A California Road Map

The Commercialization of Hydrogen Fuel Cell Vehicles

2014 Update: Hydrogen Progress, Priorities and Opportunities (HyPPO) Report

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Introduction

In June 2012, the California Fuel Cell Partnership published *A California Road Map: The Commercialization of Hydrogen Fuel Cell Electric Vehicles*.[1] This collaborative and collective work established the framework for the pragmatic steps necessary to bring fuel cell electric vehicles (FCEVs) to market. With multiple automakers introducing retail market vehicles beginning in 2014, building on the concepts laid out in the *Road Map* is essential for success.

The *Road Map* characterizes the needs of the market for customers and fuel providers during pre-commercial (2012-2014) and early commercialization (2015-2017) phases, and defines how to place stations where early adopters live, work and travel. The *Road Map* complements Governor Jerry Brown's March 2012 executive order that directed California state agencies to support and facilitate the commercialization of zero-emission vehicles (ZEVs).[2] The subsequent 2013 *ZEV Action Plan* provided specific guidance on the necessary steps to bring FCEVs to market.[3]

The *Road Map* prescribes a minimum network of hydrogen stations to establish the foundation for commercial FCEV volumes and broad consumer adoption. Situated in five early adopter areas, or clusters, in Southern California and the San Francisco Bay Area, stations are complemented with connector and destination stations that serve as the nuclei for subsequent markets. The *Road Map* also takes a critical view of the resources necessary to establish this network, providing a careful analysis of potential business models. Thereafter, the market transitions from a coverage-based approach to a capacity-based approach.[4]

The *Road Map* used the best available information to establish the foundation for early market success—the underlying data, assumptions, and analyses reflected the then-current landscape. This *Hydrogen Progress, Priorities and Opportunities* (HyPPO) report seeks to build on those assumptions and analyses by updating relevant information and offering new perspective where the landscape has changed. HyPPO builds on the *Road Map* ideas by exploring the significant, tangible progress that has been made by CaFCP members and other stakeholders while defining the priorities required for successful early commercialization. Despite new data, information and perspective, the *Road Map* concepts remain relevant and evident throughout this document.

Advancing Toward Fuel Cell Electric Vehicle Commercialization at a State and National Level

The passage of Assembly Bill 8 (Perea, 2013) was a pivotal step in 2013. By re-authorizing multiple statewide programs, including the Air Resources Board's (ARB) Air Quality Incentive Program (AQIP) and the Energy Commission's Alternative and Renewable Fuel & Vehicle Technology Program (ARFVTP), California renewed its commitment to invest in the development and deployment of advanced technologies through 2023. AB 8 establishes the programmatic foundation and the necessary funding to achieve California's air quality, climate and energy goals.

With respect to FCEVs, AB 8 addresses the hydrogen station network where the *Road Map* left off—funding the initial network of stations. The bill includes a provision to fund at least 100 hydrogen stations with a commitment of up to $20 million a year through the Energy Commission's ARFVTP. The bill establishes an unprecedented collaboration between the Energy Commission, the ARB and industry to coordinate during early commercialization to conscientiously plan the network and to ensure the network meets early consumer needs. In parallel to the bill's passage, three automakers announced plans to bring FCEVs to market in 2014 and 2015 while other automakers established FCEV technology collaborations.

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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*

[4] Since the publication of the *Road Map* in 2012, legislation (Assembly Bill 8, Perea, 2013) was developed and adopted to foster an incentive-based approach for hydrogen infrastructure development. While ultimately suspended by AB 8 through the duration of the legislative programs, the California Air Resources Board's Clean Fuels Outlet would have required major producers/importers of gasoline to ensure sufficient hydrogen fueling capacity once projected vehicle volumes reached specific thresholds. This was an important concept in the *Road Map* to ensure a transition toward long-term hydrogen infrastructure development. *http://www.arb.ca.gov/fuels/altfuels/cf-outlets/cf-outlets.htm*

California also recognized the need to establish a coordinated approach to the ZEV market across state agencies. While the Governor's executive order established specific milestones for reaching 1.5 million ZEVs in California by 2025, it also called for state agencies to work together and with industry groups to establish incremental benchmarks. In February 2013, the State published the *ZEV Action Plan*. The California Fuel Cell Partnership (CaFCP) and its members offered extensive input on the 100+ actions and strategies.

At the national level, the U.S. Department of Energy (DOE), automakers, hydrogen producers and allied organizations launched H_2USA in March 2013, a public-private partnership focused on advancing hydrogen infrastructure.[5] H_2USA brings together hydrogen and fuel cell industries, as well as automakers, government agencies and gas suppliers to advance the development of hydrogen infrastructure across the United States. The partners, which include CaFCP and the State of California, are identifying actions that will encourage early adoption of fuel cell electric vehicles, conducting coordinated technical and market analysis, and evaluating hydrogen fueling infrastructure that can enable cost reductions and economies of scale.

Fuel cell electric vehicles and hydrogen were highlighted at a national level with the National Research Council's (NRC) release of *Transitions to Alternative Vehicles and Fuels*.[6] NRC assessed the potential of the light-duty fleet to reduce petroleum consumption and greenhouse gas emissions by 80 percent by 2050, and indicated that the market potential for fuel cell electric vehicles ranked very high (highest) among the various options. The report emphasized the crucial role of hydrogen infrastructure availability in achieving market success.

Against the backdrop of these national stakeholder actions, California continues to be the focus of FCEV deployments with hundreds of fuel cell electric passenger vehicles and buses on the road and current infrastructure investments totaling more than $91 million since 2009.[7] Alongside these government incentives and complementary policies, stakeholders remain keenly aware of the need to establish market-based solutions.

The *Road Map* captures key attributes of FCEVs and technology advantages for many vehicle market segments. Using a domestically produced fuel that can be generated from natural gas and renewable resources, FCEVs can provide significant environmental benefits. FCEVs combine the convenience and utility of conventional gasoline vehicles, including large size, 300+ mile range and quick refill times, with the performance and zero emissions of electric vehicles. These FCEV attributes are also recognized in the *Vision for Clean Air*, an examination by several air quality agencies to integrate zero and near-zero emission technologies into the broader policy framework.[8]

Progress Toward Commercialization

The *Road Map* concepts relied on data analyses that carefully balanced vehicle and station deployments, ensuring the initial station network supports early commercialization. Early commercialization is about building and maintaining an initial station network, clearly communicating FCEV market launch plans, and building hydrogen station owner commitment and consumer confidence. Achieving these goals over the next 3-5 years will ensure a successful market launch, and result in a growing customer base and clear business opportunities for station operators.

The foundation of the *Road Map's* market assessment included FCEV projections, station deployments and associated capacity, and a timetable to establish the minimum number of stations to launch the early commercial vehicle market. The coverage principle, which "improves the consumer experience, ensures confidence in the technology, increases vehicle utility and enables broad market participation," remains the dominant strategy during early market launch. CaFCP members believe that routinely updating these market projections to support ongoing decision-making is a vital planning exercise.[9]

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[5] Energy Department Launches Public-Private Partnership to Deploy Hydrogen Infrastructure, May 13, 2013
http://energy.gov/articles/energy-department-launches-public-private-partnership-deploy-hydrogen-infrastructure

[6] National Research Council. *Transitions to Alternative Vehicles and Fuels*. Washington, DC: The National Academies Press, 2013 *http://www.nap.edu/openbook.php?record_id=18264*

[7] Jim McKinney presentation (27 Feb 2014) at National Fuel Cell Symposium noted $43.3 million allocated between 2009-2013. In March 2014, the Energy Commission announced a $1.2 million NOPA for operation and maintenance and in May 2014, the Energy Commission announced a $46.6 million NOPA for hydrogen refueling infrastructure.
http://www.energy.ca.gov/contracts/PON-13-607_NOPA.pdf, http://www.energy.ca.gov/contracts/PON-13-607_NOPA_Operation_and_Maintenance.pdf

[8] *Vision for Clean Air: A Framework for Air Quality and Climate Planning,* Air Resource Board, South Coast Air Quality Management District, San Joaquin Valley Air Pollution Control District, public draft, June 2012 *http://www.arb.ca.gov/planning/vision/docs/vision_for_clean_air_public_review_draft.pdf*

[9] *A California Road Map: The Commercialization of Hydrogen Fuel Cell Vehicles, June 2012*, page 7
http://cafcp.org/sites/files/A%20California%20Road%20Map%20June%202012%20%28CaFCP%20technical%20version%29_1.pdf

Automaker Announcements and Technology Developments

The *Road Map* offered the insight that many automakers anticipated FCEV commercialization in the 2015-2017 timeframe. Using the best available assumptions and projections for the number of operational hydrogen stations, it provided the automakers' collective assessment of the potential magnitude of initial FCEV sales during these years.[10] Since the *Road Map* was published, automakers have announced updated deployment plans and technology collaborations, and ARB published the first annual AB 8 report that included automaker FCEV survey results. To offer perspective on the commercialization announcements below, the survey results highlight statewide FCEV projections of 6,650 vehicles in 2017 and 18,465 vehicles in 2020.[11] The automaker surveys are explored in more detail in the Synchronizing Vehicle Market Deployment section of this report.

Three automakers have announced plans to bring FCEVs to market in 2014 and 2015.
Several CaFCP automotive members made major announcements about availability of their fuel cell electric vehicles, reaffirming that commercialization of FCEVs will begin in 2014-2015.

- Honda, in November 2013, introduced a sleek and aerodynamic, five-passenger Honda FCEV concept for their next generation fuel cell electric vehicle anticipated to launch in the US and Japan in 2015.[12]

- Toyota, in January 2014, opened the Consumer Electronics Show in Las Vegas with a mid-size sedan FCEV concept and, in June 2014, unveiled the production exterior in Japan. Toyota plans a 2015 launch date with an initial focus on California.[13]

- Hyundai, in June 2014, became the first manufacturer to offer a mass-produced FCEV in the U.S. market. The next-generation Tucson Fuel Cell CUV is now available at several Southern California dealers.[14]

[10] Ibid. See Table 5 on pages 17-19
[11] *Annual Evaluation of Fuel Cell Electric Vehicle Deployment and Hydrogen Fuel Station Network Development*, Air Resources Board, June 2014 *http://www.arb.ca.gov/msprog/zevprog/ab8/ab8_report_final_june2014.pdf*
[12] Honda FCEV Concept Makes World Debut at Los Angeles International Auto Show, November 20, 201. *http://world.honda.com/news/2013/4131120FCEV-Concept-Los-Angeles-Auto-Show/index.html*
[13] Toyota 'Car of the Future' On Sale Next Year; Opens 2014 Consumer Electronics Show (CES), January 6, 201. *http://toyotanews.pressroom.toyota.com/releases/toyota+car+of+the+future+opens+2014+ces.htm*; Toyota reveals exterior, Japan pricing of 2015 fuel cell vehicle, Los Angeles Times, June 26, 2014. *http://www.latimes.com/business/autos/la-fi-hy-autos-toyota-fuel-cell-price-20140625-story.html*
[14] Hyundai Proudly Hands Key To First Fuel Cell Customer at Tustin Hyundai. *http://www.hyundainews.com/us/en-us/Media/PressRelease.aspx?mediaid=40904*

Several automakers have announced collaborations on FCEV technology.
To further support the development of FCEV technology, automakers formed collaborations and partnerships to share technological expertise, leverage economies of scale, establish common-sourcing strategies and address challenges such as supplier development and infrastructure development.

- BMW Group and Toyota Motor Corporation, in June 2012, announced an expansion of their existing cooperation. The long-term strategic collaboration includes the joint development of a fuel cell system.[15]
- Daimler AG, Ford Motor Company and Nissan Motor Company, in January 2013, signed a unique three-way agreement for the joint development of a common, affordable fuel cell system to be launched as early as 2017.[16]
- General Motors and Honda, in July 2013, entered into a long-term collaborative agreement to co-develop next-generation fuel cell systems and hydrogen storage technologies aiming for the 2020 timeframe.[17]

Infrastructure Announcements and Developments

The deployment of hydrogen stations in a market is a precursor to a consumer purchasing decision. Multiple factors, however, influence the commercialization of hydrogen station technology as well as a customer's fueling experience. As characterized throughout this HyPPO report, private and public hurdles remain to design, install and operate an effective network of stations that meets the expectations of early customers. Despite these hurdles, progress continues to be made on station technology, as captured in recent analyses and announcements.

Building on the *Road Map*, ongoing analyses continue using UC Irvine's Spatially and Temporally Resolved Energy and Environment Tool (STREET) to refine coverage and placement needs as early station locations are planned and developed. An important market characterization relates to maximizing early adopter access to stations. An efficient network design shows that the initial network proposed in the *Road Map* provides six-minute drive time proximity for 37 percent of anticipated early FCEV adopters. Using plug-in electric vehicle (PEV) data as a proxy for early FCEV market characterization, this powerful planning tool reveals that a well-planned network can optimize access to fuel for consumers, ensure access to serve an early market sufficiently and enable hydrogen station business models. Figures 1, 2 and 3 provide a visualization of the stations relative to PEV data.

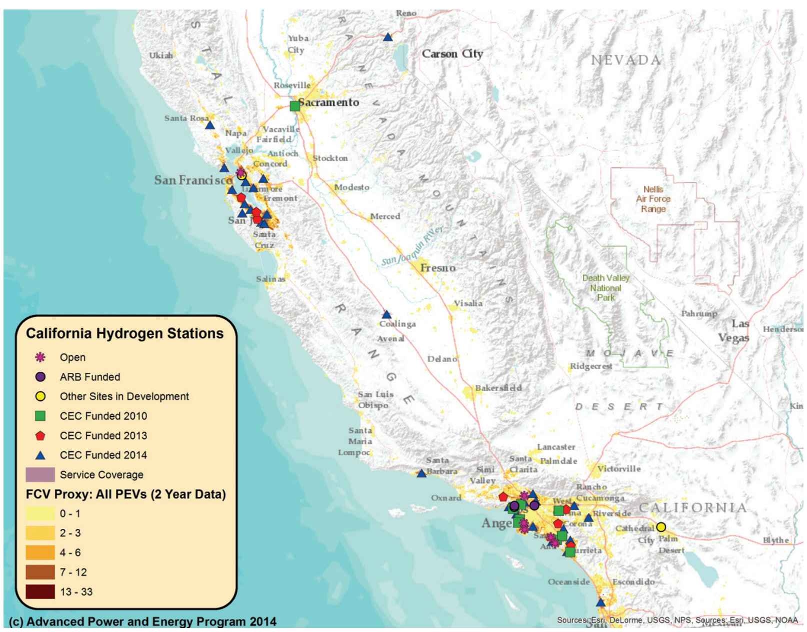

Figure 1 – California Hydrogen Stations

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[15] BMW Group and Toyota Motor Corporation Agree to Further Strengthen Collaboration, June 29, 2012 *http://pressroom.toyota.com/releases/bmw+group+toyota+motor+corporation+agree+further+strengthen+collaboration.htm*
[16] The Strategic Cooperation Between Daimler and the Renault-Nissan Alliance Forms Agreement With Ford To Accelerate Commercialization f Fuel Cell Electric Vehicle Technology, January 28, 2013 *http://www.nissan-global.com/EN/NEWS/2013/_STORY/130128-02-e.html*
[17] GM and Honda to Collaborate on Next-Generation Fuel Cell Technologies, July 2, 2013 *http://world.honda.com/news/2013/c130702GM-Honda-Collaborate-Fuel-Cell-Technologies/print.html*

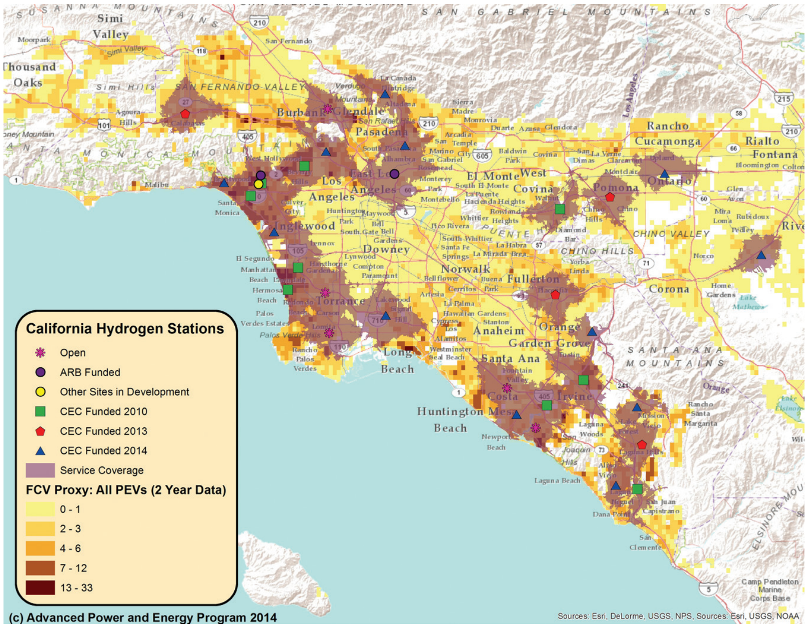


Figure 2 – Southern California Hydrogen Stations

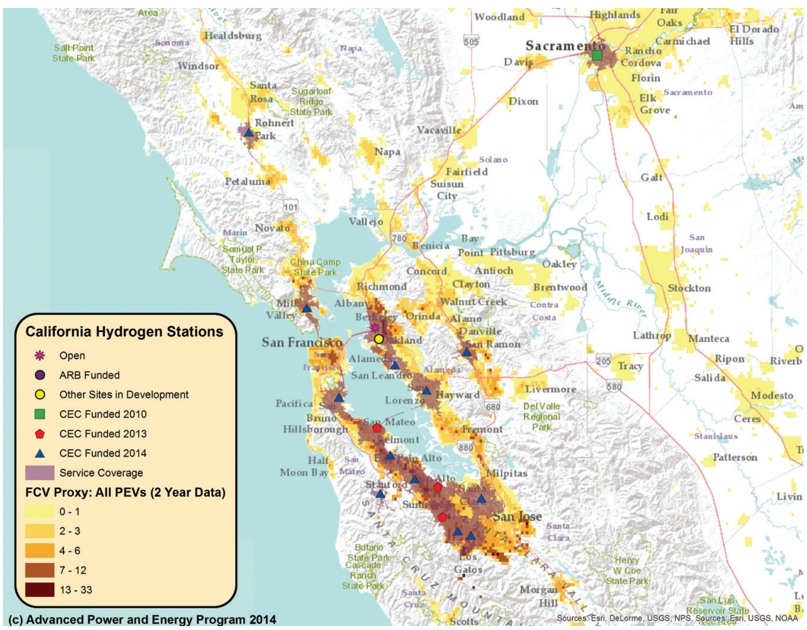


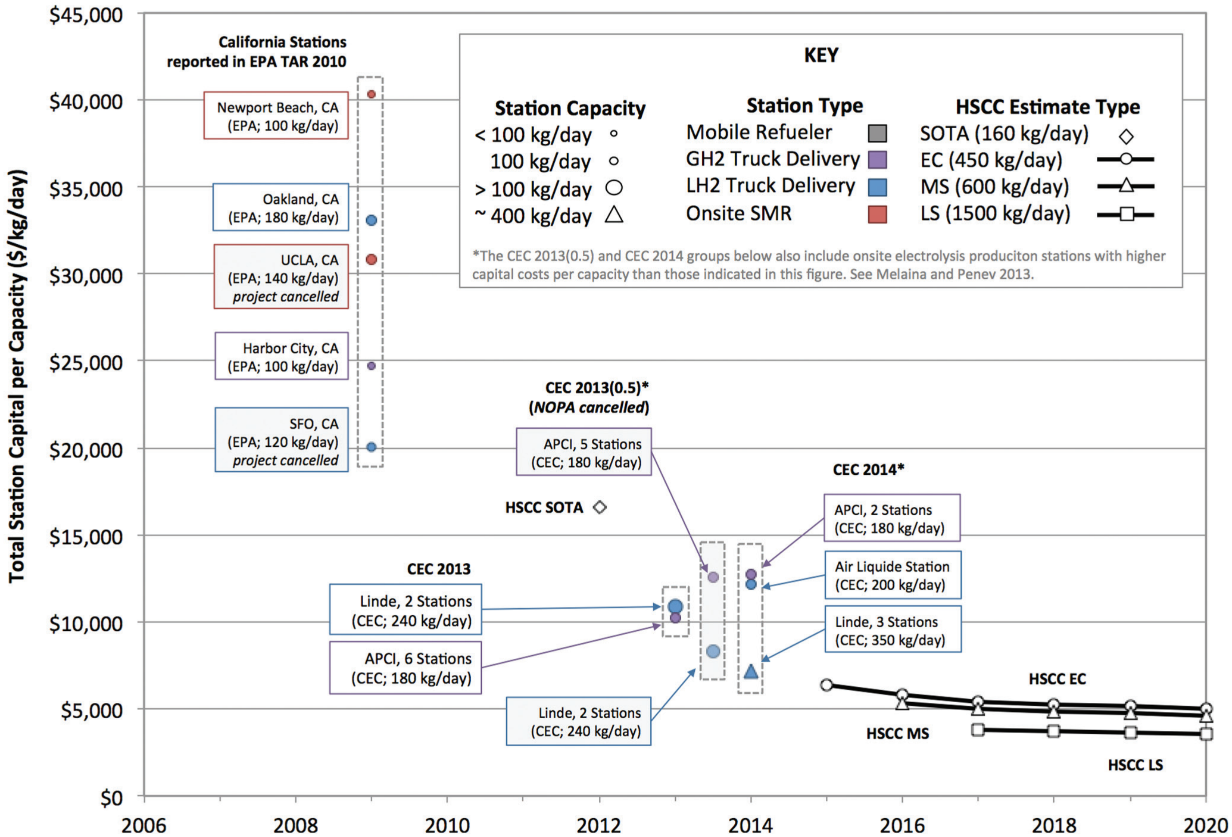
Figure 3 – Northern California Hydrogen Stations

Cost trends for hydrogen station equipment suggest significant reductions are being made.
Understanding the costs and financial risks associated with hydrogen infrastructure is an important consideration in the commercialization of fuel cell electric vehicles. A September, 2013 analysis by the National Renewable Energy Laboratory (NREL) highlights multiple facets of this issue. The Hydrogen Station Cost Calculator, which conveys cost estimates through expert stakeholders, suggests that station costs currently range from $2.5 million to $3 million; significant cost reductions are expected to continue through experience and economies of scale.[18] These trends are consistent with DOE's Hydrogen Analysis (H2A) model, research at UC Davis, as well as the cost of stations recently installed and funded in California, including the Energy Commission's July 2014 station funding awards with actual station capital costs between $2.1 million and $3.3 million (100% renewable hydrogen) per station.[19] While station costs remain relatively high and scale economies will not be realized until much wider deployments, NREL's analysis, as captured in Figure 4, indicates movement toward lower capital costs.

[18] Melaina, Marc and Penev, Mike, September 2013, Hydrogen Station Cost Estimates, NREL Technical Report No. NREL/TP-5400-56412 *http://www.nrel.gov/docs/fy13osti/56412.pdf*

[19] US DOE H2A Analysis: *http://www.hydrogen.energy.gov/h2a_analysis.html* and UC Davis Sustainable Transportation Energy Pathways research program: *http://steps.ucdavis.edu/?energy-category=hydrogen*. Total station costs include both public (grant) and private (cost-share) funding. Energy Commission: PON-13-607 awards can be located at *http://www.energy.ca.gov/contracts/PON-13-607_NOPA.pdf*

Figure 4. Comparison of Total Station Capital per Capacity



The 2013 NREL analysis highlights multiple considerations with respect to risk and opportunities, and underscores that larger capacity stations reduce the overall capital cost per kilogram of hydrogen. Yet, the opportunity for higher profit potential is balanced against the risk of installing a hydrogen station at higher capital cost with uncertain future utilization. The *Road Map* addressed this issue, considering that a "balance must be achieved between geographic coverage provided by installing multiple stations across broad market areas and cost reductions due to the economies of scale of larger stations."[20] Systematically reconciling station design, geographic considerations and financial risk will remain an overall priority.

The Hydrogen Network Investment Plan strengthened the analytical framework.
The *Road Map* provided an analysis of the remaining cost to install the initial hydrogen fueling station network utilizing two approaches: capital buy-down and cash-flow support.[21] Its financial model incorporated multiple parameters and assumptions, from station capacity to retail margin to station utilization. Building on this analysis, Energy Independence Now (EIN) published the Hydrogen Network Investment Plan (H_2NIP) in October 2013.[22]

H_2NIP is based on a more sophisticated financial model that integrates economic, policy and market scenarios. The analytical framework, as characterized in Table A, highlighted the main risks and challenges that need to be addressed in the different market phases. It also identified the set of tools that stakeholders can use to address them and transition from the initial coverage phase towards a sustainable, market-driven network. More specifically, H_2NIP characterized the need for near-term operational funding to support station operators as vehicle volumes ramp up during early commercialization.

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[20] *A California Road Map: The Commercialization of Hydrogen Fuel Cell Vehicles*, June 2012, page 7 *http://cafcp.org/sites/files/A%20California%20Road%20Map%20June%202012%20%28CaFCP%20technical%20version%29_1.pdf*

[21] The investment necessary to build the initial network of stations included prior investments made by public and private sources. Therefore, the *Road Map* only considered the future investments necessary to complete the network.

[22] *Hydrogen Network Investment Plan*, October 11, 2013 *http://www.einow.org/images/stories/factsheets/h2nip_full_paper_final.pdf*

Table A. H_2NIP Framework

			Recommendations to Address Immediate Market Issues							Recommendations for the Near Future			For Further Development				
			Sufficient Government Support	Conduct Annual Vehicle Surveys	Create Govt. Plan & Strategic Vision	Market Assurance Grants	Infrastructure Monitoring	OEM based Location Vetting	Partners for Implementation	Tax Relief & Incentives	Unlocking Debt	A Scheduled Phasedown of Grants	Special treatment for key connector stations	Non-monetary incentives	Link Grants to Performance	Revenue for Ongoing Network Support	Transfer Value ofLCFS Credits
Investment Challenges	High Risks	Vehicle Uptake Uncertainty	x	x	x	x	x										
		Station Availability Uncertainty	x		x	x	x	x	x								
		Unclear Government Support & Exit Plan			x				x			x					
	Low Returns	Low Returns for early stations	x			x				x	x			x			x
		Getting retailers off the side-lines		x	x						x	x		x	x		
		Attracting investors to connector stations			x								x			x	x
Execution Challenges		A complex coordination challenge		x	x		x	x	x								
		Streamline grant process			x			x							x		
		Slow station buildout							x						x		

At the core of this evaluation is the understanding that funding alone does not guarantee action. Working within existing paradigms as well as offering a new perspective, H_2NIP offered tangible proposals to address immediate market needs, near-future challenges and ideas for further development. These recommendations meet early customer needs while reducing market uncertainty, streamlining station development and improving access to new funding sources.

Innovative station design concepts highlight the focus on the customer experience.
Reliability, convenience and ease-of-use are only a few considerations that enable a positive customer experience, but station designers and operators understand that innovation will enable the overall market for fuel cell electric vehicles.

- H2 Logic opened the H2Station® Hydrogen Refueling Station in Copenhagen, Denmark in March 2013 with a time-lapse video of its 48-hour construction before providing its first fill. The video highlights that once a site has been approved and prepared, it is possible to quickly and cost-effectively install a station. Hydrogen is produced onsite with electrolysis and certified renewable electricity.[23]

H2Station® CAR-100 hydrogen refueling station in Copenhagen[21]

[23] H2 Logic builds hydrogen refueling station in 48 hours, March 6, 2013 *http://www.h2logic.com/com/shownews.asp?lang=en&id=424*.
Definition of certified renewable electricity: *http://en.wikipedia.org/wiki/Renewable_Energy_Certificate_(United_States)*

- Air Products introduced its consumer-friendly SmartFuel™ hydrogen dispenser in June 2013. Working with a leading manufacturer of fuel dispensing equipment, Bennett Pump Company, the dispenser became the market's first fully integrated retail hydrogen dispenser and mirrors traditional consumer gasoline fueling and payment practices.[24]
- While highlighting their hydrogen fueling stations in the U.S. reaching 500,000 fills in October 2013, the Linde Group provided a spotlight on their ionic compression technology. This replaces conventional compressor technologies (e.g. metal pistons) with specially designed, nearly incompressible ionic liquid. Linde opened the world's first small series production facility for ionic hydrogen fueling stations.[25]

Image courtesy of Air Products and Chemicals, Inc.

Image courtesy of Linde

Additional Market Developments

Fuel cell technology is not unique to light-duty vehicles. In fact, fuel cell technology is scalable and used in combination with batteries to meet various duty cycles. Today, commercial fuel cells are economically competitive and can be found in a variety of stationary applications (e.g., back-up power systems for cell phone towers) and vehicle applications (e.g., material handling).[26] Fuel cells provide clean and silent power for portable power generation and portable light towers.[27] Transit agencies use buses powered by fuel cells in revenue service and stakeholders are showing increasing interest in incorporating the technology into medium- and heavy-duty vehicles.

Fuel cell electric buses offer transit agencies a comparable alternative to conventional bus technology.
Fuel cell electric buses (FCEBs) offer comparable range and performance to meet increasingly stringent emission requirements. The U.S. Department of Transportation's National Fuel Cell Bus Program has brought the technology to the current level of development, including deployment of 12 third-generation FCEBs by AC Transit in the East Bay/Oakland region of Northern California. As described in CaFCP's FCEB roadmap, stakeholders are working to guide FCEBs to the next level of commercial development with a plan that features two Centers of Excellence, each comprised of 40 FCEBs.[28]

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[24] Air Products Introduces Advanced Retail Hydrogen Fuel Dispenser, June 11, 2013 *http://www.airproducts.com/company/news-center/2013/06/0611-air-products-introduces-advanced-retail-hydrogen-fuel-dispenser.aspx*
[25] Linde starts small-series production for hydrogen fuelling stations, July 14, 2014 *http://www.linde-gas.com/en/news_and_media/press_releases/news_20140714.html*
[26] Sprint fuel cell back up power for cell towers *http://newsroom.sprint.com/news-releases/sprint-takes-hydrogen-fuel-cell-technology-to-rooftops-with-help-from-department-of-energy.htm*
[27] Hydrogen Fuel Cell Portable Light Tower Lights Up the Golden Globe Awards, January 25, 2011 *https://www1.eere.energy.gov/hydrogenandfuelcells/news_detail.html?news_id=16676*
[28] *A Road Map for Fuel Cell Electric Buses in California: A zero-emission solution for public transit* http://cafcp.org/carsandbuses/busroadmap

Zero emission medium- and heavy-duty vehicles will be required to meet air quality goals in California and the United States.
Turning over medium- and heavy-duty fleets to new, lower-emission technologies will be necessary to meet air quality goals, such as regional air quality challenges (e.g. NO_x, particulate matter) in the San Joaquin Valley and South Coast air basins. In January 2014, the Air Resources Board announced the creation of the California Sustainable Freight Strategy which outlines the steps needed to transform California's freight transport system. Also, the U.S. Department of Energy announced $7 million in grants in December 2013 for FCEV demonstrations in parcel delivery applications, including California projects.[29]

Material Handling Equipment
More than 4,500 fuel-cell powered forklifts and material handling vehicles operate across the United States.[30] Operators suggest the vehicles contribute to increased productivity given their fast refueling times. Also, with no exhaust emissions, fuel-cell powered forklifts can be used in emissions-sensitive applications (e.g., food distribution) while supporting overall environmental initiatives. Most recently, PlugPower announced Walmart's order of more than 1,700 GenDrive fuel cell units for six distribution centers in North America.[31] This adds to the 500+ GenDrive units that Walmart already operates at three facilities in Canada and the United States.

Stationary fuel fells complement hydrogen refueling infrastructure, including tri-generation applications.
Stationary fuel cell capacity continues to grow in California and beyond.[32] At the grid level, stationary fuel cells provide 100+ megawatt deployments and low emissions as Transmissions Integrated Grid Energy Resource (TIGER) stations that can be sited to support an electric grid with high intermittent renewable penetrations. In expanded applications, tri-generation can simultaneously produce electricity, heat and hydrogen for refueling. Beyond showcasing the feasibility of tri-generation, the Orange County Sanitation District in California demonstrated the production of renewable bio-hydrogen at a wastewater treatment facility.[33] These concepts highlight the potential for distributed, renewable hydrogen and the role fuel cells and hydrogen infrastructure can play in grid storage.

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[29] Energy Department Invests Over $7 Million to Commercialize Cost-Effective Hydrogen and Fuel Cell Technologies , December 17, 2013
http://energy.gov/articles/energy-department-invests-over-7-million-commercialize-cost-effective-hydrogen-and-fuel
[30] *State of the States: Fuel Cells in America 2013* *http://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/state_of_the_states_2013.pdf*
[31] Plug Power Receives Milestone Order From Walmart For Multi-Site Hydrogen Fuel Cell Deployment, February 24, 2016.
http://www.plugpower.com/news/pressreleases/14-02-26/PLUG_POWER_RECEIVES_MILESTONE_ORDER_FROM_WALMART_FOR_MULTI-SITE_HYDROGEN_FUEL_CELL_DEPLOYMENT.aspx
[32] California Stationary Fuel Cell Collaborative *http://casfcc.org/*
[33] Energy Department Applauds World's First Fuel Cell and Hydrogen Energy Station in Orange County,
http://energy.gov/articles/energy-department-applauds-world-s-first-fuel-cell-and-hydrogen-energy-station-orange

Station Network Activation & Development

A hydrogen station network must establish the fundamental building blocks of coverage and convenience to meet specific customer needs. This is described in the *Road Map's* cluster-connector-destination approach. The development of a successful network must also be efficiently timed and geographically balanced to ensure practicality for its users and stakeholders. Essential factors like creating metrics, evaluation points, "on/off-ramps" and customer feedback are necessary to engineer the network's success. This section describes progress in meeting those goals and highlights how stakeholders are working together to address short-term priorities. This section also identifies priorities for action and their timing, as summarized in Table B.

Table B. Summary of 2014-2015 Actions for Station Network Activation & Development

Status	2014-2015 Actions	Activation in months*
Customer Experience		
	1. Define responsibility and/or processes for station network planning	6
	2. Anticipate future data and information needs.	6-18
Infrastructure Execution and Installation		
	3. Develop routine, transparent status reports on station installation and operational timelines	Immediate
	4. Support development of hydrogen refueling equipment suppliers and service providers	24
	5. Continue to assess financial risk mitigation tools for station developers	24
Synchronizing Vehicle Market Development		
	6. Continue to execute annual light-duty vehicle survey with automakers	Annual
	7. Explore market-wide multiplier effects for light-duty FCEVs, such as fleet adoption and medium- or heavy-duty vehicles	12-24
Station Performance and Monitoring		
	8. Effectively communicate station availability information to customers	6
	9. Continue to evaluate effectiveness of O&M grants and adjust accordingly	12
	10. Network design should consider size of stations and their influence on future reliability	12-24
Developing Codes & Standards, and Regulations		
	11. Integrate updated standards into state-wide planning and funding	Immediate
	12. Implement new regulations for dispensing accuracy; encourage additional devices to apply	Immediate
	13. Establish robust testing procedures to fully assess a station prior to open-for-business	12
Preparing Communities – Awareness, Education and Training		
	14. Continue to conduct outreach events and engage social media channels	Ongoing
	15. Ensure stakeholder coordination and conduct outreach permitting workshops	6-18
	16. Complete necessary readiness planning integration and associated outreach	12
	17. Support outreach and updates on the *ZEV Community Readiness Guidebook*	12
	18. Launch national emergency responder training programs with CaFCP content	6
	19. Conduct targeted emergency responder outreach to cities and counties	12-24

On track | *Attention necessary, progress needed* | *Attention necessary, planning underway* | *Not yet initiated*

*Note: "Activation" reflects the time (from report release) when the action must be finalized.

Customer Experience

A robust FCEV market will require a functioning, growing network of hydrogen stations where early fuel cell electric vehicle adopters live, work and travel. Upon closer consideration, industry stakeholders understand potential FCEV customers will also require user-friendly and reliable stations they can depend on, consistent with their current gasoline refueling experience.

Progress

- **In 2012 and 2013, the Energy Commission conducted six workshops on funding hydrogen infrastructure.**
- **State and regional funding opportunities included priorities that address the overall customer experience.**

While demonstrating station technology over the past 5-10 years, more than 35 hydrogen stations in California have provided varying looks and feels for users. This has been both useful and appropriate to meet research objectives and to evaluate options. As FCEVs approach early commercialization, industry is transitioning toward market consistency. To accomplish this goal, the Energy Commission held six workshops in 2012-2013 to design future Program Opportunity Notices (PON) to enhance and accelerate the market. The results of these workshops have been included in recent funding opportunities which prioritize customer considerations. One such example is the inclusion of operation and maintenance (O&M) funding which enables high station availability.[34]

Priorities for Further Action

(1) **Define responsibility and/or processes for station network planning**
Participants: ARB, air districts, automakers, CEC, Governor's Office (GO-Biz), station operators
Beyond a station-by-station approach, the overall customer experience will be enhanced by the associated timing of an individual station and its integration into the network. The importance of bringing initial projects online as soon as possible should not be underestimated. Furthermore, new fueling protocols with new hardware configurations are expected to be implemented across the network. Together, planning and coordination will ensure the reliability of the network during these early phases. A coordinated network approach, potentially with a stakeholder advisory board, will balance these challenges and priorities.

(2) **Anticipate future data and information needs**
Participants: ARB, academic/research organizations, automakers, CEC, station operators, US DOE/National Labs
A benefit of the recent commercialization of plug-in electric vehicles is that automakers and related stakeholders have an improved understanding about the introduction of new vehicle and infrastructure technologies. With that experience comes an appreciation of the role of data to help expand the market. While remaining sensitive to and protective of confidential business information, building a resilient hydrogen station network will require a similar exchange of information. Ahead of deployments, stakeholders should work to understand what type of data may be available and necessary to support future market growth.

Infrastructure Execution and Installation

The funding secured through AB 8 builds confidence among station operators, automakers and other stakeholders, given California's strong commitment through 2023 to develop the foundation for the FCEV market. While AB 8 made its way through the legislature, stakeholders integrated best practices into network execution and installation. As depicted in this report, timely deployment of funded stations remains a predominant challenge, yet there are examples which prove encouraging, suggesting that the timeline from agreement to "first fill" can be reached in less than one year.

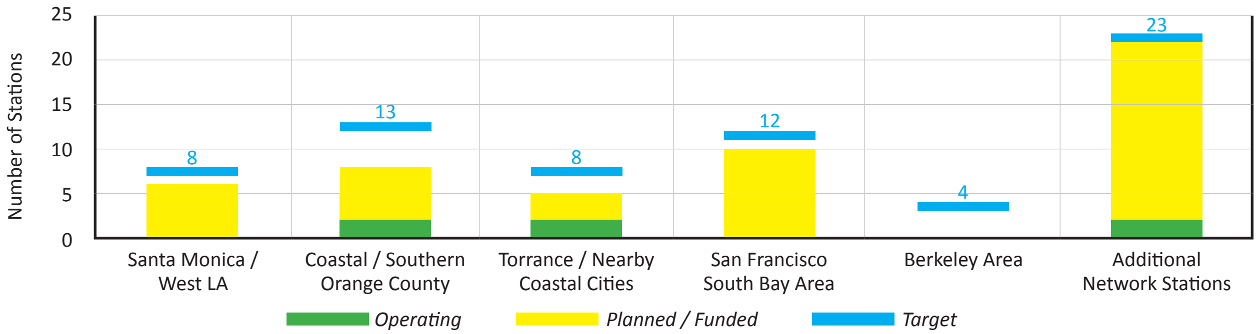
[34] California Energy Commission PON-13-607: *http://www.energy.ca.gov/contracts/PON-13-607/*

Progress

AB 8 highlights California's commitment to support hydrogen station development through 2023. Network development is progressing, yet delayed from *Road Map* assumptions and projections.

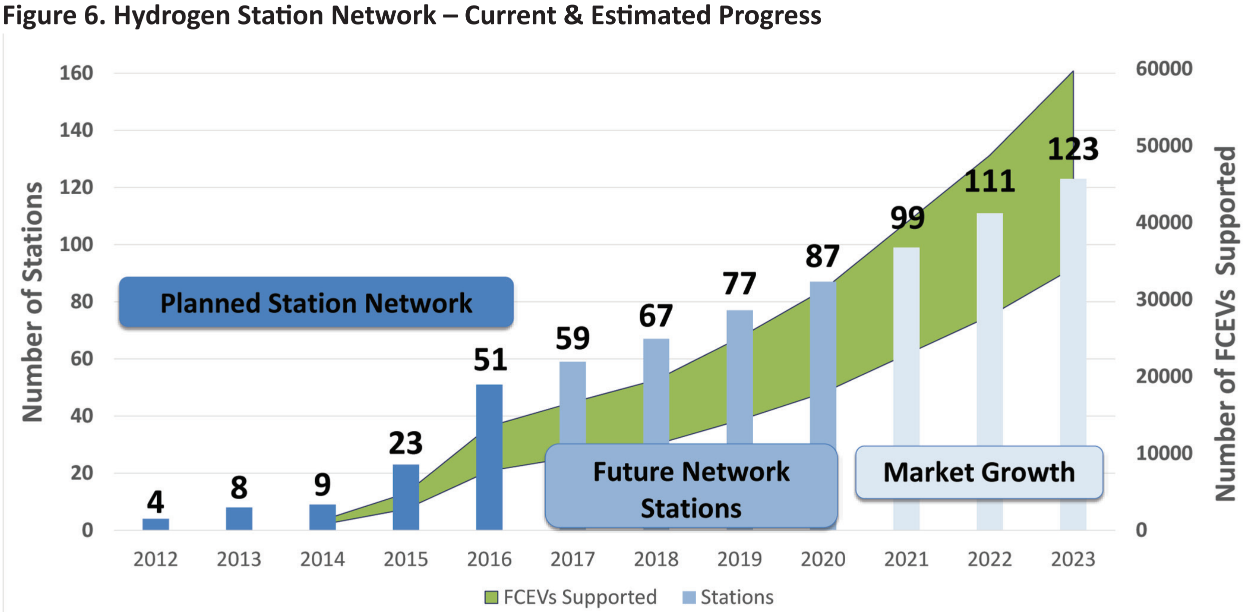
The *Road Map* described a scenario with 17 operational stations in 2014 and 37 operational stations in 2015. As captured in Figures 5 and 6, a total of 23 stations are expected to be operational at the beginning of 2015 and 51 stations in 2016.[35] Appendix A provides a complete list of stations. The regional targets (shown as blue lines) are included to understand regional progress to plan. Several early adopter clusters, namely Berkeley, Santa Monica and West LA, and San Francisco South Bay Area, highlight essential needs as these clusters have currently no operational retail stations. Stations were recently funded, however, in Santa Monica and West LA, and San Francisco South Bay Area.

Figure 5. Hydrogen Station Network – Current Progress to Plan (By Cluster[36])



Ensuring FCEVs are able to take advantage of their long range and quick refill times, the *Road Map* concluded an initial network of 68 stations offers the minimum coverage for customers to use a FCEV as they would use a conventional vehicle. The *Road Map's* initial network was projected to support approximately 20,000 FCEVs. In comparison, the cumulative design capacity (kilograms per day) for the 23 operating stations expected in 2015 is approximately 3,300 kilograms per day. Without considering necessary redundancy within the network, these stations would be able to support between 2,700-4,800 vehicles.[37] Figure 6 shows the current and estimated progress to plan with 23 stations operating in California in 2015 and reaching 68 stations in 2018-2019. From a capacity perspective, the projected 67 stations operating in 2018 would be able to support between 11,000-19,500 vehicles (as shown in Appendix B).

Figure 6. Hydrogen Station Network – Current & Estimated Progress



[35] See Appendix A for additional detail. In Figure 4, 51 stations includes currently operational (6 green) plus planned/funded (45 yellow). Although valuable to the existing network, several stations do not represent a full retail experience and future operational considerations will need to be made, such as completing technology upgrades, locating a new operator, or potentially shuttering operations. In summary, four currently operating stations (Emeryville, Fountain Valley, West LA, Thousand Palms) are not included beyond 2014 while three currently operating stations (Newport Beach, CSULA, Harbor City) are included, but will require upgrades to meet the definition of "retail."

[36] For clarification, Los Angeles – Lincoln Blvd station was placed in the Santa Monica cluster. Stakeholders generally agreed the airport (Los Angeles International Airport) was a natural boundary. Additional factors will be considered in future designation. ARB's Annual Evaluation (June 2014) placed this station in the Torrance cluster.

[37] See Appendix B. Current operating stations have a capacity ranging from 30 kg/d to 120 kg/d, while the design capacity of planned/funded stations is between 100 kg/d and 350 kg/d. To identify the range of vehicles supported, the total network capacity is multiplied by a utilization factor of 80% and divided by high usage (0.96kg/day/vehicle) and low usage (0.55 kg/d/vehicle.) Future stations are expected to range from 100 kg/d to 500 kg/d, with modest average increases over time.

Stations added each year represent the single best qualitative assessment of funding level, capital cost (i.e. design capacity, performance targets) and improvements for learning. The estimates take into account funding for O&M expenditures as FCEV deployments will not initially satisfy station utilization targets. For example, as shown in Figure 6, fewer stations will be added in 2017-2018 as stakeholders consider adding larger stations (e.g. 250-500 kg/day) into the network at a higher cost to satisfy anticipated demand; similar adjustments will be necessary with station growth beyond 2020 (e.g. 800-1,000 kg/day). These estimates will be continually adjusted as FCEV and station deployments are coordinated and station network priorities are adjusted accordingly.

Priorities for Further Action

(3) **Develop routine, transparent status reports about station installation and operational timelines**
Participants: Governor's Office (GO-Biz), CEC, station operators with support from CaFCP staff
Beyond network planning described above, stakeholders' renewed commitment to getting stations installed and operational translates into providing dynamic, transparent station status reports. This scorecard will ultimately convey status to all stakeholders while helping to identify where common crucial paths and challenges lie across projects.

(4) **Support development of hydrogen refueling equipment suppliers and service providers**
Participants: US DOE/National Labs, ARB, CEC, Governor's Office (GO-Biz) with support from industry
Building a network of at least 100 stations in a few short years will strain the existing pool of resources, from installers to equipment suppliers. Early research has identified challenges with supplier diversity and component availability, including examples of only one supplier for specific station equipment. DOE has launched a new project called the Hydrogen Fueling Infrastructure Research and Station Technology (H_2FIRST), in coordination with H_2USA, which will be co-led by NREL and Sandia National Laboratory.[38] H_2FIRST will work to "support U.S. industry innovation for new low-cost and high-performance materials, component technologies, and station architectures."[39] While more market participants will enter with a growing market, stakeholders can take early measures to support the transition of qualified engineering and construction teams capable of designing and building hydrogen stations.

(5) **Continue to assess financial risk mitigation tools for station developers**
Participants: US DOE/National Labs, academic/research organizations, ARB, CEC, station operators.
The recommendations and considerations proposed in the Hydrogen Network Investment Plan (H_2NIP) in October 2013 will need continued vetting and exploration.[40] Working toward long-term goals, stakeholders will need to evaluate the "incentive toolbox" to support both capital and operational budgets as vehicle volumes ramp up. Incentive programs should provide "early-mover advantages," meaning clear benefits for station developers who took initial risk in the early years of station deployment. In all, these monetary and non-monetary incentive programs will need to offer a well-defined path to market-based solutions that do not depend on subsidies or incentives.

Synchronizing Vehicle Market Development

A central concept within the *Road Map* is to synchronize station and vehicle deployment and ensure sufficient station coverage prior to market launch so that customers have confidence they will have access to fuel when and where they need it. This remains a foundational principle and, while station network development has been delayed as stakeholders helped to secure the passage of AB 8, automakers remain committed to commercialization beginning in 2014. As the *Road Map* highlights, the need for flexibility is necessary to ensure planning efforts adapt with new information.

[38] Leveraging National Laboratories to Support H_2USA, *http://energy.gov/eere/articles/leveraging-national-laboratories-support-h2usa*
[39] NREL, Sandia Team to Improve Hydrogen Fueling Infrastructure, April 2014 *http://www.nrel.gov/news/press/2014/10339.html*
[40] *Hydrogen Network Investment Plan*, October 11, 2013 *http://www.einow.org/images/stories/factsheets/h2nip_full_paper_final.pdf*

Progress

- **With AB 8, synchronizing market development has been formally integrated into ARB and CEC planning.**
- **In June 2014, ARB issued its first annual evaluation of FCEV deployment and station network development.**

In California, several hundred fuel cell passenger vehicles and transit buses are on the road today. Some models are leased directly to customers (Honda, Hyundai, Mercedes-Benz) while others are in fleet programs (General Motors, Nissan, Toyota). Two transit agencies, AC Transit and SunLine Transit Agency, lead efforts to operate fuel cell buses in revenue service, including AC Transit partnering with multiple San Francisco Bay Area transit agencies to operate fuel cell buses.[41]

While initial vehicle deployments are occurring today, more stations are needed to provide coverage and enable larger volume introductions. CaFCP members agree on the need for a strong message and tool to support FCEV/hydrogen station planning, which was formally adopted into AB 8 requirements. Beyond establishing a network of at least 100 publicly available hydrogen stations, AB 8 also requires the ARB to collect and make available by June 30 of each year, the aggregate number of hydrogen-fueled vehicles automakers project to be sold or leased over the following three years, as well as the number of hydrogen-fueled vehicles registered with the Department of Motor Vehicles. ARB then evaluates the need for stations on an annual basis and, together with the Energy Commission, jointly reviews progress towards network development.

In June 2014, ARB issued its first annual report of FCEV deployment and hydrogen station network development.[42] Using the results of an automaker survey conducted in spring 2014, the report provides regional FCEV projections for model years 2014 through 2017, as well as a single aggregate result for model years 2018-2020. Working with stakeholders to ensure the survey results offer as much insight as possible, it includes assumptions about station numbers to obtain single best vehicle estimates, vehicle type and model, anticipated range, and anticipated placement. To protect confidential data, only aggregated results are shared publicly.

Using modeling and database tools that adjust vehicle numbers based on real-world experience (e.g. vehicle attrition), the survey is used by ARB to analyze projected market development at various geographies over the next six years. As shown in Figure 7 below from ARB's report, the statewide projections for the future FCEV fleet in California are 6,650 vehicles in 2017 and 18,465 vehicles in 2020.[43] Furthermore, these data allow stakeholders to more easily analyze regional coverage (e.g. cluster) and capacity from a vehicle deployment perspective. For example, 6,650 vehicles represent approximately 49-86 percent of estimated capacity of currently planned stations.[44]

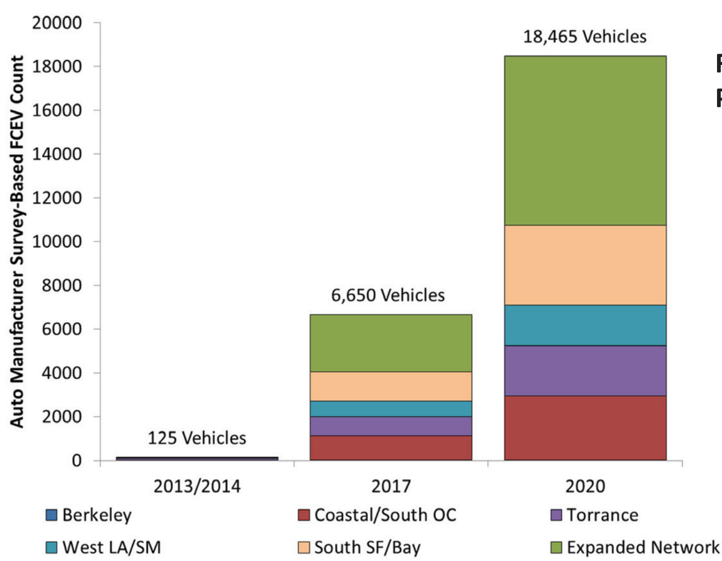


Figure 7. Cumulative Statewide FCEV Populations (By Cluster)

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[41] Includes Golden Gate Transit, Santa Clara Valley Transportation Authority, San Mateo County Transit District, and San Francisco MTA

[42] Annual Evaluation of Fuel Cell Electric Vehicle Deployment and Hydrogen Fuel Station Network Development, Air Resource Board, June 2014 *http://www.arb.ca.gov/msprog/zevprog/ab8/ab8_report_final_june2014.pdf*

[43] Ibid, Figure 4 on page 18. Based on CaFCP data, auto manufacturer surveys and station distribution

[44] The capacity of the 51 currently-planned stations is 9,260 kg/day (Appendix A). This capacity supports 7,725 (low) to 13,520 (high) FCEVs. The survey results can be compared to network progress (6,650 divided by 7,725 = 86%; 6,650 divided by 13,520 = 49%) to highlight progress.

While the initial *Road Map* vehicle survey results represented the "potential magnitude" of early market vehicles, these FCEV projections provide a more current representation of anticipated FCEVs on the road. The difference between the *Road Map* and the current survey results stems from the station deployment timeline effectively being "reset" with AB 8. As more stations open for business and as more proposed stations receive incentive funding, automakers will have greater confidence that the California market can support increased vehicle volumes.

Priorities for Further Action

(6) **Continue to execute annual light-duty vehicle survey with automakers**
Participants: ARB, automakers
The 2014 survey results establish a baseline assessment of vehicle deployments through 2017 with additional aggregate information provided through 2020. In completing future annual surveys automakers will consider—among other factors—the current and planned status of the station network to support the deployments. Furthermore, station operators and coordinating agencies will be able to target necessary station development activities. Together, the annual coordination and evaluation process is an essential part of planning for success.

(7) **Explore market-wide multiplier effects for light-duty FCEVs, such as fleet adoption, and medium- or heavy-duty vehicles**
Participants: ARB, air districts, CEC, US EPA (Region 9), US DOE/National Labs with support from industry
From light-duty vehicle retail market to freight and goods movement considerations, the efforts by CaFCP underscore the importance of the current dialogue around all low-carbon transportation. Opportunities across market sectors should be leveraged appropriately. For example, do infrastructure synergies exist to reduce costs and improve equipment performance in larger stations that support transit or heavy-duty fueling applications? Or might technology adoption across market sectors raise general awareness of FCEVs? More specifically in 2014, CaFCP is working to implement the concepts described in the FCEV roadmap and develop a medium- and heavy-duty FCEV roadmap. CaFCP is also working to understand how FCEVs integrate into complementary policies, such as those described in ARB's cap-and-trade program.

Station Performance and Monitoring

Station performance and availability play a major role in the overall customer/vehicle experience. Consumer confidence and perception are directly influenced by station reliability, as well as the availability and reliability of back-up stations. With fewer stations in the network, each individual station is essential to the network's success. With temporary or longer-term outages, the failure of one station places more pressure on other stations as stations exceed design capacity or normal operating parameters.

Beyond market confidence, these metrics affect vehicle operating range, vehicle utility and, ultimately, a potential customer's purchase decision. Field experience reveals customers may actually "compete" for fuel access, thus generating even more challenges. In the early market years, with new stations and potentially evolving technology, reliability may be as important as network coverage and capacity.

Progress

In 2013, state and regional funding opportunities recognize and prioritize operations and maintenance, including back-up solutions.

California has about 10,000 retail stations selling traditional fuels (e.g. gasoline, diesel) and consumers can choose where to fuel based on location, fuel price, rewards programs or a favorite convenience store.[45] With constrained choices in the hydrogen station network, station reliability will be a significant influence on a customer's experience. In late 2013, a few hydrogen stations were off-line for a significant period of time due to equipment failures. Tracking from a customer's perspective during the fourth quarter of 2013, the availability of network of nine stations ranged from 13 to 100 percent, with four of nine stations performing greater than 95 percent.[46]

[45] Retail Fuel Report and Data for California *http://energyalmanac.ca.gov/gasoline/piira_retail_survey.html*
[46] Availability is defined as "days available" with stations off-line for more than four consecutive hours were counted as unavailable for the day. Detailed analysis performed by an automaker with deployments in Los Angeles and Orange Counties.

Recognizing this challenge, agencies are funding station upgrades as well as operations and maintenance (O&M) to address reliability for existing, planned and newly proposed stations. For example, the latest awards from the Energy Commission (PON-13-607) included O&M support grants varying from $60,000 to $100,000 per year, depending on an operational date.[47] While specific eligible costs are covered, this O&M funding addresses the issue of supporting stations once installed. Furthermore, the PON included a mobile refueler grant; this flexible piece of equipment could be deployed in the event of an extended outage as experienced in late 2013.

Priorities for Further Action

(8) **Effectively communicate station availability information to customers**
Participants: station operators, ARB, air districts, CaFCP staff, US DOE/National Labs with support from industry
Communicating station availability to customers will become increasingly important during early commercialization. To facilitate this communication, CaFCP created a simple station operational status system (SOSS) in 2010. In 2014, CaFCP will upgrade the current system, establishing consistency across stations (e.g. capacity, reporting), communicating more detailed real-time status (e.g. when a station is expected to come back online) and allowing for user-specific profiles. Furthermore, next-generation systems are also being explored by engaging organizations who have built commercial systems around these communications, such as those developed for PEV charging and natural gas stations.

(9) **Continue to evaluate effectiveness of O&M grants and adjust accordingly**
Participants: CEC, air districts, ARB, station operators, US DOE/National Labs
It will be important to explore how current or future funding schemes for O&M funding can influence station and network availability. Correlating O&M funding schemes across the network will be an important task to ensure financial support is properly invested during early commercialization. For example, incentives may be provided to stations with higher availability to improve overall network availability. These reviews are expected to adjust future funding priorities in order to improve the overall customer experience.

(10) **Network design should consider size of stations and their influence on future reliability**
Participants: ARB, academic/research organizations, CEC with support from air districts, automakers, station operators, US DOE/National Labs
As discussed in the Infrastructure Execution & Installation section, varying station size will be an important function in future station deployment and solicitations. Stations with lower capacity, which require future upgrades, may place undue pressure on the overall network if demand grows quickly. Beyond station maintenance considerations, customers may experience congestion or be required to spend time searching for and driving to the next available station. In contrast, smaller stations may be an important solution to broader coverage as the industry learns customer preferences. All things remaining equal, stakeholders may favor station designs which offer back-up solutions or consider network redundancy. These factors mean stakeholders will need to balance the design capacity of a proposed station, the benefit of upgrading equipment in the future, or placing new stations, and the funding availability. A well-conceived network that adjusts with new information will support station availability as the network grows and transforms.

Developing Codes & Standards, and Regulations

Codes and standards are technical definitions and guidelines. They affect equipment and site design as well as the interaction between user and equipment, such as through the public sale of hydrogen. From a practical perspective, codes and standards are only enforceable as adopted by law.

[47] California Energy Commission Public Opportunity Notice (PON-13-607) *http://www.energy.ca.gov/contracts/PON-13-607/*

Progress — Fueling Protocols

- **Two key international standards—SAE J2601** (Fueling Protocol for Light Duty Gaseous Hydrogen Surface Vehicle) **and SAE J2799** (Connection Device and Optional Vehicle to Station Communications)**—were finalized in 2014.**
- **Fueling protocol validation (CSA HGV 4.3) procedures are being finalized in parallel with the design/development of a hydrogen dispenser testing apparatus.**

A hydrogen fueling protocol quickly fills a vehicle's storage system to a high state of charge while avoiding the storage system limits (i.e. overheating or overfilling the system). Some of the earliest protocol development was established by CaFCP in 2002 and the first fueling specification for 70 MPa vehicle tank systems was established in 2007.[48, 49] In 2014, industry stakeholders finalized all protocol documentation into published standards, including SAE J2799 and J2601. Furthermore, additional protocol development includes TIR J2601-2, which establishes a fueling guideline for heavy-duty applications (>10kg), and J2601-3, which establishes a fueling standard for forklifts and other small fuel tanks.

As discussed in the Station Performance and Monitoring section, ensuring fueling protocols and hydrogen dispensers are fully validated is a vital path for commercialization. A station must fill within the standard's performance guidelines. Fueling protocol validation is determined by CSA HGV 4.3 and the deployment of a hydrogen dispenser testing apparatus will ensure a device is available to determine compliance with SAE J2601.

Progress — Fueling Station Codes & Standards

The implementation of codes and standards associated with siting hydrogen stations continues to be evaluated and refined in parallel with operational experience and station technology.

The National Fire Protection Agency (NFPA) issued its first integrated codes related to the installation and operation of hydrogen stations in the late 1990s and mid-2000s, with a focus on NFPA 52 *(Vehicular Gaseous Fuel Systems)* and NFPA 55 *(Compressed Gases and Cryogenic Fluids Code)*. The latest integration of these codes is NFPA 2 *(Hydrogen Technologies Code)*, which defines the fundamental safeguards for the generation, installation, storage, piping, use and handling of hydrogen as a compressed gas or cryogenic liquid. In 2012, NREL requested that the Fire Protection Research Foundation identify the gaps and conflicts in current codes and standards for the construction of hydrogen stations. The foundation issued the report in early 2013 in which experts took a renewed look at current requirements and offered suggestions for improvement and harmonization.[50] Lastly, a July, 2014 study by Sandia Labs examined 70 commercial gasoline stations in California to determine how many could integrate hydrogen fuel. The study concluded that 14 of 70 stations (and potentially 17 more) can safely store and dispense hydrogen, more than previously thought.[51]

Progress – Selling Hydrogen in California

- **In 2014, DMS took delivery of the hydrogen dispenser testing apparatus to evaluate current and future hydrogen stations.**
- **In 2013, DMS proposed accuracy class adjustments to support the sale of hydrogen in California.**

In California, the responsibility for ensuring the accuracy of commercial weighing and measuring devices, including hydrogen dispensers, falls upon the California Department of Food and Agriculture's Division of Measurement Standards (DMS). DMS also enforces the quality, advertising and labeling standards associated with the sale of hydrogen fuel. Through adoption of National Institute of Standards and Technology's (NIST) Handbook 44,

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[48] U.S. DOE Webinar Light Duty Fuel Cell Electric Vehicle Hydrogen Fueling Protocol *https://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/webinarslides_h2_refueling_protocols_022213.pdf*

[49] Fueling Specification for 70 MPA Compressed Hydrogen Vehicles release version (A) *http://www.readbag.com/hydrogenhighway-ca-policy-funding-appendix-6-fueling-specification*

[50] Hydrogen Fueling Code Gap Assessment, March 2013 *http://www.nfpa.org/research/fire-protection-research-foundation/reports-and-proceedings/hazardous-materials/gases/hydrogen-refueling-code-gap-assessment*

[51] More California gas stations can provide H2 than previously thought, Sandia study says, July 2014 *https://share.sandia.gov/news/resources/news_releases/california_stations/#.U8ViGPldVyJ*

accuracy tolerances are established so that neither buyer nor seller suffers economic harm. Furthermore, a "type evaluation" is required before any measuring device, in this case a hydrogen dispenser, can be used to sell hydrogen by the kilogram. Specifications and tolerances in NIST Handbook 44 are verified during type evaluation or after repairs have been made to the device.

Currently, commercially available hydrogen gas measuring devices have not been type evaluated. In the interim, station operators have worked closely with customers (e.g. automakers) to agree on a predetermined fueling price. In anticipation of resolving these challenges, DMS has established procedures and equipment to support the testing of hydrogen stations, including the construction of a laboratory for hydrogen quality testing and a hydrogen dispenser testing apparatus that can field test stations' ability to deliver hydrogen fuel accurately. In June 2014, the DMS regulation to amend the accuracy classes for hydrogen was adopted by California. These amendments provide the flexibility to station operators to meet wider tolerance classes as they work toward type evaluation during early commercialization.[52] These amendments fully sunset in 2020.

<u>Priorities for Further Action</u>

(11) **Integrate updated standards into state-wide planning and funding**
Participants: industry (SAE & CSA members), ARB, CEC
Fueling protocol guidelines and standards, and the means to validate performance will become fully available during 2014 and early 2015. FCEVs will be entering the market at the same time. The status of key codes and standards is:

- Publication of SAE J2601 occurred in July 2014
- CSA HGV 4.3 is expected to be published in 2014
- Hydrogen dispenser testing apparatus is expected to be completed and validated in fourth quarter 2014
- Further harmonization of NFPA 2 and NFPA 55 will be published as 2015 documents

Station operators will need to work closely with other stakeholders to ensure consistent, immediate implementation of these fueling protocols and validation procedures.

(12) **Implement new regulations for dispensing accuracy, test stations, encourage additional devices to apply**
Participants: DMS, ARB with support from station operators, equipment suppliers
Beginning in early 2014, state and regional agencies (DMS, ARB, CEC, SCAQMD), and station operators have been testing and evaluating nine hydrogen stations; these stations include various manufacturers and dispensing equipment. The testing will assess the accuracy of any dispenser, allow for a temporary use permit to be issued or provide a full type evaluation. In all cases, data will be valuable for industry and policy considerations; however, only a temporary use permit or type evaluation will enable an operator to sell fuel by the kilogram on a retail basis. In parallel, industry stakeholders will need to work with equipment manufacturers and station operators to ensure next-generation metrology equipment is type evaluated and integrated into fueling dispensers.

(13) **Establish robust testing procedures to fully assess a station prior to open for business**
Participants: station operators, ARB, automakers, Governor's Office (GO-Biz), US DOE/National Labs with support from DMS.
Stations must be tested and commissioned before customers arrive for the first commercial fills. Currently, each automaker conducts unique filling and compatibility tests, and requires station operators to respond to individual requests and concerns. This is not a sustainable plan. Early customers will have limited patience and appreciation for these efforts, so stations will need to avoid beta testing after a station is open for business. As described above, the Hydrogen Field Standard and hydrogen dispenser testing apparatus (as defined by CGA HGV 4.3) will be crucial tools to ensure successful commissioning for all stations.

[52] The California Department of Food and Agriculture amended the California Code of Regulations sections pertaining to hydrogen gas-measuring devices. The Office of Administrative Law approved the regulation on Jun 16, 2014 and it became effective immediately. *http://www.cdfa.ca.gov/dms/regulations.html*

Preparing Communities – Awareness, Education, and Training

At the core of commercializing any new technology is the commitment by stakeholders to carefully support the messaging and learning around its commercialization, especially a technology that competes in a deep-rooted framework such as transportation. These education and outreach efforts cut across the designing, building, selling and use of FCEVs and associated infrastructure. The learning from PEV commercialization highlights how vital it is to educate consumers while ensuring dealer sales staff and technicians, first responders and local officials have access to the latest information. This cannot be underestimated during pre- and early commercialization and must be woven throughout all market development efforts.

Progress — Outreach & Market Awareness

- **In 2012-2013, CaFCP conducted more than 125 outreach activities reaching about 14,000 people.**
- **In 2013, CaFCP won a Merit Award for its innovative social media "Go" campaign.**

Since its inception in 1999, CaFCP has focused on generating community-wide awareness, broad understanding and local leadership for FCEVs and hydrogen infrastructure. More than 80,000 people drove or rode in an FCEV during CaFCP and its members' activities. In 2012-2013, CaFCP conducted more than 125 outreach activities reaching about 14,000 people. Activities range from one-day events in early adopter communities to large conferences to stakeholder workshops. CaFCP also understands the role of collaboration and remains actively involved in local groups, such as Clean Cities Coalitions, Silicon Valley Leadership Group and the Los Angeles Economic Development Corporation.

Digitally, CaFCP is actively engaged with social media and refreshed its website (www.cafcp.org) in 2013. Facebook and Twitter followers showed continued and steady interest, and in 2012 CaFCP won a Merit Award from the Sacramento International Association of Business Communicators for its innovative "Go" social media campaign that increased website traffic more than 900%, increased Facebook engagement by a factor of five, and more than doubled the number of Twitter followers.[53]

Priority for Further Action

(14) **Continue to conduct outreach events and engage social media channels**
Participants: CaFCP staff with industry support
Ahead of commercialization, communication and outreach remain essential pillars to generate public interest and customer acceptance. As vehicle launches approach, more inquiries will emerge about the science, technology and business of FCEVs and hydrogen stations. Priorities will include representation at existing and new events with traditionally responsive stakeholders, such as Alt Car Expo, as well as engaging non-industry conferences and a broader push into social media channels. Positive messaging will be required to support learning, address misconceptions and rapidly respond to questions.

Progress — Education and Engagement

- **In 2014, the Governor appointed a Zero Emission Infrastructure Project Manager to support hydrogen infrastructure and PEV charging development.**
- **In 2013, OPR issued the *Zero-Emission Vehicles in California: Community Readiness Guidebook.***

While CaFCP does not lobby or advocate for legislation or regulation, CaFCP does have an important role in providing outreach and education to a broad group of local, state and federal officials. In 2013, CaFCP directly contacted 44 legislators, more than 200 staff and seven non-governmental organizations (NGOs). As vehicles and fueling stations are a part of each community, the importance of outreach at the local level is essential. Developing

[53] Go Campaign. *http://cafcp.org/category/topics/go_campaign*

knowledge of and comfort with fuel cell and hydrogen technology cannot be understated as local officials take action to integrate ZEV readiness planning efforts, approve plans to install hydrogen stations or contemplate non-monetary incentives like free parking.

The building and safety concepts associated with the installation of a hydrogen station are not new, but many local officials are unfamiliar with the details associated with hydrogen installations. CaFCP has been working with multiple stakeholders, including NREL, to educate permitting officials about code details and act as a resource during reviews and analysis. Traditionally, CaFCP supports two or more workshops each year to engage building, safety and fire professionals who conduct permitting plan checks and inspections.

Addressing this issue more broadly, CaFCP actively participated with the Governor's Office of Planning and Research (OPR) working group to create the *Zero-Emission Vehicles in California: Community Readiness Guidebook* that was published in fall 2013.[54] The guidebook helps communities with ZEV readiness, including infrastructure planning, permitting guidelines, consumer awareness and fleet adoption. It is intended to support community-level practitioners who engage with their residents, businesses and local leaders. Hydrogen is highlighted from an infrastructure planning perspective and parallels the *Road Map* deployment strategies.

A Zero Emission Vehicle Infrastructure Project Manager position was created at the Governor's Office of Business and Economic Development (GO-Biz). The position, which was filled in January 2014, is working directly with stakeholders and local officials to ensure the successful roll out of the hydrogen infrastructure.[55] In parallel, the Energy Commission is also taking an active role with awardees as community officials are engaged. These collaborative efforts secure broad and transparent communication across stakeholders while providing direct resources for supporting local officials.

<u>Priorities for Further Action</u>

(15) **Ensure stakeholder coordination and conduct outreach permitting workshops**
Participants: Governor's Office (GO-Biz), air districts, ARB, CEC, station operators, US DOE/National Labs, with support from CaFCP staff
Unfamiliarity with permitting as well as inherent challenges when trying to meet existing codes and standards (e.g. setbacks established by NFPA 2 or NFPA 55) at both existing retail locations and undeveloped locations can hinder or slow project approvals. To raise awareness and attention in communities where station developers plan projects, station installers and operators, state and local agencies and automakers, coordinated by the ZEV Infrastructure Project Manager, will conduct outreach activities and supplement with project-specific outreach. Ongoing outreach as well as additional permitting workshops in early market communities is essential for station deployment.

(16) **Complete necessary readiness planning integration and associated outreach**
Participants: CaFCP staff, ARB, automakers, CEC, Governor's Office (GO-Biz), station operators, US DOE/National Labs.
Ahead of PEV launches, multiple electric vehicle readiness planning efforts were undertaken at the local, regional and state level. These plans, which range from infrastructure placement to signage considerations, are relevant for FCEV commercialization. In 2014, the Energy Commission issued a solicitation to provide additional funding opportunities to extend the impact of the existing planning efforts to include all ZEVs and ZEV infrastructure deployments. Including FCEV commercialization in planning efforts will appropriately overlay all advanced vehicle technologies to establish an integrated transportation plan.

(17) **Support outreach and updates on the *ZEV Community Readiness Guidebook***
Participants: Governor's Office (OPR) with support from ARB, CaFCP staff, industry, local government
The effectiveness of the *ZEV Community Readiness Guidebook* will be in part related to the general awareness around the guidebook itself and its ability to provide up-to-date and relevant information for practitioners. CaFCP will work closely with the Governor's Office of Planning and Research (OPR) to extend awareness of

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[54] *Zero-Emission Vehicles in California: Community Readiness Guidebook*, Fall 2013 *http://opr.ca.gov/docs/ZEV_Guidebook.pdf*
[55] Governor Brown Announces Appointments, January 27, 2014 *http://gov.ca.gov/news.php?id=18380*

the guidebook within communities and during conferences and events. Moreover, as California approaches various code cycles, as experienced with the adoption of the 2014 California Fire Code, stakeholders will need to educate local officials about the relevant hydrogen considerations and ensure potential permitting impediments are avoided.

Progress — Training

As a transition occurs to more-traditional national training programs, CaFCP conducted outreach to nearly 2,000 emergency responder professionals in 2013.

CaFCP has been at the forefront of emergency responder (ER) training for FCEVs and hydrogen infrastructure, including its microsite for ER professionals. In 2012-2013, nearly 2,000 safety professionals have participated in CaFCP training about hydrogen basics and safety, and FCEV technology at annual events such as Corona AutoX and Firehouse World. In parallel, CaFCP has worked closely with DOE and Pacific Northwest National Laboratory to develop training, including a prop-based course launched in Hawai'i in 2013. Alongside these stakeholders, CaFCP is working to integrate these curricula into national programs.

While automakers typically develop extensive training programs for dealership salespeople and technicians, it is equally important to engage broader workforce development programs. CaFCP has participated in and supported California programs at Rio Hondo College and Universal Technical Institute to establish appropriate curricula on topics such as hydrogen safety, including working with high-pressure gases and high-voltage componentry.

Priorities for Further Action

(18) **Launch national emergency responder training programs with CaFCP content**
Participants: US DOE/National Labs, CaFCP staff with support from training organizations
CaFCP and DOE education programs about hydrogen, infrastructure and fuel cell electric vehicles will be integrated into national training programs conducted by NFPA and the National Fire Academy. This train-the-trainer approach will ensure FCEV and hydrogen education is conducted alongside other advanced transportation technologies. For example, NFPA is adding hydrogen and fuel cell electric vehicles to their online course content supporting PEV and hybrid training.

(19) **Conduct targeted ER outreach to cities and counties**
Participants: CaFCP staff, training organizations with support from industry
While broad outreach activities will generate education and interactions with decision makers across all communities, CaFCP will conduct project-specific outreach and offer its hydrogen and fuel cell electric vehicle education program to stakeholders. This fire-station approach will ensure those individuals responding to a potential emergency at a specific station are knowledgeable and comfortable with the technology.

Maintaining Complementary Policy Frameworks

From vehicle incentives to infrastructure planning, complementary policies provide market support for FCEV commercialization. Educating stakeholders and ensuring they understand FCEVs and hydrogen infrastructure must be an integral part of a low-carbon transportation future, and CaFCP will continue to drive these policy discussions forward in California. While AB 8 established programmatic and funding support for hydrogen infrastructure through ARFVTP, the following complementary policies are also expected to shape the execution of early FCEV and hydrogen business models. Table C summarizes the actions and timing more fully described below it.

Table C. Summary of 2014-2015 Actions for Maintaining Complementary Policy Frameworks

Status	2014-2015 Actions	Activation in months*
Vehicle Incentives		
On track	20. Ensure early FCEV customers have equivalent access to meaningful incentives	3
Attention necessary, progress needed	21. Track and characterize regional and local incentives	6-12
Greenhouse Gas Mitigation (AB 32): Cap & Trade and the Low Carbon Fuel Standard (LCFS)		
Attention necessary, planning underway	22. Work with hydrogen fuel providers to begin participating in the LCFS market	12
Attention necessary, progress needed	23. Expand hydrogen pathways for transportation	12-24
Well-to-Wheel Emissions & Hydrogen Feedstock Considerations (SB 1505)		
Attention necessary, progress needed	24. Ensure the benefits of all hydrogen production pathways are supported in California policies	6-12
Public Utility Commission Proceedings		
Not yet initiated	25. Explore how FCEV commercialization interacts with current and future CPUC proceedings	12

On track *Attention necessary, progress needed* *Attention necessary, planning underway* *Not yet initiated*

*Note: "Activation" reflects the time (from report release) when the action must be finalized.

Air Quality Incentive Program's Clean Vehicle Rebate Project (AB 8)
AB 8 reauthorized program and funding for ARB's Air Quality Incentive Program (AQIP). Each fiscal year, ARB adopts an investment plan that allocates funding to various programs including the Clean Vehicle Rebate Project (CVRP) administered by the Center for Sustainable Energy, and the Hybrid and Zero Emission Truck and Bus Voucher Incentive Project (HVIP) administered by CALSTART. In June 2014, ARB approved an increase in the vehicle rebate so that a customer purchasing or leasing a light-duty FCEV now qualifies for a $5,000 rebate; this rebate level is consistent with when PEVs were introduced in 2010.[56] Stakeholders generally agree CVRP and HVIP have been widely successful with generating interest and sales for low-carbon transportation.

Since 2009, CVRP has experienced tremendous growth with PEV rebate applications reaching approximately $1.5 million per week in late 2013.[57] This level of demand significantly outstrips the yearly $20-$25 million allocation for all of AQIP. Over the past two years, additional funding has been provided through budget reallocations and legislation. In 2014, ARB staff held multiple workshops and is working closely with stakeholders to establish a sustainable plan that winds down incentives to minimize market impact. In June 2014, the Air Resources Board approved the fiscal year 2014-15 AQIP Investment Plan which included significant light-duty (CVRP) program funding from the Greenhouse Gas Reduction Fund as well as an increase in the FCEV rebate.[58]

[56] Fiscal Year 2014-15 Funding Plan for the Air Quality Improvement Program and Low-Carbon Transportation Greenhouse Gas Reduction Fund Investments, May 2014, pages 37-38 *http://www.arb.ca.gov/msprog/aqip/fundplan/fy1415_funding_plan_aqip_ggrf_final.pdf*
[57] Clean Vehicle Rebate Project Statistics *http://energycenter.org/clean-vehicle-rebate-project/cvrp-project-statistics*
[58] ARB approves funding plan for low-carbon, zero-emission vehicles; improves 'car scrap' program *http://www.arb.ca.gov/newsrel/newsrelease.php?id=632*

Priorities for Further Action

(20) **Ensure early FCEV customers have access to meaningful incentives**
Participants: ARB, air districts, Governor's Office, industry
While the approved budget for FY 2014-15 allocated an additional $200 million from the cap-and-trade auction proceeds for low-carbon transportation, overall demand for these programs remains high. With broad support, ARB has indicated CVRP remains a significant component of its low-carbon transportation programs. However, ARB has also indicated the need to begin phasing in considerations to reduce the funding demand and expand markets. These include reduced rebate levels, limiting eligibility by vehicle MSRP or by customer household income, and offering additional incentives to under-represented groups such as public fleets and lower-income customers. Stakeholders will continue to observe early FCEV commercialization and the impact of various incentives; a long-term plan will enable a smooth transition away from such incentives.

(21) **Track and characterize regional and local incentives**
Participants: CaFCP, air districts, ARB, Governor's Office (OPR) with support from industry
Local and regional incentives, whether monetary or non-monetary, can be important enablers for a consumer purchasing decision. From free parking to progressive employers, helping consumers and communities understand what options may be available to them will be an important tool. Understanding the details and why local governments and organizations have taken a proactive role will be important to overall market development.

Greenhouse Gas Mitigation (AB 32): Cap and Trade and the Low Carbon Fuel Standard

Enacted in September 2006, Assembly Bill 32 (AB 32) establishes a comprehensive program to reduce greenhouse gas (GHG) emissions in California through multiple programs.[59] ARB is required to establish regulations and market mechanisms to reduce GHG emissions through a scoping plan. Among multiple programs, these include a cap-and-trade program and Low Carbon Fuel Standard (LCFS).[60] Beginning in January 2012, the first phase of the cap-and-trade program addresses major sources of GHG emissions, such as refineries, power plants and industrial facilities. In 2015, the second phase of the program includes transportation fuels and natural gas under the cap.

Three bills—AB 1532, SB 535, and SB 1018—establish the Greenhouse Gas Reduction Fund to receive proceeds from the cap-and-trade auctions and to direct spending priorities.[61] The administration identifies priorities and investments to reduce GHG emissions through its three-year investment plan. For FY 2013-14 through FY 2015-16, investments in sustainable communities and clean transportation have been highlighted followed by energy efficiency and clean energy, and natural resources and solid waste diversion.[62]

Another program supported through AB 32 is the Low Carbon Fuel Standard regulation. Enacted in 2007, LCFS is a fuel neutral, performance-based standard that reduces greenhouse gas emissions associated with the production, transport, distribution and use of transportation fuels used in California.[63] The carbon intensity (CI) is calculated for each fuel and regulated parties are required to ensure their aggregated carbon intensity score meets the annual target for a given year. While some fuels have CI scores above the target, other low-carbon fuels can be used to offset these values.[64] Hydrogen, which currently has five CI values using central and on-site reformer pathways, is a low-carbon fuel.[65] Hydrogen fuel providers can voluntarily opt-in to become a generator of LCFS credits, sell these to regulated parties and monetize the carbon benefits of hydrogen.

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[59] Assembly Bill 32: Global Warming Solutions Act *http://www.arb.ca.gov/cc/ab32/ab32.htm*
[60] Environmental Defense Fund AB 32 Cap-and-Trade Rule fact sheet *http://www.edf.org/sites/default/files/EDF-CA-CT-Fact-Sheet-August-2011.pdf*
[61] Cap-and-trade auction proceeds *http://www.arb.ca.gov/cc/capandtrade/auctionproceeds/auctionproceeds.htm*
[62] Cap-and-Trade Auction Proceeds Investment Plan: Fiscal Years 2013-14 through 2015-16 *http://www.arb.ca.gov/cc/capandtrade/auctionproceeds/final_investment_plan.pdf*
[63] Governor's Executive Order S-01-07 *http://www.arb.ca.gov/fuels/lcfs/eos0107.pdf*
[64] Low Carbon Fuel Standard, Question and Answer Guidance Document (Version 1) *http://www.arb.ca.gov/fuels/lcfs/LCFS_Guidance_%28Final_v.1.0%29.pdf*
[65] Table 6: Carbon Intensity Lookup Table for Gasoline and Fuels that Substitute for Gasoline *http://www.arb.ca.gov/fuels/lcfs/121409lcfs_lutables.pdf*

<u>Priorities for Further Action</u>

(22) **Work with hydrogen fuel providers to begin participating in the LCFS market**
Participants: industry, ARB
To date, no hydrogen fuel provider has opted to generate LCFS credits. The average price for a LCFS credit in 2013 was $28 in the first quarter, $44 in the second, $56 in the third, $70 in the fourth and $51 in the first quarter of 2014.[66] At these prices, LCFS could be an important source of revenues for hydrogen fuel providers of all types; even a small station selling about 100 kg/day of hydrogen produced onsite could potentially generate more than $36,000 per year.[67] CaFCP stakeholders will explore making it easier for non-traditional fuel providers to opt into the process and how the economic values produced by the LCFS (and other existing or future regulatory programs) could be used to fund new station development.

(23) **Expand hydrogen transportation pathways**
Participants: industry, ARB, US DOE/National Labs with support from academic/research organizations
Stakeholders will need to work closely to establish additional standard pathways such as on-site generation of hydrogen using electrolysis. Providing additional standard pathways, some with potentially low CI values, will enable broader market participation by hydrogen fuel providers. Furthermore, this may also require addressing program designs, such as those for calculating alternative CI values through site-specific pathways, as minimum thresholds (i.e. gallon throughput) that are currently necessary to approve a specific pathway.

Well-to-Wheel Emissions and Hydrogen Feedstock Considerations (SB 1505)

When working to understand the various impacts of vehicle use, the entire footprint for energy efficiency and emissions is defined by producing and distributing a fuel (well-to-tank), and then using the fuel to propel the vehicle (tank-to-wheel). This full analysis, called well-to-wheel, allows policy makers and others to compare the impact of various technologies. Because hydrogen can be made from multiple sources, such as from natural gas (steam methane reformation) or from water (electrolysis), stakeholders review the well-to-tank portion of the assessment to understand the total well-to-wheel emissions associated with using a vehicle.

In July 2014, CaFCP updated *From Well to Wheels: A Guide to Understanding Energy Efficiency and Greenhouse Gas Emissions* to provide results from Argonne National Lab's 2013 GREET model.[68] The results show that when making hydrogen from the "California mix" of hydrogen (33 percent renewable and 67 percent from steam reforming), well-to-wheel GHGs are about 65 percent less compared to gasoline through a combustion engine in a 2020 model year vehicle.

Beyond the current benefits, including the fact that hydrogen produced across all production pathways produces almost zero criteria pollutants (e.g. NO_x), environmental and energy standards for hydrogen production were enacted through SB 1505 in September 2006. Immediately in effect for State-funded hydrogen stations and in effect for all hydrogen stations once annual throughput reaches 3,500 metric tons, hydrogen providers must produce 33 percent of the hydrogen used for transportation from eligible renewable energy resources.[69]

The Energy Commission is committed to the 33 percent policy as an integral part of the station incentive requirements, as characterized in the July 2014 funding awards. The Energy Commission has concluded FCEVs using hydrogen from refueling stations receiving Energy Commission funding will result in a 68 percent reduction in greenhouse gas reductions from a comparable gasoline-powered vehicle. This is comparable to a PEV using electricity from the California grid.[70]

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[66] Monthly LCFS Credit Trading Activity Report for March 2014 *http://www.arb.ca.gov/fuels/lcfs/credit/20140408_marcreditreport.pdf*
[67] Revenue estimate based on an onsite, steam-reforming station using 33% biogas, with LCFS credits trading at $50/MT-credit.
[68] *Well to Wheels: A guide to understanding energy efficiency and greenhouse gas emissions* http://cafcp.org/sites/files/W2W-2014_Final.pdf
[69] Facts about Environmental and Energy Standards for Hydrogen Production (SB 1505) *http://www.arb.ca.gov/msprog/hydprod/hydprod_fs.pdf*
[70] California Investing Nearly $50 Million in Hydrogen Refueling Stations *http://www.energy.ca.gov/releases/2014_releases/2014-05-01_hydrogen_refueling_stations_funding_awards_nr.html*

<u>Priority for Further Action</u>

(24) **Ensure the benefits of all hydrogen production pathways are supported in California policies**

Participants: ARB, air districts, CEC with support from industry

Currently operating and planned hydrogen stations in West Los Angeles, Fountain Valley and Chino already highlight how hydrogen can be generated using renewable sources. Establishing certainty-associated programs and policies will ensure that cost-effective solutions complement existing natural-gas based hydrogen stations. This certainty will be an important enabler in bringing a suite of practical solutions to the development of the hydrogen infrastructure.

Similarly, AB 1900 (Gatto, 2012) requires the California Public Utility Commission (CPUC) to develop standards for constituents in biogas to protect human health, and pipeline integrity and safety.[71] These rules may influence the use and distribution of biogas for making hydrogen and will require stakeholders to provide input to CPUC proceedings as needed.

Public Utility Commission Proceedings

The influence of regulations and rulemaking discussions at the CPUC may have a growing impact on the early commercialization of FCEVs. Multiple proceedings are exploring how the CPUC can influence the plug-in and natural gas vehicle (NGV) markets. The current Alternative-Fueled Vehicle Rulemaking (R.13-11-007) is reviewing vehicle-grid integration considerations such as demand response programs or the bi-directional flow of electricity from vehicle batteries.[72] CPUC is also exploring how electric rates can influence customer adoption of PEVs and NGVs, as well as how these vehicles are used and refueled. GHG Emission Revenues and Costs (R.11-03-012) is exploring how to return utility proceeds from customers who generate credits from the LCFS. In October 2013, CPUC established grid storage requirements (D.13-10-040) for investor-owned utilities that include rules for distribution-connected resources.[73] In parallel, the California Independent System Operator (CaISO), CPUC and stakeholders are exploring more detailed assessment of vehicle-based grid services through its own roadmap.[74]

<u>Priority for Further Action</u>

(25) **Explore how FCEV commercialization interacts with current and future CPUC proceedings**

Participants: CPUC, ARB, automakers, CEC, station operators

The deployment of PEVs and NGVs will inevitably influence how the market assesses the opportunities of FCEV commercialization. Understanding the rules along with their associated costs and benefits is complex, and customers' perceptions of these technologies will be impacted. More specifically, rate designs are expected to affect all alternative fuels. The value of ancillary services provided by batteries and fuel cells will be defined by the regulations, the size of the market and competition across different technologies. In addition, hydrogen may become an important enabler of storing renewable energy when supply exceeds demand. As these discussions have recently emerged in the broader utility grid setting, it is important to help educate and contextualize how fuel cell technologies may interact in the grid.

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[71] AB 1900 *http://www.arb.ca.gov/energy/biogas/biogas.htm*

[72] Alternative-Fueled Vehicles Proceedings *http://www.cpuc.ca.gov/PUC/energy/altvehicles/*

[73] Energy Storage *http://www.cpuc.ca.gov/PUC/energy/electric/storage.htm*

[74] *California Vehicle-Grid Integration (VGi) Roadmap: Enabling vehicle-based grid services*, February 2014 *http://www.caiso.com/Documents/Vehicle-GridIntegrationRoadmap.pdf*

The *Road Map* and Beyond

While progress is being made toward commercialization, significant work remains to facilitate the early FCEV market by enabling a viable, sustainable hydrogen station network. Rather than simply looking at the challenge as building an initial network of 100 stations, stakeholders must ensure the right 100 stations build early consumer confidence, establish sound business models for multiple station sizes and locations, and create a wave of FCEV enthusiasm. Early FCEV commercialization will also be played out in a competitive market with multiple advanced vehicle technologies with varying benefits, and pressure will remain to pick transportation technology winners.

Practical experience over the past five years reaffirms the challenges with hydrogen infrastructure development where installing and operating a network of stations remains a hurdle for the industry. Therefore, beyond building an efficient network, stakeholders must remain focused on pragmatic activities, from designing effective grant programs to ensuring metrology standards are implemented. The priority actions described throughout this document remain vital paths toward early commercialization. Undoubtedly, these actions will require further examination and future actions will need to be described and assigned through action plans.

Developing the initial network of stations is no easy task. Stakeholders and decision makers will need to embrace continued flexibility to ensure system-wide learning is incorporated into market development, readiness planning, rules and laws. Exploring new business models and setting the stage to manage and reduce risk across the network will be essential priorities as traditional financial models will need to take the place of government-based solutions. Captured with the 20+ actions within this document is a sense that a new phase of planning and development will continue to evolve.

CaFCP stakeholders understand these substantial investments of time and resources are the first steps toward broader market commercialization. These actions in California will be leveraged and replicated in other regions while the learning from this commercial launch will shorten learning curves elsewhere. Forums like H_2USA will be crucial to expanding the conversation. While a national market with ubiquitous infrastructure will take years to create, market development will certainly be easier as new regions build upon the initial steps taken in California. While uncertainty remains high today, vehicle deployments and station implementation must evolve in response to market-based decisions. At that stage, planning will be more adaptive and the planning community will better understand competitive station growth based upon market signals (rather than the calculus contained in the *Road Map* and this HyPPO report). CaFCP will continue to implement and expand on the pragmatic actions contained here and will transform those market signals into future learning and actions.

Early FCEV commercialization will only be realized through the continued collaboration with a broad set of dedicated stakeholders. With a coordinated approach to these implementation challenges, further progress can be made to prepare the market. This momentous step awaits California as automaker announcements highlight that vehicles are beginning to be available in dealer showrooms.

Appendix A. Current and Planned Stations

Station Location	Current Status	2015 Status	Capacity kg/d	2015 Assessment
Santa Monica / West LA				
*Los Angeles – West LA 1**	*Public Demonstration*	*Unavailable*	*30*	*Unavailable*
Los Angeles – West LA 2	Planned – 2014	Available	180	Retail Setting
Santa Monica	Planned – 2014	Available	180	Retail Setting
Los Angeles – Beverly Blvd	Planned – 2014	Available	180	Retail Setting
Los Angeles – Hollywood Blvd	Planned – 2015	Available	180	Retail Setting
Los Angeles – Lincoln Blvd	Planned – 2015	Available	180	Retail Setting
Pacific Palisades	Planned – 2015	Available	130	Retail Setting
Coastal / Southern Orange County				
*Fountain Valley**	*Public Demonstration*	*Unavailable*	*30*	*Unavailable*
*Newport Beach***	Public Demonstration	Demonstration	100	Retail Setting
Irvine – UCI	Public Demonstration	Available	180	Non-commercial setting
Irvine – Walnut Ave	Planned – 2014	Available	180	Retail Setting
San Juan Capistrano	Planned – 2014	Available	350	Retail Setting
Mission Viejo	Planned – 2014	Available	180	Retail Setting
Costa Mesa	Planned – 2015	Available	180	Retail Setting
Laguna Niguel	Planned – 2015	Available	180	Retail Setting
Lake Forest	Planned – 2015	Available	180	Retail Setting
Torrance / Nearby Coastal Cities				
Torrance	Public Demonstration	Available	60	Retail Setting
*Los Angeles – Harbor City***	Public Demonstration	Demonstration	60	Retail Setting
Redondo Beach	Planned – 2014	Available	180	Retail Setting
Lawndale	Planned – 2014	Available	180	Retail Setting
Los Angeles – LAX	Planned – 2015	Available	100	Retail Setting
San Francisco South Bay Area				
Mountain View	Planned – 2015	Available	350	Retail Setting
Cupertino	Planned – 2015	Available	350	Retail Setting
Foster City	Planned – 2015	Available	350	Retail Setting
San Jose	Planned – 2015	Available	180	Retail Setting
Saratoga	Planned – 2015	Available	180	Retail Setting
Campbell	Planned – 2015	Available	180	Retail Setting
Redwood City	Planned – 2015	Available	180	Retail Setting
South San Francisco	Planned – 2015	Available	180	Retail Setting
Palo Alto	Planned – 2015	Available	180	Retail Setting
Woodside	Planned – 2015	Available	140	Retail Setting
Berkeley Area				
*Emeryville**	*Public Demonstration*	*Unavailable*	*60*	*Unavailable*

Notes: * Represents a public demonstration station that is considered currently available and included in the total station count for 2014. However, it is not included in the total station count beyond 2014 due to considerations such as setting, single pressure availability (e.g. 35 MPa) and contract expiration.

** Represents a public demonstration station that is considered currently available and included in the total station count for 2014 and beyond. While included beyond 2014, these public demonstration stations will require upgrades (e.g. point-of-sale capability, capacity upgrade) to be considered full retail. Without these upgrades, stakeholders will re-evaluate their representation within the station network.

Appendix A. Current and Planned Stations (Continued)

Station Location	Current Status	2015 Status	Capacity kg/d	2015 Assessment
Additional Network Stations				
*Thousand Palms **	*Public Demonstration*	*Unavailable*	*30*	*Unavailable*
Los Angeles – CSULA **	Public Demonstration	Demonstration	60	Non-commercial setting
Burbank	Public Demonstration	Available	100	Non-commercial setting
Diamond Bar	Planned – 2014	Available	180	Non-commercial setting
Anaheim	Planned – 2014	Available	100	Retail Setting
Chino	Planned – 2014	Available	100	Retail Setting
Woodland Hills	Planned – 2014	Available	180	Retail Setting
Orange	Planned – 2015	Available	130	Retail Setting
Santa Barbara	Planned – 2015	Available	180	Retail Setting
Long Beach	Planned – 2015	Available	180	Retail Setting
Riverside	Planned – 2015	Available	100	Retail Setting
La Canada Flintridge	Planned – 2015	Available	180	Retail Setting
South Pasadena	Planned – 2015	Available	180	Retail Setting
Ontario	Planned – 2015	Available	100	Retail Setting
San Diego	Planned – 2015	Available	180	Retail Setting
Coalinga	Planned – 2015	Available	180	Retail Setting
West Sacramento	Planned – 2014	Available	350	Retail Setting
Truckee	Planned – 2015	Available	180	Retail Setting
San Ramon	Planned – 2015	Available	350	Retail Setting
Rohnert Park	Planned – 2015	Available	130	Retail Setting
Mill Valley	Planned – 2015	Available	180	Retail Setting
Oakland	Planned – 2015	Available	350	Retail Setting
Hayward	Planned – 2015	Available	180	Retail Setting

Notes: * Represents a public demonstration station that is considered currently available and included in the total station count for 2014. However, it is not included in the total station count beyond 2014 due to considerations such as setting, single pressure availability (e.g. 35 MPa) and contract expiration.

** Represents a public demonstration station that is considered currently available and included in the total station count for 2014 and beyond. While included beyond 2014, these public demonstration stations will require upgrades (e.g. point-of-sale capability, capacity upgrade) to be considered full retail. Without these upgrades, stakeholders will re-evaluate their representation within the station network.

Appendix B. Projected Hydrogen Fueling Station Network Development (2014 Assumptions and Characterizations)

This table characterizes CaFCP members' best assessment of the hydrogen station network rollout and how many FCEVs it could support. Using best available information, this table provides single best estimates—stations added in 2014-2016 are characterized by Energy Commission 2010-2014 funding activities; stations added after 2017 are estimated based on funding availability, size and need. To better understand how many FCEVs could be supported, stakeholders used industry-generated assumptions such as optimal station utilization and expected FCEV usage and efficiency.

														FCEVs Supported	
	Start of Year	Network Capacity (kg)	Stations Added	*Road Map* Target	Expected Station Design Capacity [kg/day] [1]	Station Utilization Factor [2]	Real Network Capacity	FCEVs miles/year [3]	FCEVs miles/day	Ave. Fuel Economy Low [4]	Ave. Fuel Economy High [5]	kg/d usage (High)	kg/d usage (Low)	FCEVs Low	FCEVs High
2012	4	400	*4*	68	Up to 100										
2013	8	800	*1*	68	100										
2014	9	900	*16*	68	100	0.8	720	14000	38.4	40	70	0.96	0.55	**751**	**1314**
2015	23	3,300	28	68	100-250	0.8	2640	14000	38.4	40	70	0.96	0.55	**2753**	**4818**
2016	51	9,260	8	68	100-250	0.8	7408	14000	38.4	40	70	0.96	0.55	**7725**	**13520**
2017	59	11,400	8	68	250	0.8	9120	14000	38.4	40	70	0.96	0.55	**9511**	**16644**
2018	67	13,400	10	100	250	0.8	10720	14000	38.4	40	70	0.96	0.55	**11179**	**19564**
2019	77	17,150	10	100	250-500	0.8	13720	14000	38.4	40	70	0.96	0.55	**14308**	**25039**
2020	87	21,400	12	100	250-500	0.8	17120	14000	38.4	40	70	0.96	0.55	**17854**	**31244**
2021	99	27,400	12	n/a	250-500	0.8	21920	14000	38.4	40	70	0.96	0.55	**22859**	**40004**
2022	111	33,400	12	n/a	500	0.8	26720	14000	38.4	40	70	0.96	0.55	**27865**	**48764**
2023	123	40,900	n/a	n/a	500-750	0.8	32720	14000	38.4	40	70	0.96	0.55	**34122**	**59714**

Notes:

(1) Current Program Opportunity Notices require minimum of 100 kilogram per day. Future solicitations are anticipated to systematically require larger size stations in high-density areas with smaller stations continued to serve initial markets, connectors, and destinations. Additional consideration was provided to replacing existing stations with higher-capacity equipment and moving "older, used" equipment to new locations.

(2) In consultation with NREL, stakeholders agreed that a target utility factor of 80 percent was a reasonable to manage multiple considerations, for example: operational and maintenance (e.g. equipment reliability), customer access (e.g. queuing, waiting), business model (e.g. positive cash flow). For comparison, H2A Forecourt model targets maximum utilization at 86 percent. *http://www.hydrogen.energy.gov/h2a_production.html*

(3) ZEV ISOR (2012) notes median life of light-duty vehicles in California at 14 years (186,000 miles). See page 65 of *http://www.arb.ca.gov/regact/2012/zev2012/zevisor.pdf*

(4) In consultation with NREL, stakeholders agreed to Average Fuel Economy (Low) of 40 mile per gallon equivalent, which translates into a high usage of 0.96 kilograms per day for each FCEV

(5) In consultation with NREL, stakeholders agreed to Average Fuel Economy (High) of 70 mile per gallon equivalent, which translates into a low usage of 0.55 kilograms per day for each FCEV

Calculations: FCEVs Supported (Low) and FCEVs support (High) reflects Real Network Capacity (Capacity * Station Utilization Factor) divided by kg/d usage.