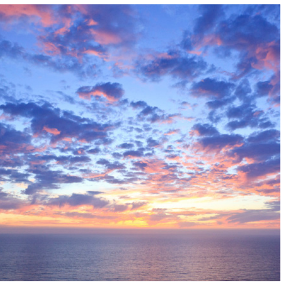
June 2014



Annual Evaluation of

Fuel Cell Electric Vehicle Deployment and Hydrogen Fuel Station Network Development

California Environmental Protection Agency
Air Resources Board

Annual Evaluation of

Fuel Cell Electric Vehicle Deployment and Hydrogen Fuel Station Network Development

Pursuant to AB 8, Statutes of 2013

June 2014

List of Acronyms

AB	Assembly Bill
ARB	California Air Resources Board
BEV	Battery Electric Vehicle
CaFCP	California Fuel Cell Partnership
CDFA	California Department of Food and Agriculture
CEC	California Energy Commission
CNG	Compressed Natural Gas
CSA	Canadian Standards Association
DMV	Department of Motor Vehicles
FCEV	Fuel Cell Electric Vehicle
GHG	Greenhouse Gas
HFS	Hydrogen Field Standard
LCFS	Low Carbon Fuels Standard
LEV	Low Emission Vehicle
LEV III	Future Low Emission Vehicle regulations, including criteria pollutant standards and greenhouse gas standards (formerly known as the Pavley Regulation, or Assembly Bill 1493)
NREL	National Renewable Energy Lab
PHEV	Plug-in Hybrid Electric Vehicle
SB	Senate Bill
VMT	Vehicle Miles Traveled
ZEV	Zero Emission Vehicle

Table of Contents

Executive Summary

The year 2014 was a pivotal year for fuel cell electric vehicles (FCEVs), with multiple factors and events paving the way for the successful commercialization of FCEVs in California:

- Assembly Bill 8 (Perea, Statutes 2013, chapter 401) dedicated up to $20 million per year to support continued construction of at least 100 hydrogen fuel stations, demonstrating California's commitment to FCEVs as a key component of achieving its air quality and climate goals;
- $200 million in cap-and-trade proceeds were allocated for low-carbon transportation projects, $116 million of which are slated for the Clean Vehicle Rebate Project, including up to $5,000 per FCEV. This further supports the State's broad mission to support zero emission vehicles (ZEVs), including FCEVs;
- California Energy Commission (CEC) conducted an innovative solicitation that provides funding for 28 new stations, resulting in an anticipated 51 operating hydrogen fuel stations by the end of 2015 (more than doubling the previous number of State-funded stations);
- ARB approved the update of the AB 32 Scoping Plan in March, emphasizing the role that FCEVs and other ZEV technologies must play to achieve the State's air quality and climate goals;
- The Governor's Office is facilitating hydrogen fuel station permitting and project management through its Go-Biz office;
- Through the continued leadership of Governor Brown, California joined the federal public/private partnership H2USA and entered into multistate ZEV action agreements (Multistate ZEV Action Plan, Pacific Coast Collaborative).

AB 8 reinforced California's commitment to fuel cell electric vehicles and other ZEVs and the transformation of personal and commercial transport in the state. AB 8 provides particular focus on development of the state's hydrogen fuel station network. In addition to AB 8 and ARB's Scoping Plan, Governor Brown's Executive Order B-16-2012[1] provides another strong policy driver for accelerating commercialization of FCEVs and their associated hydrogen fuel station network. These policy drivers give clear direction for the California Air Resources Board (ARB) and CEC to plan and fund the state's hydrogen fuel station network for its imminent FCEV market. The two agencies have been working diligently on the state's hydrogen network, and these efforts demonstrate progress towards the State's ZEV Action plan.

The hydrogen fuel station network is a key component of meeting the State's goals for air quality, renewable fuel use, and greenhouse gas mitigation. The magnitude of changes necessary to achieve the National Ambient Air Quality Standard for ozone and the State's greenhouse gas reduction commitments requires a substantial fleet of fuel cell electric vehicles and other ZEVs, in order to move the state away from conventionally fueled vehicles.

AB 8 requires ARB to assess the size of the current and future FCEV fleet annually, based on vehicle registrations with the Department of Motor Vehicles (DMV), auto manufacturer responses to ARB surveys of projected future sales, and current and future hydrogen fuel station locations

1 1B-16-2012 directs ARB, CEC, and other relevant agencies to take actions that will help the deployment of over 1.5 million ZEVs in California by 2025, with easy access to fueling infrastructure supported by a strong, and sustainable industry. The order also requires 25% of the State's new vehicle purchases to utilize ZEVs by 2020.

and capacity. This information informs the State's decisions for future funding of hydrogen fuel stations, including the number and location of stations as well as minimum technical requirements for those stations.

This report represents ARB's first annual evaluation pursuant to AB 8. The period from 2014 to 2017 is projected to be a transition from technical and market demonstration of FCEVs to beginning the early commercial market. Funding under the directive of AB 8 will be sufficient to accommodate multiple auto manufacturers' commitments to bring FCEVs to the market. Pursuant to AB 8, ARB has determined the following:

- 125 FCEVs are currently registered with DMV.
- Auto manufacturer projections indicate that California's FCEV fleet will grow to 6,650 by the end of 2017 and 18,500 by the end of 2020.
- A total of 51 stations are expected to be operational statewide by the end of 2015, providing up to 9,400 kg/day of hydrogen.
- The coverage and capacity provided by these stations will be nearly sufficient through 2018 to support the FCEV fleet within that timeframe.
- However, the coverage and capacity provided by these stations to be funded under the latest CEC award will not be sufficient for the expected vehicles out to 2020.
- Additional coverage and capacity needs in 2020 will require up to 49 additional stations.
- Therefore, CEC should maintain the course – the maximum $20 million allocation and any other potential funding sources identified by ARB and CEC should be utilized in the next CEC funding program for hydrogen fuel stations, with placement and other considerations as recommended in the findings and the main report.

ARB staff has developed six principal findings and suggestions to inform these determinations. The remainder of this report is structured to discuss these findings and determinations in more detail and provide context and supplementary information. The section immediately following this Executive Summary identifies ARB's findings along with the AB 8 provisions the findings are intended to address. This is followed by the main body of the report, which provides additional details in support of the findings.

Recent Key Automaker Activities

June 2014: Hyundai became first in the state to lease a production FCEV to a private consumer. This followed its announcement in November 2013 to lease Tucson FCEVs worldwide, with a spring 2014 target for availability in Southern California. Some cars have already arrived and have been seen visiting local hydrogen fuel stations.

June 2014: Toyota unveiled its production FCEV, expected to have about 430 mile range and performance comparable to gasoline fueled vehicles, with a 2015 target launch for California.

Nov. 2013: Honda introduced a concept FCEV for market launch in 2015 in the US and Japan.

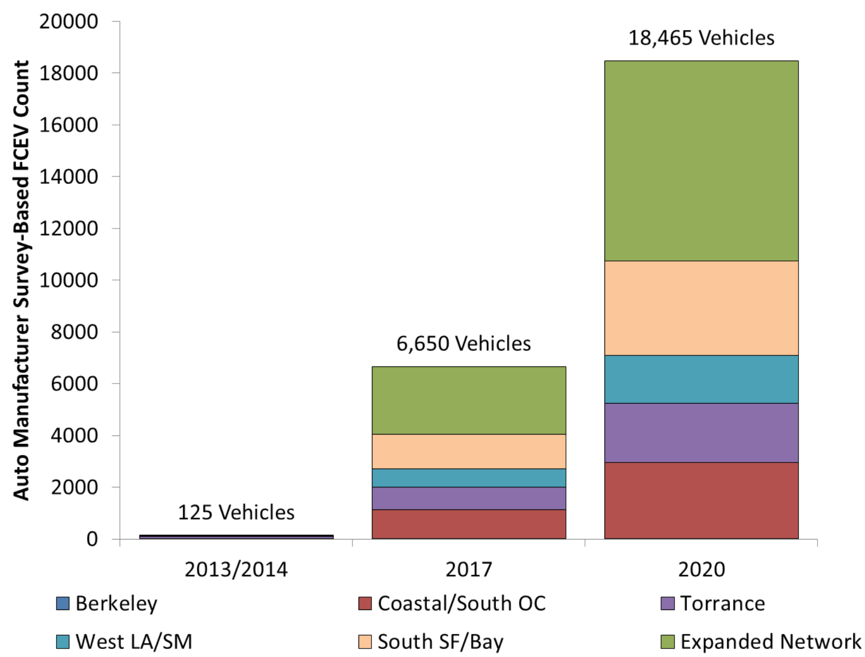
2012-2013: BMW and Toyota; Daimler, Ford and Nissan; and GM and Honda entered into or expanded existing partnerships and agreements for further development of their FCEV and related technologies.

Findings

Finding 1: The fuel cell electric vehicle fleet is poised to grow rapidly.

As Figure ES1 shows, auto manufacturers project a rapid acceleration in the number of vehicles coming to California beginning in 2015 and sustaining this growth at least to 2020, the last year included in the current ARB survey. By 2017, the state's fleet is expected to grow to more than 6,600 vehicles and, by 2020, to nearly 18,500 vehicles. Three auto manufacturers have publicly announced plans for major vehicle launches in model year 2014/2015, and more announcements are expected in the near future.

Figure ES1: Current and Projected Cumulative Vehicle Populations



Supplement to Finding 1: The rollout of fuel cell electric vehicles is expected to follow a trajectory similar to other recent advanced technology vehicles.

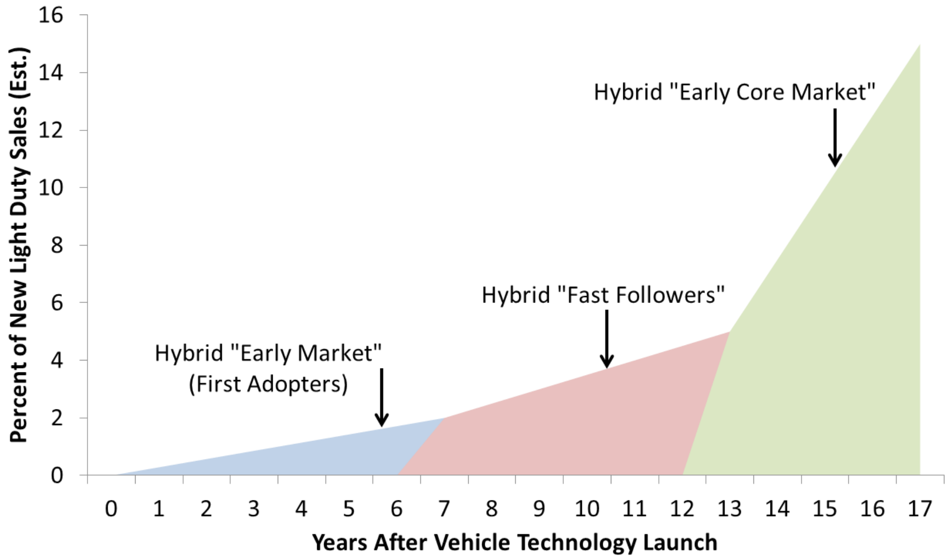
Toyota's experience with hybrids over the past 20 years provides useful perspective on the expected rollout process for FCEVs. On this basis, Dr. Tom Turrentine of UC Davis has suggested that introducing a new vehicle technology generally follows a multi-phase process, defined primarily by the progression of vehicle generations, but also correlating to years following vehicle technology launch.

Figure ES2 reproduces Dr. Turrentine's concept of the three vehicle introduction phases; each of these phases is characterized by different types of consumers, as noted. Comparing California's historical sales of hybrids to historical and projected sales of battery electric (BEV) and plug-in hybrid (PHEV) vehicles indicates that PHEVs and BEVs are following consumer acceptance and sales trajectories consistent with Dr. Turrentine's observations of hybrids. FCEVs are at the earliest point of commercial deployment, at the first model year of the first phase. Nevertheless, California's past experience suggests

> "For years, the use of hydrogen to power automobiles has been seen by many smart people as a foolish quest. That point of view is reminiscent of opinions 20 years ago of how the Prius hybrid was nothing more than a science project... and economically unfeasible. Change takes persistence."
>
> – Bob Carter (Sr. V.P. for Auto. Operations) at Toyota's unveiling its FCEV concept car at the 2014 Consumer Electronics Show.

the FCEV market may develop similarly to other advanced technology vehicles, provided the hydrogen fuel station network is established ahead of FCEV introduction.

Figure ES2: Hybrid Electric Vehicle Launch Trend



Finding 2: California's committed and planned funds for the hydrogen fuel station network appropriately address the growing numbers of FCEVs in the state during initial vehicle launch, but continued funding is needed to meet future demand.

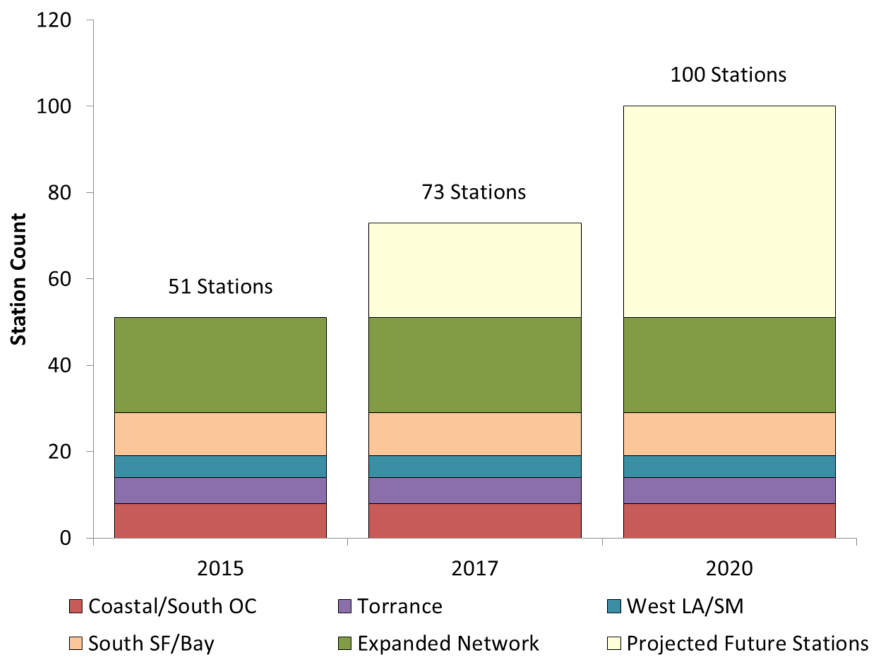
Two guiding principles, station coverage and capacity, underlie the process of determining the number and location of stations necessary to support commercial FCEV deployment. Station coverage emphasizes adequate hydrogen fueling outlets in areas of high demand; in the early years of the FCEV rollout, this can entice early adopters by ensuring positive consumer experiences. For the initial rollout of 100 stations (the minimum to be supported under AB 8), five key markets or "clusters" have been identified for a successful FCEV launch in California. In addition to these clusters, stations are necessary in the "Expanded Network" in anticipation of the first markets that will develop beyond the initial target clusters. Sufficient capacity indicates that the state's hydrogen fueling supply chain can provide enough fuel for the FCEVs projected to be on the road during the vehicle launch.

A: Coverage

Current hydrogen fuel station plans are expected to be well-matched to projected near-term vehicle adoption rates and largely meet geographical coverage needs for the early adopters in all areas other than the Berkeley cluster. The longer-term adoption rates will depend heavily on the continued ability to provide hydrogen to the markets where vehicles are sold and used. This requires a continued focus on incentivizing the construction of hydrogen fuel stations ahead of the projected demand from FCEVs.

Figure ES3 shows the projected hydrogen fuel station rollout through 2020; operational and funded stations are broken down according to the five key clusters. The successful roll out of the 51 stations expected by the end of 2015 will align well with the State's goals to ensure fueling stations are ready and available as soon as the near-term vehicle market is established. This is a critical point in the process to roll out the 100-station network to ensure adequate station coverage for the early FCEV adopters. It requires particular attention and State support for operations and maintenance costs for station operators to maintain their stations' availability until vehicle volumes increase and revenue from hydrogen sales can provide sufficient income to entice further private investment.

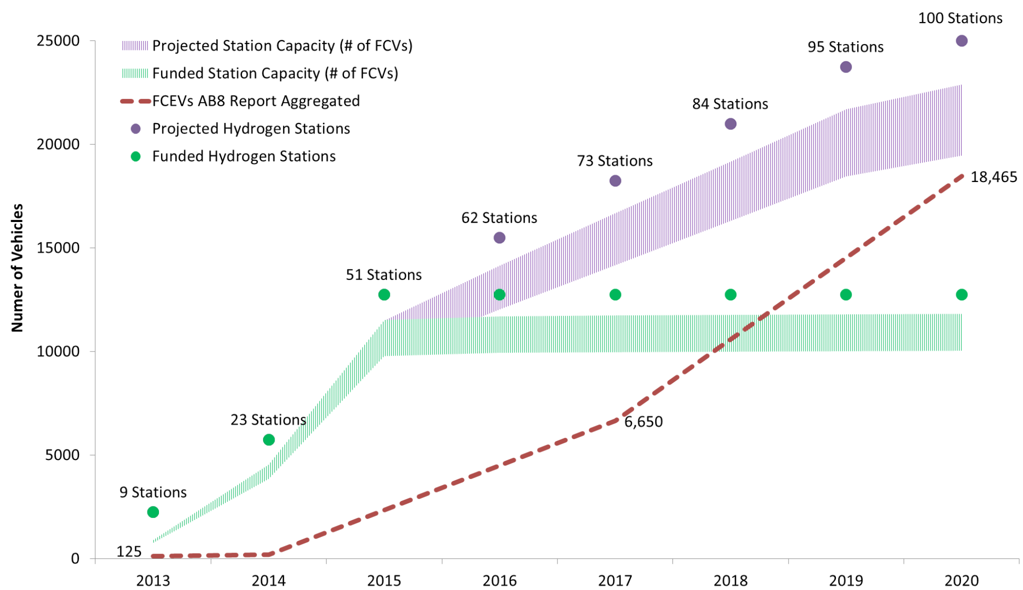
Figure ES3: Projected Cumulative Station Counts



B: Capacity

As shown by the intersection of the Funded Station Capacity (# of FCEVs) and Aggregated FCEVs in Figure ES4, the current supply of hydrogen from funded fuel stations is expected to be sufficient to meet demand out to 2018 but will be insufficient to meet projected demand from 2018 to 2020. With continued funding to support more hydrogen fuel stations, the projected hydrogen demand in 2020 can be sufficiently addressed. The funding schedule depicted in Figure ES4 is consistent with the State's plan to ensure leading hydrogen infrastructure investment can positively impact vehicle adoption rates. The intersection of the FCEV Aggregated count with the green-shaded region demonstrates that without additional funding, the state will experience a shortfall in supply from 2018 onward. By following the projected schedule of funding shown by the purple region, the state can ensure sufficient supply is maintained ahead of vehicle deployment. With the current projected number of vehicles, the 100 stations required by AB 8 will be necessary to establish sufficient supply prior to the long-term (2020) demand.

Figure ES4: Need for Continued Station Investments to Support Future FCEV Fleet



Finding 3: CEC's innovative solicitation is paving the way for a comprehensive hydrogen fuel station network in California.

In May 2014, CEC announced awards for 28 new hydrogen fuel stations and a mobile refueler to provide backup and auxiliary service statewide. This sent a strong market signal to investors and continued the State's clear commitment to provide needed funding for the development of the hydrogen fuel station network. As shown in Table I, by the close of 2015, there are expected to be a total of 51 stations statewide, providing adequate station accessibility and coverage to meet consumer expectations in the near term.

Table ES1: Statewide Hydrogen Fuel Station Locations at Close of 2015

Station Count	Station Locations
10	South San Francisco/Bay Area cluster
8	Coastal/South Orange County cluster
6	Torrance Area cluster
5	West Los Angeles/Santa Monica cluster
22	Expanded Network (New markets, connectors and destination)

The 28 new stations awarded by the CEC in 2014 will introduce many new hydrogen fuel station operators (thereby diversifying the market) and achieve several goals:

1. Increase convenient access in areas of expected high vehicle adoption.
2. Establish local network for the South San Francisco/ Bay Area.
3. Establish fueling capability in key connector and destination locations that enable trans-state travel.
4. Establish a hydrogen presence in the emerging major market of San Diego.
5. Provide operation and maintenance funding support as the market develops.

Moreover, the stations recently selected by the CEC are expected to significantly help the State meet its renewable hydrogen goals as proscribed in Senate Bill (SB) 1505. By providing priority incentive for stations with 100% renewable hydrogen and requiring a minimum of 33% renewable hydrogen for all proposals, the CEC has ensured the State's targets will be exceeded by the currently-planned stations.

Finding 4: The five cluster regions remain a priority for future funding. Berkeley in particular requires the establishment of a local retail hydrogen network. San Diego and Sacramento also require attention.

Past State funding, including CEC's 2014 announcement, has mostly addressed the short term localized hydrogen refueling needs for four of the five clusters identified by stakeholders through the CaFCP 2012 Road Map for hydrogen infrastructure. In the long term, these clusters will individually require a focus on additional coverage and capacity to meet the expected demand and provide measures of redundancy.

Ongoing discussions with automakers indicate the Berkeley cluster will be an early target market; however, the cluster is not expected to have the capability for retail service once the first vehicles arrive in California. Thus, of the five high-priority early market clusters, Berkeley will require highest priority for near-term funding. An initial investment in two new stations within the area is needed to help establish a local hydrogen network and incentivize local vehicle deployment.

San Diego and Sacramento will soon have their first operational stations. Though not included in the five key clusters, the markets in these areas have the potential to grow into future clusters and will likewise need to receive substantial focus in the near future.

Table ES2 provides an initial set of recommended locations for the next set of hydrogen fuel stations based on ARB staff's analysis.

Table ES2: Draft Recommendations for Near-Term Station Funding

Location	Purpose	Suggested Station Counts
Berkeley Cluster	Establish Market	2
South SF/Bay Area Cluster	Coverage/Capacity	1
Coastal/ South OC Cluster	Coverage/Capacity	1
West LA/SM Cluster	Coverage/Capacity	1
Torrance Cluster	Coverage/Capacity	2
San Diego Area	Coverage	1
Sacramento Area	Coverage	1
Expanded Network Areas	Coverage or Destination/Connector	1 or 2

Finding 5. Continued incentives are needed for increased station fueling capacity and innovative technology. Continued development of policies is needed to meet retail customer and station investor expectations.

FCEV drivers will expect a fueling experience comparable to conventional gasoline vehicles, with prominent station availability allowing drivers to take full advantage of their vehicles' long driving range. Thus, a well-planned hydrogen fuel station network will be a major component of consumer acceptance of the new technology, as localized fuel availability will play a significant role in vehicle purchase decisions. The State is committed to ensuring that FCEV drivers experience a near seamless transition to refueling with hydrogen. To this end, retail customer expectations need to be addressed by the technical capabilities and design capacities of the new hydrogen fuel stations. Incentives for continued innovation in areas of station design, including back-to-back and consecutive fills, should remain a focus of future State funding. Additionally, station data collection and reporting, including real-time status, will inform the State and station developers of needs and best practices for the ongoing development of the network and individual station designs.

For station investors, the need for certainty in their investments will help drive further station development, both for publicly and privately funded stations. In its station awarding process for publicly funded stations, CEC already considers location siting criteria, along with the environmental protections built into State law, and should continue to do so. To further strengthen this market signal and accelerate investments in the station network, ARB staff is investigating the feasibility of concepts governing the siting of both publicly and privately funded hydrogen fuel stations, pursuant to specified air quality and market sustainability criteria, which will help ensure a sufficient demand for each station's hydrogen. ARB staff is also exploring ways to enhance existing State fuels programs, such as the Low Carbon Fuel Standard (LCFS), to further strengthen the market signal to station builders and auto manufacturers.

Additional details on this finding are presented in the body of the report.

Finding 6: Completion of ongoing projects to address station performance certification (validation, quality, and accuracy) is necessary to ensure a smooth transition to retail hydrogen fuel sales.

Technical capabilities of hydrogen fuel stations are constantly improving, and it is essential to maintain the pace of innovation. Challenges remain for the development of a set of industry standards for performance certification of fueling stations. The State can provide guidance to station builders and operators by continuing ongoing participation in defining these standards and developing capabilities for their implementation. Multiple interagency projects are currently under consideration to support the rapid development of standards for dispensed hydrogen purity, accuracy in measuring dispensed hydrogen mass, and simultaneous and back-to-back vehicle fills.

Conclusions

Transformation requires vision, commitment, and action. California is taking the necessary actions and committing substantial public funds to begin turning the singular vision of zero emissions transportation into reality. Those actions are putting the state on the path to a zero emissions future in which FCEVs and BEVs are effective, “no compromise” alternatives to conventionally fueled vehicles. There are challenges ahead on this path to building the hydrogen fuel station network, and the State must remain vigilant in maintaining its commitment and responding to the evolving market.

The success of the hydrogen fuel station network and the FCEV rollout are interdependent. California’s station funding programs have established the basis for a fueling network to provide assurance to auto manufacturers that the necessary infrastructure will be in place to support their markets. Likewise, auto manufacturers must respond in kind by committing to increased deployment of FCEVs by orders of magnitude so that station builders will have certainty of a robust market for their stations. Thus, this report also serves as a call to action for the auto manufacturers to enhance their vehicle deployment strategies in response to California’s ongoing fueling network development. Actions such as Hyundai’s delivery of the first mass-produced FCEV to California initiate the needed progress; however, these actions must be replicated and amplified many times over by multiple auto manufacturers for this market to succeed.

I: Introduction

Through a growing understanding of the impact of light duty vehicle emissions on air quality and climate, the State of California has spent decades devoted to developing programs and technologies to mitigate the harmful effects of vehicle emissions. Significant progress has been made, but studies from a variety of experts have also repeatedly demonstrated that California must not only maintain its focus on reduced emissions, but pursue even more effective solutions than have been utilized to date. Long-term goals, such as the greenhouse gas targets in Assembly Bill (AB) 32, will require the implementation of highly effective technologies. Fuel cell electric vehicles (FCEV) have been identified as one such effective technology solution to address these challenging air quality and climate goals. The following criteria pollutants and greenhouse gases emitted by conventional vehicles are absent in FCEV tailpipe emissions:

- Nitrogen oxides: Precursors to photochemical smog and ground-level ozone; ozone has been linked to a number of cardiovascular and respiratory diseases.
- Carbon monoxide: A powerful asphyxiant in confined spaces and a precursor to greenhouse gases.
- Sulfur dioxide: A precursor to acid rain and a respiratory irritant.
- Particulate Matter: Hydrocarbon-based particles that have been linked to a number of cardiovascular and respiratory diseases; this category also includes particles made entirely of carbon from unburned fuel, known as black carbon.
- Volatile organic compounds: Various organic gases that can indirectly affect cardiovascular and respiratory health, smog, and climate.
- Carbon dioxide: A greenhouse gas that is a significant constituent of gasoline combustion products.
- Methane: Another greenhouse gas with a global warming potential more than 20 times that of carbon dioxide.
- Nitrous Oxide: Another greenhouse gas with a global warming potential nearly 300 times that of carbon dioxide.

Additionally, California's experience with developing hydrogen production technology has demonstrated that fuel lifecycle emissions (accounting for production, transportation, delivery, and use of the hydrogen) can be reduced significantly below those of gasoline; for some hydrogen production methods, emissions can be all but completely eliminated. Moreover, multiple production methods have demonstrated the ability to utilize up to 100% renewable process and/or feedstock energy. These considerations are all crucial to the motivation and goals of the Air Resources Board's (ARB) current Zero Emission Vehicle (ZEV) program. Thus, FCEVs, along with other alternative vehicle technologies like battery electric and plug-in hybrid electric, have been prioritized for incentive programs to support their market development and adoption within the state. Each alternative vehicle technology faces its own unique challenges in implementation and adoption. For the FCEV, the need for a substantial and purposefully-designed network of hydrogen fuel stations has been identified as a primary challenge that can be addressed by State programs.

As a result, AB 8 (Alternative Fuel and Vehicle Technologies: Funding Programs), signed by Governor Brown in September 2013, dedicated up to $20 million per year for the California Energy

Commission (CEC) to fund hydrogen fuel stations. In addition, the legislation directs ARB and CEC to plan and fund the development of an economically-viable and ultimately self-sustaining hydrogen fuel station network to enable market launch and growth of FCEVs within the state [1]. Particularly germane to this report, AB 8 requires that:

1. ARB aggregate and make available current DMV registration counts of FCEVs and auto manufacturer projections of future vehicle placements.
2. Beginning in June of 2014, ARB will provide CEC an annual evaluation of the need for additional hydrogen fuel stations, geographic areas of need, and minimum operating standards.
3. Beginning in December of 2015, ARB and CEC jointly review and report on the annual progress towards establishing the state's hydrogen refueling network.

The analysis included in this report addresses the first two of these requirements. It builds upon data sources specified by AB 8 and information gained through ARB's continued interactions with industry, academic, and government stakeholders. In order to facilitate the effort, ARB has developed and utilized a database-driven hydrogen and FCEV accounting tool to evaluate hydrogen supply and demand. Inputs to the tool include number and placement of hydrogen fuel stations, and number and placement of FCEVs based on DMV registration data and auto manufacturer surveys.

The vehicle data and needs assessment developed in this report are therefore intended to provide an objective analysis of CEC's recent 2013/2014 awards and help guide the development of the next funding program, for 2014/2015. Currently, the hydrogen fuel station network and FCEV fleet are in an early demonstration phase. California has recently been the focus for introduction of the first mass-market product, the Hyundai Tucson FCEV, and rollout announcements from Toyota and Honda. Auto manufacturers have established alliances for technical collaboration. Furthermore, in addition to the work in California, large public-private efforts for hydrogen fuel station deployment are taking place in Japan, Germany, and the United Kingdom. It is anticipated that the next five years will be a period of rapid acceleration in growth and development planned for both FCEV deployment and hydrogen fuel station installation. The assessments in this report address two main topics: 1) present-day trends of the nascent hydrogen FCEV market and 2) forecasts for the industry during its early growth phase in California.

California has had a longstanding commitment to funding the construction of hydrogen fuel stations, much of which has provided valuable data and lessons during the industry's demonstration and development phase. Experience with these early stations has led to better planning. This experience has also made it possible to determine best practices for siting and designing stations. The span of years from 2014-2017 is a turning point in the industry, moving from demonstration to establishment of the first commercial markets. As part of planning to accommodate this advancement in the market, State funding of hydrogen fuel stations has allowed for standards and codes for increasingly better station equipment, such as higher pressure on-site storage that reduces the needed number of on-site compressors, or the use of compressors that improve efficiency by using ionic fluid. Through coordination between CEC, ARB, and industry stakeholders, new stations meet high standards of operation through adoption of the following:

1. Standardized and consensus-based hydrogen fueling protocols based on the capabilities of currently-available technologies
2. Incentives for early completion of station construction
3. Continued requirements for use of renewable feedstock and priority for 100% renewable stations
4. Continued priority for stations with lower greenhouse gas emissions

5. Planned capability to operate with a mobile backup refueler
6. Construction of a mobile backup refueler able to provide statewide service.

Stations funded under these guidelines will be capable of providing the user-friendly service essential for a successful vehicle launch. When construction is completed, the last round of State funding will lead to a sufficiently large number of stations to support initial vehicle deployment in most local markets for the next few years. With the latest CEC station funding awards, ARB anticipates 51 stations operating by the end of 2015.

The CEC's last solicitation for hydrogen fuel stations was dramatically oversubscribed; 61 proposals were received, totaling $102 million in funding requests, well above the $20 million annual appropriation indicated in AB 8. This enabled the CEC an opportunity to fund a larger-than-expected number of stations by moving forward funds from the 2014/2015 program, a step consistent with the State's commitment to supporting a network that can supply sufficient hydrogen for the vehicles that will be on the road in the near future. In so doing, previously unaddressed target markets will now have significant hydrogen fueling capacity, as will new destination and long-distance connector sites. As the network grows, the learnings about station characteristics and performance standards will continue to evolve and lead to on-going optimization and improvements. If there is again a strong response with multiple high value proposals, the Commission could use an award process similar to that implemented in the recent program. ARB staff would work closely with CEC staff to ensure that the future awarding process is again consistent with the best available information.

Moreover, the latest solicitation issued by CEC introduced some key characteristics not previously implemented in station funding programs. In recognition of the State's goals for renewably-sourced fuels, and in accordance with the requirements outlined in Senate Bill 1505 (Statutes of 2006, Chapter 877), CEC prioritized incentives for the construction of stations utilizing 100% renewably-sourced hydrogen. CEC was able to fund two such stations as a result of the solicitation. Additionally, all station proposals were required to demonstrate a plan for sourcing at least 33% of production energy (process and/or feedstock) from renewable resources, ensuring that the currently-funded network will be able to meet the SB 1505 goals once construction is complete. The other important addition was the provision of operation and maintenance funding for up to three years available to all qualifying stations, operating, in construction, or awarded by the solicitation. This funding improves the business case for investors who choose to address California's need for hydrogen infrastructure in the earliest stage, when total hydrogen sales may not be as high as their potential when compared to the future years of the FCEV rollout. By providing this funding upfront, CEC can help ensure these stations will remain open and operational as the vehicle rollout steadily progresses.

This first annual June report directly addresses the requirements of AB 8, and provides additional context and supplemental information. The report is organized thematically, with an overarching focus on developing the evaluation of how well current infrastructure plans meet projected vehicle demand, sequentially addressing hydrogen demand, hydrogen supply (referred to as capacity), and refueling station performance requirements. These analyses are addressed by the report in the following manner (all section references are to the Health and Safety Code unless otherwise noted):

Chapter II: Location and Number of Hydrogen Fuel Cell Electric Vehicles

Based on DMV records and auto manufacturer projections specified in section 43018.9(c)(1) and (c)(2), ARB has developed an estimate of the statewide and regional FCEV fleet out to 2020. This establishes the basis for defining current and future hydrogen demand. Given the emphasis throughout AB 8 for regionally-specific analyses, Chapter II also presents a brief overview of ARB's methodology for evaluating the hydrogen network on regional scales.

Chapter III: Expected Vehicle Deployment Based on Past Experience with Advanced Technology Vehicles

Chapter III provides an extended background to support the analyses and findings of Chapter II; thus, it provides additional context for the material presented to meet the requirements of section 43018.9. Additionally, this Chapter provides an independent reference to validate the FCEV fleet rollout numbers provided by auto manufacturers required by section 43018.9(c)(1).

Chapter IV: Location and Number of Hydrogen fuel stations

Section 43018.9(d)(1) and (d)(2) require an analysis of the fueling coverage provided by the operational and funded fueling network. Analysis of coverage requires matching projections of localized vehicle deployment and adoption to localized infrastructure plans. Convenient access to sufficient hydrogen fuel stations to enable daily FCEV consumer driving habits underlies the evaluation of station coverage required in AB 8. Chapter IV assesses the known hydrogen fueling network on this basis and supplies recommendations for future station locations to meet coverage needs.

Chapter V: Evaluation of Current and Awarded Hydrogen Fueling Capacity

Section 43018.9(d)(1) requires an evaluation of the quantity of additional hydrogen needed (additional capacity) beyond currently operational and funded stations. Chapter V therefore compares the planned hydrogen capacity to the projected demand, utilizing the balance as a guideline for determining the additional required capacity. Though defined separately in AB 8, coverage and capacity are interrelated concepts and the analysis of Chapter V builds from and incorporates the analysis presented in Chapter IV.

Chapter VI: Hydrogen Fuel Station Performance Standards and Technology

Chapter VI addresses the final topic area of section 43018.9 (d)(2), minimum operating standards for hydrogen fuel stations. The analysis considers topics of customer experience, station planning and design, and operational performance. Analyses of the current stations and recommendations for short- and long-term development goals are provided.

Chapter VII: Conclusions and Recommendations

Section 43018.9(d)(1) and (e)(1) require ARB to recommend the funding level for CEC's next funding program (up to $20 million per year), geographic areas that will require increased coverage and/or capacity to meet their hydrogen refueling needs, and minimum station operating standards. ARB has condensed the analyses of previous chapters into a quickly-referenced list of recommendations for CEC's upcoming Program Opportunity Notice.

II: Location and Number of Hydrogen Fuel Cell Electric Vehicles

AB 8 Requirements: Estimates of FCEV fleet size and bases for evaluating hydrogen fueling network coverage.

ARB Actions: Distribute and analyze auto manufacturer surveys of planned FCEV deployments. Analyze DMV records of FCEVs. Develop correlations between survey regional descriptors and widely-accepted stakeholder frameworks for evaluating coverage.

As part of its responsibilities under AB 8 and under the authority of ARB's Low Emission Vehicles (LEV III) program [2,3], ARB distributed mandatory surveys to 16 auto manufacturers in March 2014. Confidential responses were collected by April 2014. The surveys requested information on the auto manufacturers' planned deployment of FCEVs in California for the current model year and the next three model years. Auto manufacturer vehicle projections were specified within five geographic regions ("San Francisco Bay Area", "Sacramento Area", "Los Angeles/Orange County/Ventura", "San Diego", and "Other") and as statewide totals. In addition, ARB distributed an optional supplementary survey to the same respondents to request 3-year statewide aggregate totals for vehicle deployments in model years 2018 to 2020. Thus, auto manufacturers had the opportunity to provide year-by-year regionally distributed data of projected vehicle deployments for model years 2014 through 2017 as well as statewide, aggregated deployments for the model years 2018 through 2020.

ARB's database tool aggregates vehicle numbers by calendar quarters. Annualized aggregates are then calculated as the average, sum, or maximum over four quarters, as appropriate. Additionally, the database works at the ZIP code-level for station placement analysis. Every ZIP code in the database is then linked to both its corresponding air district and cluster. A cluster is a group of communities and neighborhoods with similar vehicle usage patterns and, importantly, a potential for high FCEV adoption rates. The cluster definitions implemented in the tool are adopted from the California Fuel Cell Partnership's (CaFCP) 2012 Road Map for the commercialization of FCEVs [4].

Currently, the Road Map identifies five main clusters throughout the state. Coordinated hydrogen fuel station network development and vehicle deployment within the clusters will build a robust early market and provide motivation for continued geographical expansion of vehicle deployment. As published in their Road Map, the CaFCP's members determined through an iterative process that early market launch of FCEVs will be enabled by 68 strategically placed stations, two thirds of which would be located in the clusters. Similarly, AB 8 set a target of 100 stations as the minimum number of stations the State would need to support in order to enable a transition to a market-driven and increasingly privately-funded network.

The auto manufacturer surveys provide projected counts of vehicle deployment grouped by model year. But model year does not directly correlate to calendar year of sales/deployment of vehicles. Moreover, auto manufacturer data are projections of delivery to dealers; the date for vehicle purchase or lease and when the vehicle is in use is unknown until subsequent years of DMV data can be obtained. Accordingly, ARB made the following assumptions:

1. Unless otherwise indicated by an auto manufacturer, half of the vehicles reported for a given model year are assumed delivered in the calendar year preceding the model year; the other half are assumed delivered in the calendar year corresponding to model year.
2. All vehicles are assumed to be on the road from the first quarter of the year of delivery. This allows for an estimate of the upper bound of hydrogen demand.

Auto manufacturers were provided information of projected numbers of statewide stations and requested to provide projected vehicle placement by region. Figure 1 demonstrates how ARB translated regional distinctions in survey responses into the clusters and air districts implemented in the database tool. In the figure, colored areas correspond to clusters and the map boundaries correspond to air districts. Stations outside of clusters are located in regions considered to be the "Expanded Network" and are intended to provide service in areas where the market may expand beyond the early target clusters. The Expanded Network definition is adopted from the CaFCP Road Map, similar to the cluster definitions. Expanded Network locations could be targeted areas for increased coverage, destination or connector sites, or network backup and redundancy. Distribution from one survey region to multiple clusters or districts followed the annually varying trends of station counts. This regional distribution scheme was utilized throughout the ARB analysis to provide localized context of vehicle deployment, hydrogen demand, and fueling station installation.

Figure 1: Map of Auto Manufacturer Vehicle Placement within CaFCP Clusters and Expanded Network *(Colored Areas)*, and Air Districts *(Map Boundaries)* According to Survey Regions *(Text Boxes)*

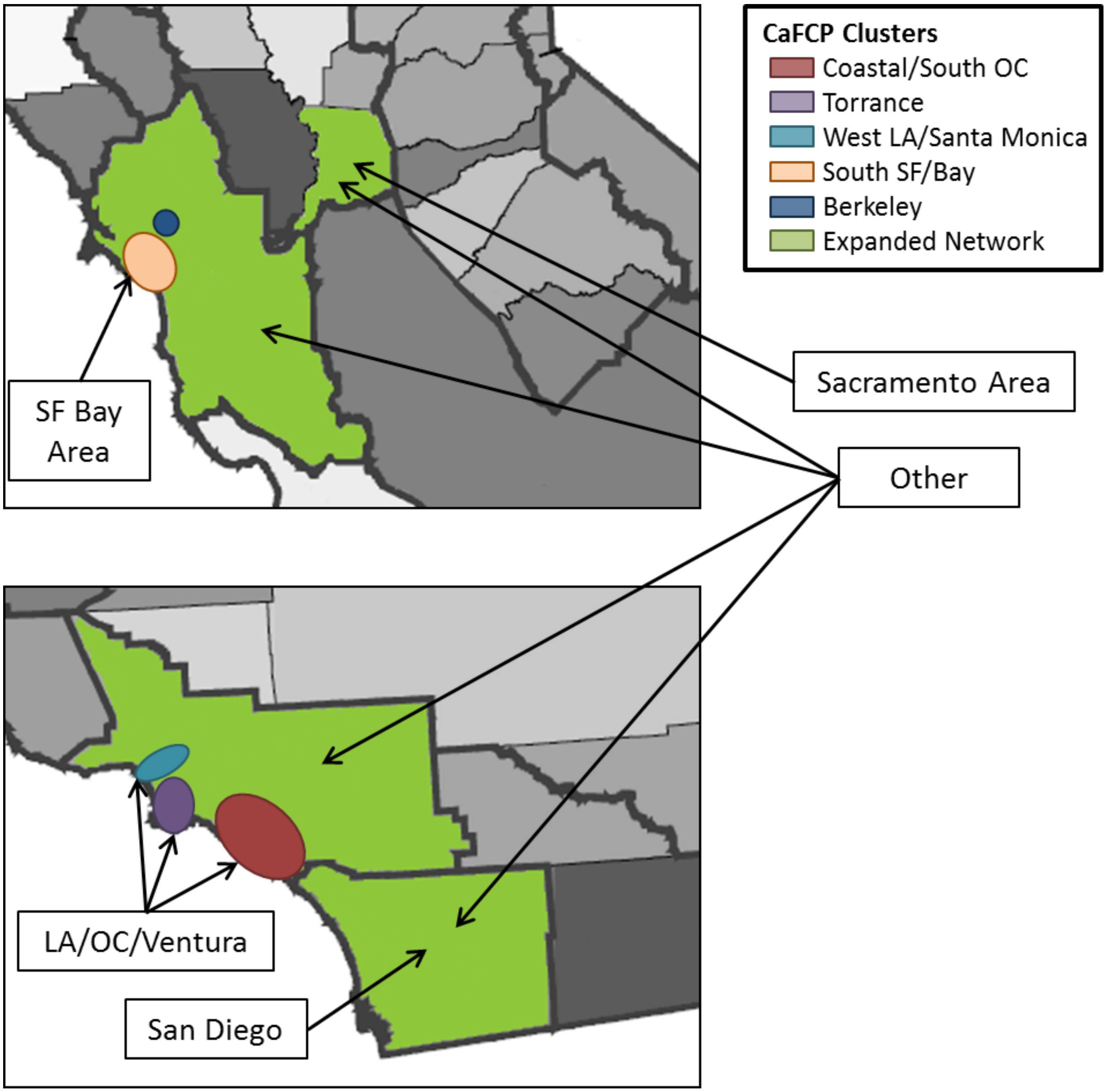
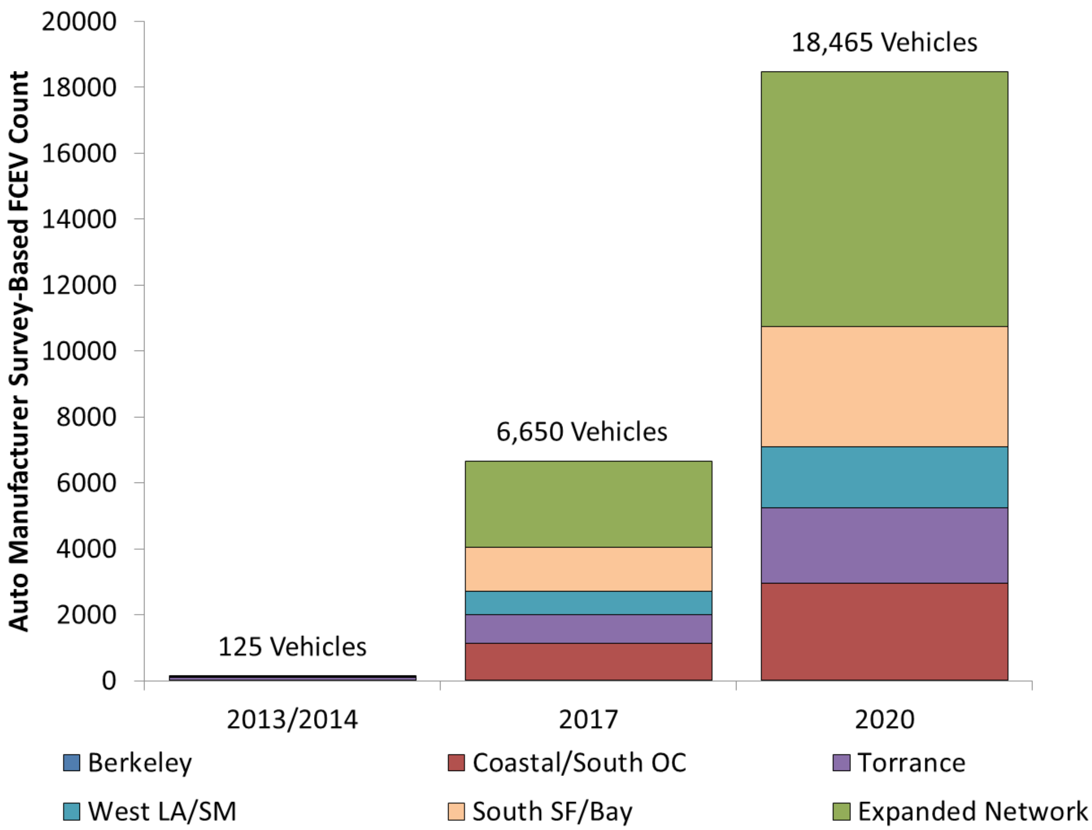


Figure 2: Statewide and By-Cluster Cumulative Vehicle Populations
Based on CaFCP data, Auto Manufacturer Surveys and Station Distribution



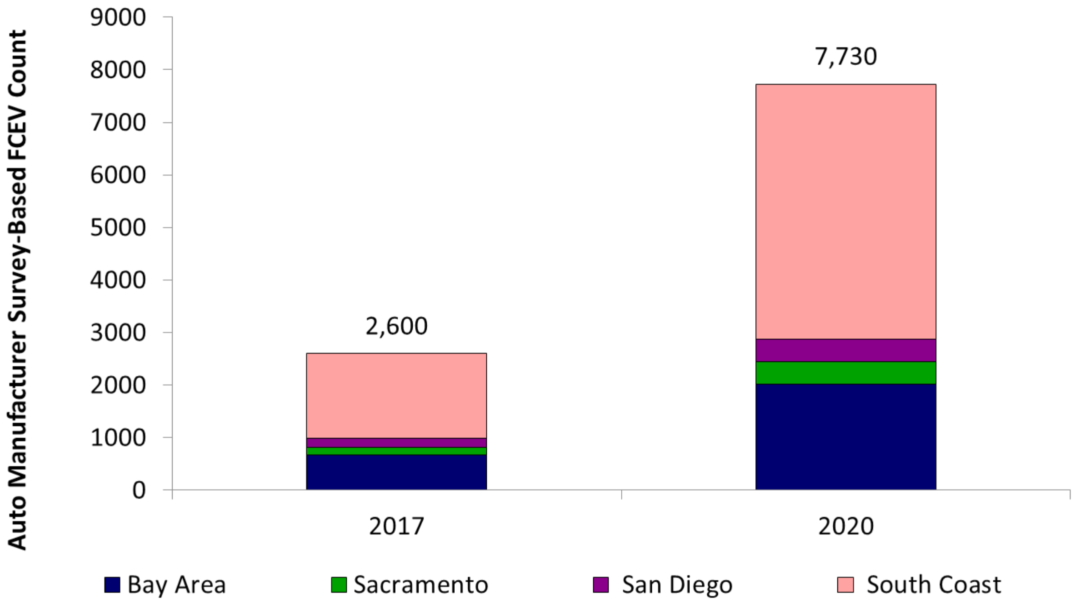
Based on the above, annualized vehicle populations were calculated as the average over four quarters, taking into account assumed attrition rates consistent with ARB's EMFAC model [5]. This accounts for factors such as voluntary vehicle retirement, retirement due to accidents, planned non-operation, and transfer of vehicles out of state. The resulting statewide projections for the future FCEV fleet are over 6,600 vehicles on the road in California in 2017 and nearly 18,500 vehicles in California in 2020. Figure 2 provides the split by cluster for the 2013-2014, 2017, and 2020 timeframes.

From the 2020 projections, approximately half of the vehicles will be located within the five clusters. Of those vehicles within the clusters, approximately two-thirds are projected to be deployed in the three southern California clusters, and the remainder predominantly in the South San Francisco/ Bay Area cluster.

Figure 3 further breaks down Figure 2's vehicle projections within the expanded networks. As shown in Figure 3, within the Expanded Network category, deployments are expected to occur mostly in the South Coast Air District, within the greater Los Angeles communities outside the clusters. The distribution of vehicles are expected to show an approximate 2-to-1 split between southern and northern regions of the state. For 2018-2020, staff assumed the vehicle distribution across the state follows the same proportions as in the 2017 period.

Comparing the projected statewide vehicle counts across the periods shown in Figure 2 suggests auto manufacturers are planning a rapid acceleration in the number of vehicles brought to market for the 2015 to 2020 timeframe. This is consistent with the current announcements indicating that 2015 through 2017 will be significant launch years for a number of vehicle manufacturers. For these reasons, the rate of hydrogen fuel station deployment also needs to be sustained and the fueling network needs to be ready for the arrival of the vehicles. Once open, it is vitally important that stations remain operational and functionally available so that the planned vehicle launches can be successful.

Figure 3: Expanded Network Auto Manufacturer FCEV Deployment by Air District



AB 8 also requires ARB to report the total number of hydrogen FCEVs registered with DMV through April of the current year. DMV currently has registrations for 125 vehicles; this is lower than industry estimates of the current FCEV population at around 230 vehicles. DMV counts may be smaller for a number of reasons: FCEVs may be registered by auto manufacturers in other states but operated in California and included in industry counts; FCEVs may currently be in California but not yet placed with customers and therefore not yet registered to DMV; or industry counts may not consider retirements and relocations. Thus, the lower number represented by DMV registrations is likely a more accurate representation of the statewide fleet utilizing today's existing fueling infrastructure.

The count of vehicles registered to DMV is small in comparison to the auto manufacturer projections of vehicles from 2015 onward, especially in the northern areas of the state. Therefore, the current DMV-registered population should not be considered an indicator for the eventual fleet distribution. However, it is worth noting that comparing statewide DMV data to current auto manufacturer plans indicates nearly a seven-fold increase of the current FCEV fleet within the year. Reaching the projected number of FCEVs in 2015 will be a landmark in California's fleet.

III: Expected Vehicle Deployment Based on Past Experience with Advanced Technology Vehicles

(Corollary to Chapter II)

AB 8 Requirements: Estimates of FCEV fleet size and bases for evaluating hydrogen fueling network coverage.

ARB Actions: Distribute and analyze auto manufacturer surveys of planned FCEV deployments. Analyze DMV records. Develop correlations between survey regional descriptors and widely-accepted stakeholder frameworks for evaluating coverage.

Consumers historically adopt new vehicle technology through a gradual process, with early adopters of the technology kick-starting demand for the new vehicles. Based on past experience, the same may be true with FCEVs, provided sufficient fueling station installation prior to vehicle launches.

Dr. Tom Turrentine of UC Davis has shown that introducing a new vehicle technology generally follows a multi-phase process, shown here in Figure 4. The shaded regions of the figure are conceptual phases in the launch of new vehicle technology.

Dr. Turrentine developed this framework based on observations of Japan's launch of hybrid vehicles (which is slightly longer than California's) [6]. Each shaded phase corresponds well to a new generation of the vehicle technology and by extension to a period of time following the vehicle technology's first introduction.

In Figure 5, the timing of Dr. Turrentine's conceptual phases has been applied to California's hybrid fleet and other advanced technologies. Figure 5 utilizes data obtained from current and past ARB studies and displays historical rates of initial vehicle deployment for conventional hybrid, and historical and projected battery electric (BEV), and plug-in hybrid (PHEV) vehicles. The dip in year nine sales of hybrids reflects the general economic downturn at the end of the last decade.

Based on experience with hybrids in both markets, there is an initial "Early Market" phase that exhibits a steady acceleration of vehicle adoption, most prominently fueled by the purchase choices of technology first adopters. The "Fast Followers" phase begins to show the first signs of a wider market entry, with a more consistent rate of vehicle adoption. Note that even in this second phase, sales of the new technology are less than 10% of all new vehicle sales. Finally, based on the example of sales in Japan, the "Early Core Market" develops, with a rapid acceleration of vehicle adoption rate, fueled by broad market acceptance of the technology. California's hybrid market appears to be on the cusp of this third phase.

All other advanced vehicle technology platforms are currently in the first phase of deployment, when vehicle sales volumes are expected to be small, but there is the possibility for a near-term rapid acceleration. The data in Figure 5 for BEV and PHEV represent actual sales and projections, especially in their later years. The FCEV fleet is exceptionally young compared to the other technologies. It is only recently that the very first commercial model year FCEV has been introduced to California. It is expected that as the vehicle launch progresses, following the installation of hydrogen fuel stations, the FCEV fleet will likely exhibit adoption rates with characteristics similar to the hybrid, PHEV, and BEV. PHEVs and BEVs entered the market with significantly smaller infrastructure requirements due to the ability to refuel at home. Installation of the necessary hydrogen infrastructure ahead of vehicle introduction will likely be the key factor in accelerating FCEV deployment beyond the projections currently available.

Figure 4: Hybrid Vehicle Technology Launch Trend and Projection

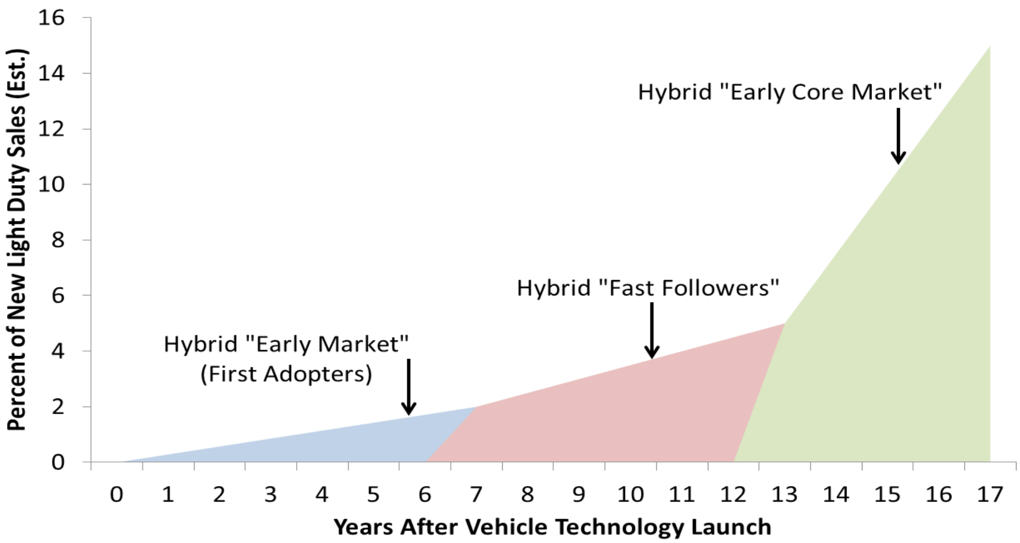
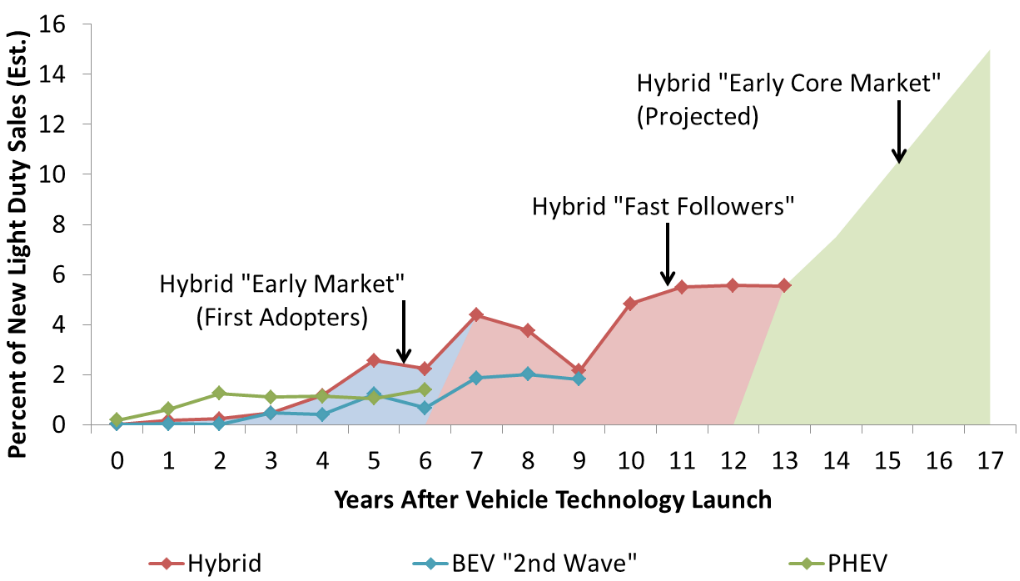


Figure 5: Comparison of Hybrid Vehicle Launch Trend and Projected Advanced Technology Vehicle Launch



IV: Location and Number of Hydrogen Fuel Stations

AB 8 Requirements: Evaluation of hydrogen fuel station network coverage.

ARB Actions: Determine the regional distribution of hydrogen fuel stations in early target markets. Assess how well this matches projections of regional distribution of FCEVs in these markets. Develop recommendations for locations of future stations to ensure hydrogen fueling network coverage continues to match vehicle deployment.

A: Overview of Coverage Concept

It is broadly acknowledged within AB 8 and by CEC, ARB, and stakeholders that maintaining sufficient hydrogen fueling capacity for vehicles is only one of two major aspects required to support the deployment of FCEVs. The first essential aspect is the geographic coverage of the hydrogen fuel station network. The idea of coverage stresses the importance of the location of each fueling station as a metric of the effectiveness of the network in providing convenient service to FCEV drivers. Prior work referenced in the Fuel Cell Partnership's Road Map indicates that a maximum six minute drive-time is the optimal distance between stations, balancing customer convenience with total investment cost [7]. In many areas of the state, this equates to a small driving distance. Thus, stations must be built near projected vehicle placements in order to optimize vehicle adoption by consumers. Customer perceptions that stations are too far for convenient access can affect their purchasing decision and ultimately hinder cumulative FCEV deployment. Similarly, auto manufacturers cannot foster consumer confidence without the ability to identify nearby hydrogen fuel stations; without fueling capability, customers will not buy a FCEV. Moreover, properly-planned coverage can enhance station utilization (and therefore the effective investment of State funds).

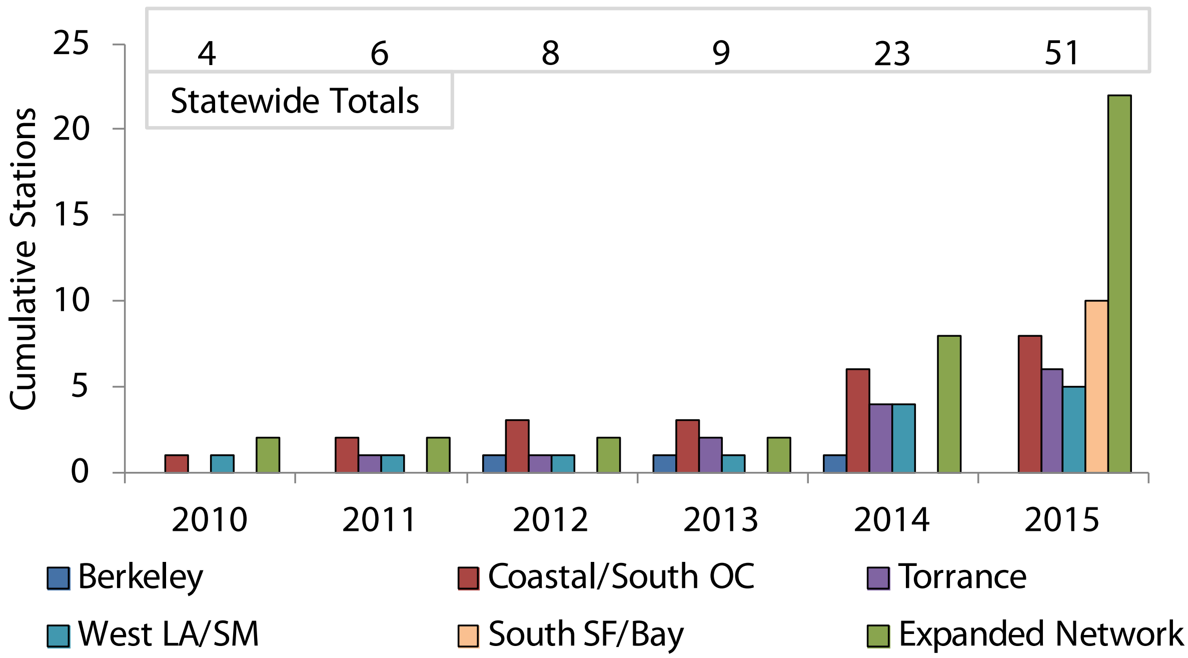
Thus, it is imperative that priority is given to building stations in areas of projected vehicle adoption. These stations must precede the vehicle placements themselves. This is especially true leading up to the early years of deployment when consumer confidence and education in a new technology and infrastructure will play a major role in the real deployment scenario. Coverage is therefore used to convey the concept that the serviceable areas of the planned stations will properly and fully align with and cover the areas of projected need.

At present, this coverage metric can only be broadly applied to large geographic regions; however, it is the intent that as time progresses, coverage can be assessed at community and neighborhood scales. Furthermore, it is the goal of AB 8 to support the development of the hydrogen FCEV market until at least 100 stations are built. Thus, tracking the regional distribution of station counts is vital to an assessment of the state's hydrogen fuel station network.

B: Current Operational and Funded Station Coverage

There are currently nine stations in operation and able to provide hydrogen to the public, either with or without familiar retail sales features. With the exception of one station in Thousand Palms and another in Emeryville, these stations are exclusively in the Coastal/South OC, Torrance, and West LA clusters, as can be seen in Figure 6. This region has historically been considered the focus area of many auto manufacturers' initial deployments and many of the associated stations were involved in early research and fleet demonstration projects. It is expected that most of these stations will transition into full public service. A full list of stations and their characteristics is provided in the Appendix.

Figure 6: End-of-Year Station Counts by Cluster and Statewide



This focus on the South Coast is expected to continue into 2014, with funded but not yet open stations largely planned for construction in the same regions, as illustrated in Figure 7. In the map, a distinction is made between the stations funded with the original appropriation (yellow markers: Funding Awarded '14) and the stations funded through the additional application of 2014/2015 funds (purple markers: Funding Awarded '14 + $20M). Due largely to the stations chosen for funding under CEC's May 2014 announcement, the clusters in the northern region of California are also expected to begin to exhibit significant growth in coverage and capacity in 2015. When all stations currently funded, under construction, and awarded are completed by the end of 2015 (provided all funded projects remain on schedule), there will be a total of 51 stations operating throughout the state, providing a familiar retail fueling experience. Thus, in terms of number of stations, by 2015 California appears to be within close reach of attaining the preliminary goal of 68 stations strategically placed throughout the state. The projection of 68 stations represents industry and stakeholder consensus as the minimum number of stations necessary to support the initial auto manufacturer vehicle launch, while the State's goal of 100 stations additionally considers the needs for a transition to a market-driven industry [4].

The South SF/Bay, Coastal/South OC, Torrance and West LA/Santa Monica clusters are planned to have significant stations counts, at 10, 8, 6, and 5 stations, respectively. While the Berkeley cluster currently has a hydrogen fuel station in Emeryville, this station is thus far expected to not meet retail customer demands after 2015. One station in Thousand Palms is similarly expected to be operating but not providing a familiar retail customer experience. Given 2015 as a major launch year, customers are likely to expect an experience very similar to current retail gasoline stations and these two hydrogen fuel stations in Emeryville and Thousand Palms do not currently have plans to provide this capability, though they will remain operational.

Generally, there is good agreement between the locations of planned stations and the locations of planned vehicle deployment. Based on 2017 projections, the furthest year for which some auto manufacturers provided information on the spatial distribution for planned deployment, the regional proportions of vehicles and stations are nearly identical. Combining all cluster and Expanded Network stations and vehicles into general north and south categories (with San Joaquin and Santa Barbara attributed to the south), the 2017 proportions for vehicle fleets are 2:1 for southern and northern California, respectively. By station counts, the split is similarly 2:1; by station capacity (shown later), the split is slightly smaller at 3:2. Thus, by all measures there is expected to be a roughly 2-to-1 ratio of hydrogen supply and demand when comparing southern and northern California out to 2017 and possibly 2020. This high-level spatial resolution is currently the most appropriate for aggregate analysis, given the numbers of vehicles and stations considered in this report.

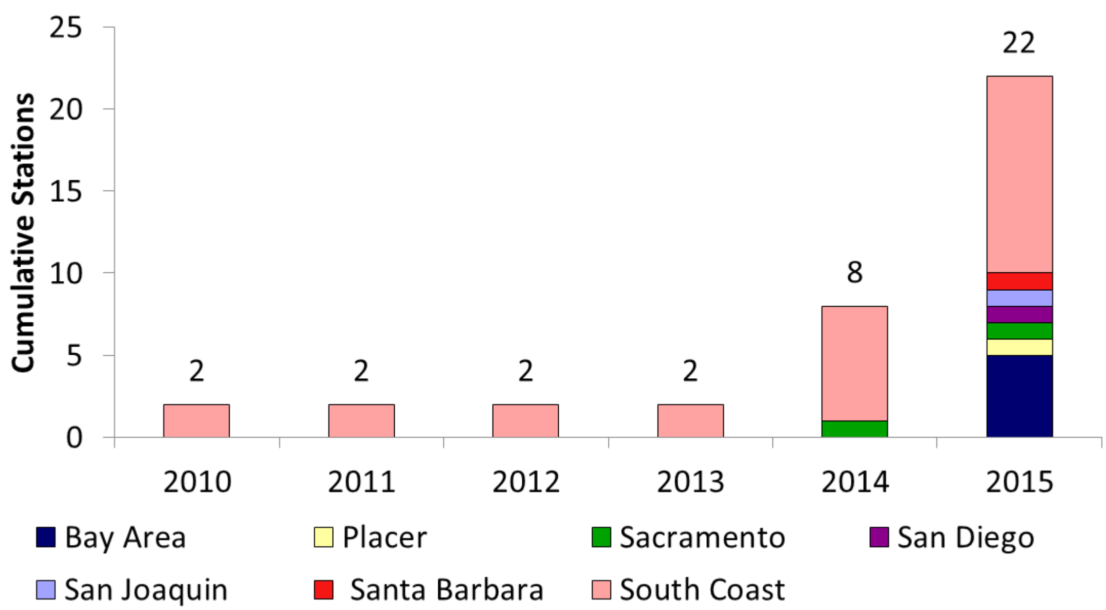
Figure 7: Station Coverage (Existing and Planned as of May 2014)

It is important to note that a significant number of the 51 stations are planned for the Expanded Network. The original 68 stations were intended to be largely within the clusters themselves. In its Road Map document, CaFCP indicated 45 stations inside the five main clusters and 23 stations outside. The currently-planned network is weighed more heavily towards the Expanded Network. The Expanded Network station count goal has nearly been met; 22 stations are currently projected to be outside of the clusters. Thus, while absolute station counts indicate that California is well on its way to achieving the original goals of the 68 stations specified in the roadmap, it is important to also acknowledge that the in-cluster coverage targets have not yet been met.

However, that is not to say the Expanded Network stations are extraneous or redundant. On the contrary, many of them are near the clusters. Therefore, although these stations are outside the clusters they may likely serve communities that the cluster definitions are meant to serve, but at slightly less convenience than the in-cluster stations. The Road Map's projected station counts within clusters were based on factors such as a minimum 6-minute drive time between stations. This method of arriving at projected stations within clusters has proven valuable for planning purposes; however, flexibility is necessary when building the actual network. Additional factors, such as willingness of individual gasoline station operators to host hydrogen dispensers, readiness of individual sites to physically accommodate hydrogen equipment, and lessons about local markets that can only be learned as infrastructure and vehicle deployment occurs, may result in slightly different in-cluster station counts than the Road Map plan. As the network is built, it is likely that the cluster definitions themselves will also evolve to accommodate lessons learned during the process.

Figure 8 displays the break-down by air district of the planned Expanded Network stations, which are distributed similarly to the in-cluster stations. The data in Figure 8 also highlight the first installation of destination and connector stations in the San Joaquin, Santa Barbara, and Placer air districts. Though they are outside the main clusters, these stations will play a pivotal role in the purchase decision for a number of potential FCEV drivers. Because FCEVs have a range comparable to conventional gasoline vehicles, FCEV drivers will expect the fueling network to enable long-distance travel. This inherent benefit of the technology can only be used to its full advantage if stations exist in appropriate destinations and midway points for those longer trips. The three stations in San Joaquin, Santa Barbara, and Placer air districts provide this essential capability and will be a factor in potential FCEV adopters' purchase decisions.

Figure 8: Expanded Network Station Counts by Air District



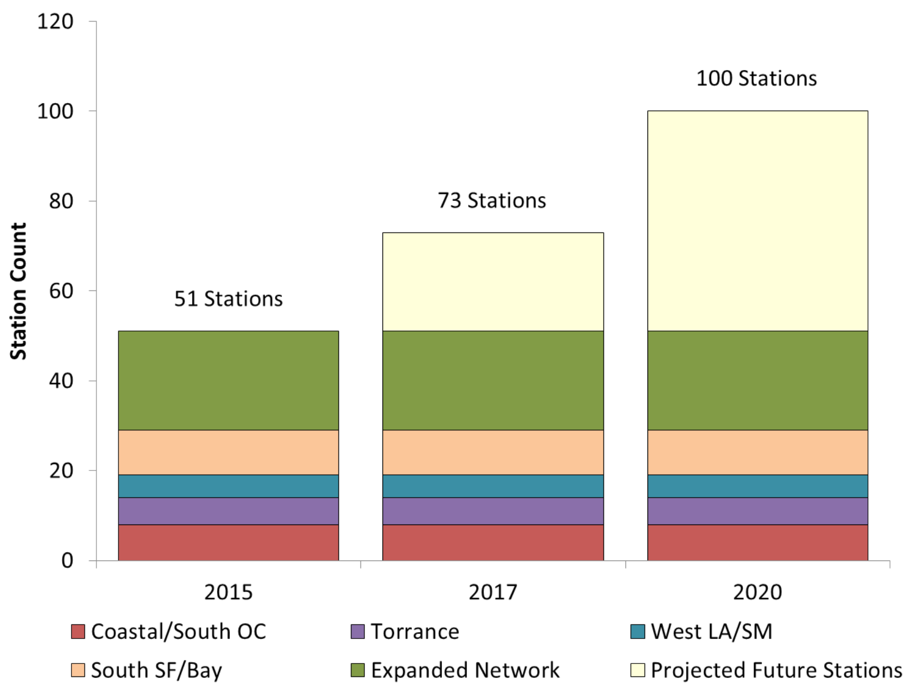
Beyond 2020, it will likely remain important to expand capacity and increase station counts in the cluster regions. Although there are plans for relatively large numbers of stations in the major clusters as compared to today's counts, the clusters are large and each represents numerous communities. Even with as many as ten stations, as expected for the South SF/Bay cluster, the stations are still separated by large distances and it is not expected that every community within a cluster will be serviced by the existing planned network. Moreover, it will be necessary to build redundancy into the network in order to provide drivers with a contingency should a station or stations go offline for an extended period of time. Thus, within the cluster regions, there is still a need to build stations to provide full coverage and to further provide system redundancy. As mentioned previously, this is especially true for the Berkeley cluster, which requires the establishment of hydrogen fuel stations that can provide a familiar, retail refueling experience.

Outside of the clusters, the local station counts are relatively small. In all regions, more stations will be necessary to at least provide redundancy. In locations such as Coalinga and Truckee, which are connector and destination stations, the need for additional stations likely does not extend beyond an eventual need for redundancy. However, in other areas like Sacramento and San Diego, which are regions with enough near-term potential to grow into their own clusters, there is a need to build out for additional coverage and capacity in addition to the need for redundancy. The area around Pasadena is another location with features similar to San Diego according to the Road Map; however, there are currently plans for enough stations in that area to satisfy the projections of local need.

C: Suggested Station Counts and Locations for Next Funding Program

As noted previously, the hydrogen fuel station deployment plan under AB 8 calls for a minimum of 100 stations; indications from CEC suggest this may be achievable by 2020. Figure 9 displays the currently operational and funded stations and their distribution by cluster as well as projections for additional station installations in the future, for which spatial distribution has not yet been determined.

Figure 9: Projected Cumulative Station Deployment by Cluster



For the Projected Future Stations, the next round of State funding for hydrogen fuel stations may be utilized best if an emphasis is placed on incentivizing construction of stations within the original five clusters, especially the Berkeley cluster, which does not yet have a plan for hydrogen fuel stations that provide a familiar retail experience. Additionally, since the San Diego and Sacramento areas have the potential to become major clusters by the time AB 8's goal of 100 stations is achieved, it may be necessary to begin expanding coverage in San Diego and Sacramento with the next round of funding.

Considering the analyses and discussion above, ARB staff has drafted a list of potential locations for the next round of CEC hydrogen fuel station network funding, as indicated in Table 1. The list assumes a total of 10 or 11 stations may be funded under the program; the actual number will depend on the requested State funding in awarded applicant responses to the next funding program. The recommendations for station counts within each region are not strict requirements; in the time leading to the next program opportunity notice from CEC, there will be new information available (related to both vehicle deployment and station construction) that should be considered during the process of designing the next funding opportunity. The recommendations in Table 1 should therefore be considered a starting point for ongoing discussion leading to CEC's next announcement of a funding program.

Table 1: Working Recommendations for Station Funding in Next Program Opportunity Notice

Location	Purpose	Suggested Station Counts
Berkeley Cluster	Establish Market	2
South SF/Bay Area Cluster	Coverage/Capacity	1
Coastal/ South OC Cluster	Coverage/Capacity	1
West LA/SM Cluster	Coverage/Capacity	1
Torrance Cluster	Coverage/Capacity	2
San Diego Area	Coverage	1
Sacramento Area	Coverage	1
Expanded Network Areas	Coverage or Destination/Connector	1 or 2

D: Additional Station Siting Considerations

Another location factor that should be considered by CEC in future solicitations and awards is the distance between stations. As noted, it is important to keep stations within reach of the vehicle users. However, it is also important from an environmental and market investment standpoint to ensure that stations are not too close to each other. CEC employs a so-called "six minute rule," which generally calls for stations being within six minutes of the vehicle users but not closer than six minutes within other stations. At this time, ARB supports this practice and recommends that CEC continue applying both elements of the six-minute rule in their award process.

ARB staff is investigating concepts that could further accelerate private investments into the hydrogen fuel station network. One such concept involves implementing an inter-station distance requirement or a similar provision, both for publicly and privately funded stations. For example, station investments could be accelerated with a "first-come, first-serve" lockout provision (i.e., no two stations should be located in a geographical area bounded by identified criteria; in the CEC example, this would be within six minutes of each other). This would ensure that as the FCEV market is developing, the siting of hydrogen fuel stations in California is consistent with the environmental protection and sustainability objectives of AB 32, SB 1505, and other authorities, while providing a clear signal to station investors that there will be sufficient local demand for their hydrogen fuel. ARB staff will work in conjunction with its sister agencies (CEC, local air districts) to explore and craft this concept or similar concepts.

ARB staff is also exploring other ways to further strengthen this market signal, not only for investors in both publicly- and privately-funded hydrogen fuel stations, but also for manufacturers of hydrogen FCEVs. For example, hydrogen providers can currently opt into the LCFS program (title 17, California Code of Regulations, section 95480 et seq.) to generate credits for low carbon fuels, such as hydrogen used for transportation in California. LCFS credits have historically traded at around $30-$70 per credit [8,9]. ARB staff is considering ways to enhance this credit system so that, among other things, it continues to encourage station owner participation in the program and, if feasible, allows auto manufacturers to receive a return on at least part of the credit value.

V: Evaluation of Current and Projected Hydrogen Fueling Capacity

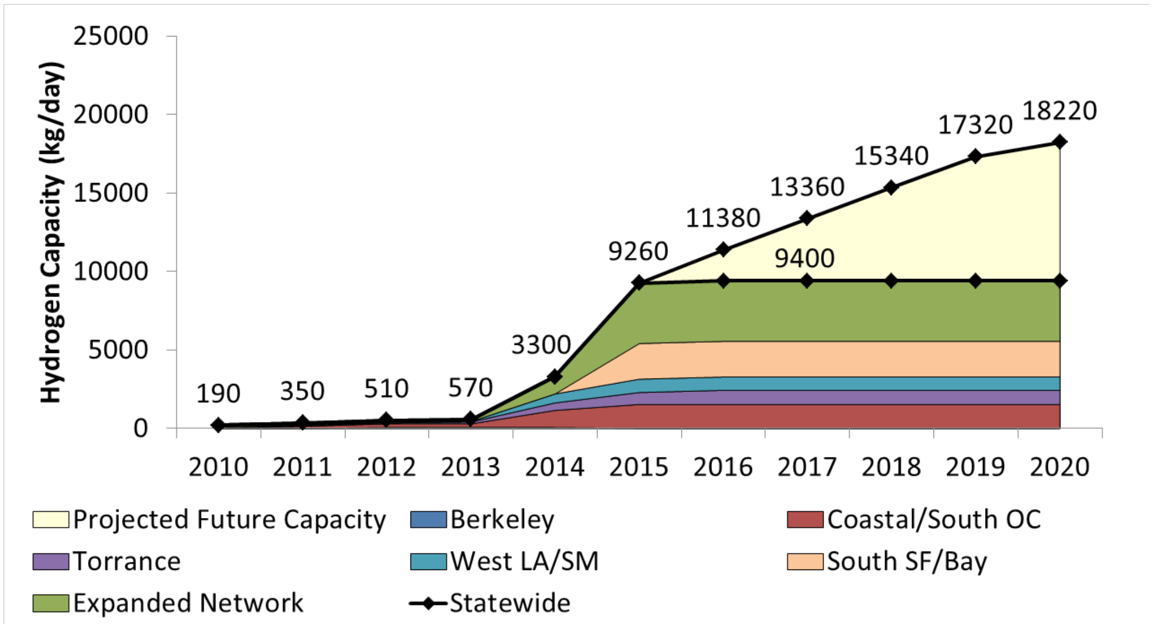
AB 8 Requirements: Evaluation of quantity of hydrogen supplied by planned hydrogen fueling network. Determination of additional quantity of hydrogen needed for future vehicles.

ARB Actions: Determine statewide and regional capacity of hydrogen supply. Translate statewide and regional vehicle counts of Chapter II to hydrogen demand. Determine balance between capacity and demand as guideline for additional amount of capacity required.

The historical and projected trend of hydrogen fueling capacity within the state, and by cluster, is presented in Figure 10 for the years 2010 to 2020. Hydrogen fuel stations in the database were aggregated according to their projected opening date; the displayed capacity in any given year is therefore the cumulative capacity at the end of that year. For example, in 2014, a total of 2,730 kg/day of additional capacity is expected to become available from stations opening this year, resulting in a total 3,300 kg/day fueling capacity by the end of the year. Currently available data for fueling stations extend only to the end of 2015, the latest projected opening year for stations currently under construction or award.

As shown in Figure 10, roughly 60% of the capacity of known stations will correspond to the cluster spatial definitions. Of these stations, 60% of the capacity is planned to be placed within the three southern California clusters. It is not until 2015 that the northern California region receives significant hydrogen capacity, almost exclusively located in the South SF/Bay Area cluster. Seven of the ten associated stations in this cluster are awardees of the 2014 CEC funding. The most recent investment from the State has initiated the development of a FCEV market in the northern California region.

Figure 10: Statewide and By-Cluster Total Hydrogen Supply



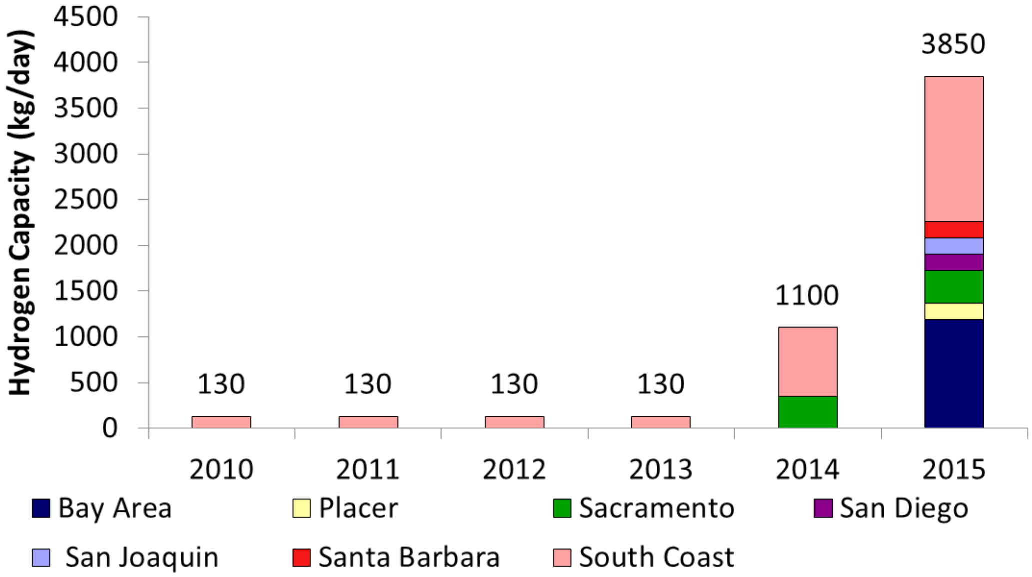
Stations in the southern half of the state have an expected average capacity of 150 kg/day, while those in the northern half have an expected average capacity of 210 kg/day. This is largely due to the fact that there are numerous small capacity legacy stations in the South Coast, Torrance, and Los Angeles areas that were built at times when technology was not as mature as it is today and the expected vehicle fleet much smaller. Additionally, these stations were built when FCEV and hydrogen fuel station technologies were largely in their demonstration phase. By contrast, most of the stations planned for northern California are still in the process of construction or planned for future construction, using newer technology with higher design capacity for a larger customer base.

The capacity planned in the Expand Network is significant, especially from 2015 onward. Figure 11 shows the breakdown of this capacity by air district. It should be noted that this figure shows the breakdown only to 2015. While the station rollout plan calls for additional stations to be built beyond 2015, it is not yet possible to determine how many of these stations would fall within the Expanded Network category.

Similar to the stations within the clusters, Figure 11 shows the southern California region and Bay Area make up a major portion of the planned capacity in the Expanded Network stations. A few areas designated as “connector” and “destination” sites are expected to begin contributing to statewide capacity in 2015. Importantly, these stations will enable transportation between the northern and southern regions of the state, and the use of FCEVs for weekend and vacation trips in addition to daily commutes.

Additionally, though not one of the initially-identified target cluster areas, San Diego is expected to eventually become a major cluster. The recently awarded funds from the CEC support construction of the first station to eventually fill initial needs of this region. This region was individually identified in the auto manufacturer survey for deployment in the near-future. Therefore, in spite of the lack of currently-registered vehicles in the region, the placement of the San Diego station will be in good agreement with the timing of the auto manufacturer rollout to the region. Similar conclusions can be reached related to the planned capacity in the Sacramento area, which is expected to have its first station open later this year.

Figure 11: Breakdown of Expanded Network Capacities by Air District



Considering the hydrogen supply and vehicle fleet information of Figure 2 and Figure 10, together with assumptions of vehicle fuel consumption, allows for an assessment of the projected hydrogen demand and balance both regionally and throughout the state. For these projections, it was assumed that every vehicle's annual vehicle miles travelled (VMT) was as specified in the most recent version of ARB's vehicle modeling tool, EMFAC [5]. Therefore, the hydrogen demand for every vehicle in the database was calculated with consideration for its age-specific annual miles traveled. In addition, vehicle fuel economy was taken from the auto manufacturer survey information and the U.S. Environmental Protection Agency (U.S. EPA) ratings; when no data were provided for a vehicle, the fuel economy was assumed to vary by model year, as in previous work with the Clean Fuels Outlet program [10].

Figure 12: Hydrogen Supply, Demand, and Net Balance in 2017 and 2020 with Current Station Plans and Projected Additional Stations

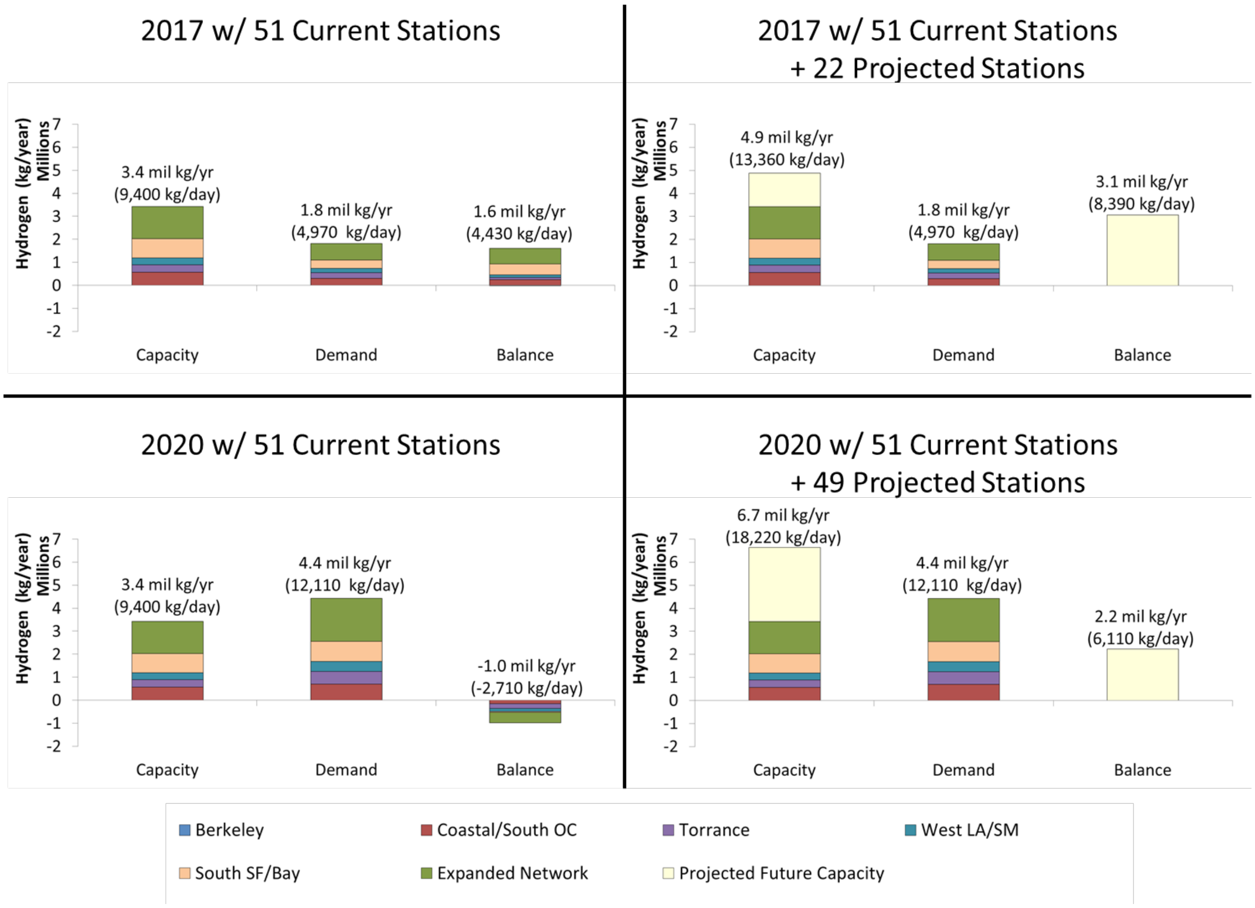
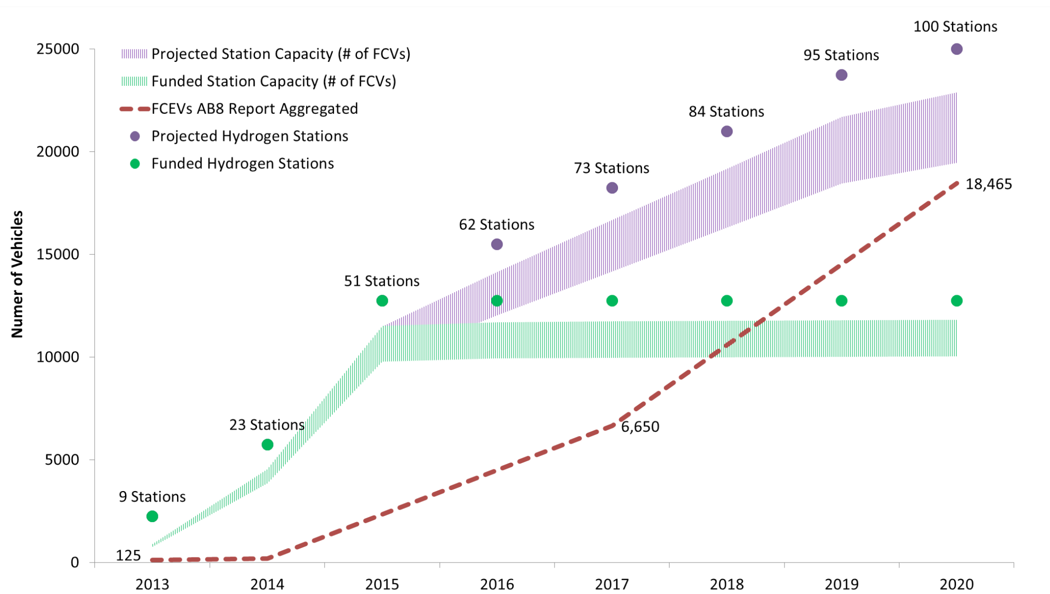


Figure 12 shows projections for the total hydrogen supply (capacity), demand and net hydrogen balance. To help assure a successful FCEV launch for the next two years, projections of new hydrogen capacity will outpace demand from new FCEVs. Out to 2018, there should be enough hydrogen fuel available statewide for the vehicles projected to be in place at that time, though not on a regional basis (the Torrance and West LA/SM clusters are projected to have a shortfall in 2018). Beginning in 2019 and without continued funding for the hydrogen fuel station network, ARB projects a widespread shortfall as a result of rapid FCEV deployment from 2018 onward. Continued funding for the hydrogen fuel station network will increase the supply and shift balances in later years away from a deficit. The future projected stations utilized in the calculations were assumed to have a capacity of 180 kg/day, similar to the average capacity of currently operating and funded stations.

It appears that in the short term, there will be adequate hydrogen to supply the fleet of vehicles that auto manufacturers plan to place in their early launch period. This does not mean CEC should cease funding additional stations. On the contrary, the hydrogen supply will quickly be diminished as auto manufacturers begin their initial expansion. Careful planning and execution for additional capacity will be especially necessary for the next round of station funding. The May 2014 awards from CEC applied funds forward from the next (2014/15) fiscal year; as a result, new funding (2015/16) will likely specify stations opening in 2017, bypassing 2016. If auto manufacturer projections grow as reported in coming years' surveys, the projected hydrogen deficit could shift to 2018 or 2017. This situation would leave little leeway for unplanned project delays on future stations.

Based on information received from CEC's last funding program, up to 11 additional new stations may be funded by the State with the annual appropriation of $20 million specified by AB 8. Figure 13 shows how the hydrogen capacity compares to the hydrogen demand in scenarios of no additional State funding (green shaded area) and annual full utilization of appropriated State funding (purple shaded area) up to 100 stations in 2020. The green shaded area reflects the range of FCEVs that can be supplied fuel for the number of hydrogen fuel stations; under this scenario, no additional funding is allocated beyond CEC's most recent award, so the number of FCEVs that can be supplied remains constant post-2015. The purple shaded area reflects a scenario where additional funding is provided post-2015 to continue expansion of the hydrogen fuel station network to 100 stations. The intersection of the red dashed line (auto manufacturer FCEV projections) with the green shaded area indicates the previously-mentioned shortfall of hydrogen in 2018. The purple shaded region demonstrates how additional funding can ensure sufficient long-term capacity. Ensuring sufficient capacity for demand out to 2020 is shown in Figure 13 to require installation of 11 new stations per year out to 2020. Thus, CEC will need to fully utilize the $20 million appropriated State funds in its next funding program in order to provide coverage in the areas noted in the previous Chapter and to ensure long-term demand is sufficiently addressed.

Figure 13: Need for Continued Station Investments to Support Future FCEV Fleet



To summarize, the planned hydrogen supply network can supply the fuel demand from the number of FCEVs expected to 2018, but it is not projected to grow rapidly enough to sustain the long-term deployment scenario reflected in auto manufacturer survey responses from 2018-2020. Carefully planned increased capacity will be required, through station capacity upgrades and installation of new stations. Present data indicate that more than a single additional round of State investment will be required; thus, the full $20 million available for CEC's next funding program should be utilized.

VI: Hydrogen Fuel Station Performance Standards and Technology

AB 8 Requirements: Evaluation and determination of minimum operating standards for hydrogen fuel stations.

ARB Actions: Assess the current state of hydrogen fuel station standards, including planning and design aspects. Identify and recommend needed additional standards. Provide recommendations for methods to address these needs through hydrogen fuel station funding programs.

The operational capabilities of California's hydrogen fuel stations have been gradually progressing as a result of numerous hydrogen program initiatives throughout State and local agencies, hydrogen technology providers, industry standards commissions, and many other stakeholder parties. Currently, hydrogen is being delivered to stations through a variety of fuel pathways and in both liquid and gaseous states. Combinations of on-site and off-site production have been and will continue to be utilized. Siting and permitting processes have taken a central focus in the ongoing network development as experience is gained and more local jurisdictions become involved in the familiarization and process of constructing hydrogen fuel stations. As a result of this past work and related achievements, the technologies and methods available today provide a significant basis for meeting today's capacity needs.

However, looking forward to the growing market according to auto manufacturer projections, the technical capabilities of individual stations must continue to evolve. Data will need to be collected to understand customer needs and experience and assess performance of the stations. A more nuanced understanding of customer usage habits will likely need to be developed and adopted as the station clusters expand and multiply, and as the focus of the network shifts towards satisfying capacity. Consumer experience information will help in the planning of future station placements and operational capacity. Stations will need to become more capable, able to serve more varied load profiles, and capable of providing hydrogen according to currently evolving standards. Thus, the following discussion assesses the current state of the "average" or "typical" hydrogen fuel station design up through May 2014 and provides suggestions for necessary improvements as the network continues to grow. The State will continue to collect information from the operation of the stations to better understand customer needs and assess station performance to aid in future station planning.

A: Station Classifications Based On Customer Usage Habits

There are varying station designs across the state's current and planned installations. It is not yet known if these earlier stations will meet customer fueling habits in the future. With the current numbers of FCEVs on the road, most station operators are concerned primarily with improving the reliability and maximizing the availability to fuel single, intermittent customers. Future stations will need to address the needs of multiple customers simultaneously; maximizing throughput, rather than availability alone, will begin to take more focus. The intermittency of current operation will quickly become insufficient under current plans for vehicle deployment. Going forward, it will be necessary to analyze and distinguish between customer usage habits at various stations. ARB proposes three station classifications be considered for the next round of funding, as detailed in Table 2.

Table 2: Recommended Station Classifications Based on Customer Habits

Classification	Daily Throughput	Hourly Peak Throughput	Dispensers	Technical Capabilities
High Use Commuter	High	High	More than 2	Back-to-back, simultaneous fills
Low Use Commuter	Low-Intermediate	Low	2	Simultaneous fills
Intermittent	Low, Intermittent	Low	1-2	Limited fuel capabilities

To illustrate the need for more varied station types, it is useful to look at the example of the current gasoline fueling infrastructure. Based on self-reported data in a survey conducted by CEC, the proportional daily sales for various station throughputs in 2012 are shown in Figure 14 alongside a similar breakdown for the planned hydrogen network [11]. Figure 15 provides a comparison of the individual station size within each category for gasoline and hydrogen, with gasoline converted to energy-equivalent hydrogen sales. From these data, it is clear that there are varying characteristics of gasoline station operation. A small proportion of stations have throughputs nearly seven times the system-wide average, 20% provide nearly double the system average, and nearly 80% have capacities below the average. The top 21% of stations combined provide half of the state's capacity, leading to this large disparity between high- and low-capacity stations. Everything else being equal, if FCEVs eventually require a similar network, then a similar variety of station capacities may be necessary.

By contrast, there is less of a distinction in the capacities between groups for the planned hydrogen fuel station network. In particular, the current hydrogen network does not demonstrate the existence of stations with very large fueling capabilities, as can be found in the top 1% of gasoline stations. The largest hydrogen fuel stations are only about twice as large as the system average and the top 21% of stations provide only 30% of the state's capacity. While the hydrogen fuel station network does not yet need stations as large as today's gasoline stations, it is clear that much larger stations than the current plan will need to be implemented for network build-out.

Figure 14: Proportion of Gasoline Throughput and Hydrogen Capacity

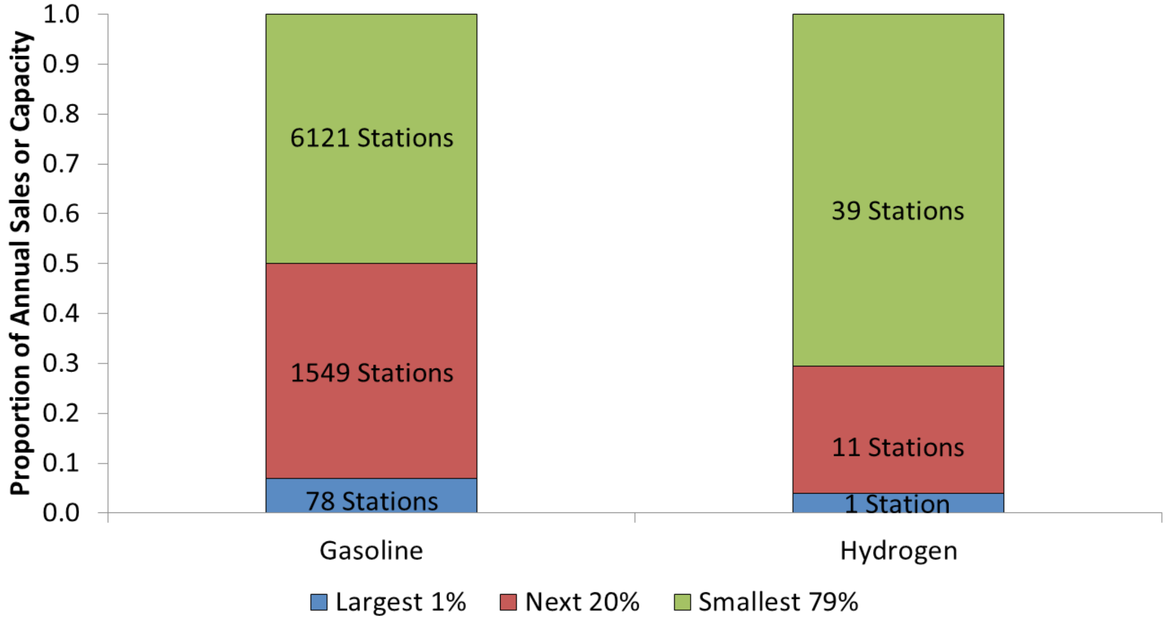
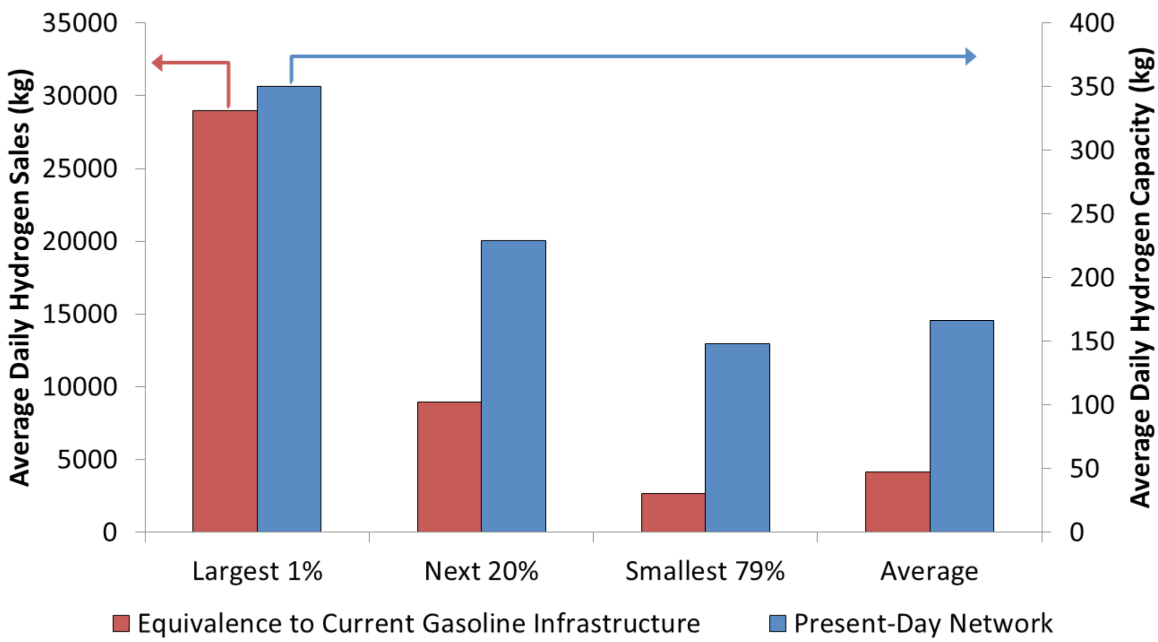


Figure 15: Comparison of Present Gasoline and Hydrogen Fuel Station Sizes



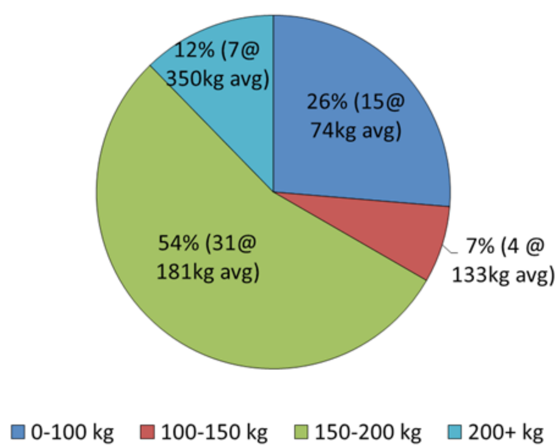
The next steps in funding hydrogen fuel stations should combine the need for larger, High Use Commuter stations with the need for more supply inside the clusters. Therefore, a priority should be placed on large (500+ kg/day) stations within the five clusters. Outside of the clusters, the majority of the stations should then follow the Low Use Commuter plan, as they will likely serve similar customers as the in-cluster stations, but may have fewer vehicle visits on a daily basis. Finally, carefully-selected build-out of connector and destination stations should continue. These stations will need to balance limited continuous use with potentially short periods of high demand that could occur during holiday travel. Such sites could be ideal candidates for local fleet vehicles or other hydrogen demand such as fuel cell electric delivery trucks or portable power units to provide a regular base load for the station.

B: Higher Capacity Stations

While the largest hydrogen fuel stations should continue to grow in capacity in order to fill the high daily-use commuter-supporting role, it is also necessary that all hydrogen fuel stations should eventually become larger to satisfy long-term projections of demand. This can be achieved through new installation of larger stations or upgrades to the capacity of existing stations. To balance the near-term costs and demand, today's funding programs do not yet require very large station capacities for eligibility since the earliest market demands will be sufficiently met with today's typical station capacity. The recently-awarded stations required a minimum capacity of 100 kg over a main operation time of 12 hours, though nearly all of the awarded stations were designed to surpass the minimum requirement (the awarded average capacity was 180 kg per day) [12]. Considering all built and planned stations, the present-day average capacity is 173 kg. The largest stations have a capacity of 350 kg per day.

Figure 16 shows the breakdown of California's full historical record of hydrogen fuel station capacities according to 50-kg increments of station size. As can be seen, the vast majority of stations have a daily capacity of 200kg or less (e.g., there are 31 stations representing 54% of the total; these stations have a capacity of 150-200 kg, with an average capacity within this group of 181 kg.). Combined with the information in Figure 15, it is clear that a steady transition to higher capacities overall will need to occur in the future in order to provide a familiar retail experience for the customer. On an energy-equivalent basis, today's gasoline stations provide 24 times the amount of fuel on average; the largest gasoline stations provide 80 times as much fuel as the largest hydrogen fuel stations.

Figure 16: Hydrogen Fuel Station Capacities by Range, Count, Proportion, and In-Group Average Capacity



Today's smaller scale (compared to gasoline) for hydrogen fuel stations is matched to the relatively smaller fleet they currently serve. Considering that the eventual goal is for FCEVs to displace a substantial portion of the gasoline fleet, it is useful to compare the energy requirements of the fleet that an average hydrogen fuel station can support to the same for an average gasoline station. At present, there are 125 hydrogen vehicles registered, compared to estimates of nearly 22.5 million automobiles on the road in total [13]. (This includes gasoline and diesel fueled vehicles; by fuel sales volumes, gasoline makes up 81% of California's on-road transportation fuel usage [11]). A first-order estimate based on the ratio of the statewide aggregate fueling capacity to the operating fleet can provide insight for the long-term goals that may need to be implemented for hydrogen fuel stations. Assuming a gasoline vehicle fleet of 18.2 million, statewide gasoline sales volumes, and the 2020 projected fuel cell fleet of 18,465 vehicles, the capacity-to-fleet ratios for gasoline and hydrogen are 1.8 gallons per day per vehicle and 0.5

kg per day per vehicle, respectively. Given that a gallon of gasoline contains roughly the same amount of energy as a kilogram of hydrogen, it can be inferred that the average hydrogen fuel station should eventually have nearly four times the capacity of current designs. In addition, even the largest hydrogen fuel stations should become at least double their current size, given the ratio of 2:1 between the largest and average hydrogen fuel station capacities shown earlier. This first-order estimate can change as the relative numbers of vehicles, stations, and differences in engine efficiency for both vehicles become clearer and evolve.

Finally, total daily capacity is not the only measure of fueling capability that must be addressed with hydrogen fuel stations. When comparing gasoline and hydrogen fuel stations, a major difference in operation comes about due to the high pressure at which hydrogen must be provided to FCEVs. Maintaining pressures high enough to provide complete fills to today's vehicle tanks (typically near 7kg capacity) may require a period of time to "recharge" the supply tank to operational pressures via compressor work. Today's standards, as required for CEC funding, are to provide three of these 7-kg fills per hour in succession, without any customer wait time for system recharge [12]. This standard is an improvement from previous stations, but it must be further enhanced for stations built further in the future. The next round of awarded stations should take a significant step towards the capability to complete at least five consecutive 7kg fills in one hour.

C: Increased Dispenser Count per Station

The vast majority of stations built or planned for construction operate with a single dispenser, capable of fueling one vehicle at a time. There are two exceptions among the currently-built stations, and both have two dispensers available for fueling. One of these stations is designed to fuel two vehicles simultaneously, while the other may fuel four vehicles simultaneously. When looking towards gasoline infrastructure as a benchmark for the future station performance requirements of hydrogen, it is clear that eventually the majority of stations will need to be multi-dispenser stations that are capable of multiple simultaneous fills.

Based on the rapidly-accelerating auto manufacturer projections, the FCEV fleet will be large enough by 2020 to require significantly more multi-dispenser stations. There is more work that must be completed to properly assess when hydrogen fuel stations need to make a transition to multiple dispensers; however, there may be some early guidance available from comparison to a recent report on Compressed Natural Gas (CNG) vehicle infrastructure developed by the consulting firm TIAX for the group America's Natural Gas Alliance [14]. In the report, station designs are specified that indicate a two-hose design that supports "15 light-duty/15GGE [gasoline gallon equivalent vehicles] consecutively fueling in a 1-hour peak period." It is worth noting that the CNG market is more developed than the hydrogen FCEV market, and these station designs therefore are expected to serve much larger vehicle populations.

Using the Low Carbon Fuel Standard Energy Economy Ratio for hydrogen (2.5) [15], which allows direct comparison of range for the same fuel energy content across vehicle types, 15 light-duty/15GGE natural gas vehicles is equivalent to 15 light-duty FCEVs fueling to 5.8 kg in the same timeframe. This compares well to the current per-dispenser requirements of the SAE J2601 hydrogen fueling standard, which specifies five consecutive 7-kg fuels in the same hour. Thus, the capacity per fill is well-matched by today's standards and technology. In order to meet the same throughput as in the CNG planning case, there would therefore need to be three dispensers (or dispenser hoses) with the capability for the central system to provide hydrogen to all 3 dispensers simultaneously. Moreover, the current US CNG fleet is estimated to be 112,000 vehicles [16]; the number of current CNG stations in the US is 1,000 [14] which provides a service ratio of 112 vehicles per station. The FCEV projections shown earlier indicate nearly 18,500 vehicles by 2020; if 100 stations are assumed to be available at that time, the hydrogen service ratio would be 185 vehicles per station. This indicates that the hydrogen fuel stations might need to provide even more than the 15 consecutive vehicle fills discussed and therefore more than three dispensers will be required per station. Thus, as the hydrogen FCEV fleet grows, it is clear that the single-dispenser station design will not be sufficient.

Therefore, future funding for hydrogen fuel stations should prioritize high dispenser counts, especially for stations that are expected to provide high, daily throughput or with significantly enhanced peak fueling requirements. Table 2 has specified at least two dispensers for these types of stations. This should be considered a lower-bound compromise between the calculated needs as described above and an understanding of current technology; stations with at least two and expandable to three, four, or more dispensers should be emphasized.

D: Overall Hydrogen Fueling Performance

The preceding discussions regarding station capacities and numbers of consecutive and simultaneous fills primarily address issues of station design. The main work for progress in those areas will be engineering on the part of the station equipment manufacturers and their partners and subcontractors. In addition to this long-term engineering work, there is also a need to address more near-term concerns based on actual in-place station operation. Once a station is commissioned, there must be a set of standardized methodologies, procedures, and devices to assure that the station can perform as expected when it opens and as it continues to operate during its lifetime. The root motivation for this type of verification is based in maintaining safe and convenient operation for the customer, the station operator, and any maintenance or repair personnel who come in contact with the station equipment. A number of related concerns and their current status are presented in the following subsections.

1: Demand-Response Validation

As mentioned in discussion above, hydrogen fuel stations receiving State funding are typically required to adhere to the SAE J2601 standard for operational performance. The goal of the standard is to ensure that during projected high-use periods, the station design is capable of safely meeting high consumer demand and providing full tank fills over a given period of time. In the case of J2601, this is the requirement for multiple consecutive fills within a one-hour timeframe; stations funded by CEC in May 2014 are required to complete three such fills within the hour [12]. Additionally, there is a need to ensure that stations can supply their expected throughput (based on claimed capacity) during a typical daily load-profile. For example, a 150 kg station may need to be able to supply 100 kg of its total capacity during the 12-hour high-use period between 6am and 6pm.

At the time of this report, there is not yet an adopted testing standard or device for validating station performance metrics of this type. Currently, stations are required to demonstrate their compliance with J2601 and any funding program requirements by individually testing their stations with vehicles from every auto manufacturer. This is typically a long, tedious, and costly process for station owners and auto manufacturers alike. Often times, schedules are set and must be delayed as testing reveals a need for adjustment and coordination between the station operator and the auto manufacturers must begin anew. Fortunately, the Canadian Standards Association (CSA) has developed a set of test methods and standards for hydrogen fuel stations in CSA HGV 4.3 and 4.9. Adherence to the J2601 standard is required and CSA standards are currently suggested for the most recently-funded stations when the final version becomes available [12]. However, even with the standardized procedure, there is a need to develop a testing device that can sufficiently evaluate station capabilities without requiring testing on every available FCEV model. Ideally, the single device will be able to operate in a manner such that it can serve as a sufficient proxy for all vehicles collectively. Such a device does not currently exist; however, State and national agencies and labs are discussing the development of such a tool.

In addition to a tool to evaluate station performance for commissioning purposes, it will be useful for State agencies to have a means of collecting and evaluating station performance data on a continuous basis. Such data can serve as a significant information source for developing the understanding of varying station performance and customer habits, as previously described. The most recent CEC hydrogen fuel station solicitation included a requirement for awarded stations to collect station operation data for a period of one year and report the data to the National Renewable Energy Laboratory (NREL). Applicants were allowed to propose the nature of the data. Future funding programs should maintain a data collection requirement, though inclusion of State-specified requirements of the nature of the data can ensure collection of the metrics necessary to support the goal of developing a station classification system.

2: Quality

Hydrogen quality (also referred to as hydrogen purity) is a primary concern for the longevity and performance of FCEVs. Potential contaminants in the fuel supply, primarily carbon monoxide (CO) and Sulfur (S), can degrade the catalyst material in the fuel cell and have long-term, irreversible impacts on efficiency and durability. Because of the stringent requirement for hydrogen purity, there is a need to continually test dispensed hydrogen at the pump, as opposed to an upstream location. This is because very small concentrations of contaminants introduced during compression, shipping, storage, and other processes have been sufficient to damage the vehicle fuel cell stack. Under current funding initiatives, hydrogen fuel stations are required to comply with SAE standard J2719, and pass a dispensed-hydrogen quality test on at least a semi-annual basis [12].

Compliance currently with this standard is costly and consumes large amounts of time, as current measurement technologies that are sensitive enough to the low levels and wide array of potential impurities are all laboratory-scale units. Measurement in the field or on-line during a test fill is not currently possible. With today's technology, samples must be collected on-site, transported to a central lab, processed, and the result eventually returned to the station operator. This long delay does not allow the station operator to respond in a timely manner to the potential impurities in their dispensed product, thereby potentially providing damaging fuel to a number of customers before they can apply corrective action. As above, multiple parties and agencies are involved in discussions to develop specifications for such a tool. Stakeholders are investigating the use of "canary" elements that could be cost-effectively and timely monitored and used to trigger a timely action. The goal is to provide station operators with a cost-effective means to quickly identify a potential hydrogen quality issue at or near their dispensers and take immediate action. Accounting for current technological limitations, it is likely that this benefit will come at lower sensitivity than laboratory equipment and will not provide as wide of an array of information (fewer species will likely be analyzed) that could help the station operator determine the root cause of the impurity. Thus, a combination of procedures leveraging the new device and the current laboratory method may be necessary.

3: Accuracy

In order for station operators to offer their fuel for retail sale, they must receive a Certificate of Approval that indicates the dispenser accurately measures the amount of hydrogen it dispenses during sales to customers. Towards this end, California's Department of Food and Agriculture (CDFA- the authoritative agency for motor fuel sales certification) has adopted the standards outlined in the National Institute of Standards and Technology Handbook 44 (NIST 44), which is a comprehensive document including many weighing and measuring devices. Section 3.39 is the relevant section for hydrogen dispensing and specifies a tolerance of 1.5% for acceptance (typically for commissioning) and 2% for maintenance (or continued operation). This standard is similarly prescribed for new stations [12].

In support of the adoption of this standard, CEC, ARB, and CDFA have worked with NREL to design, build, and test a Hydrogen Field Standard (HFS) Metrology Testing Device. This device was built to follow the requirements of NIST 44 and has tested most of the currently-operating hydrogen fuel stations. Based on the results and analyses completed to date, CDFA has adopted a regulation to establish three additional accuracy classes of 3%, 5%, and 10%, based on certification with the HFS device. (See 4 CCR §§ 4001, 4002.9, effect. June 16, 2014.) It is anticipated stations will be able to receive certification to one of these degrees of accuracy; a distinction will also be made between accuracy at station commission and testing completed afterwards. The national labs are also bringing to bear their scientific and engineering expertise through H2FIRST (led by Sandia National Laboratories and NREL), a public-private partnership, to address a number of considerations such as fueling accuracy, materials compatibility, and other technical challenges; successful implementation of this partnership is expected to yield significant benefits that will further the rollout of hydrogen fuel stations, both in California and across the U.S.

4: Pressure

Current hydrogen fuel station solicitations maintain a requirement for the capability to provide hydrogen to vehicles at on-board storage pressures of 35 megapascals (MPa) and 70 MPa (equal to 5,000 to 10,000 pounds per square inch [psi]). This dual pressure dispensing requirement has been adopted as a result of auto manufacturers having adopted one or both of these pressures as they developed their FCEV technology. Today, one auto manufacturer has vehicles on the road with 35 MPa onboard storage pressure. Thus, for at least the near-term there is limited need to continue providing hydrogen dispensed at this pressure in order to support legacy vehicles. In recent years, the focus has shifted to the 70 MPa pressure for light-duty passenger vehicles, largely motivated by considerations for extending the range of the FCEVs. However, vehicles designed for 70 MPa storage can also be fuelled by a 35 MPa source, with a filling capacity of half the vehicle's design. Additionally, much of the balance of plant for 35 MPa fills (including compressors and buffer storage) is typically separate from the 70 MPa equipment. Thus, by maintaining dual-pressure capability, 35 MPa fill capability can also serve as a backup for 70 MPa vehicles when there is an interruption in the station's ability to provide the higher-pressure fills.

Although it is not a primary focus for projected light-duty vehicles in California, 35 MPa storage may find application in a number of alternative applications that can refuel at the same stations. Examples include fleet applications (such as parcel delivery trucks, refrigerated units on trucks, and auxiliary power units for freight trucks), which typically have more available space for hydrogen storage and can take advantage of smaller fuel lifecycle energy consumption at the lower pressure. Additionally, there are examples of other modes of transportation with 35 MPa storage, such as scooters and motorcycles, known to exist in the international industry that may eventually find adoption by California's market.

E: Carbon Intensities and Resource Consumption

The intent and efforts of AB 8 dovetail with those of Senate Bill 1505, which sets standards on the production of hydrogen for California's FCEV fleet. Among its requirements are standards for [17]:

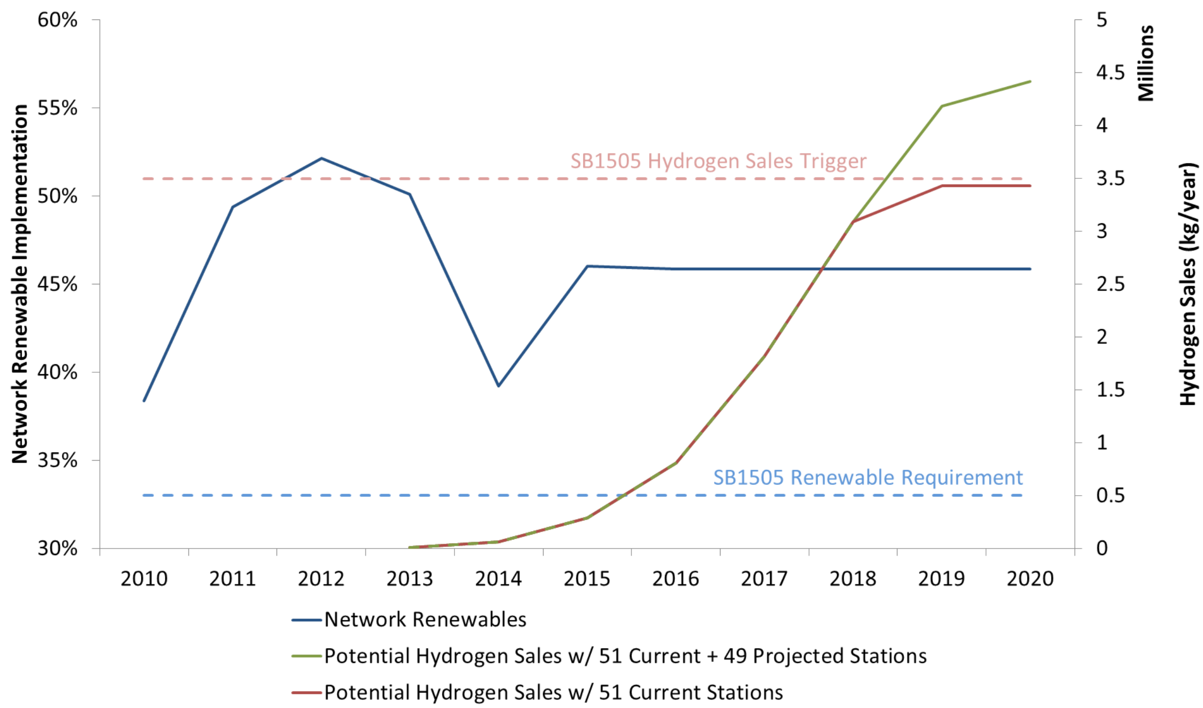
1. Well-to-wheel greenhouse gas (GHG) emission reductions compared to gasoline
2. Utilization of renewable energy resources for feedstock and/or process energy
3. Well-to-tank criteria pollutant emission reductions as compared to gasoline
4. Well-to-tank local air toxics equivalence or better as compared to gasoline.

The first requirement has a direct reference in AB 8, with its requirement for hydrogen funding programs to utilize a well-to-wheel benefit-cost score based on greenhouse gas emissions. Thus, hydrogen fuel station funding programs utilize considerations of GHG as a basis for evaluation. The second requirement has a parallel in AB 8, which broadly requires the effective use of renewable resources in support of alternative fuels; SB 1505 provides a specific requirement of 33.3% for all State-supported hydrogen infrastructure. Accordingly, CEC has required 33.3% renewable utilization in all stations that it funds.

Moreover, the April 2013 and May 2014 awards also provided incentive for 100% renewable stations, and to date CEC has funded 8 stations that meet this enhanced capability. The latter two requirements are well-addressed by current hydrogen production methods, based on current ARB knowledge of predominant hydrogen production methods.

The above considerations currently apply only to State-funded hydrogen fuel stations. Additionally, SB 1505 sets a statewide hydrogen sales minimum as a "trigger" for the enforcement of the same environmental performance requirements on all hydrogen fuel stations throughout the state, whether or not they receive State funding. This trigger is set at 3.5 million kg of hydrogen in a 12-month period (equivalently specified in the legislation as 3,500 metric tons). Thus, it is important to understand where the current hydrogen network stands in relation to both the trigger amount and the minimum performance requirements of SB 1505 and supported by AB 8. Figure 17 depicts the historical and projected renewable energy implementation for the state's developing hydrogen network, as well as the projected sales of hydrogen statewide on a year-by-year basis. The projected sales were taken as the lesser of statewide hydrogen capacity and demand. As shown, with the currently operational and funded stations and auto manufacturer projections of increasing vehicle deployment, the SB 1505 sales trigger to require enforcement of environmental performance on all stations in the state would not be reached. However, if additional stations are funded and installed to reach 100 stations as previously discussed, the trigger could be reached in 2018, requiring enforcement on all hydrogen fuel stations within the state.

Figure 17: Evaluation of Compliance with SB 1505 Renewables Requirement and Trigger for Enforcement of the Requirement



The currently operational and funded hydrogen network's renewable implementation is well within compliance with the SB 1505 standard. As shown in Figure 17, the network-wide implementation of renewable hydrogen varies between 38% and 52%, reaching 46% after all currently-planned stations are built in 2015. Thus, the 33.3% renewable hydrogen requirement is being met by State-funded hydrogen fuel stations. In terms of GHG emission reductions, SB 1505 requires that well-to-wheel emissions of FCEVs are at least 30% below their conventional gasoline counterparts. A well-to-wheels analysis of the stations funded by CEC in May of 2014, using applicant-supplied (and adjusted when necessary) values for carbon intensities of the proposed hydrogen fuel pathways, shows a collective GHG emissions savings of about 77% for the funded set of stations. This is well above the SB 1505 requirement of a 30% emission reduction, indicating that current technologies are more than capable of meeting the bill's requirement.

F: Station Availability, Maintenance Readiness, and Online Status

Finally, there is a need for station operators to respond quickly, safely, and effectively to equipment malfunctions and other situations that may cause unplanned station outages. One way to address this readiness has been achieved by CEC's recent awards. One of the funded projects will result in the construction of a mobile refueler. This refueler will be able to serve either as backup hardware for the station when possible, utilizing the station's built hydrogen storage capacity to deliver hydrogen to customers, or operate as a stand-alone onsite replacement for the pump(s) at the station. In addition to funding this refueler, the program requires that all funded stations also be built to accommodate a mobile/back-up refueler. Thus, for certain situations, the stations will be ready to have a backup source of hydrogen for their customers [12].

This will help alleviate concerns of station availability during equipment failures. However, another aspect of the same concern is the length of time that will be required before the station can again be operational on its own. One potentially effective option is the implementation of a service technician network alongside maintaining a significant stock of standard maintenance equipment that can be utilized quickly at multiple stations. Many applicants for the funded stations have mentioned similar plans in their application materials, and there is likely to be significant learning potential for both the State and the station operators as these plans are implemented. Additionally, given the limited extent of the hydrogen network, especially its current lack of redundancy, it will be useful for customers to be aware in real-time of the availability of nearby hydrogen fuel stations. Online status monitoring and reporting by the station operators can be an effective tool for providing this information to customers. This practice has been proposed by a number of station awardees and its implementation should now become a requirement for State-funded hydrogen fuel station projects.

VII: Conclusions and Recommendations

AB 8 Requirements: Provide evaluation and recommendations to CEC to inform future funding programs.

ARB Actions: Recommend funding level for next CEC program. Recommend priority locations to meet coverage needs in next CEC program. Recommend minimum operating requirements and station design features to incentivize in next CEC program.

In summary, recent investments in the hydrogen fuel station network have established the capability to meet most of the near-term needs of the projected hydrogen FCEV market. The strong commitment of State funds by CEC to the development of the hydrogen fuel station network has laid the groundwork for the industry to transition away from its previous demonstration phase and into the early commercial retail market. Based on auto manufacturer reports of FCEV deployment, there is a need to enhance the coverage, capacity, and technical capability of the network, through the next and subsequent rounds of station solicitation and awards, in order to address the needs of the longer-term vehicle fleet, from 2017 onward.

Based on the vehicle fleet currently operating in California, auto manufacturer reports of vehicle deployment, and the known hydrogen fuel station network planned for the states, ARB staff has developed the following recommendations for future hydrogen fuel station network funding:

1. There is a clear need for continued funding of hydrogen fuel stations to support the projected demands of the future FCEV fleet; the full funding level of $20 million is recommended for the next CEC funding program, and the potential for additional funding should be investigated jointly by ARB and CEC;
2. Hydrogen fuel station funding should continue to focus on the five cluster areas where the highest vehicle adoption rates are expected;
3. The Berkeley cluster should receive priority, as it is the only cluster without the ability to provide a retail customer experience;
4. The Expanded Network should continue to be developed, with a focus on the San Diego and Sacramento areas since they are projected to become major clusters and their local infrastructures will soon have their first stations;
5. A set of hydrogen fuel station classifications based on expected local customer habits should be adopted and specified for future station funding opportunities;
6. Current requirements for station operational data collection should be expanded to address requirements for data needed to develop the set of station classifications, assess network performance, learn from the early market, and improve future station designs;
7. Large capacity stations (compared to today's designs) should be incentivized in future station funding opportunities;
8. Hydrogen fuel station capacities, numbers of dispensers, and capabilities for consecutive and concurrent fills will need to be increased as the network develops;

9. Ongoing discussions for field accuracy testing, field quality testing, and field demand response testing should continue and the resulting actions applied to future station funding opportunities;
10. Dual pressure filling capability should remain a specification for future hydrogen fuel stations; and
11. Online station status monitoring and reporting should be required in future station funding opportunities.

In addition, ARB has found that the planned hydrogen fuel station network to date would not require the broad enforcement of SB 1505's hydrogen-related requirements prior to 2020. However, with continued funding provided annually by CEC and installation of new stations, the hydrogen sales requirement for enforcement of environmental performance standards on both State-funded and non-State-funded stations would be met in 2018. The hydrogen fuel station network currently in operation and funded is exceeding the State-funded station requirements for GHG reductions and renewable feedstock implementation described in SB 1505. Additionally, current hydrogen production pathways meet the bill's requirements for criteria pollutant and toxic emissions, according to ARB's most recent understanding of the industry's common technologies. Therefore, the currently planned hydrogen fuel station network supports the State's goals for cleaner vehicle fuel production and utilization.

VIII: References

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IX: Appendix A

List of Known and Projected Hydrogen Fuel Station Status, 2010-2020

Station Name	Status	Date	Capacity (kg/day)	Cluster	Air District	Service Type	Market Role
Burbank	Open	2010, Q1	100	Expanded Network	South Coast	Public Retail	Early Station/Demo
LA\West LA	Open	2010, Q1	30	West LA/SM	South Coast	Public Demo	Early Station/Demo
SunLine	Open	2010, Q1	30	Expanded Network	South Coast	Public Demo	Early Station/Demo
UC Irvine	Open	2010, Q1	30	Coastal/South OC	South Coast	Public Retail	Early Station/Demo
Torrance	Open	2011, Q2	60	Torrance	South Coast	Public Retail	Early Station/Demo
OCSD	Open	2011, Q3	100	Coastal/South OC	South Coast	Public Demo	Early Station/Demo
AC Transit	Open	2012, Q2	60	Berkeley	Bay Area	Public Demo	Early Station/Demo
Newport	Open	2012, Q3	100	Coastal/South OC	South Coast	Limited Retail	Early Station/Demo
Harbor City	Open	2013, Q2	60	Torrance	South Coast	Limited Retail	Early Station/Demo
LA\CSULA	Open	2014, Q2	60	Expanded Network	South Coast	Limited Retail	Early Market/Expansion
Diamond Bar	Open	2014, Q3	180	Expanded Network	South Coast	Public Retail	Market Expansion
Anaheim	Open	2014, Q4	100	Expanded Network	South Coast	Public Retail	Market Expansion
Chino	Open	2014, Q4	100	Expanded Network	South Coast	Public Retail	Market Expansion
Irvine North	Open	2014, Q4	180	Coastal/South OC	South Coast	Public Retail	Early Target Market
LA\Beverly Hills	Open	2014, Q4	180	West LA/SM	South Coast	Public Retail	Early Target Market
LA\Santa Monica	Open	2014, Q4	180	West LA/SM	South Coast	Public Retail	Early Target Market
LA\West LA #2	Open	2014, Q4	180	West LA/SM	South Coast	Public Retail	Early Target Market
Lawndale	Open	2014, Q4	180	Torrance	South Coast	Public Retail	Early Target Market
Mission Viejo	Open	2014, Q4	180	Coastal/South OC	South Coast	Public Retail	Early Target Market
Redondo Beach	Open	2014, Q4	180	Torrance	South Coast	Public Retail	Early Target Market
San Juan Capistrano	Open	2014, Q4	350	Coastal/South OC	South Coast	Public Retail	Early Target Market
UC Irvine	Upgrade	2014, Q4	150 add'l	Coastal/South OC	South Coast	Public Retail	Early Target Market
West Sacramento	Open	2014, Q4	350	Expanded Network	Sacramento	Public Retail	Future Cluster
Woodland Hills	Open	2014, Q4	180	Expanded Network	South Coast	Public Retail	Market Expansion
AC Transit	Non-Retail	2015, Q3	[redacted]	Berkeley	Bay Area	[redacted]	[redacted]
LA\West LA	Close	2015, Q1	[redacted]	West LA/SM	South Coast	[redacted]	[redacted]
SunLine	Non-Retail	2015, Q1	[redacted]	Expanded Network	South Coast	[redacted]	[redacted]
LA\LAX	Open	2015, Q2	100	Torrance	South Coast	Public Retail	Early Target Market
OCSD	Close	2015, Q2	[redacted]	Coastal/South OC	South Coast	[redacted]	[redacted]
Cupertino	Open	2015, Q3	350	South SF/Bay	Bay Area	Public Retail	Early Target Market
Foster City	Open	2015, Q3	350	South SF/Bay	Bay Area	Public Retail	Early Target Market
Mountain View	Open	2015, Q3	350	South SF/Bay	Bay Area	Public Retail	Early Target Market
Campbell	Open	2015, Q4	180	South SF/Bay	Bay Area	Public Retail	Early Target Market
Coalinga	Open	2015, Q4	180	Expanded Network	San Joaquin	Public Retail	Connector
Costa Mesa	Open	2015, Q4	180	Coastal/South OC	South Coast	Public Retail	Early Target Market
Hayward	Open	2015, Q4	180	Expanded Network	Bay Area	Public Retail	Market Expansion
La Cañada-Flintridge	Open	2015, Q4	180	Expanded Network	South Coast	Public Retail	Market Expansion
LA\Culver City	Open	2015, Q4	180	Torrance	South Coast	Public Retail	Early Target Market
LA\West Hollywood	Open	2015, Q4	180	West LA/SM	South Coast	Public Retail	Early Target Market
Laguna Niguel	Open	2015, Q4	180	Coastal/South OC	South Coast	Public Retail	Early Target Market
Lake Forest	Open	2015, Q4	180	Coastal/South OC	South Coast	Public Retail	Early Target Market
Long Beach	Open	2015, Q4	180	Expanded Network	South Coast	Public Retail	Market Expansion
Mill Valley	Open	2015, Q4	180	Expanded Network	Bay Area	Public Retail	Market Expansion
Oakland Airport	Open	2015, Q4	350	Expanded Network	Bay Area	Public Retail	Connector
Ontario	Open	2015, Q4	100	Expanded Network	South Coast	Public Retail	Connector
Orange	Open	2015, Q4	130	Expanded Network	South Coast	Public Retail	Market Expansion
Pacific Palisades	Open	2015, Q4	130	West LA/SM	South Coast	Public Retail	Early Target Market
Palo Alto	Open	2015, Q4	180	South SF/Bay	Bay Area	Public Retail	Early Target Market
Redwood City	Open	2015, Q4	180	South SF/Bay	Bay Area	Public Retail	Early Target Market
Riverside	Open	2015, Q4	100	Expanded Network	South Coast	Public Retail	Market Expansion
Rohnert Park	Open	2015, Q4	130	Expanded Network	Bay Area	Public Retail	Market Expansion
San Diego	Open	2015, Q4	180	Expanded Network	San Diego	Public Retail	Future Cluster
San Jose	Open	2015, Q4	180	South SF/Bay	Bay Area	Public Retail	Early Target Market
San Ramon	Open	2015, Q4	350	Expanded Network	Bay Area	Public Retail	Market Expansion
Santa Barbara	Open	2015, Q4	180	Expanded Network	Santa Barbara	Public Retail	Destination
Saratoga	Open	2015, Q4	180	South SF/Bay	Bay Area	Public Retail	Early Target Market
South Pasadena	Open	2015, Q4	180	Expanded Network	South Coast	Public Retail	Market Expansion
South San Francisco	Open	2015, Q4	180	South SF/Bay	Bay Area	Public Retail	Early Target Market
Truckee	Open	2015, Q4	180	Expanded Network	Placer	Public Retail	Connector/Destination
Woodside	Open	2015, Q4	140	South SF/Bay	Bay Area	Public Retail	Early Target Market
Torrance	Upgrade	2016, Q1	140 add'l	Torrance	South Coast	Public Retail	Early Target Market

X: Appendix B

The following is an excerpt of AB 8, with the language from section 43018.9 relevant to this report.

Section 43018.9 is added to the Health and Safety Code, to read:

43018.9.

(a) For purposes of this section, the following terms have the following meanings:

(1) "Commission" means the State Energy Resources Conservation and Development Commission.

(2) "Publicly available hydrogen-fueling station" means the equipment used to store and dispense hydrogen fuel to vehicles according to industry codes and standards that is open to the public.

(b) Notwithstanding any other law, the state board shall have no authority to enforce any element of its existing clean fuels outlet regulation or of any other regulation that requires or has the effect of requiring that any supplier, as defined in Section 7338 of the Revenue and Taxation Code as in effect on May 22, 2013, construct, operate, or provide funding for the construction or operation of any publicly available hydrogen-fueling station.

(c) On or before June 30, 2014, and every year thereafter, the state board shall aggregate and make available all of the following:

(1) The number of hydrogen-fueled vehicles that motor vehicle manufacturers project to be sold or leased over the next three years as reported to the state board pursuant to the Low Emission Vehicle regulations, as currently established in Sections 1961 to 1961.2, inclusive, of Title 13 of the California Code of Regulations.

(2) The total number of hydrogen-fueled vehicles registered with the Department of Motor Vehicles through April 30.

(d) On or before June 30, 2014, and every year thereafter, the state board, based on the information made available pursuant to subdivision (c), shall do both of the following:

(1) Evaluate the need for additional publicly available hydrogen-fueling stations for the subsequent three years in terms of quantity of fuel needed for the actual and projected number of hydrogen-fueled vehicles, geographic areas where fuel will be needed, and station coverage.

(2) Report findings to the commission on the need for additional publicly available hydrogen-fueling stations in terms of number of stations, geographic areas where additional stations will be needed, and minimum operating standards, such as number of dispensers, filling protocols, and pressures.

(e) (1) The commission shall allocate twenty million dollars ($20,000,000) annually to fund the number of stations identified pursuant to subdivision (d), not to exceed 20 percent of the moneys appropriated by the Legislature from the Alternative and Renewable Fuel and Vehicle Technology Fund, established pursuant to Section 44273, until there are at least 100 publicly available hydrogen-fueling stations in operation in California.

(2) If the commission, in consultation with the state board, determines that the full amount identified in paragraph (1) is not needed to fund the number of stations identified by the state board pursuant to subdivision (d), the commission may allocate any remaining moneys to

other projects, subject to the requirements of the Alternative and Renewable Fuel and Vehicle Technology Program pursuant to Article 2 (commencing with Section 44272) of Chapter 8.9.

(3) Allocations by the commission pursuant to this subdivision shall be subject to all of the requirements applicable to allocations from the Alternative and Renewable Fuel and Vehicle Technology Program pursuant to Article 2 (commencing with Section 44272) of Chapter 8.9.

(4) The commission, in consultation with the state board, shall award moneys allocated in paragraph (1) based on best available data, including information made available pursuant to subdivision (d), and input from relevant stakeholders, including motor vehicle manufacturers that have planned deployments of hydrogen-fueled vehicles, according to a strategy that supports the deployment of an effective and efficient hydrogen-fueling station network in a way that maximizes benefits to the public while minimizing costs to the state.

(5) Notwithstanding paragraph (1), once the commission determines, in consultation with the state board, that the private sector is establishing publicly available hydrogen-fueling stations without the need for government support, the commission may cease providing funding for those stations.

(6) On or before December 31, 2015, and annually thereafter, the commission and the state board shall jointly review and report on progress toward establishing a hydrogen-fueling network that provides the coverage and capacity to fuel vehicles requiring hydrogen fuel that are being placed into operation in the state. The commission and the state board shall consider the following, including, but not limited to, the available plans of automobile manufacturers to deploy hydrogen-fueled vehicles in California and their progress toward achieving those plans, the rate of deployment of hydrogen-fueled vehicles, the length of time required to permit and construct hydrogen-fueling stations, the coverage and capacity of the existing hydrogen-fueling station network, and the amount and timing of growth in the fueling network to ensure fuel is available to these vehicles. The review shall also determine the remaining cost and timing to establish a network of 100 publicly available hydrogen-fueling stations and whether funding from the Alternative and Renewable Fuel and Vehicle Technology Program remains necessary to achieve this goal.

(f) To assist in the implementation of this section and maximize the ability to deploy fueling infrastructure as rapidly as possible with the assistance of private capital, the commission may design grants, loan incentive programs, revolving loan programs, and other forms of financial assistance. The commission also may enter into an agreement with the Treasurer to provide financial assistance to further the purposes of this section.

(g) Funds appropriated to the commission for the purposes of this section shall be available for encumbrance by the commission for up to four years from the date of the appropriation and for liquidation up to four years after expiration of the deadline to encumber.

(h) Notwithstanding any other law, the state board, in consultation with districts, no later than July 1, 2014, shall convene working groups to evaluate the policies and goals contained within the Carl Moyer Memorial Air Quality Standards Attainment Program, pursuant to Section 44280, and Assembly Bill 923 (Chapter 707 of the Statutes of 2004).

(i) This section shall remain in effect only until January 1, 2024, and as of that date is repealed, unless a later enacted statute, that is enacted before January 1, 2024, deletes or extends that date.

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