of 375,000. GCTD's fixed-route buses served 3.8 million passenger boardings in FY 2013/2014, an increase of 7% from the previous year, and operated 2 million miles of revenue service. CNG buses have been well-received by both drivers and the public, and GTCD plans to continue with its CNG fleet operations.[29]

Waste Management, Inc. (WMI) – Ventura County: Waste Management Industries is operating 23 CNG waste collection vehicles in Ventura County that are 50% quieter than comparable diesel engines, while emitting 95% less particulate matter (PM) and 90% less carbon monoxide (CO) than the diesel vehicles they replaced. "Waste Management is committed to lead the waste industry with advanced technology that will foster a cleaner, greener world," according to Mike Smith, director of operations for Waste Management of Ventura County. "The investment in these CNG vehicles is one more step towards improving air quality and meeting the growing needs of the cities and customers we serve."

The implementation of CNG collection vehicles was made possible with the assistance of both the City of Thousand Oaks Transit Yard and City of Simi Valley's Bus Transit CNG fueling stations, where the trucks are currently being fueled. The addition of alternative fuel vehicles in Ventura County is part of Waste Management's commitment to a larger corporate sustainability goal of reducing fleet emissions by 15 percent and increasing fuel efficiently by 15 percent by 2020. Waste Management operates more than 1,400 CNG vehicles in North America, which is the largest fleet of CNG recycling and collection trucks on the continent. Locally, Waste Management operates 58 percent of its fleet on alternative fuel vehicles, including Liquefied Natural Gas (LNG) and CNG. Each class 8 diesel truck replaced with a natural gas vehicle reduces diesel use by an average of 8,000 gallons per year and cuts annual greenhouse gas emissions by an average of 22 metric tons.[30]

Mission Linen – Santa Barbara: Headquartered in Santa Barbara, Mission Linen is a national leader in the uniform and linen services industry, with more than 2,500 employees in five western states. As part of an ongoing commitment to lead the textile services industry in

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[28] City of Thousand Oaks Public Works Department website. https://www.toaks.org/government/depts/public_works/alternate/default.asp

[29] Gold Coast Transit District website - http://www.goldcoasttransit.org/about-gct

[30] "Cleaner, Greener Trucks: Waste Management Launches Compressed Natural Gas Fleet In Ventura County," WMI website, June 2012, http://www.wm.com/location/california/ventura-county/_documents/press/060612.pdf

sustainable practices, Mission Linen quintupled the number of alternative fuel vehicles in its fleet by increasing the number of compressed natural gas vehicles (CNG) in its fleet from six to 32, and added six new propane vehicles to its fleet of 500. These clean vehicles are utilized in the Central Coast as well as in other customer operations in Arizona and Texas. “In addition to our broad range of sustainable corporate practices, we are excited to expand our alternative fuel vehicles within our fleet,” said John Ross, President and Chief Executive Officer. “In just a short period of time, we have seen positive effects on the environment, natural resources, and on route optimization. Thanks to our commitment to these environmentally accountable practices, we’re able to provide our customers with the exceptional delivery service they demand while also preserving our environment.“

Mission Linen’s new propane vehicles consist of ROUSH CleanTech Ford E-450 propane autogas step vans, which burn cleaner fuel. Since adding these vehicles to the fleet, the company has seen savings in fuel cost, a 24% reduction in greenhouse gas emissions, a 20% reduction in nitrogen oxide emissions, and a 60% reduction in carbon monoxide emissions. The new Mission Linen vehicles meet Environmental Protection Agency and California Air Resources Board certification requirements.[31]

MarBorg Industries – Santa Barbara: MarBorg was the first hauler on the South Coast to use CNG collection vehicles, and has continued to add CNG vehicles to its fleet. In September of 2010, MarBorg completed construction of a new CNG refueling station to support its CNG fleet, and is able to fill its 30 CNG vehicles overnight. To ensure a comprehensive fleet of sustainable collection vehicles, MarBorg Industries is also using Bio-Diesel fuel (B5) in all of its existing diesel vehicles. Through modernization of older equipment, integration of CNG vehicles, and utilization of cleaner burning fuels MarBorg Industries has proven to be an environmental leader in Santa Barbara County.
http://www.marborg.com/sustainability.html

MarBorg Industries Santa Barbara Refueling Facility for 30 CNG Refuse Trucks
Source: MBI News, Winter 2011.
http://www.marborg.com/images/news/publications/2011newsletters/MBI_NEWS_Winter_2011_CitySBDraft1_4PageRE4.pdf

[31]Mission Linen website, 2015, http://ucsf.mlswebstore.com/press/Alternative%20Fuel%20Press%20Release%20FINAL.pdf

Revolution CNG – Paso Robles Waste & Recycling: Revolution CNG has begun fueling vehicles at a new station in its hometown of Paso Robles. Revolution built the third generation CNG facility for Paso Robles Waste & Recycling, which is converting its fleet to compressed natural gas. Time-fill posts are functioning for fleet access and a public-access twin-hose fast-fill dispenser is also available. The station has a redundant compressor system including a Bauer C-25.0 and an Ariel EA 125/4 via JW Power, designed to provide both time fill and fast fill, says Revolution CNG co-owner Mata Iaia.

A Tulsa Gas Technologies dispenser has two hoses, one with a transit-capable nozzle. The station has a BroadLux/Fuelforce card reader which will accept all major credit and fleet cards, and a Xebec gas dryer. A second dispenser can be installed when demand warrants. The Paso Robles station closes a missing link in the CNG fueling gap along Highway 101 between Los Angeles and the San Francisco Bay Area.

Revolution CNG maintains natural gas fueling stations throughout the region, with clients including Hearst Castle with its fleet of CNG visitor buses, and UC Santa Barbara, as well as Bauer, JW Power, and TGT. Taking advantage of the new CNG station, Revolution has acquired a new bi-fuel Chevy Silverado 2500 pickup with Impco CNG installation. Paso Robles Waste also has six new Autocar Xpeditor trucks running on CNG. "Going forward, all of our diesel vehicles will be replaced by CNG vehicles," says Revolution co-owner Ian Hoover. Three affiliate companies operate a total of 22 refuse and roll-off trucks, he says.[32] Paso Robles Waste & Recycle in partnership with Revolution received $300,000 to build its CNG refueling station and provide public fueling.

Revolution CNG Station serving Paso Robles Waste & Recycling
Source: http://www.revolutioncng.com/3g-cng-pumps-fuel-paso-robles-fleets-fuels-com/

Lompoc Unified School District: The Lompoc Unified School District opened a CNG filling

[32]Revolution CNG website, 2015. http://www.revolutioncng.com/3g-cng-pumps-fuel-paso-robles-fleets-fuels-com/

station to serve its CNG fleet, located near the LUSD transportation center in the 600 block of East Central Avenue. It is the lone public-use CNG pumps on the Central Coast between Santa Barbara and San Luis Obispo. The new Lompoc station is part of a larger project in which LUSD upgraded its CNG facilities to serve the 15 district school buses (out of 43) that run on CNG. The total project cost about $1.2 million, with $300,000 of that coming from a grant the district received from the California Energy Commission. A key reason LUSD was able to secure that grant was because it included a public-use station in the plans.

District officials anticipate the pump will ultimately pay for itself over the next 10 years. Once the initial cost is recouped, any money brought in by the filling station will be used for facility upgrades and operational costs. Frances Lemons, LUSD's transportation manager, said the district has already seen significant savings from using CNG. Lemons said that the entire school bus fleet racks up about 403,000 miles per year. The buses that run on CNG — which are the larger vehicles that carry more students — cost about $10,000 less to refill each month than if they were running on diesel fuel. That adds up to annual savings of more than $100,000. Smith worked with the Lompoc City Council, city planners and Lompoc and Santa Barbara County fire departments over three years to get the station built and operational. The District is hopeful that other entities, such as the City of Lompoc or the Santa Ynez Band of Chumash Indians or other private businesses, will use the new public-use station, which accepts Visa and Mastercard as payment, to refill buses and other CNG-powered vehicles.

The station will also allow tourists and other CNG drivers to trek into previously inaccessible Central Coast coastal regions. "(Now) someone could travel the coastline and come up Highway 1 from Los Angeles or the Long Beach area," Lemons said. "Before, you had to stay on the 101 and could fill up in Santa Barbara and then San Luis (Obispo). Now you can come into the coast and go anywhere."[33]

[33] Willis Jacobson, "LUSDs New Refueling Station Open to the Public," *Lompoc Record,* August 20, 2015, http://lompocrecord.com/news/local/lusd-s-new-cng-refilling-station-open-to-the-public/article_7740a801-6fa6-5613-a337-a69f72850d33.html

The Lompoc Unified School District CNG station is open to the public and refuels LUSD School buses. The station received a $300,000 grant from the CEC in part due to serving both fleet and public uses. District Transportation Manager Frances Lemons is at left.
Source: *The Lompoc Record,* August 20, 2015.

5.28. NGV Safety and Training for Technicians and First Responders: Natural gas has significantly different properties and characteristics than gasoline or diesel fuels, and natural gas fuel-specific training is essential for both technicians and safety personnel. On CNG vehicles, portions of the fuel system operate at extremely high pressures (3,600 psi), while LNG vehicles use cryogenic (-260 degrees Fahrenheit) fuel systems. Both types of fuel systems are very safe when handled appropriately, yet they require unique components and special safety procedures for all levels of maintenance, diagnostics, repair, and emergency response. This section of the Plan will review recommended training resources.

Several training options for first responders and technicans exist through the National Alternative Fuels Training Consortium (NAFTC), and training for technicians is available both through NAFTC, and the Natural Gas Vehicle Institute (NGVi), as well as through many California Community Colleges and Clean Cities Coalitions. Most courses are available in both in-person and online formats. Shorter format courses are typically four hours, while two-day in-depth trainings and train-the-trainer curricula are also available.

The NAFTC offers course offerings are extensive, with multiple courses tailored to each fuel type, and separate courses available for technicians, firefighters, emergency medical services, and law enforcement. The foundational course for any type of First Responder is entitled: ***First Responder Safety Training: Gaseous Fuels and Gaseous Fuel Vehicles,*** and is available online at http://naftc.wvu.edu/course_workshop_information/first_responders/first-responder-safety-training-cclp#gas. In this course, First Responders (or other relevant safety-rekated staff) are trained on the differences in procedures for safely addressing incidents involving CNG, LNG, propane, and hydrogen powered vehicles. Anyone can attend these classes as a participant, however only a first responder with a training background can participate in the train-the-trainer level course. The foundational course enables participants to:

- List the key properties, characteristics, and functions of gaseous fuels
- Explain the operation of gaseous fuel vehicles
- Recognize gaseous fuel vehicle components
- Identify the risks and hazards common to gaseous fuel storage
- Explain the major components of gaseous fuel vehicle fueling systems
- Describe gaseous fuel vehicle fueling station safety systems
- Identify the risks involve with the transport and handling of gaseous fuels
- List personal protective equipment necessary for first responders when responding to a gaseous fuel vehicle incident
- List the steps required to secure a gaseous fuel vehicle
- List the steps for rescuing occupants from a damaged gaseous fuel vehicle
- Demonstrate proper fire response to gaseous fuel fire
- Demonstrate proper response to a gaseous fuel leak

Separate courses are also available that cover similar material with greater specificity from the perspective of individual First Responder job types. These courses include:

- Firefighter Alternative Fuel Vehicle Safety Training
- Emergency Medical Services Alternative Fuel Vehicle Safety Training
- Law Enforcement Alternative Fuel Vehicle Safety Training
- First Responder Safety Training: Gaseous Fuels and Gaseous Fuel Vehicles
-

Technician training is also available from NATC in multiple AFV categories including:

- Introduction to Natural Gas Vehicles
- Introduction to Propane Vehicles
- Liquefied Natural Gas Vehicles
- Propane Autogas Vehicle Technician Training
- Light-Duty Natural Gas Vehicles
- Heavy-Duty Gaseous Fuel Applications
- Compressed Natural Gas Vehicle Fuel System Inspector
- Compressed Natural Gas Vehicle Conversion

Official NATC regional training centers closest to the Central Coast are at El Camino College and Fresno City College. At El Camino, the contact is Eldon Davidson – edavidson@elcamino.edu. At Fresno City College, the contact is Martin Kamimoto –

martin.kamimoto@fresnocitycollege.edu.

Integrated NGV Technical and Safety Training in Modular Format: In addition to NATC, the Natural Gas Vehicle Institute offers a seven module technical training course that integrates technical and safety training, and addresses: The Properties and Characteristics of Natural Gas; Function of CNG Fuel System Components and Safety Procedures; CNG Fueling Station Equipment and Operation; CNG Depressurizing and Defueling; LNG Fuel and Vehicles; and LNG Fueling and Defueling. The modules can be taken separately. This course is viewed as appropriate for:

- Technicians who will perform basic preventative maintenance on natural gas vehicles (oil changes, tire rotations, etc.)
- Technicians who will perform mandated CNG fuel system inspections
- Technicians who will perform NGV diagnostics and repair procedures
- All employees involved in NGV fleet operations
- Fleet or dealer service managers and supervisors
- Corporate/agency safety managers
- Risk management staff

Course objectives are to:

- Describe the properties and characteristics of natural gas.
- Identify the differences between natural gas and other liquid fuels.
- Identify all major low- and high-pressure CNG fuel system components; describe their operation and safety precautions.
- Describe the differences between dedicated, bi-fuel and duel-fuel NGVs.
- Identify and employ safety practices when working with natural gas powered vehicles.
- Be familiar with CNG fueling station equipment, safety devices, operation and fueling procedures
- Identify CNG and LNG depressurizing and defueling methods and the related safety precautions

Available in instructor led or e-learning formats, the Natural Gas Vehicle Institute's Level 1 course is designed for technicians and support teams performing routine maintenance, inspection, diagnostics and repair of natural gas vehicles. It is also a prerequisite for technicians who will take NGVi's CNG Fuel System Inspector Training or NGV Heavy-Duty Maintenance and Diagnostics Training. More information on the Natural Gas Vehicle Institute is available at: http://www.ngvi.com/index.html

5.29. Summary of Key Issues and Tools for Assessing Fleet Adoption of NGVs: This Chapter of the AFV Plan has provided a large body of material relevant to Fleet Managers to help assess the economics and environmental attributes of NGVs, as well as their operational characteristics. At this juncture, it may be useful to "boil down" this knowledge into a few key questions to guide the internal process of assessing the possible role of NGVs in local application contexts.

- **Types of Vehicles – New or Retrofit, Bi-Fuel or NGV:** A key initial question is whether to purchase new OEM-produced CNG vehicles, purchase new gasoline or diesel vehicles and have them converted to CNG by a third-party upfitter, or retrofit existing vehicles currently operating in the fleet. As with any key business decision, there are trade-offs to consider. One of the most prevalent for many fleets is the trade-off between the fuel cost savings and the loss of cargo space and payload capacity. The number and variety of factory- and conversion-ready CNG vehicles available from OEMs is increasing. Some of the NGVs built by the OEMs include popular models such as the Chevrolet Silverado HD, GMC Sierra HD, Ram 2500, and the Chevrolet Impala. (Unfortunately, the stalwart Honda Civic CNG vehicle will be discontinued in 2016.) Fleet customers can also order many Ford vehicles, including the F-150, with an optional gaseous engine prep package (with hardened engine components), making it ready for conversion to CNG by a Ford Qualified Vehicle Modifier (QVM). Many vehicles are also available in bi-fuel or NGV only configurations. A good resource for assessing the merits of each can be found in Green Fleet Magazine at: http://www.greenfleetmagazine.com/channel/natural-gas/article/story/2014/12/deciding-whether-bi-fuel-or-ngv-is-the-best-for-your-fleet.aspx

- **Fueling System Options and Configurations on the Vehicle:** Beyond finding the right vehicle model for a fleet's specific needs, there are key operational criteria to be considered when deciding to shift to NGVs. For example, the Chevrolet Express CNG cargo van offers customers the choice of a three- or four-tank configuration. The three-tank version offers a fueling capacity of 15.8 GGE, while the four has 23.1 GGE. That means an extra 100 miles of range with the four-tank option; however, because of the weight of the extra tank, 300 pounds of payload are traded off. In the Chevrolet Express dedicated CNG van, the tanks are fitted around the frame under the vehicle body. An optional fourth is placed in the cargo area. Fleet managers may face a similar trade-off if considering CNG pick-up trucks. Ram, Chevrolet, and GMC place the CNG tank in the truck bed. In the case of the Ram 2500 Crew Cab, this utilizes 3 feet of the 8-foot bed. For some fleets, that space is precious and the loss of it can be a non-starter. Automakers and upfitters are working to reduce these kinds of trade-offs. While many NGVs use steel CNG tanks (known as Type I), growing numbers are using (equally safe) tanks made of lighter materials such as fiberglass-wrapped aluminum (Type II and Type III) or carbon fiber and other composites (Type IV). These types of tanks cost more than Type I tanks, but they also reduce the payload vs. fueling range trade-off due to their lighter weight.

- **Matching Duty Cycles to Fuel Infrastructure:** To further drill down on the question of vehicle type, a fleet manager considering purchasing CNG light, medium or heavy duty vehicles should ask the following questions to determine what type of infrastructure is needed and/or available.

    - What are the daily distances travelled?
    - What is the typical duty cycle—one way or round trip?

- Are there existing public access fueling stations suitable for the duty cycle?
- Can the vehicles be filled overnight or do they need to be fast-filled?
- Public vs. private access to a fleet fuel depot—will there be public access to the station?
- What are the economics of building a station vs. using public infrastructure?
- Are there upcoming grant opportunities for supporting NGV procurement or fueling infrastructure? (Local Clean Cities Coalitions and Air Pollution Control Districts may be able to help identify emerging opportunities)
- Can your organization partner with another public agency, fleet operator, or service provider to share the costs of new fueling infrastructure?

- **Fuel Cost Calculations and Payback Periods:** All fleet operators must meet bottom line financial performance expectations. While it is challenging to predict future fuel prices, some assumptions must be made to drive an ROI calculation. To assist with this process, the DOE's Alternative Fuel Data Center has cost calculators that can generate simple back-of-the-envelope estimates of how much a fleet can save. See www.afdc.energy.gov/vehicles/natural_gas.html for more information. Additional key tools are listed below. Also, fleet management companies can help calculate a company's specific costs of ownership more precisely with models incorporating many more operational variables. Searches on fleet management companies will provide numerous options.

- **Kicking the Tires – Leading Conferences:** There is no substitute for direct interaction with both vehicles, the companies that stand behind them, and one's peers in the industry. Leading conferences include the Alternative Clean Transportation - ACT EXPO (in Long Beach), NAFA (the National Association of Fleet Administrators), the Fleet Technology Expo, the Green Truck Summit, the Work Truck Show, the Government Fleet Expo & Conference, ALTCAR Expo & Conference, the North American NGV Association.

- **Use These Essential Tools for Economic and Environmental Cost/Benefit Analysis:** The following tools are invaluable for making the final assessment of both economic costs and benefits of incorporating NGVs into the fleet, and assessing both economic and environmental benefits on a full life-cycle basis. These tools are considered industry-standard and assessments backed up by these tools will be helpful in seeking potential grant funding for NG vehicles and infrastructure.

    - VICE 2.0: Vehicle and Infrastructure Cash-Flow Evaluation Model
      The VICE model version 2.0 is the second generation of the financial model developed by the National Renewable Energy Laboratory for fleet managers to assess the financial soundness of converting their fleets to run on compressed natural gas (CNG).

- DNGI Fuel Savings Calculator

  The Natural Gas Fuel Savings Calculator, produced by The Drive Natural Gas Initiative, a collaboration between natural gas utilities and producers, helps with the preliminary analysis of the total costs associated with converting a fleet.

- Argonne AFLEET Tool, AFLEET Tool Instructions for environmental/economic cost-benefit analysis

  The Department of Energy's Clean Cities Program has enlisted the expertise of Argonne develop a tool to examine both the environmental and economic costs and benefits of alternative fuel and advanced vehicles. Argonne has developed the Alternative Fuel Life-Cycle Environmental and Economic Transportation (AFLEET) Tool for Clean Cities stakeholders to estimate petroleum use, greenhouse gas emissions, air pollutant emissions, and cost of ownership of light duty and heavy duty vehicles using simple spreadsheet inputs. For more information, visit the Argonne AFLEET Tool website here.

5.30. Recommended Actions to Support NGV Assessment and Readiness: The following recommendations describe high-level actions that fleet managers and policy leaders can take to assess the potential role of CNG vehicles and low-carbon natural gas fuel pathways in advancing their organization's economic and environmental performance goals. Note that the numbering system for the recommendations corresponds to the overall AFV Plan recommendations (addressing all fuel types), which is presented in the introduction to this Plan.

Domain	Recommendation	Lead
2.4. CNG Vehicles & Infrastructure	**2.4.1. Assess potential of CNG vehicles to meet local GHG reduction, cost, and sustainability goals** -- taking into account the most recent and authoritative research on GHG and air quality impacts and integration of NGV readiness into General Plans, Climate Plans, and other sustainability related plans as appropriate **2.4.2. Determine need for additional local CNG fueling infrastructure** (if any) to meet planned CNG fleet needs **2.4.3. Partner with other cities and the Central Coast AFV Council to outreach to CNG fuel providers** to develop CNG fueling sites (if applicable) -- utilizing the *Drive Natural Gas Infrastructure Guide* from the California Natural Gas Vehicle Partnership to ensure consistency with applicable codes (ANSI, National Fire Protection Association, and Uniform Building, Fire, and Plumbing Codes) **2.4.4. Develop a comprehensive best-practice based maintenance plan for CNG vehicles,** ensuring that NGV maintenance facilities conform to National Fire Protection Association requirements	**Planning Departments** **Fleet Departments**

Discussion of the Potential Contribution of Natural Gas Vehicles to Air Quality and Climate Goals: The discussion in this chapter as well as additional material in the Appendix reveals that the environmental performance of NGVs relative to other vehicles – especially diesel trucks – is both complex and highly dynamic. The dynamic elements include evolving NGV engine technology, evolving biomethane and Renewable Natural Gas (RNG) fuel pathways with potential for dramatically improved carbon intensity vs. fossil fuel pathways, and potentially improved capability to assess and mitigate fugitive methane leakage in the natural gas supply chain. Moreover, NGVs are not competing against diesel or hydrogen or other vehicles and fuels that are themselves in a static position relative to their own environmental performance. Diesel and gasoline powered vehicles are poised to make significant strides in air emissions with both new engine technologies coming on-line and potentially expanded production and use of biodiesel, Renewable Diesel, and other biofuel blends.

5.31. High-Level Strategies for Clean Fleet Decision-Making: In today's complex and extremely dynamic fleet environment, it is recommended that fleet managers and other leaders incorporate these strategies into their vehicle assessment and decision-making approach.

1. **Shift away from *generalizations* about vehicles and fuel types to look at *specific* application contexts and *specific* fuel and vehicle combinations.**
   - Every vehicle exists within an ecosystem that includes its natural environment, the fuel pathway environment (including feedstocks, production, and fuel delivery systems), and the operating environment (duty cycles and economic imperatives.) In some cases, the cleanest vehicle available may not be practical because of insurmountable challenges in the fuel pathway or the operating environment at a given point in time. On an interim basis, a vehicle with somewhat lower environmental performance may be required – or a new workaround may be found to enable deployment of the cleaner vehicle and fuel. Rather than rest with potentially outdated assumptions about fuel and vehicle types, delve into the detail of specific use cases with the latest information to see how a specific operating need can be met with the cleanest available technology.

2. **Find the best combination of high-efficiency vehicle technology and low-carbon fuel for each relevant fuel and vehicle in your fleet.**
   - Virtually all vehicle types – including NGVs – can operate on a very low carbon basis given the right combination of high-efficiency engine, lightweight and aerodynamic vehicle design, best operating practices (e.g. idle reduction), and low-carbon fuel. By approaching fleet management and transportation policy from a whole-systems perspective, fleet managers and other key leaders can optimize both the vehicle and fuel pathway choice (and fleet and vehicle operations) to *dramatically* reduce the environmental harm that vehicles can otherwise cause.

3. **Regularly re-assess the state of technology development and the economic and environmental performance attributes of Alternative Fuel Vehicles.**
   - Transportation technology, policy, and practice is evolving at the fastest pace in history, with breakthroughs occurring every year in vehicle design, fuel pathways, and operating strategies. New approaches to connectivity and telematics, vehicle sharing, and autonomous driving will further revolutionize the transportation landscape in the next 5-10 years. To ensure that vehicle procurement, fleet management, and transportation policy decision-making reflects current information in all these key domains, it is essential to implement state-of-the-art approaches to professional development, training, and knowledge management. Simple strategies include participation in leading conferences, keeping up with relevant list serves, and consulting knowledgeable colleagues, subject matter experts, and professional associations.

4. **Develop a clear understanding of the urgency of the climate crisis and the link between air emissions and health – and make decisions with these in mind.**

   - Virtually all qualified scientific experts and leading research institutions agree that decisions make in the next 5-10 years on climate-related policies and greenhouse gas emissions will determine whether the global climate system enters the "runaway" stage -- with catastrophic consequences for all life on earth. Because of the systemic nature of the challenge, all decision-making on transportation, energy, and emissions issues is inherently local and global in impact, and every decision has importance in whether the overall trendline is toward dramatically reduced emissions or "business as usual." The state of California made a science-based decision that economy-wide emissions can and must be cut by at least 80% below 1990 levels by 2050 at the latest. The most recent science presented to the UN Intergovernmental Panel on Climate Change and in authoritative, peer-reviewed journals indicates that the level of reductions needed and the timetable for achieving them is likely much tighter than even these targets suggest. Moreover, in order to achieve the existing 2050 targets, the Air Resources Board's Scoping Plan indicates that the transportation sector must deploy nearly 100% zero and near-zero emissions vehicles by 2030 in order to meet the 2050 goals. Given the 12+ year time lag in fleet turnover, there is no time to waste to achieve this benchmark. Finally, research by the American Lung Association and others demonstrates that more than 7,000 Californians are dying prematurely each each from air pollution, while 5 million are suffering from respiratory disease (including 1 million children.)[34]

     If we wish to improve the health of our children and communities, and sustain a livable climate for the generations to come, it will be essential to deploy the cleanest-available technologies, that reduce the greatest amount of toxic air emissions and greenhouse gases, at the most rapid possible pace, and in the most cost-efficient manner.

[34] "*Breathing Easier in California,"* Fact Sheet developed by the California Lung Association, *2015,* accessed at http://www.lung.org/local-content/california/documents/california-delivers-public.pdf

5.32. Information Resources on NGVs, Fueling Stations, Funding, and Local Readiness

Vehicle Information

AFDC Vehicle Buyer's Guide for Consumers

Features information about natural gas vehicles and connects users to a database of current model year cars and trucks available to lease or purchase.

GSA Fleet Auction Site

GSA Fleet operates over 23,000 AFVs. Each year GSA Fleet sells 2,000 to 4,000 used AFVs as they are replaced by new vehicles. All the information you need to purchase AFV vehicles at a public auction is available on this site. You can learn about AFVs, view vehicles expected to be available in 2012, look for specific vehicles for sale now, and search for auction locations in your area.

NGV Fueling Station Locators

Fuel Station Locator (CNG), Fuel Station Locator (LNG)

The Alternative Fuels Data Center contains refueling stations for various alternative fuels, including CNG and LNG, throughout the country.

Fleet Calculators

VICE 2.0: Vehicle and Infrastructure Cash-Flow Evaluation Model

The VICE model version 2.0 is the second generation of the financial model developed by the National Renewable Energy Laboratory for fleet managers to assess the financial soundness of converting their fleets to run on compressed natural gas (CNG).

DNGI Fuel Savings Calculator

The Natural Gas Fuel Savings Calculator, produced by The Drive Natural Gas Initiative, a collaboration between natural gas utilities and producers, helps with the preliminary analysis of the total costs associated with converting a fleet.

Argonne AFLEET Tool, AFLEET Tool Instructions

The Department of Energy's Clean Cities Program has enlisted the expertise of Argonne develop a tool to examine both the environmental and economic costs and benefits of alternative fuel and advanced vehicles. Argonne has developed the Alternative Fuel Life-Cycle Environmental and Economic Transportation (AFLEET) Tool for Clean Cities stakeholders to estimate petroleum use, greenhouse gas emissions, air pollutant emissions, and cost of ownership of light duty and heavy duty vehicles using simple spreadsheet inputs.

For more information, visit the Argonne AFLEET Tool website here.

Cylinder Inspection

CNG Cylinder Inspectors

This registry database will provide the name, listing of current certifications, and contact information for individuals who have passed an exam for the CSA Standards Personnel

Certification programs.

CNG Cylinder Inspector Training

Clean Vehicle Education Foundation lists organizations that offer CNG cylinder inspection training for the CSA certification test.

Federal Government Information

National Renewable Energy Laboratory

Transportation Research Board

Department of Energy's Office of Alternative Fuels

Department of Energy's Alternative Fuels Data Center

Department of Energy's Fuel Economy Information

Other Alternative Fuel Sites

Clean Cities

Clean Vehicle Education Foundation

National Alternative Fuels Training Program Consortium

Publications and News Services

Clean City News

The official quarterly publication of the Clean Cities Program and the Alternative Fuels Data Center, providing information about Clean Cities's projects, designations, and conferences as well as up-to-date information about developments in the alternative fuels industry.

The Fuels Fix

The quarterly ezine from the Clean Cities Coordinators in the Southeast.

Fleets & Fuels A biweekly newsletter highlighting AFV news and info.

The NGV Forum

NGVAmerica's national news and dialogue service for the natural gas vehicle industry.

NGT News

Next-Gen Transportation is an alternative fuels news site.

NGV Global

International news service of NGV Global, the International Association for Natural Gas Vehicles.

Research and Development

Gas Technology Institute

Navigant Research, Alternative Fuel Vehicles

U.S. LNG Fuel Production Plants

This regularly updated information service of NGVAmerica and Zeus Intelligence provides information on U.S. LNG facilities with the capability to offload LNG into trailers for truck delivery.

California NGV-Related Information

California Air Resources Board (CARB)
California Energy Commission's AFV Site
California Natural Gas Vehicle Coalition California NGV Partnership

International NGV Associations

NGV Global, International Association for Natural Gas Vehicles

Environmental Web Sites Addressing NGV Issues

Energy Vision
Environmental Defense
Natural Resources Defense Council
Union of Concerned Scientists
The World Bank Group

Appendix 1: Natural Gas Vehicle Emissions and Climate Impact Analysis

A-1. Establishing a Risk Management Assessment Framework Relative to the Global Warming Potential (GWP) of Methane and Carbon Dioxide: In addition to the issue of the methane leakage rate – which is well beyond the scope of local jurisdictions to manage – there is another key factor in determining whether policy-makers at every level (local, state, and national) choose to go forward with a large-scale transition to natural gas fueling in the transportation sector.[35] That is determining the appropriate timeframe with which to assess the Global Warming Potential (GWP) of methane. The concept of a Global Warming Potential has been developed to enable comparison of the ability of each greenhouse gas to trap heat in the atmosphere relative to the performance of the largest anthropogenic greenhouse gas, which is carbon dioxide (CO_2) over a specified time horizon. To enable this comparison, greenhouse emissions are typically calculated in terms of how much CO_2 *equivalent* (or CO2e) would be required to produce a similar warming effect oven the chosen time horizon. GWPs are based on the heat-absorbing ability of each gas relative to that of carbon dioxide (CO2), as well as the decay rate of each gas (the amount removed from the atmosphere over a given number of years). Thus, GWPs are used to define the impact greenhouse gases will have on global warming over different time horizons. To enable standardized international reporting regimes, these time horizons are generally reported as 20 years, 100 years, and 500 years. For most greenhouse gases, the GWP declines as the time horizon increases. This is because the greenhouse gas is gradually removed from the atmosphere through natural removal mechanisms, and its influence on the greenhouse effect declines.[36] Assigning a GWP value enables policy makers to compare the impacts of emissions and reductions of different gases using a common analytic framework.

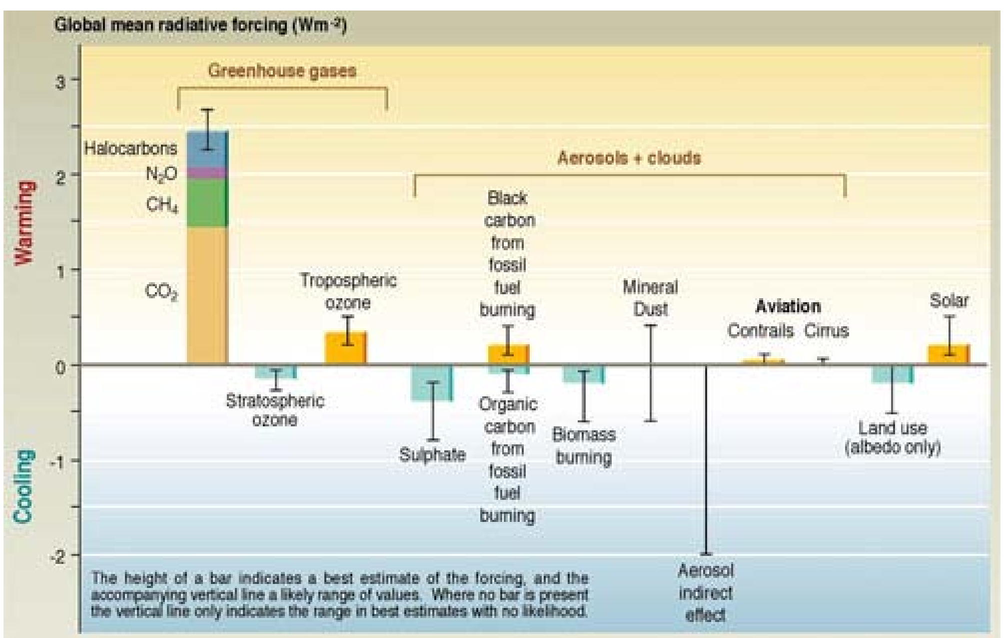
The CO_2 equivalent value is calculated by multiplying the amount of gas by its associated global warming potential (GWP). The determination of a global standard for Global Warming Potential is developed primarily through the mechanisms of the UN Intergovernmental Panel on Climate Change (IPCC) via its periodic *Assessment Reports,* which delineate the required inventory reporting framework under the United Nations Framework Convention on Climate Change (UNFCCC). The most recent updates on the Global Warming Potential of various greenhouse gases was provided in 2013-14 via the *Fifth Assessment Report (AR5),* which are painstakingly prepared over a five year period by thousands of scientists working in the collaborative international UNFCCC framework. These global warming potential (GWPs) are then gradually adopted by national regulators (such as the U.S. EPA) and by organizations that facilitate voluntary industry reporting efforts.

Methane is a significant contributor to the greenhouse effect and has been newly determined

[35]Note that we are speaking here of conventionally produced natural gas. Biomethane as a fuel pathway has much more favorable GHG and emissions profile and will be discussed separately.
[36]Some GHGs – such as the chlorofluorocarbons (CFCs) however, have long atmospheric lifetimes, and their 100-year GWP may be greater than their 20 year GWP. These GHGs are beyond the scope of this Plan.

(via the UN's Fifth Assessment Report) to have a GWP of 86 over twenty years, when counting the influence of carbon cycle feedbacks -- or a GWP of 84 without addressing carbon cycle feedbacks.[37] Over a 100 year timeframe, the Global Warming Potential of methane is 34 with carbon cycle feedbacks, and 28 without including the feedbacks. (It is anticipated that most reporting regimes WILL incorporate the more conservative and comprehensive approach that includes the carbon cycle feedbacks, which were newly introduced into UNFCCC protocols via the Fifth Assessment Report.) This GWP factor means methane is approximately 86 times more heat-absorptive than carbon dioxide per unit of weight when considered in a twenty year timeframe, and 34 times more heat-trapping in a 100 year timeframe. For the 20 year timeframe, the GWP factor has been revised upward from a previously assigned GWP factor of 25, representing a 40%+ increase in the potency assigned to methane. This reflects new scientific research that more accurately captures the actual chemical behavior of methane in the atmosphere. While this number may be revised in the future based on ongoing research, it is unlikely to be so substantially reassessed again soon.

While methane is thus a much more potent greenhouse gas than CO2 per unit of mass, when assessed on a static basis, there is over 200 times more CO2 in the atmosphere. Currently, global CO2 levels are over 380 ppm (parts per million) while methane levels are 1.75ppm. Hence, on a snapshot basis, the aggregate amount of warming contributed by methane (shown by its chemical designation CH4 in the chart below) is calculated at 28% of the warming CO2 contributes. (This chart provides a quick snapshot of <u>all</u> the influences on global warming as expressed via the "radiative forcing" or heat-trapping impact of each greenhouse gas, with temperature impacts in centrigrade shown on the vertical axis.)



SOURCE: https://www.skepticalscience.com/methane-and-global-warming.htm

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A strong case for utilizing the 20-year vs. the 100 year Global Warming Potential timeframe to evaluate climate impacts has been made by many scientists and policy analysts who note that, per the warnings of the UN IPCC and other national and international scientific bodies, we are only a few years away from crossing "points of no return" for key climate impacts, notably the irreversible loss of enough ice on Greenland and Antarctica to raise sea levels 40 feet or more. An even more serious tipping point on the immediate horizon is large-scale release of frozen methane trapped in bubbles underneath the arctic ocean and in terrestrial permafrost, which could result in a dramatic "temperature pulse" that would send global warming impacts into a zone of serious danger for human sustainability.

Recent studies estimate that not less than 1,400 gigatons of carbon is presently locked up as methane and methane hydrates under the Arctic ocean and tundra (this nearly double current anthropogenic atmospheric accumulations), and 5-10% of that area is subject to puncturing by unfrozen layers of ground or water within the permafrost that are known as *taliks.* They conclude that "release of up to 50 gigatons of predicted amount of hydrate storage [is] highly possible for abrupt release at any time".[38] A sudden release of methane at this scale from currently destabilizing arctic sources would increase the methane content of the planet's atmosphere by a factor of twelve.[39] In 2008 the United States Department of Energy National Laboratory system identified potential clathrate destabilization in the Arctic as one of the most serious scenarios for abrupt climate change, as noted in a U.S. Climate Change Science Program report in late December 2008 -- which assessed the gravity of the risk of clathrate destabilization, alongside three other credible abrupt climate change scenarios.[40] Scientific consortia such as the Arctic Methane Emergency Group present a significantly more recent (and alarming) view of the data on sudden methane releases than the conservative projections characteristic of the IPCC. These warrant the attention of policymakers and the general public in light of consistent underestimates of warming trajectories in past IPCC reports.[41] Of particular note is the work of the policy advisory group, Climate Code Red, which published in 2015 a new summary of global "climate math" that takes into account numerous natural feedback loops as well as more recent data that were not included in the 2013-14 *Assessment Report 5* (AR 5) of the UN's International Panel on Climate Change (IPCC).[42]

When assessing methane or other GHG impacts, the choice of time horizon should be informed by intelligent consideration of the evidence of the impact of emissions on various time scales. At the Copenhagen meeting of the UN Framework Convention on Climate Change, the importance of the threshold of 1.5 degrees – 2 degrees centigrade of potentially "allowable" global warming

[38]"Arctic Methane Release" in Wikipedia, https://en.wikipedia.org/wiki/Arctic_methane_release
[39]N. Shakhova, I. Semiletov, A. Salyuk, D. Kosmach (2008), Anomalies of methane in the atmosphere over the East Siberian shelf: Is there any sign of methane leakage from shallow shelf hydrates?, EGU General Assembly 2008, *Geophysical Research Abstracts*, 10, EGU2008-A-01526
[40]CCSP, 2008: Abrupt Climate Change. A report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research (Clark, P.U., A.J. Weaver (coordinating lead authors), E. Brook, E.R. Cook, T.L. Delworth, and K. Steffen (chapter lead authors)). U.S. Geological Survey, Reston, VA. See also Susan Q. Stranahan (30 Oct 2008). "Melting Arctic Ocean Raises Threat of 'Methane Time Bomb'". *Yale Environment 360*. Yale School of Forestry and Environmental Studies. May 2009.
[41]See reports of the Arctic Methane Emergency Group at http://ameg.me
[42]See David Spratt, "Recount: It's time to 'Do the Math' Again," Breakthrough, http://www.climatecodered.org/2015/04/its-time-to-do-math-again.html

was formally acknowledged by the world community as the point beyond which runaway climate change will pose unacceptable risks to the human future, radically destabilizing the climate for future generations (in the absence of as-yet unproven strategies for rapid decarbonization and global cooling.) The carbon "budget" for maintaining the climate system below the 1.5 degree to 2 degree C. threshold has been variously estimated at zero (for 1.5 degrees C.) to 565 gigatons (for two degrees C.) of additional anthropogenic carbon emissions beyond current levels -- depending on the risk levels that are considered tolerable for exceeding the upper limit. At present rates (31 gigatons globally during 2011 and rising at a rate of just over 3% annually) this figure will be reached by 2028.[43] ZERO EMISSIONS AFTER 2025

Whether policy makers adopt the 1.5 degrees centrigrade target or the 2 degrees centrigrade target is another judgment call. Thus far, with just over 400 ppm of CO2e in the atmosphere, the average temperature of the planet has been raised approximately 0.8 degrees Celsius, which has caused substantially more damage than most scientists expected just a few years ago. One third of summer sea ice in the Arctic has disappeared, the oceans are 30 percent more acidic, and the atmosphere over the oceans is a five percent wetter, which is producing devastating floods in some parts of the world. Changes in the jet stream due to warmer air and water over the Arctic has created blocking patterns that are believed responsible for much of the persistent drought in the western U.S. and many other areas of the globe – threatening global food security. Given these impacts, many leading scientists believe two degrees is too lenient a target, and that any substantial risk of exceeding 1.5 degrees of total warming must be avoided.

That said, achieving less than a 10% risk of exceeding even the higher 2 degree target, for example, will require near zero new net emissions for industrial economies. Obviously, achieving zero net new emissions would require immediate carbon sequestration efforts (e.g., via increased use of biochar and revised agricultural practice, carbon absorbing algae, and new strategies such as potential use of aerosols at scale to reflect more of the light and heat that will be entering the atmosphere as coal soot is reduced.) This would also require dramatic retooling of energy systems and radical energy efficiencies on the order of the economic re-mobilization in World War II.

Determining a Risk Management Approach to GHG Impacts: In the face of increasingly stark evidence of the deleterious impacts of a runaway climate, combined with the uncertainties that exist around "upper limits" -- policy making in the climate domain has been increasingly framed in risk management terms. Carbon budgets are particularly amenable to risk management analysis. Simply put, the more fossil fuel emissions are allowed in the carbon budget, the higher the risk of exceeding 1.5. - 2°C. The smaller the budget, the lower the risk of failure. As some analysts have pointed out, carbon budget math can also be analogized to human blood alcohol impacts: the more alcohol in the system, the more likely a crash. In the IPCC's most recent assessment, the carbon budget for 2°C is 1420 billion tons of CO2 for a 66% risk of exceeding the target, but 1000 billion tons of CO2 for a 33% risk of exceeding the target.

[43] Bill McKibben, "Global Warming's Terrifying New Math," *Rolling Stone*, July 2012, *http://www.rollingstone.com/politics/news/global-warmings-terrifying-new-math-20120719*

In 2009, the climate activist organization 350.org began utilizing the number of 565 gigatons based on analysis of the 40 climate models used in the IPCC modeling to arrive at a number with an 80% likelihood of success. (Of course, as Bill McKibben noted, that is equivalent to the odds of losing at Russian roulette with a six-shooter – not a very robust risk management approach.)

The reason why a two degree centigrade maximum warming threshold is still considered the goal of the UN framework process has more to do with what is viewed as politically achievable in the context of international (and intra-national) politics rather than what is optimum or technically and economically achievable from an ecosystem risk management perspective. According to the IPCC's most recent reporting, their amalgam of computer models suggest if human-cause emissions stopped entirely now, the temperature would likely still rise another 0.8 degrees C., as previously released carbon continues to overheat the atmosphere (primarily by means of heat trapped in the ocean being transferred back to the air through regular current oscillations). Thus, available data indicates that cumulative carbon emissions have effectively already advanced three-quarters of the way to the two-degree ceiling. Moreover, computer models and various authoritative reports – notably the 2012 *Report for the World Bank* by the Potsdam Institute for Climate Impact Research and Climate Analytics -- predicts that current emissions put us on track for a temperature increase between 4˙ and 6˙C by 2100.[44] Based on a "business as usual" case, the International Energy Agency predicts no change in the current growth in emissions of more than 3% annually between now and 2050.

What are the risks of the current emissions pathway? The most widely cited and authoritative report on this subject is generally regarded as the 2007 Stern Review on the Economics of Climate Change -- a 700-page report released for the British government by economist Sir Nicholas Stern and a team of economists at the Treasury Ministry of the United Kingdom. Stern is chair of the Grantham Research Institute on Climate Change and the Environment at the London School of Economics and also chair of the Centre for Climate Change Economics and Policy (CCCEP). In this report, Stern warned that: "The annual flow of emissions is accelerating, as fast-growing economies invest in high carbon infrastructure and as demand for energy and transport increases around the world. The level of 550ppm CO2e could be reached as early as 2035. At this level there is at least a 77% chance - and perhaps up to a 99% chance, depending on the climate model used - of a global average temperature rise exceeding 2˙C by the end of the century, giving at least a 50% risk of exceeding 5˙C global average temperature change during the following decades. This would take humans into unknown territory."[45] According to the Stern report and other scientific research, the "unknown territory" includes persistent drought, global food insecurity, multi-meter sea level rise requiring evacuation or rebuilding of coastal cities, and a substantial increase in wildfires and extreme weather phenomena including floods and hurricanes. The Stern Review indicates that this level of emissions would cost at least 20% or more of global GDP, whereas (in a 2008 update of the report) it was estimated that the all-out

[44]World Bank Group. 2014. *"Turn Down the Heat: Confronting the New Climate Normal." Washington, DC: World Bank.* *https://openknowledge.worldbank.org/handle/10986/20595*

[45]Bill McKibben, "Global Warming's Terrifying New Math," *Rolling Stone,* July 2012, *http://www.rollingstone.com/politics/news/global-warmings-terrifying-new-math-20120719*

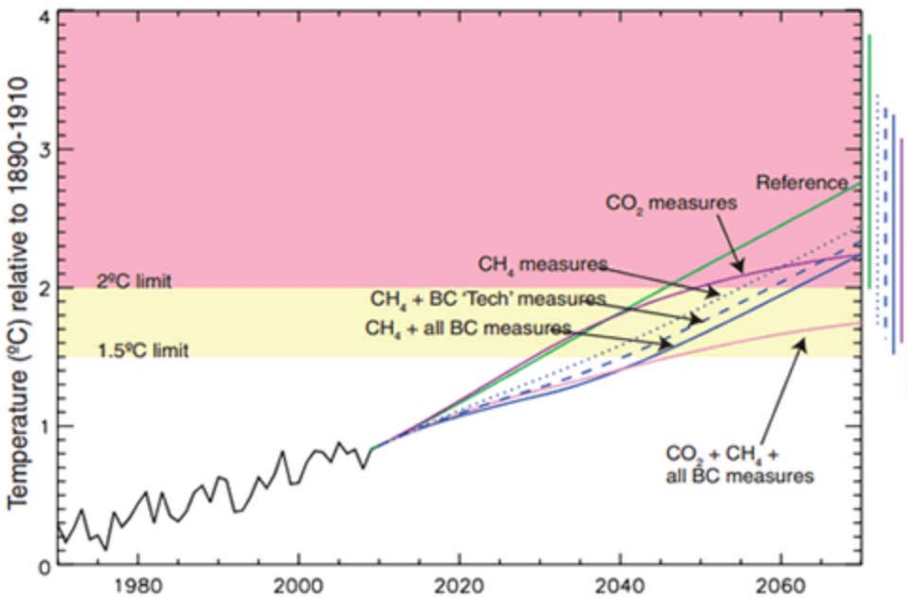
effort needed to prevent runaway climate change would require an investment of 2% of annual global GDP, effective immediately.

To understand the importance of methane, it is necessary to break down the IPCCs "representative concentration pathways" (RCPs) for carbon dioxide vs. methane by time period. While carbon dioxide is expected to be responsible for more than 80% of warming influence in 2100, its short atmospheric lifetime of 12.4 years makes it especially important over the next few decades. NASA's former Chielf Climate Scientist, James Hansen noted in a 2007 paper:

Non-CO2 climate forcings are important, despite the fact that CO2 is the largest human-made climate forcing. Indeed, expected difficulties in slowing the growth rate of CO2 and eventually stabilizing atmospheric CO2 amount make the non-CO2 forcings all the more important. It now appears that only if reduction of the non-CO2 forcings is achieved, and CO2 growth is slowed, will it be possible to keep global temperature within or near the range of the warmest interglacial periods. The most important 'non-CO2 forcings' for short term climate influence are methane and black carbon (fine particulate carbon). Despite the fact they aren't nearly as important as carbon dioxide in the long run their mitigation holds significant short term potential as well as promise of health and agricultural benefits.[46]

In a 2012 study on mitigation pathways entitled *Simultaneously Mitigating Near-Term Climate Change and Improving Human Health and Food Security* mitigation strategies addressing carbon and methane could potentially slow warming over the coming decades, when combined with CO2 mitigation approaches as noted in the graph below, which correlates emissions with their global warming potential over relevant near-term timescales.

Short Term Potential of Methane and Black Carbon Mitigation



Source: Simultaneously Mitigating Near-Term Climate Change and Improving Human Health and Food Security. Schindel et al 2012

Given that methane resides in the atmosphere for 12.4 years, and these years are in the crucial timeframe needed to limit global climatic tipping points, reducing methane emissions can have disproportionate climate change benefits in the near term. Moreover, of all the short-lived climate forcers, methane has a large reduction potential and cost-effective mitigation technologies are available. On this basis, many climate policy strategists are beginning to focus on methane, black carbon, and other highest-global warming potential GHGs to produce the greatest CO2 *equivalent* reductions possible in the near-term (based on a 20 year or shorter GWP timeframe.) This strategy requires suggests a dual strategy of reducing reliance on natural gas as a primary energy and transportation feedstock where cleaner alternatives are available; and utilizing all available technologies to minimize existing methane leakage from the petroleum, natural gas, and coal supply chains, and from agricultural, livestock, and landfill sources. U.S. leadership on these measures would also have potential to advance ongoing global negotiations on methane mitigation, which is particularly important and urgently needed in the fossil fuel production and municipal waste sectors in China, Russia and Central Africa.[47]

Recommendations re. Global Warming Potential Timeframes for Policy Analysis of Natural Gas: In summary, given the imminent crossing of key climatic tipping points, and the potential of methane-related policies to either exacerbate or mitigate global warming, it is recommended that policy makers and other stakeholders utilize the 20-year Global Warming

[47] "Methane Emissions in Context," from *Shrink That Footprint,* accessed July 2015, **http://shrinkthatfootprint.com/methane-emissions-in-context.**

Potential timeframe for assessing the potential shift to natural gas from other fuel sources.[48]

A-2. Assessing Natural Gas vs. Diesel Emissions: Given the importance of the methane leakage issue in establishing the true global warming impact of natural gas, for the purposes of the UC Davis report and other similar analyses, scientists and policy makers use an estimate of the *breakeven leakage rate* (BLR) for particular fuel applications. This is defined as "the maximum acceptable upstream methane leakage rate at which the combined warming effects of CH4 (methane) and CO2 from natural gas balance out the combined effects of CO2 and CH4 of the fuels it substitutes."[49] To provide policy-makers with a more nuanced understanding of the issue, the UC Davis report provides access to the full model and its sensitivities and uncertainties, rather than establishing a single distinct determinant of the appropriate leakage rate, which will be the province of EPA and CARB, based on analysis that is still ongoing as of early 2016 and will remain the subject of continuous refinement for some time to come. However, by referencing the authoritative meta-analysis of leakage rates performed to date, it is possible to suggest a conservative approach to policy-makers to help guide near-term planning, and to inform stakeholder input to the policy process.

As noted above, the UC Davis analysis utilizes the 2014 version of Argonne's GREET1 model to calculate the warming impact of natural gas in various transportation applications. The key unit in the analysis is the carbon intensity (CI) of natural gas defined as grams of CO2 equivalent emitted per mile driven (gCO2e/mi). The GREET 1 model uses the latest IPCC figures for the 20-year Global Warming Potential of methane (86 – meaning that methane is 86 times more potent per gram than CO2 over a 20 year timeframe), while it uses the 100 year GWP figure of 30. (Note that if expected carbon cycle feedbacks are included in this calculation, the 100 year GWP increases to 34). To review the GWP "math" -- in the twenty year timeframe, one gram of methane emitted today would have created the equivalent warming of 86 grams of CO2 emitted today but in 100 years it will have the effect of only 30 grams of CO2 emitted today.

The UC Davis researchers note that their calculations using the national GREET-1 standard differs from the CA-GREET standard used to assess fuel carbon intensity due to the choice of the functional unit used for the analysis. The CARB analysis using CA-GREET to assess fuels for the LCFS is targeted to fuel producers – and thus the LCFS lookup tables show the carbon intensities of fuels expressed as grams of carbon dioxide equivalent per Mega Joule (gCO2e/MJ) of energy. In the UC Davis study and in the GREET-1 model, the carbon intensity of NGVs is expressed as grams of carbon dioxide equivalents per mile driven (gCO2e/ mile) -- thus incorporating relative vehicle efficiencies in the metric. According to the study authors when the LCFS values are translated to gCO2e/mile, the CA-GREET values are close to the values presented in the UC Davis study.[50]

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[48] To be consistent, of course, the role of methane leakage in the petroleum fuel supply chain, as well as in electricity feedstocks, needs to be computed in the same manner as in the case of natural gas as such. It is anticipated that CARB's upcoming update of the California GREET fuel model will provide the basis for such an apples-to-apples comparison using the new methane leakage rate data, as well as the most recent IPCC GWP multipliers.

[49] Rosa Dominguez-Faus, Ph.D., "The Carbon Intensity of NGV C8 Trucks," UC Institute for Transportation Studies, March 2015, p. 6.

[50] Rosa Dominguez-Faus, Ph.D., "The Carbon Intensity of NGV C8 Trucks," UC Institute for Transportation Studies, March 2015, p. 20.

A-3. The Role of Methane Leakage in the Determination of Natural Gas Climate Impacts: New research into methane leakage rates is taking place at multiple levels of government, research universities, and in the private and NGO sector. However, this research will not likely result in a fixed methane leakage rate that will persist for years at the same level – as there are also ongoing efforts to identify and mitigate fugitive methane emissions and thus reduce the methane leakage rate over time. Some of these efforts are coordinated on a cross-sector basis by the Environmental Defense Fund, which has linked universities, natural gas producers, and utilities to collaboratively assess the extent of methane leakages throughout the natural gas supply chain. [51] Studies on the new baseline are beginning to be released in 2015 and will inform future carbon intensity values identified for the LCFS. In addition, new initiatives to mitigate the leakage rate – including the EPA's voluntary Natural Gas Star Producer program -- are being upgraded as new (mandatory) regulations are in the development phase by the EPA. Given that it may be a considerable period of time before methodological issues about methane leakage rates are fully resolved, local policy makers need to be generally aware of methane assessment issues and options, as this information is vital to inform local transportation and energy policy choices.

According to the EPA's 2014 Greenhouse Gas Inventory, the natural gas system leaked about 1.12% system-wide as a national average -- from which 0.2% results from pre-production (i.e., drilling and fracking), 0.4% result from production, 0.2% from processing of gas, and 0.7% from transmission and distribution.[52] By contrast, an authoritative meta-analysis of 20 years of scientific literature, published in 2014 in the peer-reviewed journal *Science* by Brandt et al., concludes the actual leakage rate is most likely between 1.85 - 2.95%.[53] Reasons for the substantial discrepancy between the 2014 EPA inventory and other non-EPA inventories include the following:

- EPA has excluded leaks from the three million abandoned oil and gas wells in the United States. Further, the inventory of abandoned wells is growing rapidly due to the fracking boom, in which fracking operators are drilling increasing numbers of wells per unit of gas extracted due to the fact that the most productive locations are typically drilled first.[54]
- EPA includes in its dataset only companies participating in the voluntary GasSTAR best practice production program. An analysis by Environmental Defense Fund demonstrated that this exclusion is skewing data because a small number of "bad operators" who do not participate in this program are responsible for a large share of

[51] Environmental Defense Fund, "What Will It Take to Get Sustained Benefits From Natural Gas?" http://www.edf.org/methaneleakage.
[52] Rosa Dominguez-Faus, Ph.D., "The Carbon Intensity of NGV C8 Trucks," UC Institute for Transportation Studies, March 2015, p. 9.
[53] Brandt AR et al. (2014) "Methane Leaks from North American Natural Gas Systems." *Science* 343.
[54] Most importantly, an accurate assessment of the impact of abandoned wells will encourage appropriate regulation to reduce their emissions and preserve the integrity of natural gas as a "cleaner fuel" than coal, for example, as it pertains to electric generation or other applications. A recent analysis by the World Resources Institute suggests that 40-60% of leaks can be preventable profitably with current technology, which could help bring the leakage rate back down to the level currently reported by EPA. However, a relatively elaborate regulatory and inspection regime would be needed to achieve this result, with uniform deployment across states that now regulate natural gas in a very uneven pattern. For more discussion of this issue, see the ICF report, "Economic Analysis of Methane Emission Reduction Opportunities in the U.S. Onshore Oil and Natural Gas Industries." March 2014. http://www.edf.org/sites/default/files/methane_cost_curve_report.pdf

methane leaks. [55]

- Both the EPA and the meta-analysis in *Science* exclude leaks from refueling stations or vehicles, which are certain to be non-zero.

In light of the factors identified above, policy-makers favoring a precautionary approach would likely choose the higher value of ~3% as an appropriate "breakeven leakage rate" at which natural gas powered vehicles are environmentally preferable to diesel. Of course, any such well-to-wheels calculation performed at a fleet level (where specific vehicle and fuel types are known) also needs to take into account the differential emissions rates of different diesel engines as well as any known variation in the fuel supply change, such as potential utilization of biogas.

A-4. The Emissions Profile of Emerging Natural Gas Engine Technologies: As is the case with all vehicle technologies, natural gas engine development is in a highly dynamic state. To summarize, there are three important technologies to consider when assessing cleaner diesel technologies: compression ignition (Ci) engines, spark ignition (Si) engines, and High-Performance Diesel Ignition (HPDI) engines. As the names indicate, spark-ignition engines are internal combustion engines in which the combustion process of the air-fuel mixture is ignited by a spark from a spark plug. In compression-ignition engines, the heat generated from compression together with the injection of fuel is sufficient to initiate the combustion process, without needing any external spark. The High Performance Diesel Ignition technology combines a diesel ignition stage with a natural gas engine, utilizing the same diesel thermodynamic cycle used by diesel fuel. Spark ignition engines are currently standard in the industry. However, both Compression Ignition and High Performance Diesel Ignition engines are in advanced development and are expected to deliver significant efficiency improvements. According to the UC Davis study on NGV truck emissions, these technologies produce the following efficiencies and emissions.

- **Spark ignition (Si) engines** can run on LNG or CNG. Based on the 100 year global warming timeframe (which understates near-term impacts), and a scenario of 3% methane leakage, an Si engine would produce 13% more carbon emissions than diesel when running on LNG, and 23% more when running on CNG.

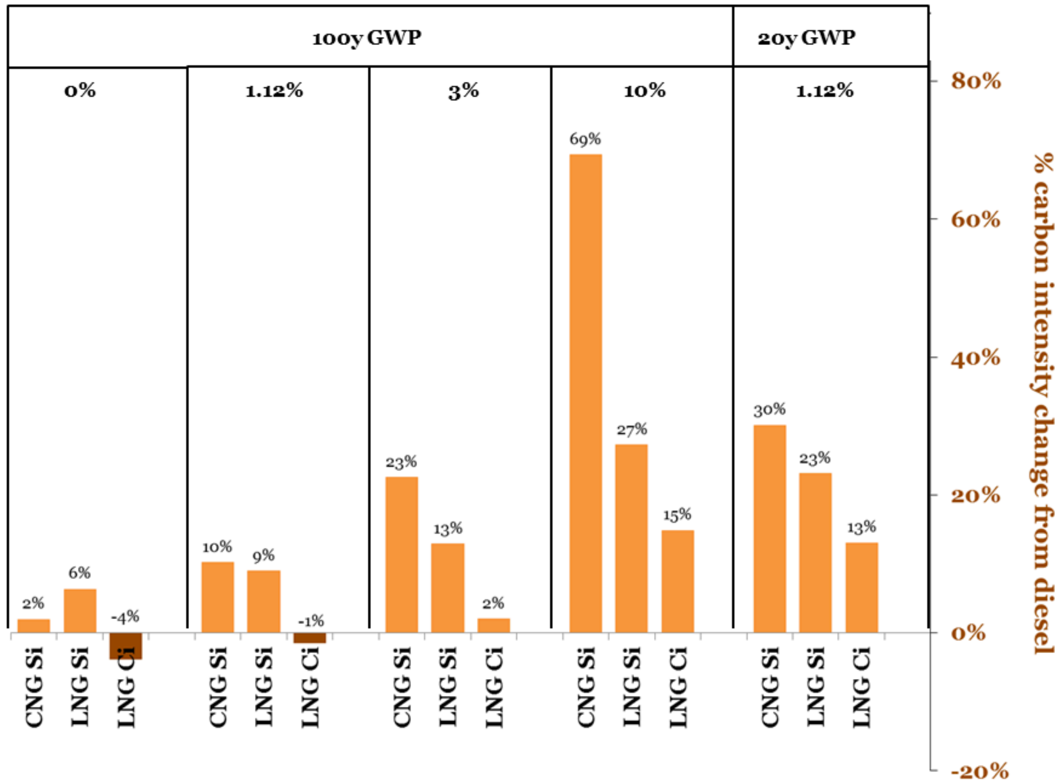
- **Compression ignition (Ci) engines** are about 10-15% more efficient than **Spark ignition (Si)** engines. However, the Ci models at this time are more expensive -- and production by a joint venture between Cummins and Westport is currently suspended due to lack of customer interest and the high cost to officially certify environmental compliance. It is anticipated that compression ignition engine production will restart in coming years, particularly if the price differential between natural gas and diesel fuel increases.

[55] Environmental Defense Fund, *Harnessing the Potential of Natural Gas: Addressing Methane Emissions,* http://csis.org/multimedia/video-harnessing-potential-natural-gas-addressing-methane-emissions

- **High efficiency HPDI** or ***High Performance Diesel Ignition****:* This technology is currently being developed by Westport in collaboration with Cummins and the Chinese engine supplier Weichai. The technology is being developed primarily for deployment in Class 8 (C8) natural gas trucks and can run on CNG or LNG, although fuel economy and emission performance will be superior on LNG. With the 100 year timeframe and 3% leakage scenario, an HPDI natural gas engine would produce 2% *more* carbon emissions than a diesel truck. HPDI environmental performance on key criteria pollutants, including Particulate Matter (PM), is also superior to both spark ignition and compression ignition technologies. According to Westport, the HPDI Diesel cycle is inherently more efficient than the so-called Otto thermodynamic cycle used by spark ignited (SI) gasoline and natural gas engines. in SI gasoline and natural gas engines, air and fuel are pre-mixed before entering the combustion chamber, which can cause engine knock to occur unless a lower compression ratio is used, resulting in lower energy efficiency and higher emissions. To enhance efficiency and emissions performance, the Westport HPDI uses natural gas as the primary fuel along with a small amount of diesel as an ignition source. The two fuels are not pre-mixed with the intake air before they enter the combustion chamber -- so there is no risk of engine knock and therefore no need to lower the compression ratio and peak torque output. Compared to diesel fuel, this directly injected natural gas burns with a lower adiabatic flame temperature and has a low propensity to the formation of carbon particles and therefore offers inherent nitrous oxide (NOx) and particulate matter (PM) emissions benefits.[56]

A-5. Summary of Diesel vs. Natural Gas Carbon Emissions Using the 100 Year Global Warming Timeframe and the 3% Leakage Rate: The UC Davis report provides policy makers with a range of analyses of diesel vs. natural gas engines, using both the 100 year and 20 year global warming timeframe. However, the UC Davis analysis (without explanation) *excludes* the combination of a 3% leakage rate and a 20 year GWP timeframe. This is unfortunate, given that this is a reasonable "precautionary" analytic framework and consistent with evolving science now being integrated into both the IPCC climate forecasting and EPA natural gas regulatory processes. However, it is noteworthy that when applying **either** the less conservative 100 year timeframe in combination with the more conservative 3% leakage rate **or** the more 20 year GWP timeframe and the EPA's current 1.12% leakage rate, ***natural gas trucks become clearly disadvantageous with respect to diesel trucks relative to carbon emissions alone*** (panel 5 below). Of course, natural gas vehicles **do** have important local emissions benefits relative to criteria pollutants, notable the Particulate Matter that is especially significant in terms of public health impacts for children, the elderly, and those with respiratory challenges. The various columns below show the impact of leakage rates varying from 0% to 10% using the 100 year GWP framework, and show the results in a 20 year GWP analysis using just the 1.12% leakage rate factor.

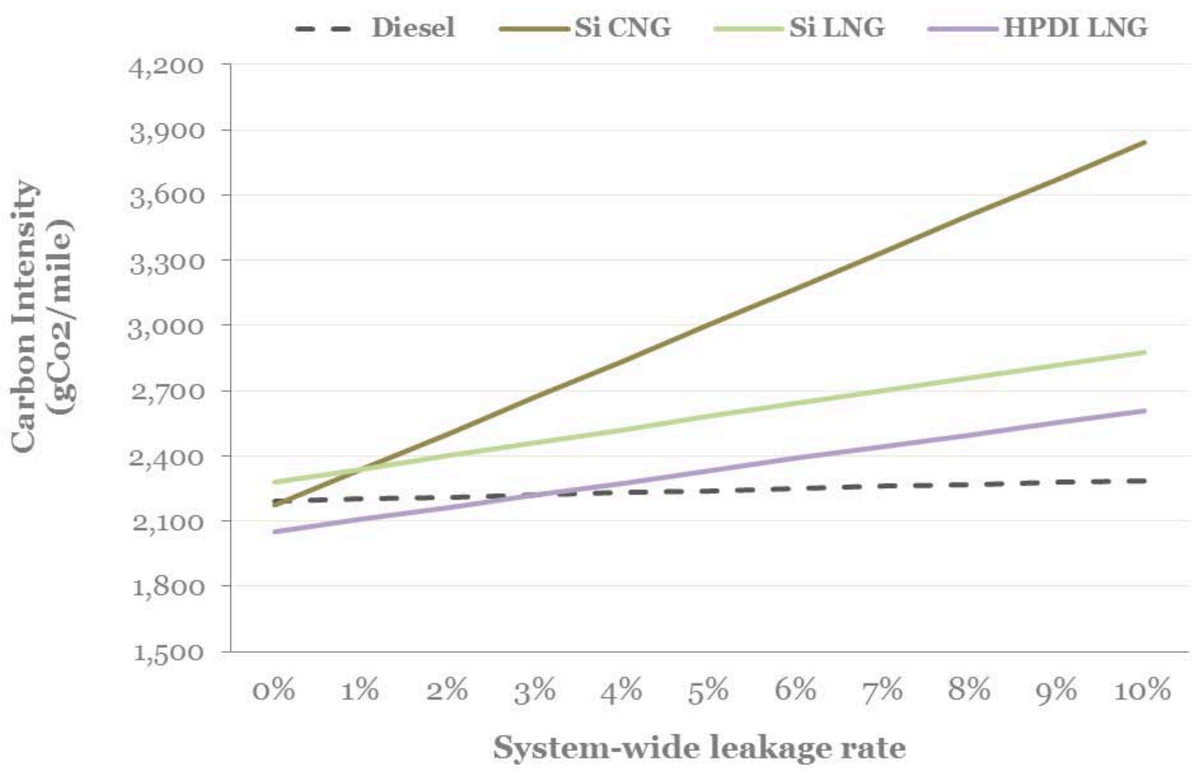
[56]For more information, see the Westport website at http://www.westport.com/is/core-technologies/hpdi-2



Source: "The Carbon Intensity of NGV C8 Trucks," UC Institute for Transportation Studies, March 2015, p. 14.
Acronyms: Si = Spark ignition; Ci = Compression Ignition.

In their summary, UC Davis researchers conclude that natural gas can achieve lower carbon intensity than diesel under current leakage assumptions of 1.12% only if a 100 year Global Warming Potential timeframe is assumed – and only through the use of the high efficiency engines such as the HPDI (which is not yet currently available) but not with less efficient Si engines. However, the leakage rate of 3% or higher (as suggested by the recent meta-analysis published in *Science)* would make all types of current natural gas engines undesirable, even with the 100 year GWP. Using the 20 year GWP, natural gas is even more problematic. In the event that a 0% leakage rate is achieved across the entire natural gas fuel supply chain, then trucks utilizing LNG fuel and compression ignition technology would yield a 4% advantage over the diesel baseline under the 100 year assessment. However, it may not be technically or economically feasible to achieve a 0% leakage rate given the economic, technical, and legal challenges of locating, sealing, and maintaining the more than three million abandoned wells.

Establishing a "Breakeven Point" for Natural Gas Vehicle Emissions Under Varying Methane Leakage Rates and Engine Technologies: It should be emphasized that nothing in the natural gas vehicle ecosystem is static – methane leakage rates at various points on the production and supply chain will almost certainly change, vehicle engine efficiencies will change, and the emissions profile of diesel and other alternative fuels will change. To serve the analytic process under these dynamic conditions, UC Davis researchers provide a chart showing the effect of greater or lesser methane leakage across the fuel supply chain. This analysis pinpoints the "maximum acceptable" upstream methane leakage rate at which the combined warming effects of methane and CO2 from natural gas as a transport fuel are equal to the combined effects of CO2 and methane of the fuels it substitutes, in this case, diesel. In the 100 year time frame considered here, leakage rate below 2.8% justify a switch to natural gas powered heavy-duty trucks only if they use HPDI technology and LNG storage. The feedstock pathway of LNG produces lower emissions and lower sensitivity to leakage as it bypasses the local natural gas pipeline distribution system.



Source: "The Carbon Intensity of NGV C8 Trucks," UC Institute for Transportation Studies, March 2015, p. 16.

A-6. Prospects for Methane Leakage Reduction to Lower Natural Gas Carbon Intensity: According to the UC Davis analysis, natural gas can achieve lower carbon intensity than diesel under current leakage assumptions of 1.12% with a 100 year GWP through the use of the high efficiency engines such as the HPDI but not with less efficient Si engines. When using HPDI engines, natural gas will be beneficial as long as leakage rate remains under 3% (though not with the 20 year GWP timeframe.) Until HPDI technology can be widely adopted, natural gas production and distribution methane leakage must be completely eliminated for today's fleet of Si NGV trucks to have lower carbon intensity than standard diesel trucks. A variety of technologies with short payback periods could achieve significant reductions at different stages of the natural gas supply chain, as demonstrated under the EPA Natural Gas STAR program. However, until all operators are required to implement best available technology to reduce methane leakage, the theoretical opportunity for improvements are not likely to be realized. Further, the leakage associated with abandoned wells may require a kind of Superfund program for methane, which has yet to be developed. In light of the above factors, local policy makers are advised to maintain a close watch on developments in the methane leakage issue, and to seek out authoritative, peer-reviewed, and independent analyses to supplement state and federal data sources.

Appendix 2: Information Resources on EV Issues

The resources in this section provide additional information about Electric Vehicles for fleet and consumer use, charging infrastructure, sales trends, and policies.

- **DriveClean:** A guide for zero and near-zero emission vehicles from the California Air Resources Board. http://www.driveclean.ca.gov
- **California PEV Collaborative**: Statewide official resource for California PEV readiness. http://www.evcollaborative.org/
- **Community Environmental Council**: Provides leadership for greater Santa Barbara and Central Coast EV advocacy, renewable energy, and environmental sustainability. http://www.cecsb.org/index.php
- **Clean Cities Coalition of the Central Coast**: Provides leadership for electric and alternative fuel vehicles for fleet managers and other stakeholders throughout the Central Coast. http://www.c-5.org/
- **San Luis Obispo County Air Pollution Control District**: Provides leadership on clean air issues for San Luis Obispo County and on the Plug-in Central Coast Steering Committee http://www.slocleanair.org/index
- **Santa Barbara County Air Pollution Control District:** Provides leadership on clean air issues for Santa Barbara County and on the Plug-in Central Coast Steering Committee http://www.sbcapcd.org/
- **Ventura County Air Pollution Control District:** Provides leadership on clean air issues for Ventura County and on the Plug-in Central Coast Steering Committee http://www.vcapcd.org/
- **Santa Barbara EV Association:** The regional chapter of the Electric Auto Association (EAA) provides advocacy and information on EV issues. http://sbeva.org/ls/
- **Recargo** : Provides charging station maps, links to points of interest near charging stations, and EV community communication and social media tools. http://www.recargo.com/
- **Plug-Share**: Provides charging station maps, and access to residential EV charging stations on a peer-to-peer basis, along with smartphone apps for EV charging, trip planning, and energy management. http://www.plugshare.com/
- **Best Practices in regional and state EV programs:** The Hawaii EV program website offers reports and case studies on Hawaii's aggressive EV transition programs. http://energy.hawaii.gov/programs/transportation-on-the-move/ev-ready-program

- **Department of Energy (DOE): Alternative Fuels & Advanced Vehicle Data Center**: Provides information on EV and alternative fuel vehicles and petroleum reduction strategies.
- **Department of Energy resources**: The Department of Energy provides the following resources at: http://www.afdc.energy.gov/fuels/electricity.html
    - Hybrid and Plug-In Electric Vehicles fact sheet
    - Plug-In Electric Vehicle Handbook for **Consumers**
    - Plug-In Electric Vehicle Handbook for **Electrical Contractors**
    - Plug-In Electric Vehicle Handbook for **Fleet Managers**
    - Plug-In Electric Vehicle Handbook for **Public Charging Station Hosts**
- **Plugging In – A Consumer's Guide to the Electric Vehicle** - From the Electric Power Research Institute (EPRI). http://www.epri.com/search/Pages/results.aspx?k=Plugging%20In:%20A%20Consumer's%20Guide%20to%20the%20Electric%20Vehicle
- **Plug-in America** - A non-profit coalition of electric car owners and advocates. This site includes compendiums of **information on current electric car models and charging equipment**. http://www.pluginamerica.org
- ***Ready, Set, Charge California! - A Guide to EV Ready Communities*** – provides detailed information on community EV readiness: http://www.baclimate.org/impact/evguidelines.html

- **U.S. DOE Clean Cities EV fleet handbook** http://www.afdc.energy.gov/pdfs/pev_handbook.pdf

- **U.S. DOE Clean Cities EV and Alternative Fuel Vehicle (AFV) fleet case studies** http://www.afdc.energy.gov/case/

- **American Public Works Association (APWA) fleet resources** http://classic.apwa.net/ResourceCenter/index.asp?Section=equipment&SectionName=Equipment+%26+Fleet+Management

- **California Energy Commission (CEC) links to funding for EVs and EV infrastructure**: http://www.energy.ca.gov/drive/projects/electric.html

- **Methods for Estimating EV Deployment in the Region: Online Tool Tracks Electric Vehicle Purchases:** The California Center for Sustainable Energy (CCSE) released an online tool that shows details of **EV purchasing trends** based on rebates awarded by the statewide Clean Vehicle Rebate Project (CVRP). This is currently the most comprehensive single tool for estimating PEV deployment in the region, as it includes zip code level tracking. However, the tool does not take into account legacy EVs from the 1990's (such as the original Toyota RAV.) It also does not take into account the initial portion of 2012 model year Chevrolet Volts, which were not eligible for the state clean vehicle sticker. Subsequent Volts are included. It should be noted that as many as 25% of EV drivers may not take the state rebate. Therefore, CVRP data may undercount actual EV deployment.

Sample Checklist for Workplace Charging: Establishing a workplace charging initiative can be a straightforward process for most organizations. It requires an executive to put together a team of key stakeholders to assess options and decide key issues. The following checklist references the major steps and components of the process.

1. **Determine employer/employee interest** in an EV charging program, including strategic drivers and potential for short-term and long-term utilization.
2. **Assess the concerns of property owners** and landlords.
3. **Have a certified electrician evaluate the power infrastructure** and upgrade options.
4. **Confirm utility rates, local permit requirements and operating revenue and expense**.
5. **Determine site plans** for EVSE infrastructure design.
6. **Select appropriate EVSE vendors** and equipment.
7. **Develop internal policies and programs** for EV drivers.
8. **Build-out site infrastructure**, including permits, power, charger installation, and signage.
9. **Turn on charging infrastructure and orient users** to charging policies and procedures.