August 2017






2017 Annual Evaluation of

Fuel Cell Electric Vehicle Deployment and Hydrogen Fuel Station Network Development

California Environmental Protection Agency

Air Resources Board

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California Fuel Cell Partnership and Keith Malone

2017 Annual Evaluation of

Fuel Cell Electric Vehicle Deployment and Hydrogen Fuel Station Network Development

Pursuant to AB 8, Statutes of 2013

August 2017

List of Acronyms

AB 8	Assembly Bill 8 (Perea, Chapter 401, Statutes of 2013)
AHJ	Authority Having Jurisdiction
ARB	California Air Resources Board
ARFVTP	Alternative and Renewable Fuel and Vehicle Technology Program
BEV	Battery Electric Vehicle
CaFCP	California Fuel Cell Partnership
CDFA	California Department of Food and Agriculture
CHAT	California Hydrogen Accounting Tool
CHIT	California Hydrogen Infrastructure Tool
CHSS	Compressed Hydrogen Storage System
CSD	Compression, Storage, and Dispensing
CTEP	California's Type Evaluation Program
DMS	Division of Measurement Standards
DMV	Department of Motor Vehicles
FCEV	Fuel Cell Electric Vehicle
GFO	Grant Funding Opportunity California Energy Commission's formal communication of a current grant program)
GO-Biz	Governor's Office of Business and Economic Development
HEV	Hybrid Electric Vehicle
H2FIRST	Hydrogen Fueling Infrastructure Research and Station Technology
H35	Hydrogen at a pressure of 35 megapascal
H70	Hydrogen at a pressure of 70 megapascal
HFS	Hydrogen Field Standard
HGV	Hydrogen Gas Vehicle
HyStEP	Hydrogen Station Equipment Performance
IrDA	Infrared Data Association
LCFS	Low Carbon Fuel Standard
LLR	Loan Loss Reserve
LODES	Longitudinal Employer-Household Dynamics Origin-Destination Employment Statistics
NIST	National Institute of Standards and Technology
NREL	National Renewable Energy Laboratory
OEM	Originally Equipment Manufacturer (in this report, this is synonymous with auto manufacturers)
PHEV	Plug-In Hybrid Electric Vehicle
PON	Program Opportunity Notice (California Energy Commission's formal communication of a grant program in prior years)
POS	Point-of-Sale
RSA	Registered Service Agent
SB 1505	Senate Bill 1505 (Lowenthal, Chapter 877, Statutes of 2006)
SB 535	Senate Bill 535 (De León, Chapter 830, Statutes of 2012)
SOC	State of Charge
SOSS	Station Operational Status System developed by CaFCP

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Executive Summary

California's hydrogen fueling and fuel cell electric vehicle (FCEV) markets continued world-class growth over the past year. As of April 5, 2017, more than 1,600 FCEVs currently have active registrations with the California Department of Motor Vehicles (DMV). Drivers of these early-market cars are able to fuel at a variety of locations across the state of California; 29 currently Open-Retail stations span from as far south as San Diego, to the coastline in Santa Barbara, and as far to the northeast as Truckee. These represent net additions of 1,300 FCEVs (1,600 currently registered vs. 331 at the same time last year) and nine new fully retail fueling stations since June 2016 (29 currently vs 20 at the same time last year). Day-to-day commutes, long-distance travel between northern and southern California, and trips to popular holiday and vacation destinations are all possible thanks to the development to date in the state's hydrogen fueling network.

In the three years since reporting began on Annual Evaluations of Fuel Cell Electric Vehicle Deployment and Hydrogen Fuel Station Network Development, the State of California has accomplished many important milestones and first-of-their-kind achievements not often repeated, even on the global stage. Today's 29 Open-Retail stations represent a vast improvement not only in sheer numbers but also in the quality of the customer experience over the 9 non-retail stations that were in operation in 2014. In 2015, the hydrogen fueling station on the California State University, Los Angeles campus became the first in the world to demonstrate sufficiently accurate metering to approve the sale of hydrogen by the kilogram directly to fueling customers. This achievement was championed in California, but further translated into national impact, as the National Institute of Standard and Technology adopted new hydrogen meter accuracy requirements informed by California's program. Over the course of 2016 and into 2017, the Hydrogen Station Equipment Performance device has accelerated and streamlined confirmation of hydrogen stations' ability to fuel vehicles according to industry-developed standard protocols, alleviating what was once a cumbersome and time-intensive process involving coordination between station operators and multiple auto manufacturers. The state's FCEV market has also grown, and is expected to continue to grow, not only in numbers but also in diversity of vehicles; in addition to pre-commercial models, there are now three commercial-era production models on California's roads, with at least three more expected in the near future. All of these advances together clearly signal that California's hydrogen fueling and FCEV markets have transitioned from a nascent, pre-commercial phase into the early commercial phase.

> *There has also been a marked increase in vehicles using our stations, and an even greater outlook for the volume of hydrogen fuel cell electric vehicles to be coming to market in 2017 and 2018.*
>
> Ed Kiczek
> Global Business Director
> Hydrogen Energy Systems
> at Air Products

Continued expansion of the fueling market, and corresponding growth in deployed FCEVs, is expected to continue throughout the rest of 2017 and beyond. The total number of Open-Retail stations may increase to 34 by the end of the year. The stations that may open between now and the close of the year will expand fueling coverage in the San Francisco Bay Area, communities surrounding Torrance, and within the counties of Riverside and San Bernardino. In addition, the Energy Commission's February 2017 announcement of proposed awards for 16 new stations will both expand coverage and build redundancy in many major first adopter markets across the state.

> *The potential for hydrogen derived from renewable sources, like solar and wind, as an alternative fuel and zero-emission solution for public transit remains strong. This important program provides New Flyer and our electric propulsion suppliers the production volume to gain efficiencies and drive costs down.*
>
> Paul Smith
> Executive Vice President of Sales, Marketing and Customer Programs at New Flyer

There is much to celebrate about these accomplishments, but there is also a renewed sense of urgency among stakeholders in the hydrogen and FCEV industries. Infrastructure development and FCEV deployment rates are mutually dependent on one another; slower-than-expected growth in the hydrogen fueling network may lead to delays in FCEV deployment. For this reason, although the last year has seen tremendous growth in the on-the-road FCEV population, auto manufacturer feedback to the California Air Resources Board (ARB) indicates more limited future FCEV deployment plans than previously reported, at least until hydrogen station network development can accelerate.

There is urgency among stakeholders to understand a near-term plan to address coming challenges in the expected transition from nascent fueling and vehicle markets to rapidly-expanding full-fledged consumer markets. Beyond the timing of development are also questions of how to continue improvements in the customer fueling experience, consensus on station design standards and codes, independent station performance certification, hydrogen procurement cost, and renewable hydrogen supply. These are significant challenges, but the State and its partners are taking steps to ensure the developing markets are prepared to face them. The necessary optimism among stakeholders to consider these challenges and have the will to address them should be recognized, as it is fundamentally important to maintaining momentum. In spite of today's individual challenges, stakeholders remain confident and committed to the prospect for large-scale success of the FCEV market in California.

As in past Annual Evaluations, ARB has followed and expanded upon the guidelines of Assembly Bill 8 (AB 8; Perea, Chapter 201, Statues of 2013) in order to convey a comprehensive narrative of the current status of the State's hydrogen and FCEV efforts [1]. Quantitative analyses and ongoing discussions with stakeholders throughout the past year inform ARB's assessment. The impacts of the last year's multiple accomplishments are accounted for in determination of remaining needs for the program. Experience gained in the past year and anticipated challenges in the future are characterized. Based on the ongoing efforts and information within various State agencies and with industry stakeholders, ARB has made the following determinations:

> *We call on business leaders across the globe to back our efforts in hydrogen development, so that we can meet our shared targets in environmental policy and give new impetus to the growing hydrogen economy.*
>
> Benoît Potier
> Chief Executive Officer at Air Liquide, on the announcement of the Hydrogen Council

- California's hydrogen fueling network has continued to expand in the past year, with 29 Open-Retail and 4 Non-Retail stations now in operation. Revised projections, based on improved understanding of issues facing certain station developers' project timelines, show 37 stations total are expected to be open by the end of the year (including retail and non-retail). Continuing development of individual funded stations may extend as far as 2020, based on current understanding.
- Grant Funding Opportunity (GFO) 15-605 resulted in the addition of 16 new high-capacity, highly-capable fueling stations to the future projections of California's expanding hydrogen fueling network. ARB and the Energy Commission anticipate that incentive and reimbursement eligibility mechanisms put in place through GFO 15-605, combined with the extensive experience of the awardees, has significant potential to ensure these stations open for retail operations by 2019.

Clean hydrogen powering fuel cell electric vehicles provides huge benefits for all including cleaner air, reduced carbon emissions, the elimination of petroleum dependence and economic growth... We have the cars, we have the fuel, we have the fueling infrastructure. Hydrogen fuel cell electric vehicles are in day-to-day use by drivers and this success can only grow in the years ahead.

Joel Ewanick
President and Chief Executive Officer at True Zero

- Nearly 1,300 new FCEVs have been deployed on California's roadways since June of 2016 (based on active registrations reported by DMV in April 2017; 331 were registered at the same time last year), and ARB projects that a total of 13,400 FCEVs will be driving in California by 2020, and 37,400 by 2023. These projections are later than prior reported estimates (37,400 FCEVs are now projected on-the-road in 2023, compared to the previous estimate of 34,300 by 2021), but it is ARB's understanding and estimation that they are largely in reaction to missed projections for the pace of hydrogen fueling station development. Accelerated station development through the remainder of the AB 8 program may re-energize these vehicle deployment projections. These developments and expectations are in agreement with the foundational principles of AB 8; vehicle and station deployments are significantly interdependent and should be appropriately coordinated (with station deployment leading vehicles) to ensure sustained success of both efforts.
- As a result of the recent investment in several new hydrogen fueling stations in high-priority locations across the San Francisco Bay Area, ARB finds that Los Angeles and Orange counties are now the highest priority for new fueling station development (with communities near Torrance identified as their own high-priority area). San Francisco and La Jolla are other important areas for new development.
- In addition to dispensing capacity, the state's hydrogen network may similarly face a shortage in hydrogen production capacity, especially for hydrogen produced in-state and with large contributions from renewable resources. Industry stakeholders are increasingly sharing the expressed desires of their customers to make the greatest environmental impact possible by choosing to drive an FCEV. Continued adoption of the vehicles may rely critically on ensuring the availability of renewably-sourced hydrogen at a reasonable, competitive market-driven price. Incentives like the Low Carbon Fuel Standard may help build industry interest in establishing new hydrogen production facilities in California, especially for low-carbon production methods.
- Even with reduced vehicle projections, local and network-wide hydrogen fueling capacity are still expected to become a cause for concern around 2021 under business-as-usual station network growth assumptions. Additionally, the revised projection for network growth anticipates 94 stations by the end of 2023, if the State were to proceed at the current pace with the current station capabilities. The 100 stations referenced in AB 8 would be funded by this time, with some stations remaining in development at least through the bill's expiration date of January 1, 2024. GFO 15-605 resulted in meaningful advances, with much larger stations than previously awarded becoming a new standard. GFO 15-605 also implemented enforcement of critical milestones for awarded stations (pre-application meetings with authorities having jurisdiction for permitting and appropriate entities for granting site control) to ensure faster and more successful station development than previously exhibited. Additional methods to maintain momentum and further accelerate overall station network growth rate may still be necessary, possibly through implementation of new funding structure(s) as appropriate to match the fully commercial phase of today's hydrogen fueling and FCEV markets. A new business-as-usual case, with more stations funded per year due to decreasing costs and build times, may become apparent through future analyses such as the upcoming 2017 Joint Agency Staff Report. ARB recommends that the State agencies currently working toward this goal work closely with station developers to identify an appropriate resolution.
- The State of California currently has a unique role in station performance testing and validation. The Hydrogen Station Equipment Performance (HyStEP) program and device provide unique insights into implementation strategies and gaps in existing codes and

standards. The State should find ways to increase its role in developing these codes and standards in order to ensure the specifications are informed by the on-the-ground experience gained over the past two years of the HyStEP program. ARB's participation in this regard could help maintain momentum towards developing solutions for faster station performance validation and overall development time in the future.

H2 and FCEVs in the News

Progress continues in the light duty FCEV market. New model announcements and strategic partnerships in the supply chain demonstrate auto manufacturer commitments to continuing the pursuit of fuel cell technology.

- Honda's model year 2017 Clarity fuel cell sedan received an estimated range rating of 366 miles from the Environmental Protection Agency. The vehicle's release was launched early in 2017 with the vehicle available for lease in 12 dealerships around California [2], [3].
- At the 2017 Geneva Motor Show, Hyundai unveiled its Future Eco (FE) concept vehicle. The concept previews Hyundai's expectations for its next FCEV model, which will replace the current Tucson Fuel Cell. Hyundai expects the FE to have a range greater than 490 miles, due to a 20% reduction in powerplant weight and 10% improvement in efficiency [4].
- Following the future release of Hyundai's FE, Kia also announced that it will bring a new FCEV model to the market in 2020. It is expected that the Kia model will similarly benefit from the new powerplant developments for the Hyundai FE [5].
- The new luxury brand Genesis, associated with Hyundai-Kia, unveiled its GV80 fuel concept at the 2017 New York International Auto Show. The GV80 is a high technology SUV concept with an advanced plug-in hydrogen fuel cell powertrain. Launch plans for a commercial product have not yet been announced [6].
- Honda and GM established the auto industry's first manufacturing joint venture to mass produce a hydrogen fuel cell system for use in future products released by both companies [7].

Several announcements across the fuel cell and hydrogen fuel industry in 2017 highlight continuing advances and the expanding market presence of fuel cell and hydrogen technology in several transportation applications.

- Air Products announced that it will now be able to offer hydrogen for FCEV fueling at a price of less than $10 per kg at its five stations in California. Air Products cites advances in fueling station and hydrogen distribution technology as well as projected FCEV deployments as enabling factors in reaching this pricing milestone [8].
- Nippon Steel and Sumitomo Metal Corp. announced a new steel hydrogen storage tank product for fueling stations that promises a 30% cost savings compared to conventional carbon fiber-wrapped tanks [9].
- Several announcements regarding hydrogen-powered fuel cell heavy duty trucks were made this past year. Toyota unveiled a proof-of-concept demonstration for an 8,000 pound class 8 fuel cell truck-and-trailer combo powered by two Mirai fuel cell stacks. The truck has a range of 200 miles and will be utilized in drayage operations at the Ports of Los Angeles and Long Beach [10]. Truck manufacturer Kenworth also announced the development of a drayage truck prototype for use in the Southern California ports, integrating Ballard fuel cell stacks [11]. At the 2017 Advanced Clean Technology Expo, US Hybrid announced a fuel cell-powered truck for port drayage demonstration in Southern California, built on its own FCe80 80 kW fuel cell stack [12]. Finally, Nikola, a new truck manufacturing company, unveiled its Class 8 over-the-road semi-truck. The truck is anticipated to provide 800 to 1,200 miles of range. Nikola's offering is also unique in that commercial leases will include hydrogen fuel, provided by a network of nationwide stations the company is planning to develop [13].
- United Parcel Service (UPS) has announced that its first prototype fuel cell extended-range delivery van will be deployed in Sacramento in the third quarter of 2017. Development of the van has been completed in collaboration with United States Department of Energy [14].
- French rail equipment company Alstom unveiled and demonstrated its Coradia iLint, the world's first fuel cell-powered passenger train. Letters of intent have been signed with various local jurisdictions throughout Germany for the delivery of 60 trains, beginning in 2018 [15].
- Partners Ivys, McPhy Energy, and PDC Machines won the Department of Energy's H2 Refuel HPrize with the SimpleFuel hydrogen fueling appliance. SimpleFuel is designed to be a cost-effective solution for small-volume opportunity refueling applications. The device generates hydrogen through electrolysis and is able to dispense up to 10 kg/day at 700 bar pressure [16].

California's on-the-road FCEVs continue to demonstrate the usability of the growing hydrogen network and make meaningful contributions to the State's environmental and climate change goals.

- In celebration of Earth Day, several members of the California Fuel Cell Partnership, including leadership at ARB, the Energy Commission, and the Governor's Office of Business and Economic Development, drove a caravan of FCEVs from the State Capitol to Hayward, San Jose, Treasure Island, and back. The road trip demonstrated the ease of owning and driving an FCEV throughout northern California [17].
- Hydrogen station developer FirstElement estimates that in 2016, its network of hydrogen fueling stations provided fuel to power more than 3.7 million zero-emission miles, avoiding 2.3 million pounds of greenhouse gas emissions. The company estimates the effect is equivalent to planting a forest nine times the size of Disneyland [18].

Hydrogen fuel and FCEVs are increasingly becoming an international collaborative effort.

- At the 2017 World Economic Forum in Davos, Switzerland, 13 multinational transportation and energy companies announced the formation of the Hydrogen Council. The main objective of the council is to accelerate the commercialization of hydrogen and fuel cell-powered transportation. The council plans to invest €10 billion in the next five years and to work with appropriate public agencies towards achieving this goal [19].
- The United Kingdom's (UK) Department of Transport announced a new £23 million fund for hydrogen station developers and FCEV auto manufacturers to apply for funding of new hydrogen fueling stations, in an effort to increase the adoption of FCEVs [20]. Earlier in the year, Shell also announced the launch of its first hydrogen fueling station in the UK. The station, located in Cobham, is the first of three the company expects to launch in the UK in 2017 [21].
- The South Korean Ministry of Land Transportation renewed the country's commitment to FCEVs, announcing plans to build 200 alternative fueling stations by 2025. The stations will be required to include at least one charger for battery electric vehicles and one hydrogen dispenser for FCEVs, with profits from the stations being reinvested into fuel cell research [22].
- Japan's Prime Minister Shinzo Abe directed his government to draft a hydrogen society strategy by the end of 2017. The strategy will address the nation's goal of deploying 40,000 FCEVs by 2020 as well as the need to build international collaboration to develop the hydrogen and fuel cell supply chain [23].
- Eleven Japanese companies from the automotive, oil and energy, industrial gas, and financing industries signed a memorandum of understanding to collaborate on accelerating hydrogen fueling stations in Japan. The collaboration is meant to ensure the goals of Japan's Strategic Roadmap are met (specifically, 160 operational hydrogen fueling stations and 40,000 on-the-road FCEVs by 2020) [24].

Several efforts across the United States are expanding on California's success and setting the stage for a future nationwide deployment of FCEVs.

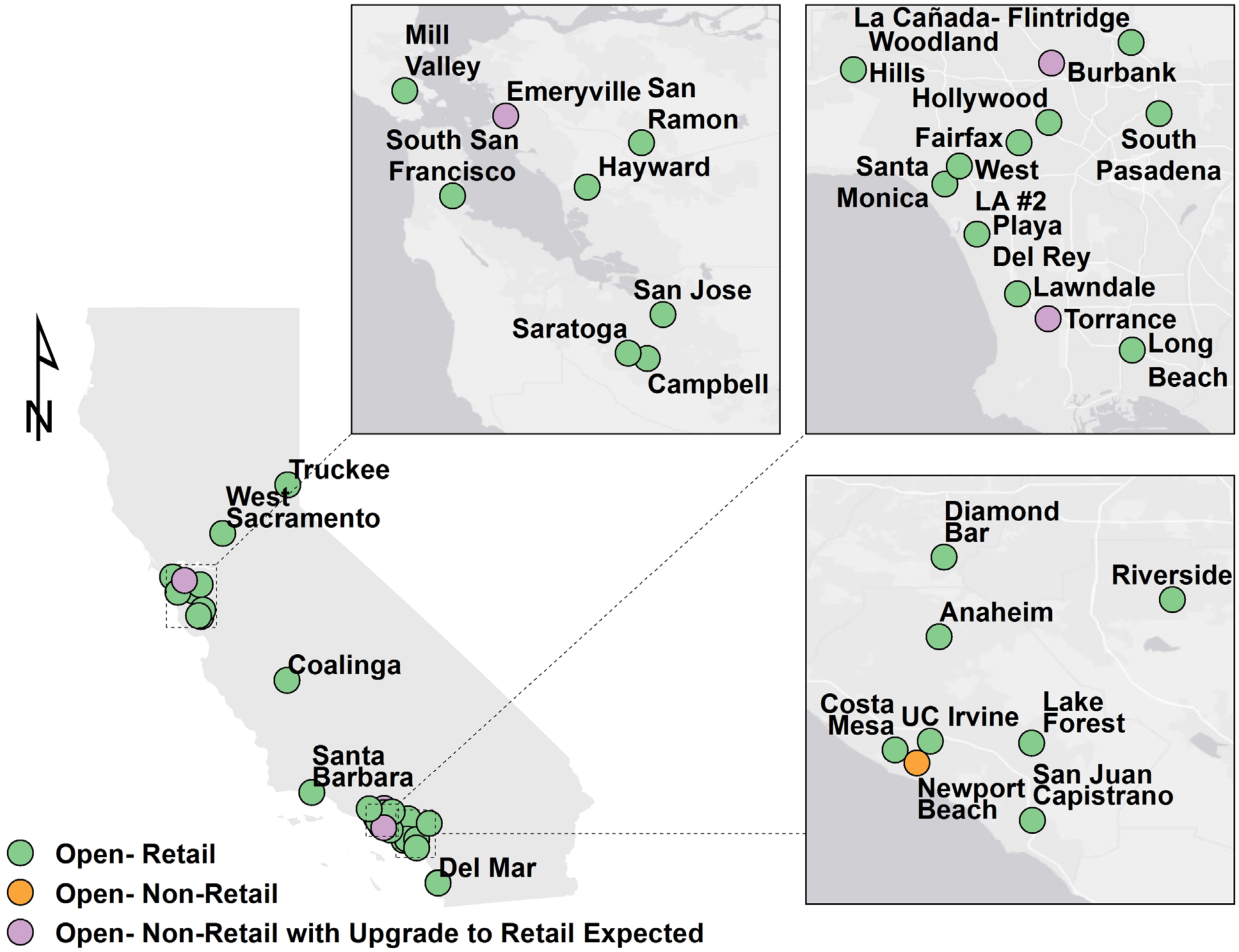
- On January 13, 2017, the Federal Highway Administration announced the first round of designations of hydrogen corridors, in accordance with the Fixing America's Surface Transportation Act of 2015. Highways with an alternative fuel corridor designation are eligible for federally-provided signage indicating the designation and priority consideration in applications to federal Congestion Mitigation and Air Quality project funding [25].
- In 2016, the National Park Service and the Department of Energy opened Washington D.C's first hydrogen fueling station. The station is intended as a demonstration of hydrogen fueling technology and an important tool in educating stakeholders to advance the deployment of hydrogen and FCEVs across the country [26].
- The City of San Francisco was selected by the Department of Energy as the first Climate Action Champion to focus on local hydrogen and fuel cell deployment. Funding under the award will help the city perform several outreach and education tasks, including customer education, permitting agency outreach, and other hydrogen training projects [27].
- Industrial gas company and station operator Air Liquide, in partnership with Toyota, has announced the development of 12 hydrogen fueling stations in the northeast. Stations are expected to begin operations as early as 2017. Announced locations include one station in Connecticut, four in Massachusetts, four in New York, two in New Jersey, and one in Rhode Island [28], [29], [30].
- On January 30, 2017, the Energy Commission held a public pre-solicitation workshop to discuss technologies, strategies, and challenges for the implementation of a potential grant opportunity for an in-State renewable hydrogen production project. The Energy Commission is currently accepting and reviewing comments to the docket for this project [31].

Findings

Finding 1: California's 29 Open-Retail hydrogen fueling stations provide critical fueling opportunity to enable FCEV sales in several of the state's first adopter markets.

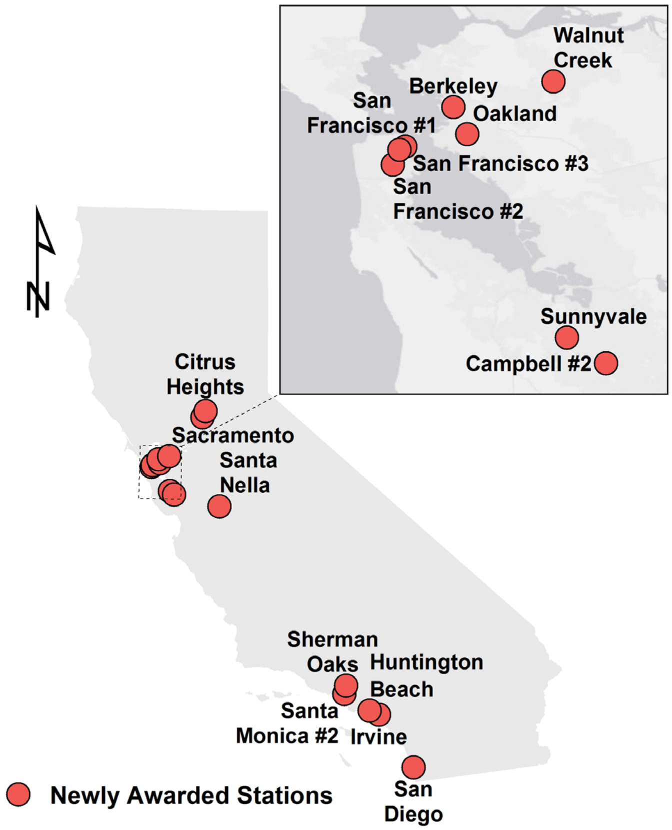
Since the June 2016 Annual Evaluation, hydrogen fueling stations opened for full retail operations in Anaheim, Del Mar, Hollywood, Lawndale, Playa Del Rey, Riverside, San Ramon, South Pasadena, and Woodland Hills. These new stations have expanded the coverage provided by the open hydrogen fueling station network, especially in the greater Los Angeles region. In some areas, the stations additionally provide much-needed redundancy for high-priority early adopter markets of FCEVs. In addition to the 29 Open-Retail stations, three Open-Non-Retail stations are in various stages of completing an upgrade to enable full Open-Retail status. The station in Torrance is expected to be the first of these stations to re-open as a retail station, potentially in Quarter 3 of 2017. Figure ES1 shows the latest status of California's Open-Retail hydrogen fueling network.

Figure ES1: California's Currently Open Hydrogen Fueling Network as of July 27, 2017



Finding 2: New station awards made through the Energy Commission's Grant Funding Opportunity GFO 15-605 significantly expand opportunities for marketability and functionality of FCEVs in California.

Figure ES2: Stations Funded in February 2017 through GFO 15-605

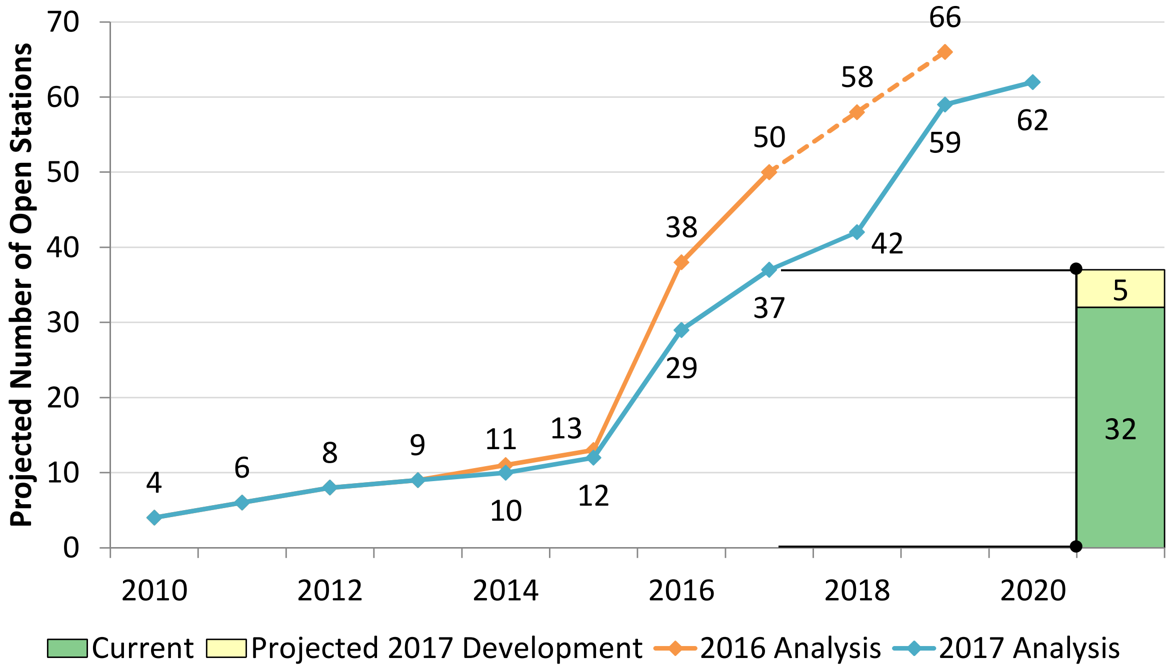


The Energy Commission's grant solicitation GFO 15-605 added 16 new stations to the network, shown in Figure ES2. Based on the expected opening dates reported in the applications and follow-up meetings with the developers, these stations are projected to open in 2019. These new station awards continue the trend of adding functionality to the network through new State investments:

- The first sub-network in San Francisco has been established with a high degree of redundancy, due to the three stations awarded within the city
- New East Bay stations in Oakland, Berkeley, and Walnut Creek will enable market deployment in this important FCEV early adopter region
- Two more stations in the southern end of the Bay Area will provide needed redundancy to support the growing FCEV fleet in the area
- Two new stations in Sacramento will enable increased FCEV deployment, with coverage providing service to a large portion of the projected local market
- A new station closer to San Diego's population center extends the usability of the sub-network that has been established near the city
- Additional stations in Orange County add redundancy to the network and re-establish fueling opportunities near recently closed demonstration era stations.

Finding 3: While station development progress has continued overall, some individual sites have continued to present ongoing difficulty.

Figure ES3: Comparison of Statewide Station Projections between 2016 and 2017 Annual Evaluations[1]



Current understanding of hydrogen fueling station development progress indicates a station deployment pace one year slower than previously expected. In the 2016 Annual Evaluation, 38 stations were expected to be complete by the end of 2016; a similar number of stations (37) are now expected to be open by the end of 2017. Similarly, 50 stations were previously expected by the end of 2017; the updated projection is 42 by the close of 2018. This shift in expectations is indicative of ongoing difficulties with particular stations. Difficulties typically center on either securing a mutually acceptable lease agreement between the station developer and the host gas station's owner and/or operator and protracted permitting and planning approval processes. In a small number of cases, there have been difficulties with equipment procurement or the station has undergone multiple rounds of tuning in order to complete the station testing and validation process. GFO 15-605 introduced the enforcement of critical milestones to help ensure these types of delays are prevented with newly-funded stations. Between November of 2016 and March of 2017 the Energy Commission issued Stop Work Orders on nine stations funded in previous years due to station developers' lack of significant progress in construction of the stations and the state's fiscal deadline to utilize the funds. Station developers were required to provide a viable and reasonable plan to complete station construction to potentially lift the Stop Work Orders. The Energy Commission has lifted the Stop Work Order for the Mountain View station and is currently considering whether to proceed with the Emeryville station. Completion of the Orange, Rohnert Park, and North Hollywood stations remains uncertain. These five stations have been included in the projections of this report. However, the Chino, Encinitas, Los Altos, and Newport

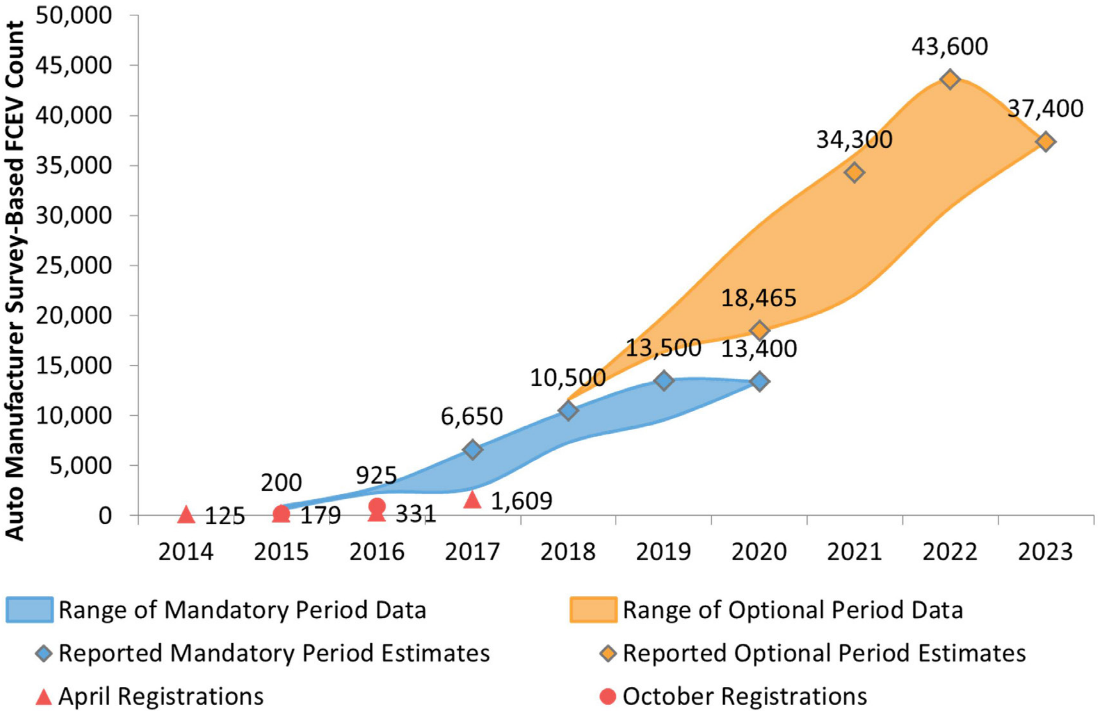
1 Three Non-Retail stations currently have plans for upgrade to retail. Harbor City closed in Q4, 2016. Years 2014 and 2015 include a historical data correction. Three stations and one upgrade to retail no longer included due to lack of substantial progress. CSULA included from 2014 on in this figure.

Beach upgrade (moved from the former Foster City station) are not proceeding since viable and reasonable plans for completion were not received; hence, these stations are not included in projections. Figure ES3 shows the latest expectation for cumulative hydrogen fueling network development for all funded stations.

Finding 4: The connection between infrastructure and vehicle deployment remains strong; new survey data indicate a short-term delay of one year and a long-term delay of two years in projected FCEV deployment. Auto manufacturers emphasize larger deployments could be possible with accelerated station development timelines.

Due to network development that has been slower than previously anticipated, auto manufacturers' responses on the annual FCEV deployment surveys show a decrease in both the short and the long term deployment plans compared to prior years. In addition, several of the station development Stop Work Orders were put into effect during the month the survey was given to auto manufacturers; these announcements may have had an impact on the total number of FCEVs reported for future planned deployment. Figure ES4 shows the auto manufacturer projections of FCEV deployments provided for all years in all surveys collected to date. Ranges of reported FCEV deployments are shown by the shaded areas, divided into mandatory and optional period estimates. On-the-road estimates from the end of the mandatory and optional periods in each of the last four surveys are shown by the blue and orange diamonds, respectively, and labeled with the reported projection. Based on the most recent survey, 13,400 FCEVs are expected to be on-the-road in 2020. This also matches nearly exactly with a one year delay from the previous 2019 estimate of 13,500 and the observed delay in infrastructure development. By 2023, 37,400 FCEVs are expected to be on the road. This is between the values previously reported for 2021 and 2022, indicating a one to two year delay in the long term. In separate survey response content and several separate discussions, auto manufacturers have indicated that deployment schedules could be accelerated with faster station network development. In fact, several auto manufacturers have begun to voice concern over the business-as-usual projection for AB 8-funded station development (eight stations per year average pace, reaching 100 around the close of 2023) and have asked that the State find a way to accelerate the overall network development timeline. Alternative funding mechanisms that may be able to increase the number of stations funded per annual allocation are discussed further in Finding 7, Chapter IV, and Appendix E.

Figure ES4: Current and Projected On-Road FCEV Populations and Comparison to Previously Collected and Reported Projections[2]



Finding 5: Revised assessment of the FCEV market and funded station coverage finds that major portions of Los Angeles County are the highest priority for new station funding. Select areas across the San Francisco Bay Area, Orange County, and San Diego are also among the highest priority.

Based on an updated assessment of the potential FCEV market in California, and the 62[3] funded and operational stations (16 stations funded through GFO 15-605 and 46 of the 50 stations funded and reported in prior years), ARB recommends that new station funding priorities are as presented in Table ES1. The analysis leading to the development Table ES1 relied on the California Hydrogen Infrastructure and Accounting Tools (CHIT and CHAT) as in previous years, though ARB has made substantial updates to CHIT in response to stakeholder requests and its own observations from utilization of the tool over the past two years. Several cities in Los Angeles County now form the bulk and highest priority of targets for new funding. San Francisco is also a high priority in terms of coverage, though capacity needs are projected to be satisfied through 2020. Several additional potential targets have been identified as a Second Priority tier; the full list is detailed in Chapter III.

2 ARB identifies a one-year short-term delay based on comparison of the previously-reported 2019 projection of 13,500 FCEVs and the most recent 2020 projection of 13,400 FCEVs. ARB identifies up to a two-year long-term delay based on comparison of the previously-reported 2021 projection of 34,300 FCEVs and the most recent 2023 projection of 37,400 FCEVs.

3 60 of the 62 stations have been funded by the Energy Commission through the Alternative and Renewable Fuel and Vehicle Technology Program, and are currently or are expected to become Open-Retail. Two stations are currently Open-Non-Retail and were funded in earlier efforts by ARB.

Table ES1: Recommended First Priority Areas, based on 13,400 FCEVs in 2020 (City Names in the Description Correspond to the Highest Scores within a Priority Area)[4]

	Priority Areas	Description	Number of Stations
First Priority	1 (Region A)	Downtown Los Angeles - West Hollywood - Glendale - Northridge - Calabasas - Pacific Palisades	5
	1 (Region B)	Long Beach - Arcadia - West Covina - Claremont - Cerritos - Downey - Hacienda Heights	
	2	Manhattan Beach - Redondo Beach -Torrance - San Pedro	1
	3	San Francisco	0
	4	San Mateo - Foster City - Belmont - San Carlos	2
	5	South San Jose	1
	6	Santa Clarita	1
	7	North Tustin	1
	8	Dana Point - Aliso Viejo - Laguna Beach	1
	9	East Yorba Linda - East Anaheim	1
	10	La Jolla	1
	11	San Clemente	1

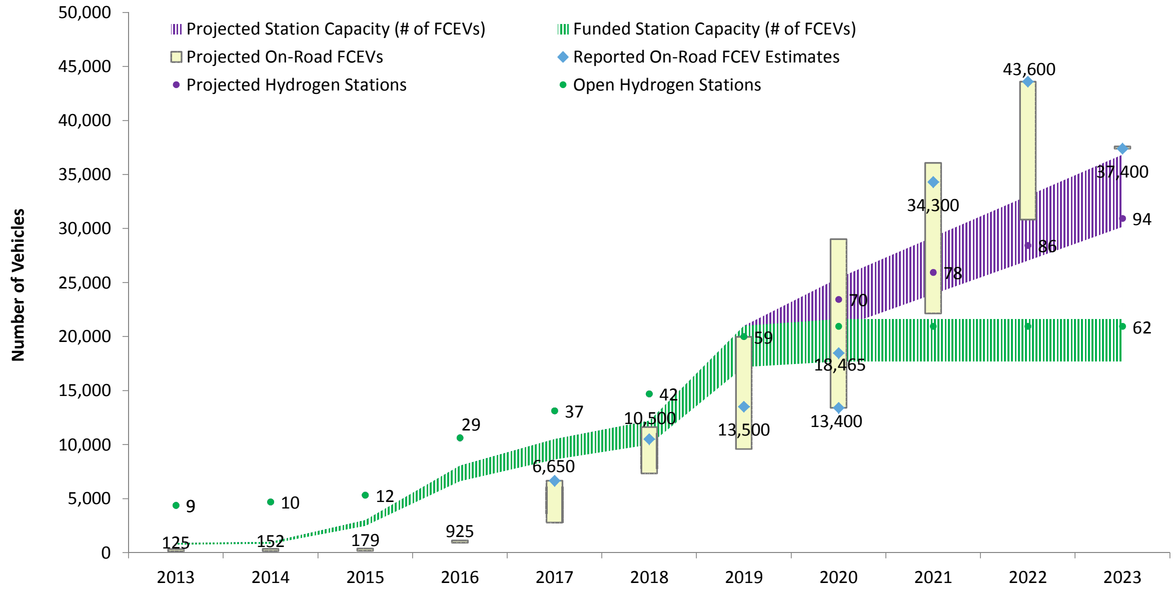
Finding 6: Long-term FCEV deployment plans continue to indicate a need for dispensing capacity beyond the currently-funded stations and business-as-usual development under AB 8. Significant coverage and capacity needs indicate the full $20 million (subject to allocation) should be utilized in the next funding cycle.

Previous projections of business-as-usual fueling station development assumed eight stations, each with a dispensing capacity of 180 kg/day, could be built for every $20 million made available through AB 8 grant programs. All but one of the 16 stations funded under GFO 15-605 far exceeded this expectation, providing a minimum of 300 kg/day dispensing capacity at each station. Multiple station developers have also publically discussed the need for planning and building larger stations today than were previously anticipated for this timeframe. This emphasis on larger stations is reflected in this year's business as usual projections, which partially closes the gap between the long-term dispensing capacity and expected demand. While the capacity of funded stations has been assumed to increase under business as usual conditions, the number of stations that may be funded through each annual allotment of $20 million under AB 8 has been maintained at eight per year, based on consistent observations thus far in the pre-commercial period. As the station network and FCEV markets have recently entered into an early commercial market phase, this business as usual rate may accelerate in the future, due to potential changes in AB 8 funding structures and/or increased investment of private funds. Figure ES5 shows that, based on the business-as-usual scenario of annually funding eight 300 kg/day stations, hydrogen dispensing capacity in California may be able to keep up with demand until 2021, one year later than previously reported. Without continually investing the full $20 million available, the State risks a capacity shortfall. More importantly, continued or even accelerated station network development is expected to incentivize greater FCEV deployment. With many core market areas still without sufficient coverage and backup fueling options, halting or slowing investment in hydrogen fueling stations will push auto manufacturers' FCEV deployment plans further into the future. With two consecutive years of reductions in deployment plans indicated on the annual FCEV survey, ARB recommends that the State collaborate with stakeholders to identify potential strengths and weaknesses of various options of alternative funding mechanisms designed to

4 See Figure 14 on page 43 for a map delineating these priority areas. Additionally, Table ES1 is in order of calculated priority, though ARB does not intend for use of the table to strictly follow the displayed order. Flexibility as necessary for future funding efforts should be exercised. Finally, San Francisco has been identified as a need for additional coverage, but not capacity with current FCEV projections. For this reason, it is identified in Table ES1 though not recommended for a new station in the next funding effort.

obtain more than eight 300 kg/day (or larger) stations through the annual $20 million allotment. These efforts have begun and will help maintain California as a focal point of FCEV deployments.

Figure ES5: Projected Hydrogen Demand and Fueling Capacity, Given Business as Usual Assumptions in State Incentive Programs



Finding 7: Focus for hydrogen station funding may need to shift to supporting rapid growth and approach to self-sufficient business ventures in the industry. Alternative funding mechanisms with AB 8 funds can and should be evaluated and pursued in order to maintain California's leadership position in FCEV deployment.

The current business-as-usual station deployment schedule may result in fewer than the minimum 100 stations referenced in AB 8 before the bill expires on January 1, 2024. As shown in Figure ES5, a continuous deployment of eight stations per year results in 94 stations built in 2023, assuming the earliest stations could open under the next funding cycle will be 2020. Thus, to reach the minimum goals of AB 8, station development needs to be accelerated. In addition, stakeholders have expressed a desire for the 100 station minimum goal to be reached prior to 2023, if possible. Achieving such an ambitious goal could help maintain California's competitiveness on the global market for FCEV deployment. Thus far, AB 8 funds have been utilized through a grant award process, with varying amounts of cost-share expected from awarded project grantees. This has provided certainty of capital to station developers when evidence of a self-sufficient business case was not yet apparent, allowing more station developers to enter the hydrogen fueling station industry. The large over-subscription of proposed project funds in PON 13-607 and GFO 15-605 is evidence of the effectiveness of these grant programs to jump-start the industry in California. However, there are now several indications that the emphasis of the funding programs may need to change from supporting the establishment of a nascent industry to developing that industry into a self-sufficient business venture. Making this switch would require an emphasis on rapid growth of overall market size. This could require greater leverage of State dollars to affect a more rapid growth in the hydrogen station network. In order to achieve the necessary pace of growth, the State may need to consider alternatives to the current program design of capitol grants that require grant awardee cost share between 15% and 30%. Loan loss reserves, loan guarantees, certificates of guarantee, additional coordination with private investors and entities interested in investment opportunities within sustainable energy technologies, and renewable fuel reimbursements are a few options that the Energy Commission may wish to consider for future station development.

Finding 8: The HyStEP device and program have demonstrated unique and impactful success in progressing hydrogen fueling station performance validation efforts. The State should seriously consider near-term expansion of the program, whether through the State or private entities.

The HyStEP device and program represent a major advancement in hydrogen fueling station deployment that is unique to the California experience. Confirmation of station performance has been accelerated, streamlined, and standardized in this one-of-a-kind effort. The program and device have proven to be a valuable tool to station developers and FCEV auto manufacturers alike. The work of the program has helped ensure that stations are ready to properly fuel FCEVs from the first day they are open, per the industry-developed standards in SAE J2601. However, program experience has shown there is significant variation in J2601 implementation among station developers. Given that the HyStEP device is currently one-of-a-kind, the State has been able to gain unique insight into portions of codes and standards that are left open to discrepancies in interpretation. With the perspective gained by interfacing with technology and staff of widely varying stakeholder organizations, ARB and the State of California as a whole are in a unique position to provide valuable feedback to committees completing ongoing codes and standards development. The State's role in these efforts is currently limited; participation by the State should be enhanced going forward. In addition, with the acknowledgement that hydrogen fueling network development will need to quickly accelerate sometime in the near future, additional resources for more devices and staff time will represent a mission-critical need. Eventually, the HyStEP program may evolve into a more rigorous regulatory program on its own, or it may transition into a private enterprise with independent certification companies providing testing and review of station performance. Whichever way the program develops, it is clear that significant resources will need to be rapidly deployed in order to ensure that station validation does not become a bottleneck in the overall hydrogen network development timeline.

Finding 9: Renewable and conventional hydrogen production capacity within California are quickly becoming a priority among stakeholders and FCEV customers and need to be expanded.

While California is currently at the forefront of hydrogen fueling network development in the United States, hydrogen production capacity and renewable production feedstocks (such as renewable natural gas or landfill gas) largely reside out-of-state. As a result, hydrogen must often be transported long distances to fill California FCEV drivers' tanks. This transport increases the overall lifecycle greenhouse gas and pollutant emissions, reducing the overall environmental benefit. Even with these constraints, hydrogen remains significantly less detrimental to the climate and air quality than conventional fuel options. However, station developers, auto manufacturers, and most importantly FCEV drivers themselves have similarly begun conveying a desire for hydrogen with greater utilization of renewable resources and reduced lifecycle emissions. Establishment of new production capacity, especially renewable production capacity, within California would be a significant step. This would also help ensure the State's goals of renewable hydrogen throughput, implemented through Senate Bill 1505 (SB 1505; Lowenthal, Chapter 877, Statutes of 2006) could continue to be met in the future [32]. Currently, California's open and funded fueling network is expected to dispense 37% of its hydrogen utilizing renewable resources, exceeding the 33% requirement of SB 1505.

According to data collected by the Pacific Northwest National Laboratory, California facilities produce approximately one-fifth of the nation's supply of hydrogen, but nearly all that hydrogen, which is largely produced on-site, is used directly for oil refining. Merchant hydrogen production (hydrogen produced in smaller quantities for sale on the open market and a variety of end-uses) in California for customers other than oil refineries is only 55 tons/day, or 1% of the national merchant non-oil production capacity [33]. Considering the leading role of FCEVs in California compared to the rest of the nation, there appears to be a clear need for new production capacity to be developed within the state. The Energy Commission has taken the first step towards this goal by hosting a solicitation concepts workshop for renewable hydrogen production facilities on January 30, 2017, with stated intent to release a Draft Solicitation Concepts document. ARB suggests that the outcomes of this workshop should be pursued as one of the top priorities for near-term hydrogen investments by the State. Increased production capacity within the state may ultimately address customers' desire for low-emissions hydrogen, long-term concerns of a gap in production capacity, and high costs of hydrogen procurement that are currently a significant barrier to a viable hydrogen station business case.

Conclusions

California's hydrogen fueling network has continued to make substantial progress in the past year, especially with the new funding proposed for 16 high-capacity stations in key communities across California. At the same time, there have been project execution hurdles, and for some stations the station as funded is no longer expected to be a part of the state's hydrogen fueling network (funds may become available in the future to restore projects at these locations to active development). The net effect is a slower development pace in the overall station network than projected in prior reports. Most of this delay is associated with a few stations from the earliest grant programs that have annually exhibited difficulty making progress. Corresponding delays in auto manufacturers' expectations of FCEV deployments highlight the need for consistent, reliable market development progress.

As network development and FCEV deployment progress continue to mature, the needs of both fueling and vehicle industries have begun to shift. There is renewed emphasis on the scale and pace of development as more auto manufacturers bring commercial vehicles to market. Potential future issues of renewable hydrogen production and availability and lower costs for hydrogen procurement are becoming increasingly prevalent in stakeholder discussions. Stakeholders have begun establishing expectations and visions for an approach to a thriving, competitive, self-sufficient fueling market. With the progress made and the challenges faced in the past year, California appears to be at a critical juncture in ensuring the promise of the AB 8 program.

This year's analysis finds that several previously-highlighted challenges for future FCEV deployment and hydrogen fueling network development remain a priority. Particular attention must be directed toward station deployment timing and the fueling capacity of the projected network. Combined with the newly-identified challenges facing hydrogen production and renewable implementation, there may be a need and opportunity for the State to adopt new strategies in the design of its funding support for the developing hydrogen fueling network. New strategies will need to recognize the transition in the past year from pre-commercial to early market phase of FCEV launch and capitalize on the success of the earlier funding efforts that enabled this transition. New and additional sources of funds may be a direct resolution, but a redesigned funding mechanism within AB 8 may enable faster and more efficient network development.

It is imperative that the State and station developers find solutions to the current uncertainties in the hydrogen fueling network's expected progress. Three auto manufacturers currently have commercial FCEVs for sale or lease. At least four new models (one a replacement for a current commercial vehicle) are expected to be launched in California within the next few years. Large deployment volumes of these vehicles will be critically dependent on the successful development of a robust and extensive fueling network in a large number of markets. As several auto manufacturers have indicated, greater certainty in the station network development would have a lasting impact on the possibilities for the state's hydrogen fueled vehicle fleet.

Medium and Heavy Duty Applications for Hydrogen Gain Momentum

As several of the news items show, hydrogen fuel and fuel cell power have made important strides into medium and heavy duty applications in the past year [10-15]. These advances may even occur sooner than previously expected. Continuing advances in deployment of medium and heavy duty vehicles may have an important impact on light-duty vehicle deployment. The larger vehicles correspondingly have a much greater hydrogen consumption need. This could translate into greater momentum in developing the hydrogen production and distribution supply chain, eventually creating opportunities for lower-cost hydrogen across the industry. This of course would rely on the ability for all vehicle sectors to take advantage of high-volume hydrogen procurement on a much greater scale than exists today outside of the petroleum refining industry. Co-location of fueling for multiple vehicle types may be one option to achieving this goal, but individual station providers are likely to develop their own unique and creative approaches as these various fuel cell vehicle markets mature. There will certainly be challenges to face, but it is encouraging to see new opportunities and new ideas develop simultaneously. There are promising signals of future success, such as Nikola's stated desire to source its hydrogen from 100% renewable solar electrolysis farms. ARB will continue to monitor these developments and consider what opportunities may exist to further capitalize on the successes of AB 8 through these endeavors. The CaFCP's medium and heavy duty action plan, released in October 2016, provides several concepts and recommended actions valuable to this consideration [34].

Introduction

In the early morning of September 14, 2016, two fuel cell-powered Toyota Mirai vehicles stopped briefly in front of the state Capitol building. Time was taken for a photo-op, passengers and drivers exchanged positions, and some riders headed out to other endeavors for the day while others joined the group for the first time. The cars themselves had just come from a fueling stop at the Linde-operated hydrogen fueling station in West Sacramento and were bound for their next destination: Truckee, with a potential extension out to Reno.

What made the vehicles' presence special that day was two-fold. First, these fuel cell vehicles had started their long journey in Long Beach much earlier in the morning. In just the prior year, such a trip was not possible. With the opening of the fueling station at Harris Ranch in Coalinga six months prior, north-south long-distance travel in an FCEV became a reality. Second, the road trip that these Mirai sedans were undertaking was itself to become special: by the next morning, these vehicles would break a world record for the most miles driven on electric drive within a single 24-hour period [35]. More importantly, the record set by the Mirai sedans was done so on California's highway system with all its infamous traffic and congestion, not on a tightly controlled record-setting route.

After leaving Sacramento, the fuel cell electric vehicles did make it to Truckee and even to Reno. Their travels after that included a return to Sacramento followed by a journey to and around the San Francisco Bay Area, back south to Santa Barbara, returning to Los Angeles and Orange Counties, and even including an extension down to San Diego for good measure. In total, the record-setting vehicle logged 1,438 miles. All of this was made possible by the availability of hydrogen fueling stations in key locations across the state of California. For all but the West Sacramento station, these were TrueZero stations operated by station developer FirstElement Fuel, who not so coincidentally comprised the crew that took the two Mirai vehicles on their tour of California.

The drive completed by FirstElement is certainly special for setting a new world record and showcasing the long range and fast-fueling capabilities of hydrogen-powered fuel cell electric vehicles. But it is equally a showcase of the progress in development of California's hydrogen fueling network during the recent years, thanks in large part to the efforts of the AB 8 program. Today, the hydrogen fueling station network is even more extensive than it was during this record-setting drive, and there are plans for even more additions to extend the reach and utility of the fueling network to potential FCEV first adopters.

AB 8 is California's signature enabling legislation for the development of its hydrogen fueling network. Establishment of a robust, technically capable, well-planned network of fueling stations enables successful launch and release of FCEVs into the consumer market. This fundamental principle drives today's AB 8-related efforts. The State helps co-fund the development of new hydrogen fueling stations, while acting as a constant support for the efforts of station developers, fuel cell vehicle manufacturers, hydrogen producers, and local jurisdictions alike. The program, and related State and private-public efforts, have been integral in the establishment of standards for retail station operations, the opening of 29 retail hydrogen fueling stations, and ongoing discussions for opportunities in the future of the hydrogen and fuel cell electric vehicle markets.

In accordance with the requirements of AB 8 (see Appendix A for an excerpt of relevant original text), ARB annually completes an assessment of the progress of the related hydrogen fueling and FCEV markets in California. Progress and challenges faced in the last year and anticipated in the future are likewise analyzed and reported. Each year provides new insight into the factors that lead to successes and challenges in launching world-leading zero-emission personal transportation such as California's hydrogen and FCEV markets.

The 2017 Annual Evaluation is informed by similar analyses as used in prior years. ARB incorporates information from DMV registration data, annual auto manufacturer surveys indicating future FCEV plans, and station development progress as obtained by the Energy Commission and GO-Biz. Important new analyses and capabilities include:

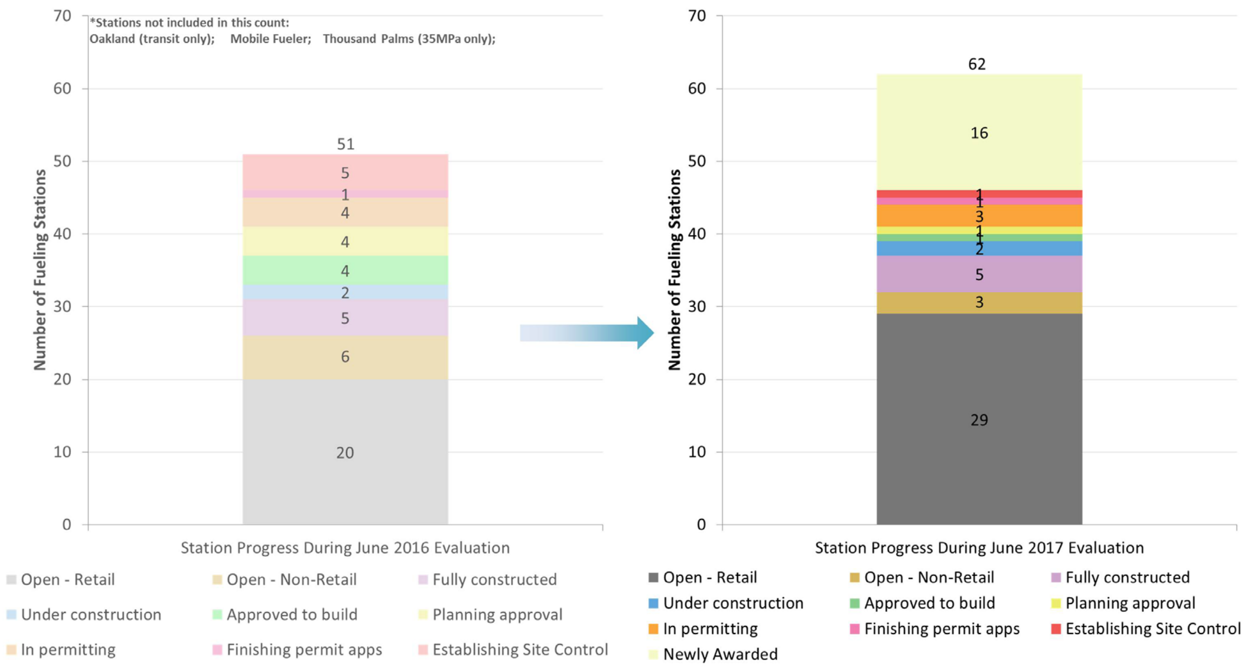
- New analysis tools and input data developed in the past year for CHIT, ARB's geospatial tool for analysis of gaps in the open and funded hydrogen fueling network. This report briefly presents these new features; ARB expects to publicly release the 2017 version of CHIT later in the year and host a public webinar to describe the tool's core functions and revisions.
- Expanded reporting on and comparisons between current and previous auto manufacturer survey results.
- Analysis of Clean Vehicle Rebate Project FCEV driver survey data as it pertains to identification of the first adopter market and its current needs.
- Exploration of alternative funding concepts that may have the potential to accelerate station deployment and provide more constant fund availability.
- Expanded discussion of the HyStEP program's progress and impact, along with insights gained through the program that could prove useful to current and future station developers as well as codes and standards organizations.

Station Development Progress

The funded hydrogen station network in California has continued to expand since the 2016 Annual Evaluation. A net gain of nine new retail stations has been made, and several other stations have made significant progress towards completing construction and station confirmation, as shown in Figure 1. In addition, some stations that previously operated without full retail capability have begun the process of transitioning into fully retail stations. At least one of these stations is expected to re-open as a full retail station by the end of the year. Figure 1 additionally shows the composite station development progress between the 2016 Annual Evaluation and the current network status (see Appendix B for a station-by-station assessment of opening dates and other important station status changes).

There has also been a meaningful addition of 16 newly funded hydrogen stations to California's expected fueling network. These stations have all been proposed for award by the Energy Commission staff through GFO 15-605. Announced in February of this year, these sixteen stations will be high-throughput and high-performance. They will serve first adopter markets in important FCEV launch areas like San Francisco, the Berkeley/Oakland area, Los Angeles, San Diego, and Orange County. One award has also been made for a second connector station along the north-south I-5 travel route, in Santa Nella. It is important for long-distance drivers to have multiple fueling options along their trip and this station provides necessary reassurance of fueling availability for FCEV owners. On June 14, 2017, nine of these stations received formal approval at an Energy Commission Business Meeting.

Figure 1: Hydrogen Fueling Station Network Status, as of July 27, 2017 (the lightened figure on the left is reproduced from the 2016 Annual Evaluation; the full-saturation figure on the right is the current status)



The connector station will be built by industrial gas company Air Liquide, which is also developing a network of 12 stations in the northeast United States, has built the Anaheim station, and is currently building the LAX and Palo Alto stations. FirstElement, a hydrogen fueling station start-up company that began its station development efforts with 19 stations funded through Program Opportunity Notice (PON) 13-607 (17 are currently open), will build eight more through awards in GFO 15-605. Finally, Shell will build the remaining seven newly-funded stations, all with branded dispensers under the canopy and in-line with gasoline fueling. The entry of an energy company such as Shell into California's hydrogen fueling market has become a prominent signal of the promise of hydrogen and fuel cell technology and the potential commitment of members of the petroleum industry to developing viable solutions for the future's necessary transition away from fossil fuels.

The State recognizes that the organizations receiving these new awards have demonstrated extensive experience in the fueling station industry (and some with extensive experience particular to hydrogen). The ultimate hope is that these organizations will be able to use that experience to ensure swift development of these new station projects. New requirements in GFO 15-605 for completion of important permitting milestones, on top of funding incentives for early project completion dates, may also motivate an accelerated timeline compared to past station development awards.

Major Developments Guiding the 2017 Annual Evaluation

The 2017 Annual Evaluation incorporates significant amounts of new material due to the progress made and evolving business needs among California's hydrogen fueling network stakeholders. Important changes in the funded hydrogen fueling network have occurred in the last year, including several stations opening, a sharp increase in FCEV deployment volumes, and awards proposed for 16 new, high-capacity fueling stations that will feature technical capabilities and a customer experience surpassing the stations that have been built to date. These developments all have a significant positive impact in maintaining momentum within the state's developing FCEV and hydrogen fueling markets.

At the same time, a number of challenges have become touch points for various industry reactions and developing concerns. A few individual stations that have had difficulty progressing towards completion did not improve their situation this past year. The Chino, Encinitas, and Los Altos stations and the planned upgrade to Newport Beach are no longer included in State projections of the hydrogen fueling network's development because the lack of progress has put the availability of the projects' enabling funds at risk. The Orange, Rohnert Park, North Hollywood, Emeryville, and Mountain View stations are expected to be completed, but with much later completion dates than previous projections. In each case, the challenge is unique either to the developer or the site and does not signal systematic difficulties. Still, the overall effect is slower progress than expected towards the minimum goal of 100 stations opened through the funding opportunity provided by AB 8, and this has been at least partially responsible for auto manufacturers' shifting projections of FCEV deployment volumes in the next six years.

In spite of these near-term difficulties, conversations among stakeholders still look towards the future, optimistic that progress will ultimately continue. Over the past year, new emphasis has been placed on planning for development at scales much larger than those described by AB 8. This includes significantly more and larger stations, with greater throughput and the potential for improving business cases for station owners and potential private investors. Because of the expectation of large and rapid increase in hydrogen demand, several stakeholders have expressed a need for concentrated attention on building hydrogen production scale (especially within California), ensuring hydrogen is sourced from as much renewable resource as possible, and ultimately finding ways to reduce the cost of hydrogen to the station operator and the customer paying at the pump.

Taken together, these factors indicate excitement surrounding the prospects for industry development borne by the 29 currently Open-Retail stations. However, the expectations of the momentum that these stations bring are also great, and industry stakeholders emphasize the importance to plan for acceleration in the near future. It is clear that business-as-usual progress will not meet the needs dictated by FCEV deployment and station operation plans. The next round of station funding within the AB 8 program may represent a critical juncture in California's leading FCEV deployment role. Past funding programs have had exemplary success at enabling the first entrants into a new high-technology market. However, from this point on, it appears that at least some portion of the State's efforts will need to focus on transitioning that pioneering market into a full-fledged self-sufficient industry. Much of this year's analysis focuses on factors motivating this needed transition and explores potential near-term solutions within the scope of AB 8.

Location and Number of 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.

Information Sources for FCEV Projections

For the 2017 Annual Evaluation, ARB further increased the detail requested in its annual auto manufacturer survey. The primary data collection method of the survey is through an interactive Excel spreadsheet, though additional information is often also requested in other forms. As with the previous annual surveys, the 2017 version asked auto manufacturers to provide FCEV deployment plans for the current model year (model year 2017) and two periods of future deployment. The first period is the mandatory period, which all auto manufacturers must respond to and covers model years 2018 through 2020. The second period is an optional period, which individual auto manufacturers may choose to complete, and includes model years 2021 through 2023.

Auto manufacturers are asked to base their deployment projections on the latest information available regarding hydrogen fueling station network development. The map shown in Figure 2 was provided as information regarding the location and capacity of funded hydrogen stations and the aggregate fueling capacity available to drivers within each county. This fueling capacity availability followed the method first detailed in the 2016 Annual Evaluation, which divides any given station's fueling capacity among the markets in any county within a 15 minute drive and assigns a part of the capacity to each overlapping county proportional to the counties' aggregate FCEV first adopter market intensity as calculated by CHIT. Auto manufacturers were also provided with the individual station data, including expected open dates, addresses, and capacities, shown in Appendix C.

The 2016 annual survey was the first to ask for the optional period data to be specified for each of the three model years. The 2017 annual survey added to this level of detail by also requesting that the optional period data be further split according to county, as is done for the mandatory period. Thus, the 2017 annual survey is the first for which the granularity of requested data is the same across all years of responses. In addition, for the 2017 annual survey, default county-based market share splits were provided, according to a CHIT evaluation adjusted for observations from the 2016 survey responses. Auto manufacturers therefore had the option to supply only a statewide deployment number for each model year and then choose whether or not to edit the default county-based splits coded into the Excel-based survey. Auto manufacturers also had the option of adding additional counties that ARB did not include in its default set, though none made use of this option. It is important to note that while ARB requests this level of granularity in expected FCEV deployments, there is not consistency among all auto manufacturers in responding with the requested granularity, especially for the division of deployments among counties.

Figure 2: Map Provided with Auto Manufacturer Survey, Indicating Existing and Planned Hydrogen Dispensing Capacity by County, as of March 1, 2017

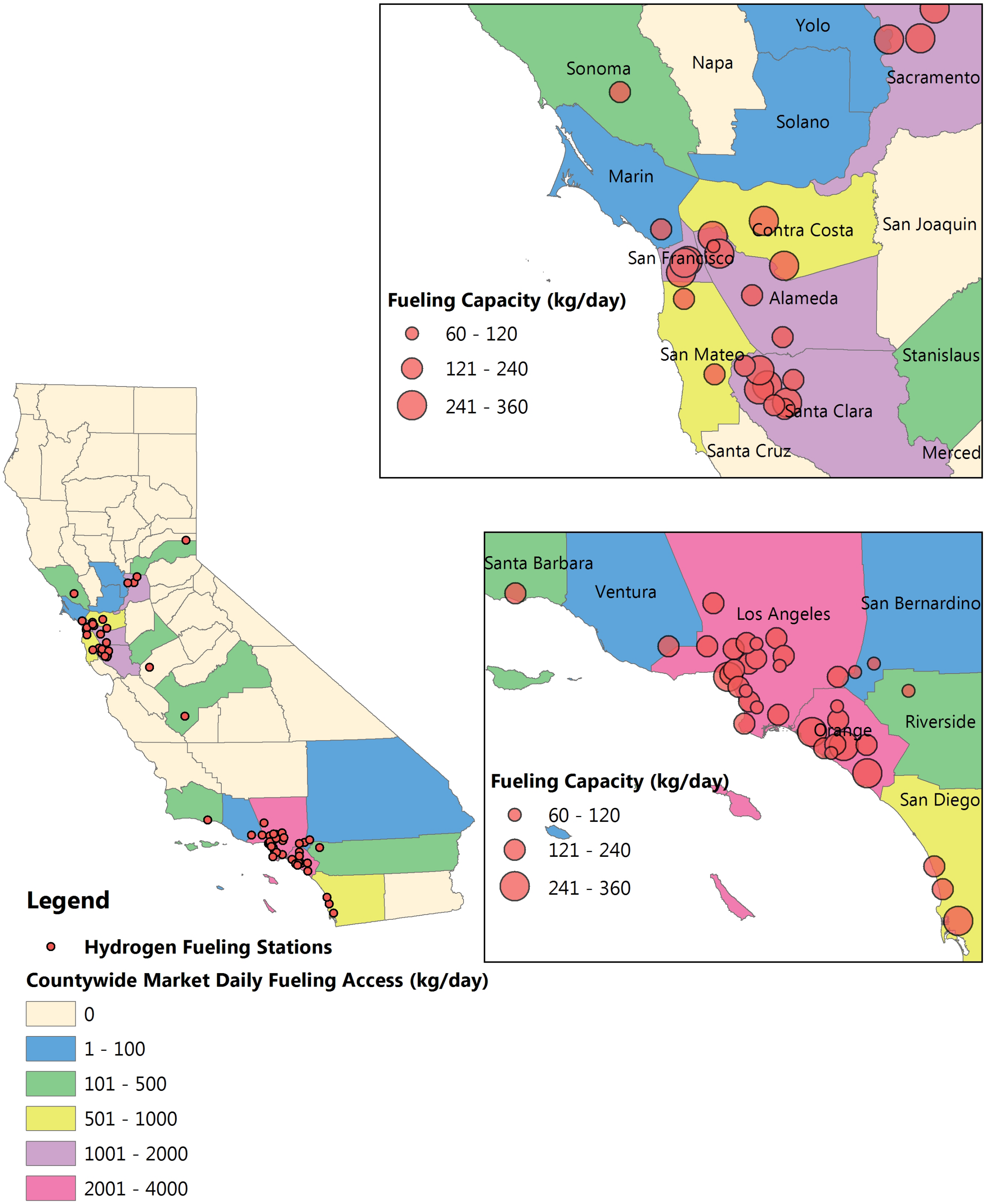


Table 1 shows the default county-based market shares provided in the survey along with a comparison to the information gathered from the auto manufacturer responses. For the auto manufacturer responses, only those where the returned response contained information in the individual cells for each county are counted. That is, any response which gave only a statewide number is not included in the data for developing Table 1. Comparison of the default values to the aggregate values shows good agreement across all counties, though in some cases there is considerable variation among auto manufacturers. There is also a degree of uncertainty that must be acknowledged when comparing the default values to the aggregate of responses. One source of uncertainty is the exclusion of auto manufacturers who did not include individual county data; if their deployment volumes were included, they could affect the results as displayed in Table 1. A second source of uncertainty is that in the optional period, the auto manufacturer themselves may not have a high degree of certainty of the expected market share of each county for such long-term deployments. Individual auto manufacturers may therefore have decided to simply accept the default values in this case. The effect of this uncertainty has been limited in Table 1 by only including those auto manufacturers who appeared to have a market share significantly different from the default within the optional period data. Finally, within the mandatory period, there is no guarantee that an auto manufacturer that disagrees with the default market shares feels it necessary to indicate the discrepancy on the annual survey itself; this could therefore be unreported information that the ARB does not have a method to gauge or account for.

Table 1: Comparison of Default CHIT-Based FCEV Market Shares Provided in Auto Manufacturer Survey and Auto Manufacturer Responses

	CHIT Default	Range in Responses	Aggregate of Responses
Alameda	6.0%	2.1% - 8.3%	6.3%
Contra Costa	2.7%	0% - 3.3%	2.4%
Fresno	1.3%	0% - 1.9%	1.0%
Los Angeles	32.7%	18.6% - 34%	30.3%
Marin	0.8%	0% - 1.4%	0.9%
Orange	13.3%	12.9% - 43.6%	14.7%
Placer	0.5%	0% - 2.3%	0.8%
Riverside	3.0%	1.4% - 3.8%	2.8%
Sacramento	2.4%	0% - 3.3%	2.4%
San Bernardino	2.9%	0% - 3.8%	2.6%
San Diego	8.5%	2.1% - 10%	8.0%
San Francisco	9.4%	2.8% - 10%	8.1%
San Mateo	2.9%	0% - 15.3%	4.8%
Santa Barbara	0.9%	0% - 1.2%	0.7%
Santa Clara	9.0%	9% - 18.1%	10.5%
Santa Cruz	0.6%	0% - 1.2%	0.5%
Solano	0.7%	0% - 1.2%	0.6%
Sonoma	0.9%	0% - 1.2%	0.7%
Ventura	1.5%	0% - 4.7%	1.9%
TOTAL	100%	N/A	100%

While ARB relies on the annual auto manufacturer survey for projections of future vehicle deployments, current vehicle counts are obtained through registration data provided by the California DMV. The data received represent a snapshot in time of the registration status of all known FCEVs currently within the DMV's databases, as of April 5, 2017. In ARB's reporting, certain vehicles are not included in the count of currently registered vehicles because of one or more issues with the data for those vehicles. This includes vehicles registered to ZIP codes out of state and vehicles for which the registration is uncertain, including those with a status of "Not Currently Registered" and "Planned Non-Operational."

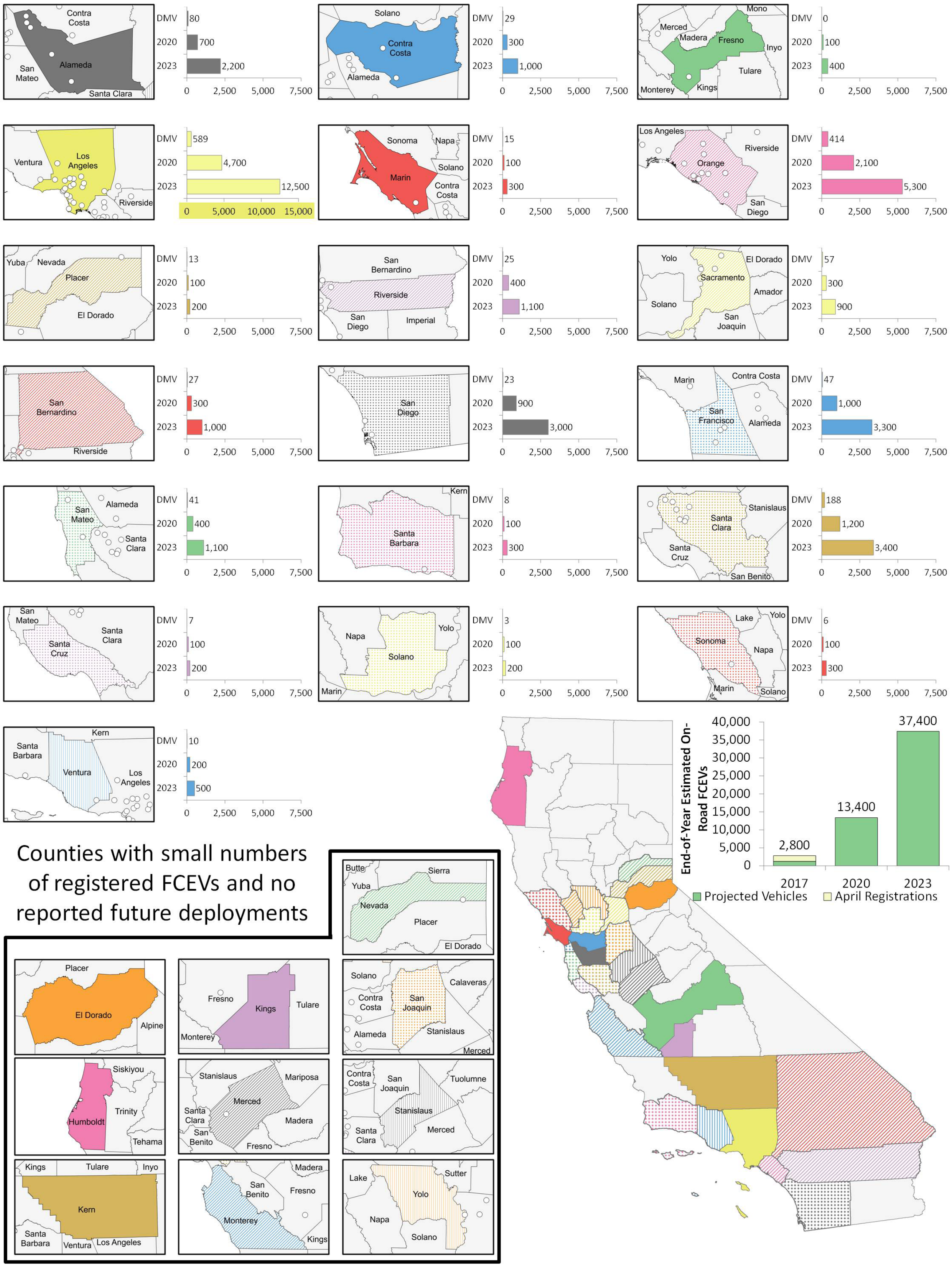
ARB Analysis of Auto Manufacturer Survey Responses

Based on the April 5, 2017 DMV registration data, there are currently 1,609 FCEVs operating on California's roads. The distribution among counties is shown by the bars labeled "DMV" in the various charts on Figure 3. While deployment projections were not provided for several counties shown in the bottom left corner (such as El Dorado, Humboldt, etc…), it is interesting to note that almost all of these counties do have at least one registered vehicle. Notable exceptions are Monterey and Stanislaus, where no vehicles are currently registered, and Yolo, where 17 vehicles are currently registered, but no auto manufacturer indicated a planned future deployment. Three-quarters of on-the-road FCEVs are currently registered to Los Angeles (37%), Orange (26%), and Santa Clara (12%) counties combined.

Projections for statewide on-the-road FCEV populations by the close of 2017, 2020, and 2023 are provided in the chart at the lower right of Figure 3. These projections have been calculated in a manner identical to methods used in prior Annual Evaluations. For all auto manufacturer survey data, model year deployment plans were translated to calendar year plans by assuming one-third of the vehicles reported for a given model year would be placed in the prior calendar year; the remainder are placed in the matching calendar year. All vehicles in future deployments are counted as placed in Q1 of the corresponding year. Vehicles are assumed to attrition out of the on-the-road population according to an exponential decay with a 15-year half-life and calculated on a quarter-by-quarter basis, consistent with assumptions in ARB's EMFAC vehicle fleet emissions model. All reported counts in Figure 3 represent an average over the four quarters of a given year. By the end of 2017, approximately 1,200 additional FCEVs are expected to be on-the-road (together with the 1,609 currently on the road, the end-of-year estimate is 2,800); the population is then expected to grow to 13,400 and 37,400 by the end of 2020 and 2023, respectively.

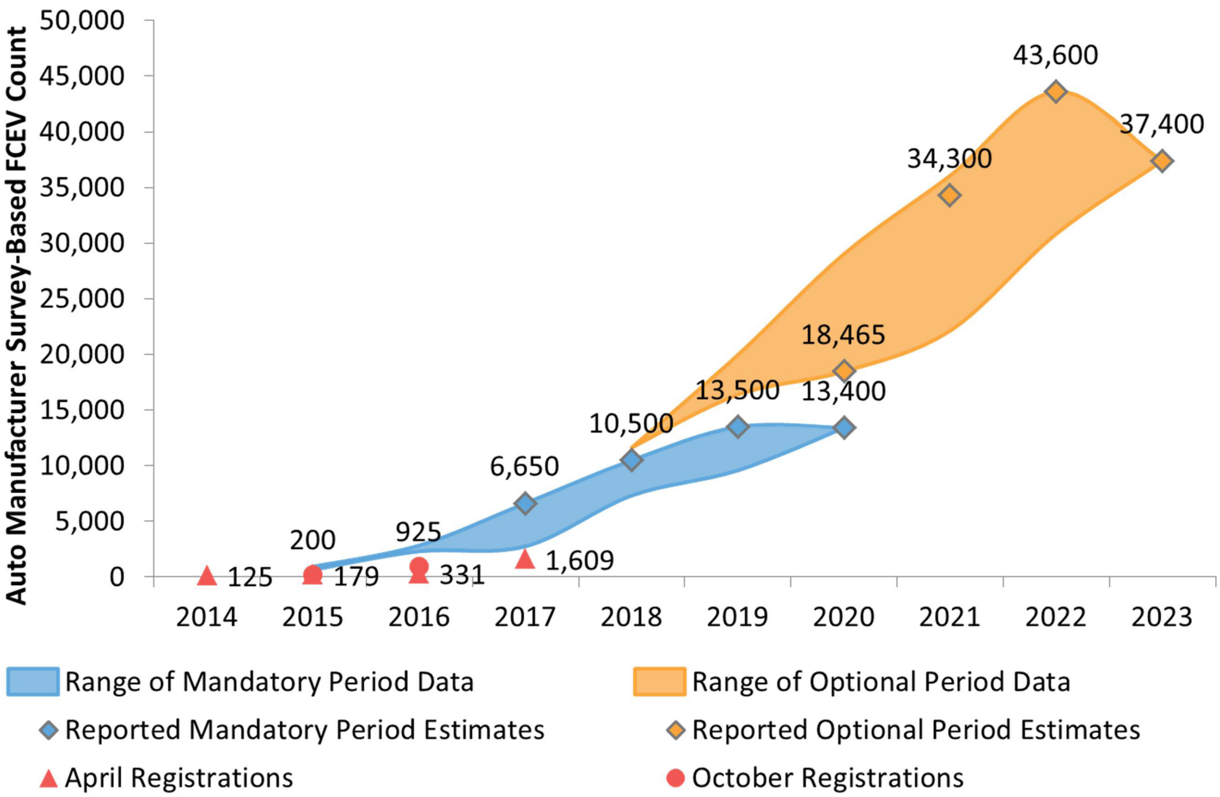
Individual county-based projections are also provided in the various bar charts of Figure 3. Note that all charts are on the same scale with the exception of Los Angeles, which has a scale twice as large as the remaining counties. Based on the auto manufacturer survey responses, Los Angeles County is expected to remain the largest focus of FCEV deployment by far (35% and 33% in 2020 and 2023, respectively), with Orange County (16% and 14%) receiving the next-largest focus. Santa Clara (9% and 9%), San Francisco (7% and 9%), and Alameda (5% and 6%) counties are also expected to receive significant, though not as large, focus. San Mateo (3% and 3%), Riverside (3% and 3%), Contra Costa (2% and 3%), San Bernardino (2% and 3%), and Sacramento (2% and 2%), counties appear to comprise a tertiary role in future deployments.

Figure 3: County Level Vehicle Projections Based on DMV Records, Auto Manufacturer Surveys, and CHIT Early Adopter Market Assessment



Trends in FCEV deployment are further explored in Figure 4, which compares estimates between the current and previous Annual Evaluations. In past evaluations, only the current DMV count and the projection for the end of the mandatory and optional survey periods were published, in the interest of protecting survey respondents' confidential information. However, the method of data sharing in the past did not allow for direct comparison between different vintages of survey responses, did not provide perspective on the variation in responses received over the course of multiple years, and did not clearly indicate that published values from multiple survey years were not intended to be combined as a single deployment rate schedule. The new format in Figure 4 is designed to address these shortcomings, to provide perspective on differences between registered and projected vehicles, and provide perspective on differences between projected vehicles for the same year when treated as part of a mandatory reporting period and an optional reporting period.

Figure 4: Comparison of FCEV On-The-Road Vehicle Counts in 2014-2017 Annual Evaluations[5]



Shaded areas in Figure 4 represent the range of projections for on-the-road FCEVs in a given year, including all data from 2014 through 2017 annual surveys. The blue-shaded area represents estimates from mandatory reporting periods; the orange area represents the optional period data. Data from DMV registrations are shown by red symbols, with April data shown as triangles and October data (typically reported in December Joint Agency Staff Reports) as circles. Reported projections from the ends of the mandatory and optional survey periods are shown as blue and orange diamonds, respectively.

5 ARB identifies a one-year short-term delay based on comparison of the previously-reported 2019 projection of 13,500 FCEVs and the most recent 2020 projection of 13,400 FCEVs. ARB identifies up to a two-year delays based on comparison of the previously-reported 2021 projection of 34,300 FCEVs and the most recent 2023 projection of 37,400 FCEVs.

Based on auto manufacturer surveys, projections for future on-the-road FCEV counts have varied significantly over the last four years of reporting. In general, the further into the future, the larger the range of estimates for on-the-road FCEVs. Additionally, registrations for actual vehicles have consistently lagged projections. Since projections are made for the end of a given year, projections that become realized deployments should fall between the October DMV data for the same year and the April DMV data for the next. However, inspection of Figure 4 shows that for the past two years, April registrations have been less than the reported projection for the previous year. Consistent with the observation of a one-year delay in deployment plans reported in the 2016 Annual Evaluation, the 2017 April registrations are less than the 2016 end-of-year projections but greater than the 2015 projections. Thus, the near-term delay projected in the previous Annual Evaluation is apparent in Figure 4.

Based on the minima and maxima of estimates provided in Figure 4, projections for FCEV deployment in any given year tend to be greater for optional reporting than for mandatory reporting. The most direct observation for this is shown in the data for 2020. This marks the only year so far that has been the end of both the mandatory and optional survey periods. When reported as the end of the optional period in 2014, the projected on-the-road FCEV volume for 2020 was 18,465, 38% greater than this year's mandatory period estimate of 13,400. Additionally, the range of estimates for 2018-2020 show the maximum value came from an optional reporting period while the minimum value came from a mandatory reporting period. While it is worth noting these early indications and to continue tracking them, there are not enough data to state definitively that there is a significant discrepancy between mandatory and optional period reporting. In fact, given the continuation of delays in the hydrogen fueling network compared to reported expectations in the past two years, the differences may be explained simply as changes in auto manufacturer expectations of fueling network development progress.

Compared to the projections reported in previous Annual Evaluations, there again appears to be a delay of approximately one year in the short-term (13,400 vehicles expected in 2020 as compared to 13,500 previously reported for 2019) and a one-to-two year delay in the long term (37,400 vehicles projected for 2023 versus 34,300 and 43,600 previously reported for 2021 and 2022, respectively). This is more severe than the delay reported in the 2016 Annual Evaluation, as the delay now potentially affects deployment plans for the next six years, as opposed to the previous expectation of recovery after three.

Developments in the pace of rolling out the hydrogen fueling network are the most likely reason for the delay. The revised projected station deployment schedule is delayed compared to projections made in 2016. At least some portion of the observed delays in hydrogen fueling station deployment are due to obstacles that developers in general would face, regardless of the nature of the project. These delays are not necessarily inherent to the installation of hydrogen fueling equipment, and include factors such as expressed needs for esthetic or infrastructure upgrades at the host site, requirements for environmental mitigation to accompany any new development at the host site, and coordination with local utility schedules for connection to the new on-site equipment. As indicated in the December Joint Agency Staff Report, newer stations have on average had a shorter development period. On the other hand, many of the older station projects (those funded under Program Opportunity Notices 09-608 and 12-606) historically had difficulty meeting major development milestones. Difficulty with securing the proposed hydrogen fueling station site and some developers' early risk aversion behavior (which has since been addressed through incentives for timely development in the most recent two solicitations) have been referenced as major reasons for these delays [36]. In addition, through the HyStEP program, ARB has observed that some station developers have required a longer period of time than expected to fine-tune their station equipment and ensure performance meets expectations of the SAE J2601 fueling protocol and J2719 hydrogen quality standard. Some stations that include an on-site electrolyzer also encountered civil engineering requirements that were unknown at the time the station was designed.

As a result of these station development difficulties, the Energy Commission, as the stewards of public funds, issued Stop Work Orders on nine stations during the period of November 2016 through March 2017 due to insufficient progress on station construction and impending state fiscal deadlines. Station developers were required to provide reasonable and viable plans demonstrating a clear path forward for station construction. As a result of these plans, one station was approved to proceed, four were not approved to proceed, and three remain under a Stop Work Order. One station remains under consideration by the Energy Commission.

The four stations not approved to proceed (Chino, Los Altos, Encinitas, and the proposed upgrade for Newport Beach), which represent 7% of total State co-funded projects, are no longer included in projections of future station counts. The State remained in constant communication with these station developers and other industry stakeholders throughout the past year to exhaust every option available before fund liquidation and maintain industry-wide understanding of the latest status as information became available.

The auto manufacturer survey was distributed on March 1st and responses submitted by April 1st. It is likely that these Stop Work Orders played a role in the reduced projections of FCEV deployments shown in the auto manufacturer survey. Auto manufacturers have made several indications, both within and outside the survey process, that acceleration of the expected station network development (for funded stations and stations to be funded in the future) would result in equivalently accelerated future plans for FCEV deployment. Industry and State partners in this effort must collaborate to ensure acceleration of station development going forward. FCEV deployment is now a global effort and will soon take place in states in the northeast region of the United States. California is currently a leader in both hydrogen fueling and FCEV deployment, but it must be recognized that further allocation of FCEVs for deployment in California may soon be determined based on comparisons to fueling network progress in other regions nationally and globally.

Northeast and Zero Emission Vehicle States Optional Survey

In the 2017 annual auto manufacturer survey, ARB provided respondents with an additional (and optional) data request. In 2016, Air Liquide and Toyota announced the development of 12 hydrogen fueling stations in the Northeast, with several of those stations' host cities now announced. ARB provided the publically-available information regarding the Northeast station locations to auto manufacturers and asked for their expected vehicle deployment in nine states (Connecticut, Massachusetts, Maryland, Maine, New Jersey, New York, Oregon, Rhode Island, and Vermont). The data request asked for two deployment numbers in each state, covering the periods 2018-2020 and 2021-2023. While most auto manufacturers provided some response, there were not enough numerical responses to allow publication of detailed deployment expectations without jeopardizing the confidentiality of individual responses. The most information that ARB is able to publish at this time is that responses indicated deployment in the hundreds of vehicles for the near term and thousands of vehicles in the long term. In addition to the numerical responses provided, there were several indications that plans for future FCEV deployment in these states are currently being considered.

Location and Number of Hydrogen Fueling Stations

AB 8 Requirements: Evaluation of hydrogen fueling station network coverage

ARB Actions: Determine the regional distribution of hydrogen fueling 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.

Current Open and Funded Stations

Several changes have occurred over the past year within California's open and funded hydrogen fueling network. Altogether, ARB now counts 62[6] stations in the state's funded hydrogen fueling network, with 29 of those Open-Retail and three Open-Non-Retail, as indicated in Figure 1.

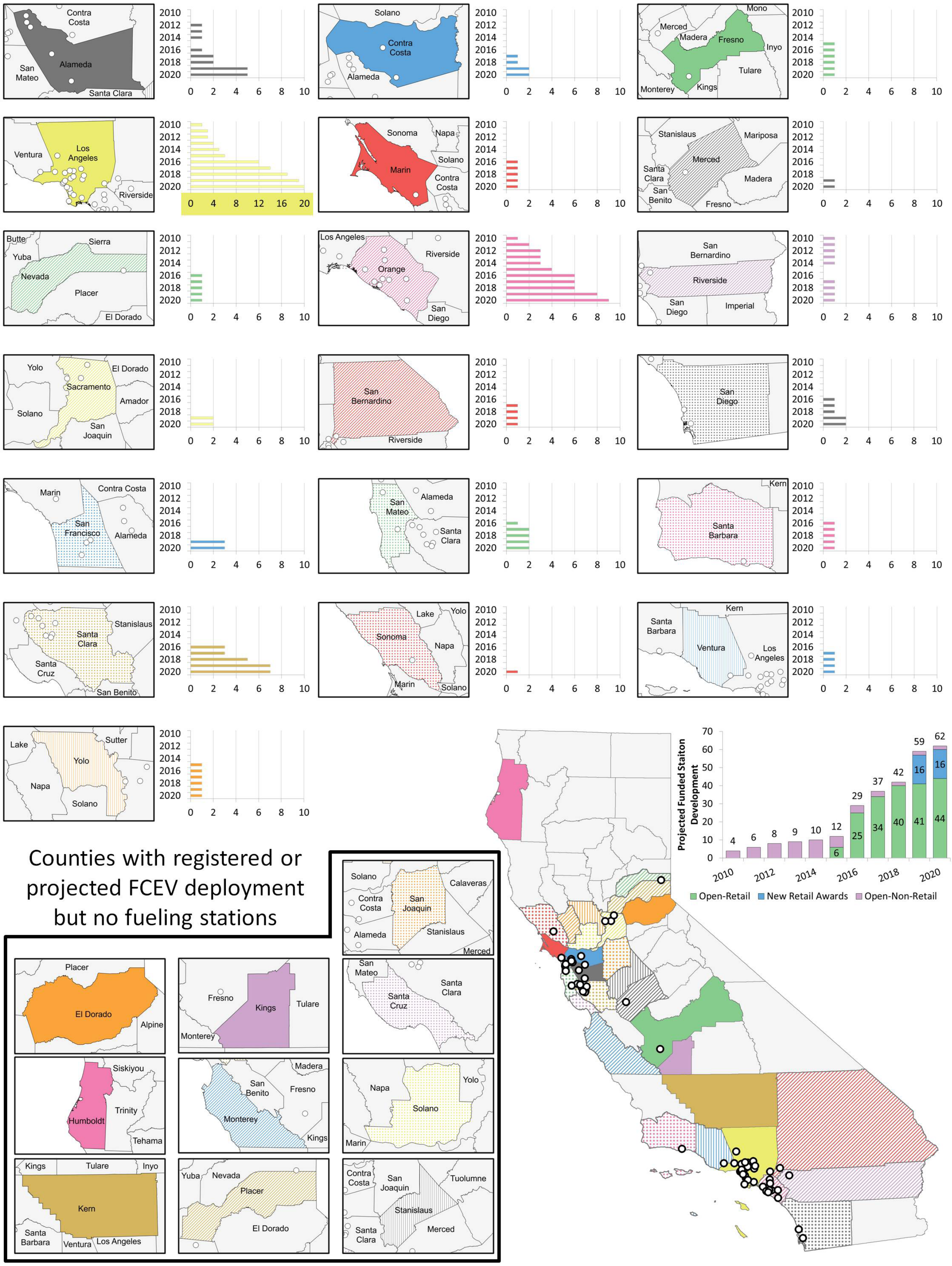
Major changes to the overall station network counts in the past year include:

- The Anaheim, Del Mar, Hollywood, Lawndale, Playa Del Rey, Riverside, San Ramon, South Pasadena, and Woodland Hills stations have become Open-Retail.
- The previously Open-Non-Retail station in Torrance has begun construction to become a full retail station and is expected to re-open before the end of 2017.
- The station in Harbor City closed, effective Q4 of 2016.
- The funded Foster City station, proposed to be changed into a station upgrade for the Newport Beach station, was issued a Stop Work Order due to impending fund liquidation. This upgrade is no longer included in analysis, though the Newport Beach station as originally built is assumed to continue operations. No station is currently planned for Foster City.
- The stations in Chino, Encinitas, and Los Altos were issued Stop Work Orders due to impending fund liquidations. These stations are no longer included in analysis.
- Stations in North Hollywood, Orange, and Rohnert Park were issued Stop Work Orders and a near-term plan for progress is not yet clear. The opening date for these stations has been assumed to be Q3 of 2020, the fund liquidation date.
- The station in Mountain View was issued a Stop Work Order which was lifted. A plan was developed for completion of the station, with a contractually-specified completion date. The station is now assumed to open by this date, in Q4 of 2018.

The projected evolution of hydrogen fueling stations achieving Open status is shown in Figure 5. As shown, all 16 new stations funded under GFO 15-605 have been assumed to open sometime in 2019. This is based on the approval of nine of the funded stations at the June 2017 Energy Commission Business Meeting, with the expectation that the remaining seven will be approved at another Business Meeting in Q3 of 2017. In addition, the Newport Beach and CSULA stations are assumed to be the only stations to continue as a Non-Retail station. There are indications of interest in continued operation and a conversion to Retail for both stations, but no detailed plan is currently known for this transition.

6 60 of the 62 stations have been funded by the Energy Commission through the Alternative and Renewable Fuel Vehicle and Technology Program, and are currently or are expected to become Open-Retail. Two stations are currently Open-Non-Retail and were funded in earlier efforts by ARB.

Figure 5: End of Year Station Projections by County and Statewide (as of June 17, 2017)

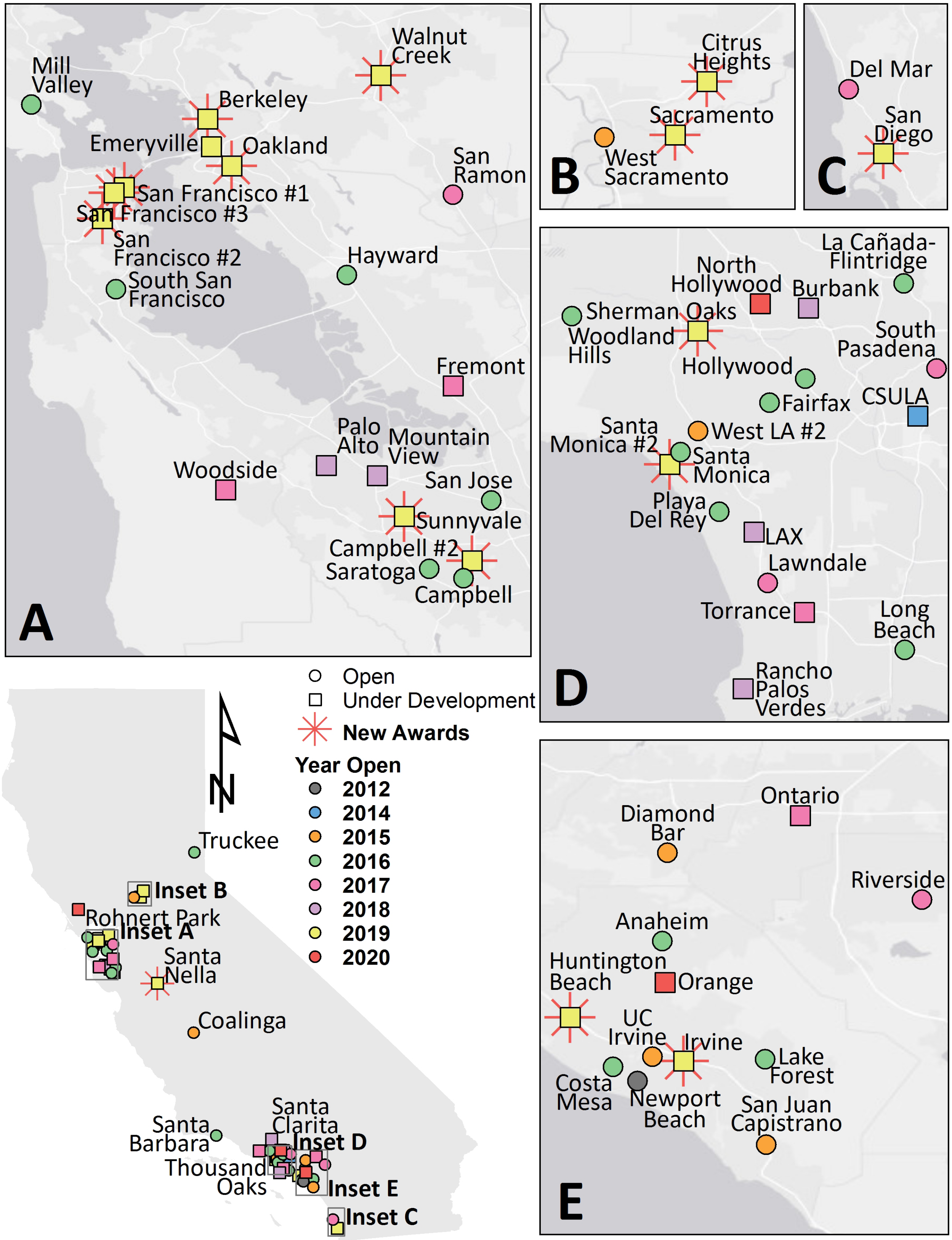


County-based data shown in Figure 5 indicate that Los Angeles County is and will continue to be the location of the most activity in hydrogen fueling station development. Orange County is the second-most active, with approximately half the number of total stations planned. These station development plans agree well with the relative amounts of expected FCEV deployment shown in Figure 3. Santa Clara and Alameda counties will receive the next-highest emphasis on station development. This is also in agreement with FCEV deployment projections, considering the possibility that vehicles may actually fuel in adjacent counties, especially in the San Francisco Bay Area. For example, the high number of FCEVs projected for deployment in San Francisco County can actually be served by the relatively few stations in the same county and stations in adjacent Alameda County.

Figure 6 shows the historical and projected Open dates for individual stations, based on the latest information available regarding the current status of each station and the expected timeline to completion. Stations currently open are shown as circular dots; stations in some phase of development towards open status are shown as squares. The year that each station is expected to or did become open is indicated by the color of the symbol representing the station. For stations built prior to the establishment of the Open-Retail station definition and no current plan for upgrade to Retail, the Open-Non-Retail date is shown. For any station with a plan and active funding for an upgrade to Retail, the expected Open-Retail date is shown.

All 16 of the stations newly awarded under GFO 15-605 are also indicated in the figure by an asterisk beneath the station location symbol. The new stations will provide redundancy and fill coverage gaps in the sub-networks established in West and North Los Angeles, Orange County, and the southern end of the San Francisco Bay Area. Additionally, GFO 15-605 funded the first development within San Francisco, and did so with a high degree of redundancy by funding three stations on the eastern side of the city. New stations in Berkeley, Oakland, and Walnut Creek will provide new expansion of coverage in the East Bay Area. Two new stations in the Sacramento region will also expand fueling coverage in that market. A new station closer to downtown San Diego will provide coverage to this important future market expansion area. Finally, a station located off Interstate 5 in Santa Nella will provide redundancy to the existing Coalinga connector station and the Santa Clarita station just south of the Tejon Pass, ensuring that long-distance drivers have multiple fueling opportunities traveling in either direction along Interstate 5.

Figure 6: Individual Station Open Year History and Projections



Coverage of the Open and Funded Hydrogen Station Network

Since the 2015 Annual Evaluation, ARB has relied on CHIT as the primary analysis tool for assessing the coverage provided by funded hydrogen stations, the spatial distribution of the potential FCEV first adopter market, the spatial distribution of need for new station coverage and redundancy, and the spatial distribution of need for additional hydrogen fueling capacity. Methods and data inputs have been developed since the first implementation for the 2015 Annual Evaluation; expansion of the tool's capabilities has occurred in response to information needs for GFO 15-605 and stakeholder input over the last two years. A more thorough overview of these new features will be presented later in this Chapter. Even with these changes, the fundamental methods of assessing coverage remain the same as in previous years.

The following is presented as a brief review of the coverage concept; readers interested in further details are encouraged to read the 2015 and 2016 Annual Evaluations and visit ARB's Hydrogen Analysis webpage[7]. The evaluations of coverage in CHIT are based on the premise that fueling coverage provided to a given location increases with proximity to individual hydrogen fueling stations and the number of hydrogen stations that are within a convenient driving range of the location. The coverage impact of three stations on six different neighborhoods in Orange County is illustrated in Figure 7 and Figure 8. Taking into consideration that a greater number of stations nearer to a given location indicates greater coverage, the coverage provided to the neighborhoods in this example, in order from least to greatest, is as follows:

- Turtle Rock
- Corona Del Mar and South Costa Mesa
- North Costa Mesa and Newport Beach
- Newport Back Bay

The CHIT-determined assessment of coverage provided by the currently Open and funded hydrogen station network in California is shown in Figure 9. The color shading in the map indicates relative degrees of coverage, with red areas showing the highest relative coverage and blue areas the lowest. Areas without any color shading have no coverage per the CHIT analysis. Compared to the same map from the 2016 Annual Evaluation, coverage has spread to new areas, provided by many of the new stations awarded under GFO 15-605. In addition, the east side of San Francisco now has almost the same degree of coverage as the southwest end of the San Francisco Bay Area. While it appears that coverage is less intense in many parts of the state (such as the southern parts of Los Angeles County between Playa Del Rey and Torrance) than previously reported, this is only because maps developed with CHIT are presented as relative evaluations. The same shade does not represent the same absolute amount of coverage from one year to the next.

Taking the example of the stretch between Playa Del Rey and Torrance, where no changes in station placement have occurred since 2016, the apparent reduction in coverage is a result of the planned stations providing less coverage (than previously estimated) relative to the maximum coverage provided anywhere in the state. This is simply because new stations have been awarded in the southwestern part of the San Francisco Bay Area, where coverage was already highest. Upon normalization, additional coverage in this maximally covered region reduces the relative and apparent coverage elsewhere.

7 https://www.arb.ca.gov/msprog/zevprog/hydrogen/h2fueling.htm

Figure 7: Coverage Provided to Neighborhoods within a 9 Minute Drive (Lesser Degree of Convenience and Coverage) of Southern California Beach City Stations

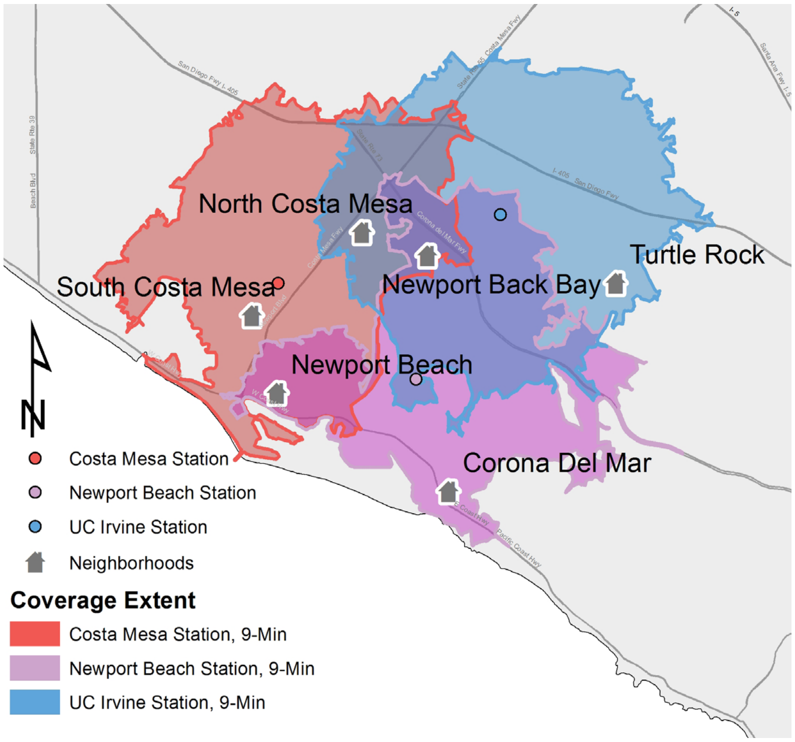


Figure 8: Coverage Provided to Neighborhoods within a 6 Minute Drive (Greater Degree of Convenience and Coverage) of Southern California Beach City Stations

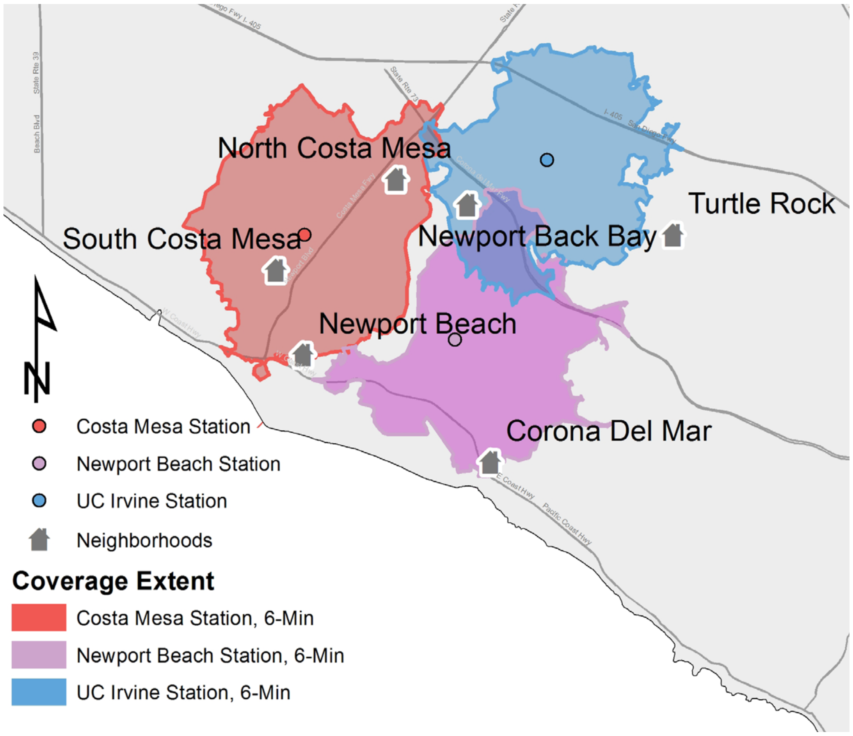


Figure 9: Assessment of Coverage Provided by Existing and Funded Stations

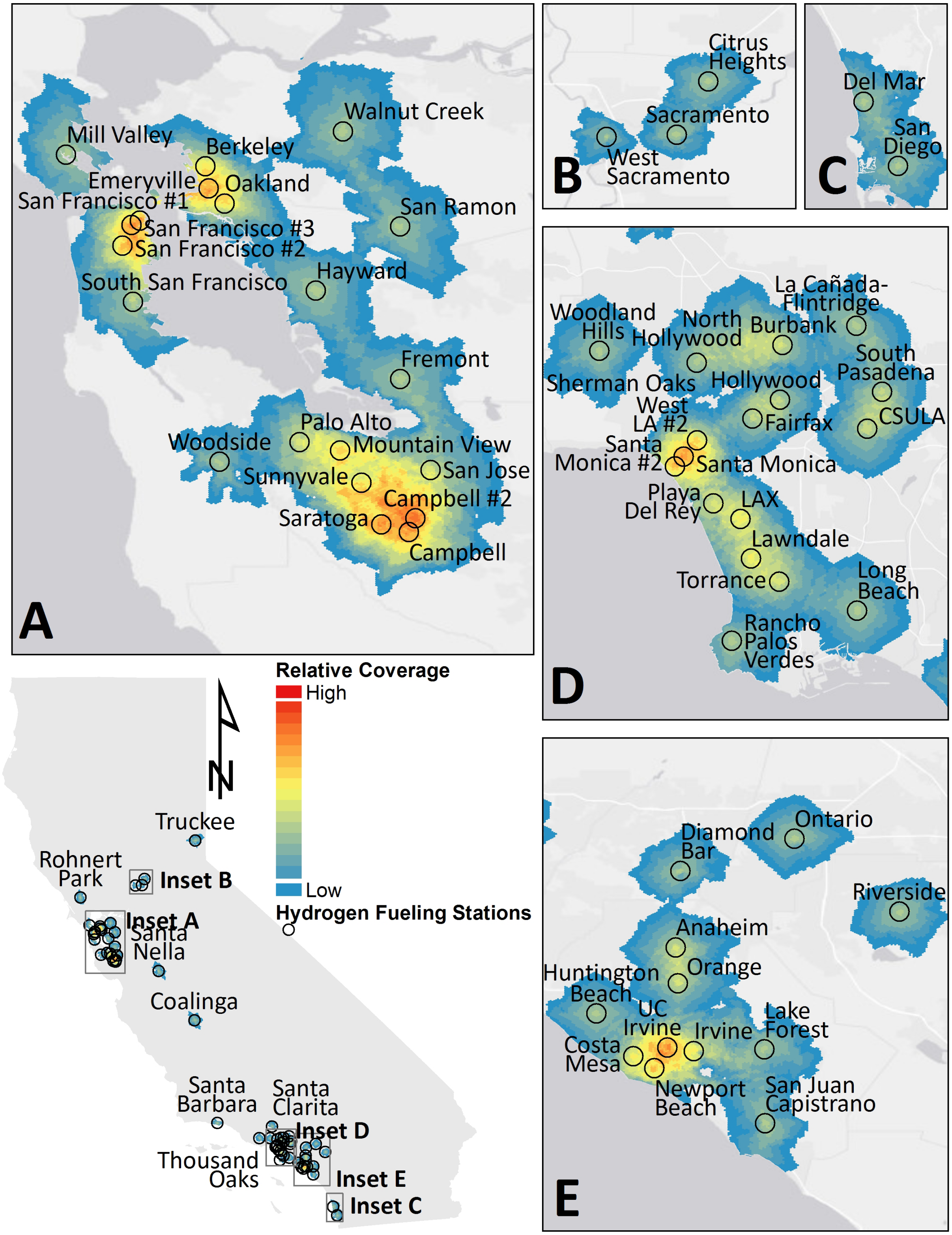
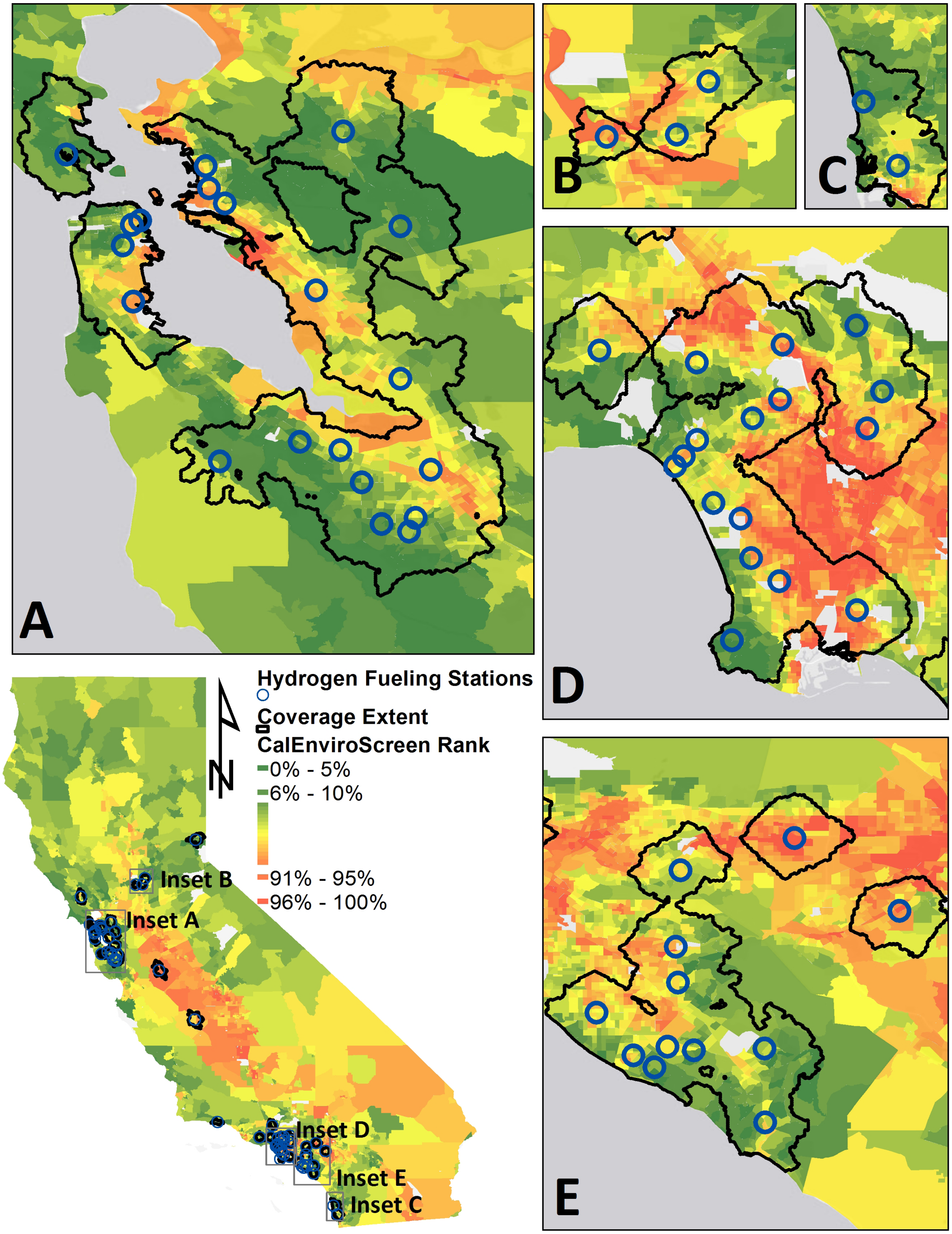


Figure 10: CalEnviroScreen 3.0 [37] Identification of Environmentally Burdened and Vulnerable Communities Compared to Hydrogen Fueling Station Network



The California Global Warming Solutions Act (SB 535; De León, Chapter 830, Statutes of 2012) provides guidance to ensure that an appropriate proportion of Greenhouse Gas Reduction Funds would be spent on projects either located within or benefitting Disadvantaged Communities (DACs) [38]. DACs are communities that have a combination of high environmental burden and socio-economic vulnerability. Identification of DACs was relegated to the California Environmental Protection Agency; the Office of Environmental Health Hazard Assessment (OEHHA) and ARB collaborated to develop CalEnviroScreen, a geospatial analysis tool that relies on several data inputs to assess the environmental impacts and socio-economic vulnerability of California's communities [37]. Communities (based on census tracts) are given a score based on several factors within these two broad categories and ranked based on score. DACs are defined as those communities with either a CalEnviroScreen score in the top 25% or a community in the top 5% of pollution burden scores but with no overall CalEnviroScreen score [39]. While AB 8 funds do not directly fall within the requirements of SB 535, since the bill was passed additional emphasis has been placed on ensuring California's climate and environment investments in general continue to serve DACs.

Table 2: Analysis of Coverage Provided by Funded Station Network to Disadvantaged Communities as Identified by CalEnviroScreen 3.0

CalEnviroScreen Score	Count of Stations	Population in Station Home Tract	Population in 15-Minute Coverage*	Percent of CA Population in 15-Minute Coverage	Percent of Covered Population
NON-DAC Subtotals	49	250,005	13,257,654	35.6%	78%
DAC Subtotals	13	56,870 (~1% of all DAC)	3,653,564 (~40% of all DAC)	9.8%	22%
Totals	62	306,875	16,911,218	45.4%	100%
For Reference: CalEnviroScreen Indicates 9,152,019 Residents Living in Disadvantaged Communities					
* Populations based on census tract populations provided by CalEnviroScreen. Tracts partially covered by hydrogen fueling network have full population counted in this table. Block level population counting may provide slightly different totals.					

Comparison of the open and funded hydrogen fueling network, the coverage provided by the network, and CalEnviroScreen scores is provided in Figure 10. Given the mobile nature of FCEVs, the pollution benefit of fueling at any hydrogen station may or may not be attributable directly to the census tract where the station resides. Though it is impossible to know the driving patterns of all FCEV owners in detail, the coverage area provided by the stations can be utilized as a reasonable surrogate. In terms of pollution burden and socioeconomic factors, California's hydrogen fueling stations are actually located within, and provide service to, a variety of communities as shown in Figure 10. Analysis of the station locations themselves shows that 13 of the 62 funded stations (21%) are located directly in a DAC, as shown in Table 2. On a population basis, nearly 57,000 of California's disadvantaged residents live in the same community as a hydrogen fueling station. While this is a small portion of the state's DAC residents (less than 1%), a much larger portion receives some benefit, as indicated by the coverage provided by the station network. On this basis, nearly 17 million (45%) of California's population lives within the area of coverage provided by today's network, 3.7 million of which live in DACs. This represents 40% of the state's entire DAC population, and 10% of the state population overall. Thus, 22% of all residents that may benefit from hydrogen fueling station operations live within a DAC.

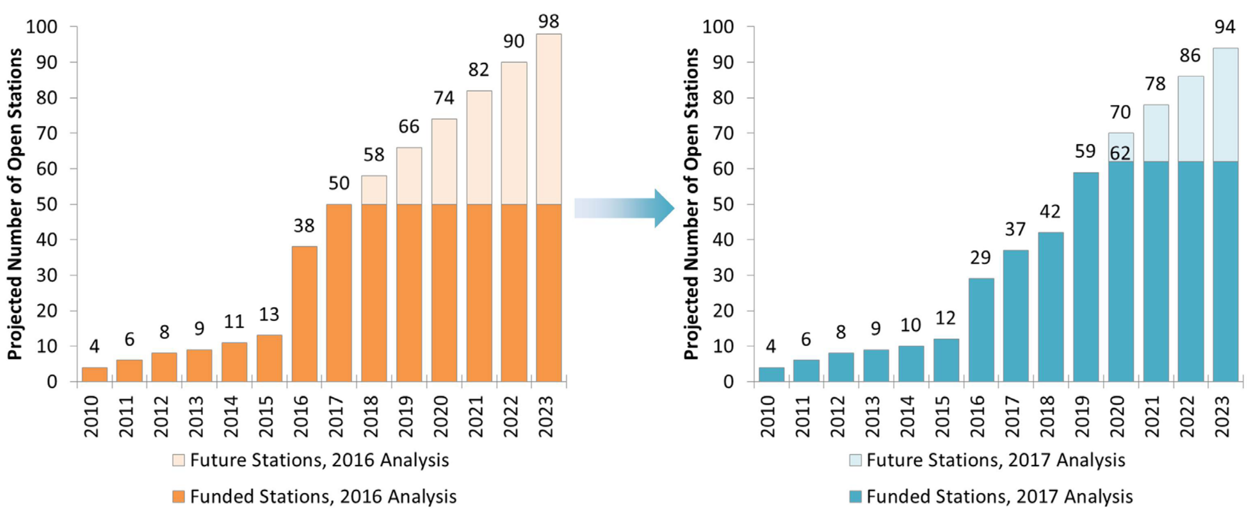
Trends of Station Deployment Rates

The expected trend in station deployment rates is shown in Figure 11, along with the expected trend reported in the 2016 Annual Evaluation. Compared to the previously-reported expectation, there is a near-term delay of one year in station deployment. Whereas 38 stations were expected to be Open by the end of 2016, the actual number was 29 and the number expected by the end of

2017 is 37. A total of 42 stations are expected to be Open by the end of 2018, all funded prior to GFO 15-605. Critical milestone requirements in GFO 15-605 have been designed to ensure many of the delays that affected stations with earlier funding will not affect the newly-awarded stations. An additional four stations funded before GFO 15-605 are expected to open between 2018 and 2020. Newly awarded stations are assumed to become open in accordance with an operational date providing the maximum State cost-share incentive within GFO 15-605 (Q3, 2019). This assumes agreement approval at Energy Commission Business Meetings in Q3, 2017 (nine stations were approved on June 14, 2017). Stations that have been removed from this year's projections are apparent in the continuing gap between projections in the period 2020 to 2022.

As in previous years, there is a continuing assumption of eight additional stations per funding year in the future. This is based on a business-as-usual assumption of grant funding programs similar to those that have so far been implemented under AB 8. New funding mechanisms may be able to accelerate the pace of funding hydrogen fueling stations, though the pace of actually building a funded station remains a separate concern. The State does attempt to assist in accelerating station projects whenever possible, especially through the direct engagement by the Governor's Office of Business and Economic Development (GO-Biz) and the Energy Commission and through the HyStEP program, but ultimately many factors outside of the State's control have a significant effect on the pace of individual stations' development.

Figure 11: Comparison of Statewide Station Projections between 2016 and 2017 Annual Evaluations[8]



2017 CHIT Evaluation of Priority Areas

CHIT is ARB's primary tool for evaluating coverage provided by the existing hydrogen fueling network and the spatial distribution of need for additional hydrogen fueling station coverage and capacity in California. CHIT's evaluations are primarily based on the fundamental assumption that a successful early hydrogen fueling network is one in which convenient access to fueling is provided near FCEV first adopters' homes. In the absence of proprietary and confidential industry-led market research data, relative local densities of likely first adopters can be assessed through demographic and automobile market indicators found within publicly-accessible data sources. New data and methods included in this year's analysis have expanded upon these fundamental assumptions. It is now possible to additionally assess proximity to heavily-travelled commuter traffic routes as an indicator for locations where fueling access may be conveniently

8 Three Non-Retail stations currently have plans for upgrade to retail. Harbor City closed in Q4, 2016. Years 2014 and 2015 include a historical data correction. Three stations and one upgrade to retail no longer included due to lack of substantial progress. CSULA included from 2014 on in this figure.

placed. Other updates incorporate registration and auto manufacturer survey response data as observational (rather than predictive) indicators of the developing FCEV market.

The process of the various tools run through CHIT completes the following tasks:

1. **Market and Commuter Traffic Assessment:** Assess the relative strength of the FCEV first adopter market across the state according to various demographic and vehicle market indicators and observational data from the developing FCEV market
2. **Coverage Assessment:** Assess the relative degree of hydrogen fueling station coverage across the state
3. **Coverage Gap:** Compare coverage, market, and commuter traffic assessments to determine gaps in hydrogen fueling network coverage
4. **Priority Areas:** Utilize geostatistical methods to analyze patterns in the spatial distribution of coverage gap, and identify and prioritize greatest coverage needs
5. **Local Capacity Need:** Distribute projected vehicle population according to the market assessment, calculate localized hydrogen demand, and new capacity needs

Figure 12: CHIT Evaluation Process Comparing Market and Coverage Assessments to Determine Coverage Gaps and Capacity Need

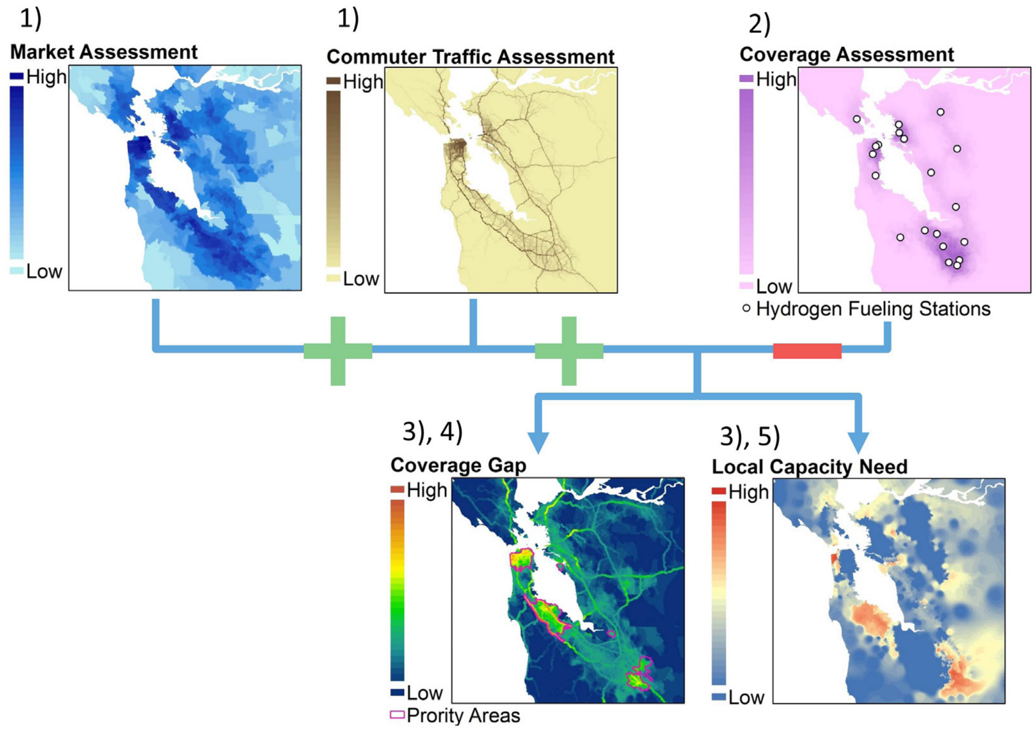


Figure 12 shows the conceptual process of combining a market assessment, coverage assessment, and commuter traffic assessment to develop an overall coverage gap and capacity need evaluation within CHIT. In general, higher-scoring market indicators and traffic data will increase the calculated coverage gap in an area while greater degrees of coverage will decrease the calculated coverage gap. Areas with a concentration of high coverage gap scores, which are additionally identified as statistically significant local hot spots, comprise the Priority Areas determined by CHIT. In addition to CHIT, ARB relies on CHAT, which is a database tool with various query functions to maintain a record of DMV registrations, station development progress, and auto manufacturer survey responses. Many of the calculations for projections of on-the-road vehicles and hydrogen fueling capacity are accomplished through CHAT. Figure 13 illustrates the various types of input and output data involved with CHIT and CHAT and the interactions between the tools.

Figure 13: Thematic Overview of CHIT/CHAT Tools, Input Data, and Output Goals

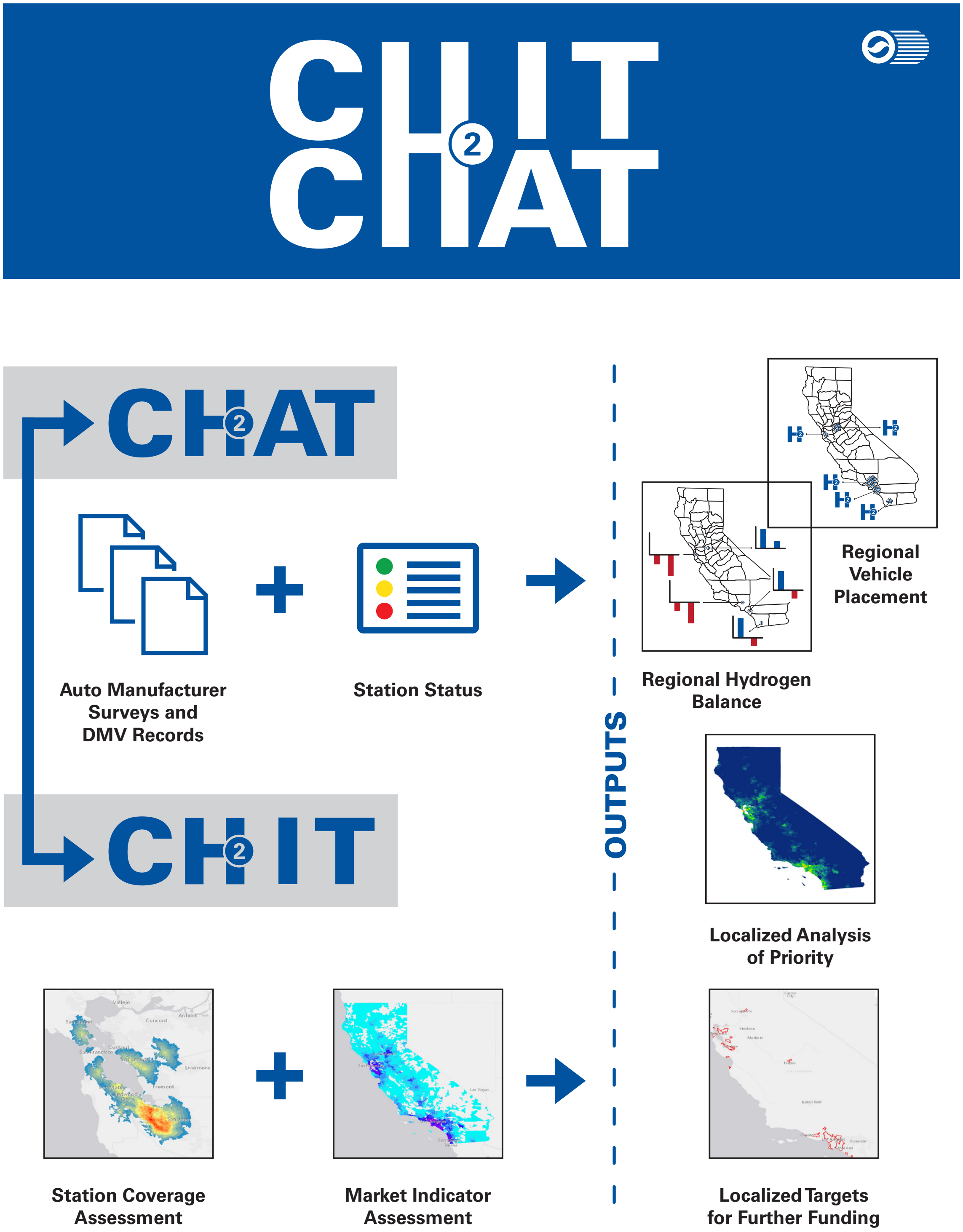
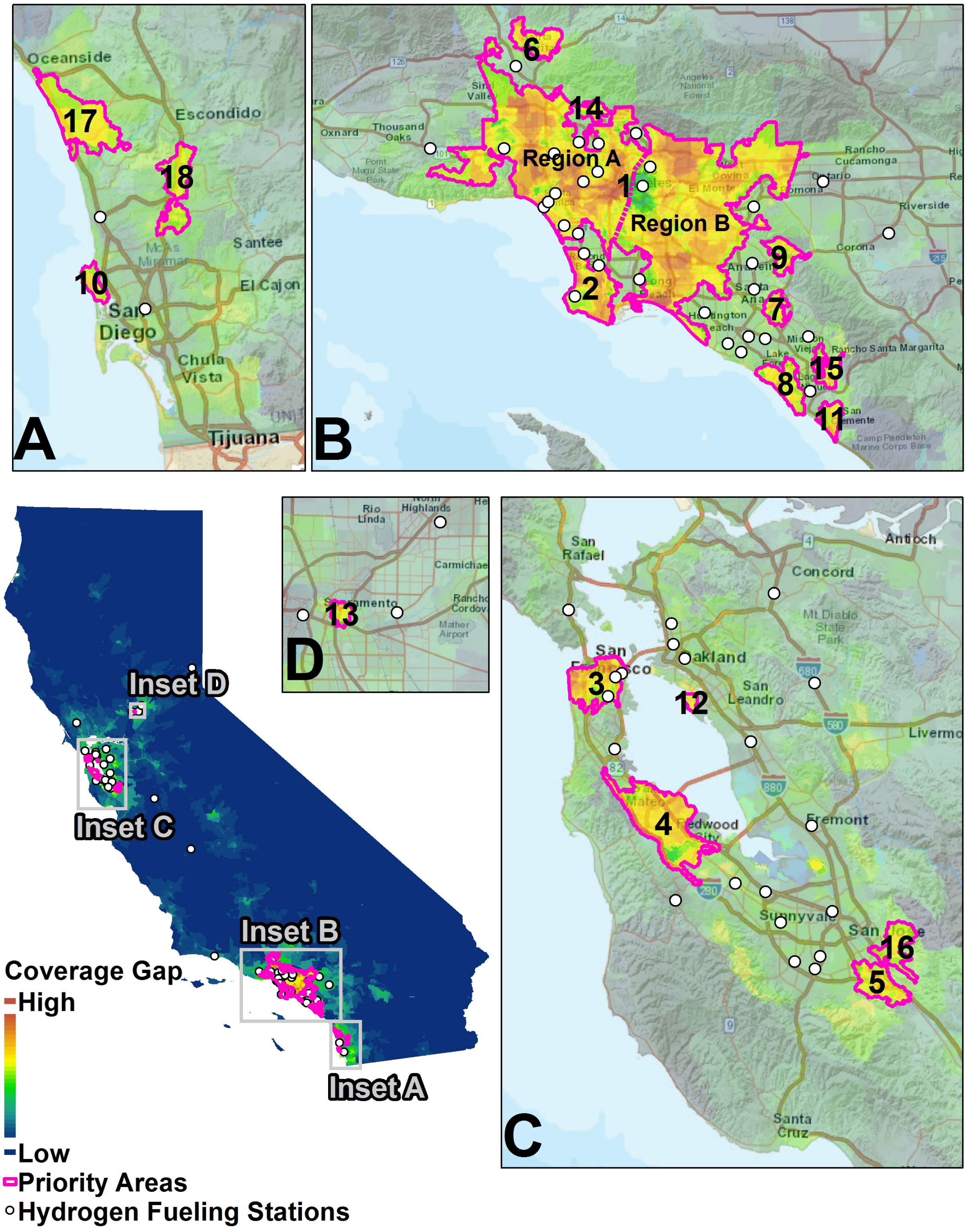


Figure 14: Evaluation of Coverage Gap and Identification of Priority Areas



The Priority Areas identified by this year's analysis are indicated in Figure 14; each area is labeled with its priority rank according to the average and highest coverage gap value within its borders. Many areas that have appeared in previous Annual Evaluations are still included, though changes in their overall shape and priority have occurred. For example, San Francisco is now the third-highest priority, and the northwest corner of the city is now an area of high coverage gap. In addition, cities in the greater Los Angeles region that previously formed separate priority areas have now coalesced into a single, larger area. This is largely because of the many stations that have been funded throughout the region, especially in the neighborhoods of highest market viability. Thus, coverage gap across the region has become more evenly distributed. Such a large area is difficult to target through a funding program, so ARB has divided this priority area into two regions. The split has been based on clustering of high-scoring neighborhoods within the larger area. Additional subdivision may be developed as necessary to support future Energy Commission funding efforts.

New areas have also appeared, such as Santa Clarita, North Tustin, and Alameda. In this year's Annual Evaluation, cities in the East Bay Area, such as Berkeley and Oakland, do not exhibit a high coverage gap, likely due to the addition of new stations in the region through GFO 15-605. Additionally, Fresno, Monterrey, and Santa Cruz no longer appear as high-priority areas.

Several new factors were considered in the development of the CHIT analysis for this Annual Evaluation that were not considered in prior years' analyses. These changes were made in response to feedback from stakeholders, analytical needs of ARB and other State agencies, and new developments within California's hydrogen fueling network. ARB anticipates a public release of the revised tool and data layers later in 2017 for the benefit of the public and interested stakeholders. The new version will be posted to ARB's hydrogen infrastructure analysis page[9] and a public webinar to discuss and demonstrate the new capabilities may occur before the end of the year. The following is a review of the major changes that have been implemented in the latest version of CHIT.

Traffic Data

In several public meetings with hydrogen station stakeholders, especially in support of the development of CHIT and the Energy Commission's GFO 15-605, multiple requests were made for CHIT to consider traffic information. The common concern was that hydrogen fueling stations close to home may be the most convenient option for FCEV early adopters, but stations near commonly driven routes could also play an important role. Inclusion of traffic-based information in geospatial analysis tools like CHIT requires finely detailed data about traffic flow across the entire state. In October of 2015, ARB reported in its CHIT development webinar that staff had investigated implementing such an analysis at the time, but no publically-available data set was identified with sufficient detail and completeness across the entire state. Ideally, the traffic data set would be based on real-world observations and contain traffic volume information on all grades of roads within California.

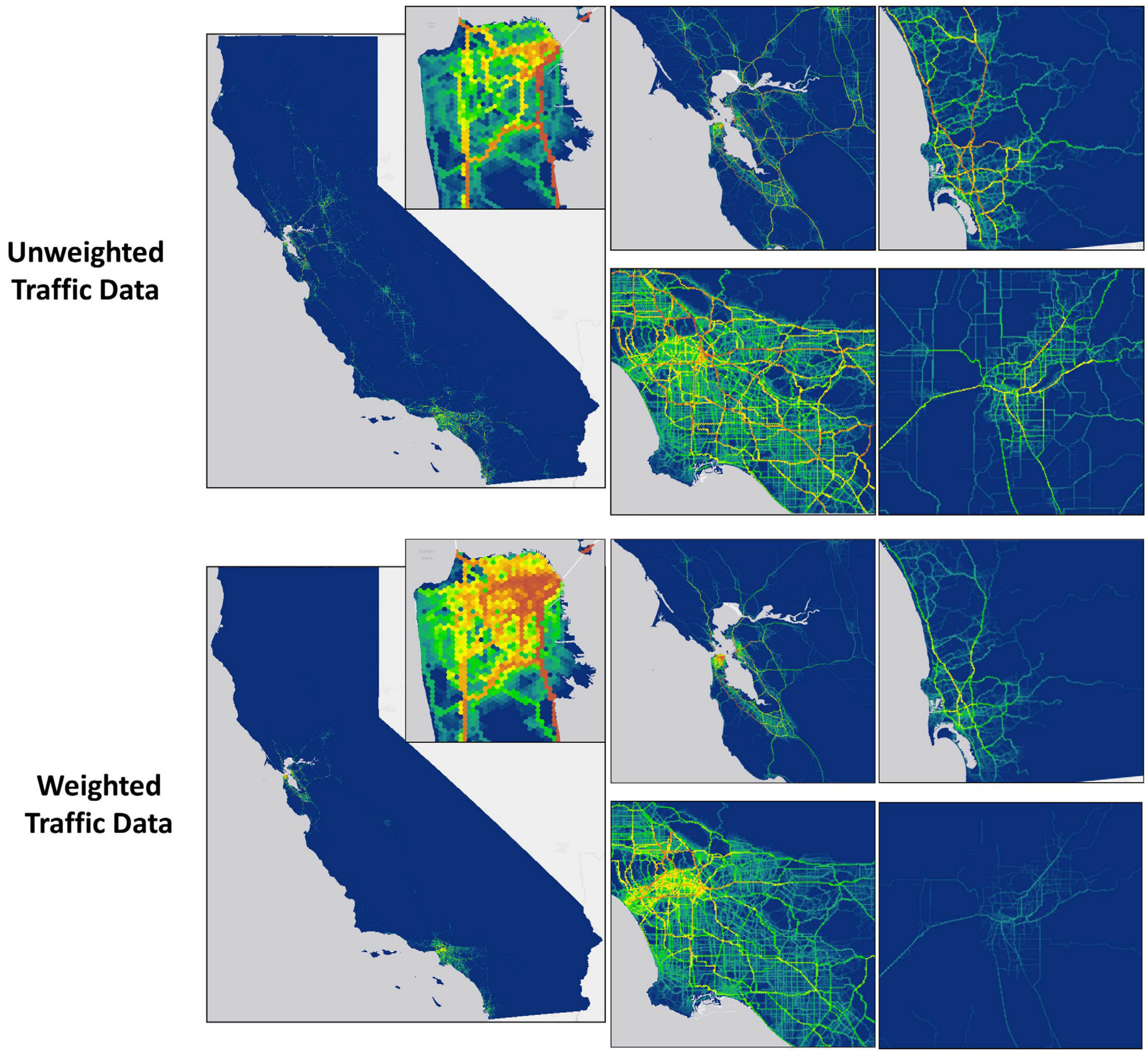
Since a data set with these characteristics was not available, ARB investigated the possibility of developing a simulated traffic volume data set. The results of that simulation were presented in a webinar in March of 2017; presentation materials and a recording of the webinar are posted on ARB's hydrogen infrastructure analysis page[9]. In order to perform the simulation, ARB relied on the [L]ongitudinal Employer-Household Dynamics [O]rigin-[D]estination [E]mployment [S]tatistics (LODES) data set, which provides the home and work census block for all respondents of this information in the decennial census. Within California, data were available for nearly 8.4 million commuters. ARB utilized these data along with its TIGER-ITN traffic speed data set to calculate the optimized route for each entry in the LODES data set. After removal of routes that could not be calculated, and any commutes calculated to take more than two hours, ARB's simulated traffic data set represented the potential commute route of 7.6 million Californians.

9 https://www.arb.ca.gov/msprog/zevprog/hydrogen/h2fueling.htm

It is important to stress that the calculated routes are only potential travel routes of commuters. ARB's traffic data set is based on an optimized simulation, not direct observation of driver behavior. Because of this, ARB has endeavored to utilize the data set with an appropriate degree of restraint. Once these routes were obtained, they were overlaid with the CHIT analysis grid, and the number of commuters passing through each analysis grid cell was summed.

A further refinement was developed based on feedback from the March 2017 webinar. Stakeholders at the webinar suggested that weighting each route according to CHIT's market evaluation at the home-based origin might be appropriate so the traffic data could more narrowly represent the commute patterns of likely first adopters than the population in general. ARB maintains both sets of data and will distribute both with the 2017 release of CHIT, but has implemented the weighted version in this analysis. Figure 15 shows the traffic intensity calculated by the weighted and unweighted versions of the data set. ARB has applied a low weighting on this data input in this year's coverage gap analysis.

Figure 15: ARB Simulated Traffic Inensity Data



Auto Manufacturer Survey Layer

The market evaluation performed in CHIT is based on ARB's best understanding of demographics-based data that may indicate likelihood for consumers to become FCEV first adopters. In addition to its own market evaluation, ARB annually receives data that could be considered an independent market evaluation, in the form of the annual auto manufacturer survey. The benefit of the survey data is that the auto manufacturers have more direct contact with consumers and may therefore have more direct information on which to develop their projections for future deployments. However, there are also limitations to the data. The first is that it does not have a high degree of granularity- ARB only receives projections on a county basis. Second, ARB does not have access to the actual factors that individual auto manufacturers considered when developing their projections; thus, ARB has limited understanding of their appropriate implementation. Finally, the survey data likely have an element of feedback built in; as the station development progress changes, the auto manufacturers may vary the volumes of projected vehicles or their relative placement among the counties. By contrast, ARB's market assessment is meant to be an assessment independent of the dynamics of the fueling market in order for gaps to be more appropriately identified. ARB has developed a method to optionally use auto manufacturer survey data as a scaling factor for all market assessments within each county. In this year's evaluation, ARB did not implement this option, largely because the county-based auto manufacturer projections already match well with CHIT's market assessment as shown earlier in Table 1.

DMV Registration Layer

In its first iteration, CHIT's assessment of the FCEV first adopter market was fully based on projections derived primarily from demographic-based indicators. As the FCEV market develops and increasing numbers of FCEVs are released, it will become important for CHIT to have the means to progressively shift from projections to actual market-based observations. That is, CHIT should be able to shift from analyzing where the FCEV market may be more or less likely to develop to analyzing where it is actually being observed to develop. Therefore, the market evaluation has been expanded to include both projected and observed aspects. ARB implemented a low weighting to the observed aspect in this year's Annual Evaluation, but anticipates gradually increasing that weight as the station and FCEV markets develop.

The coverage gap equations of the 2015 and 2017 versions of CHIT are provided below:

CHIT 2015 Release:

Let
Coverage Gap = Coverage * Market
Coverage= (1-a) * Existing + a * Potential
Market= x * Financial + y * P/HEV + z * Education, and
Financial= u * Income + v * MSRP + w * Luxury,
with the following requirements on scaling factors:
$x + y + z = 1$,
$u + v + w = 1$, and
$0 \leq a \leq 1$.

CHIT 2017 Release:

Let
Coverage Gap = Coverage * ((1-p) * Market + p * Traffic),
Coverage= (1-a) * Existing + a * Potential,
Market= ((1-r) * (x * Financial + y * P/HEV + z * Education) + r* Registrations) * Auto Manufacturer Survey, and
Financial= u * Income + v * MSRP + w * Luxury,

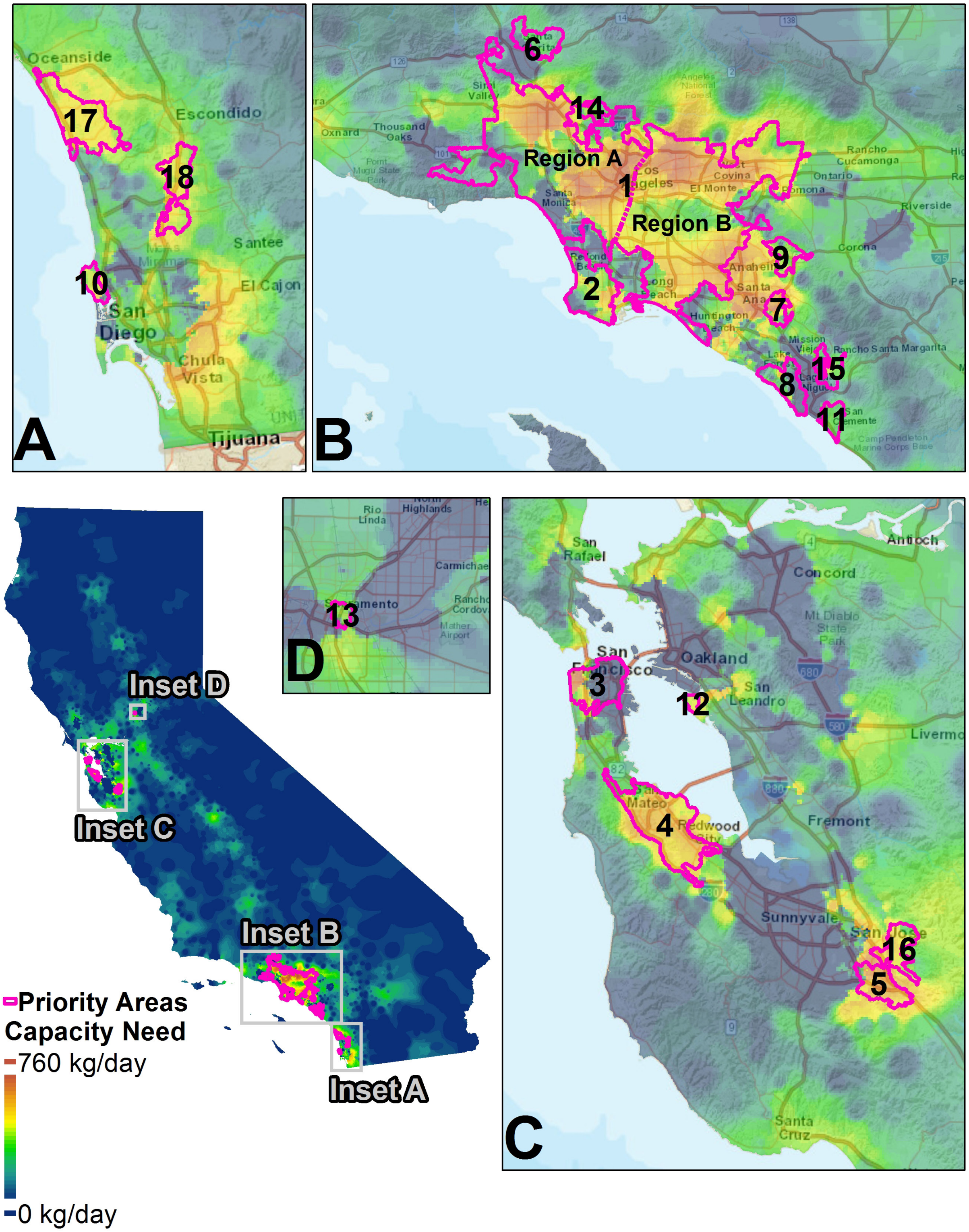
with the following requirements on scaling factors:
$x + y + z = 1$,
$u + v + w = 1$,
$0 \leq a \leq 1$, and
$0 \leq r \leq 1$.

Local Capacity Need Estimation Tool

In support of the Energy Commission's GFO 15-605, ARB developed a tool to utilize CHIT input and output data layers along with CHAT vehicle projections to calculate the localized new capacity need across the state. The tool assumes all existing and funded stations provide fueling to any FCEV owners within a 15-minute drive. It then uses census blockgroup centroids as the center of the 15-minute drive time calculation. Market evaluation and population distributions within each 15-minute extent form the basis for distributing the number of FCEVs that CHAT projects for a given year. With standard assumptions of daily fuel consumption, local demand is calculated and compared to local fueling capacity. The difference determines the local need for new hydrogen fueling capacity. In the context of GFO 15-605, applications were then assessed for how well their proposed fueling capacity matched the calculated need for their location.

The revised assessment of local capacity need, accounting for the 16 new stations awarded in GFO 15-605, is shown in Figure 16. Priority areas in the figure have not been redefined on a capacity basis; they are the same coverage-based priority areas displayed in Figure 14. While many of the areas with highest capacity need are similar to areas of need for additional coverage, comparison of Figure 16 with Figure 14 highlights some of the differences between coverage- and capacity-based analyses. For example, while all of the city and county of San Francisco scores relatively high in the coverage gap analysis, the comparatively higher need for new stations particularly in the northwest of the city is highlighted by the capacity need evaluation. Similarly, some areas in southern Orange County have a strong need for additional coverage, but the projected demand in 2023 for these areas appears fairly well-met by the currently funded hydrogen fueling network.

Figure 16: Localized Capacity Need Determination for 37,400 FCEVs projected in 2023



Alternative Formulation for Coverage Gap

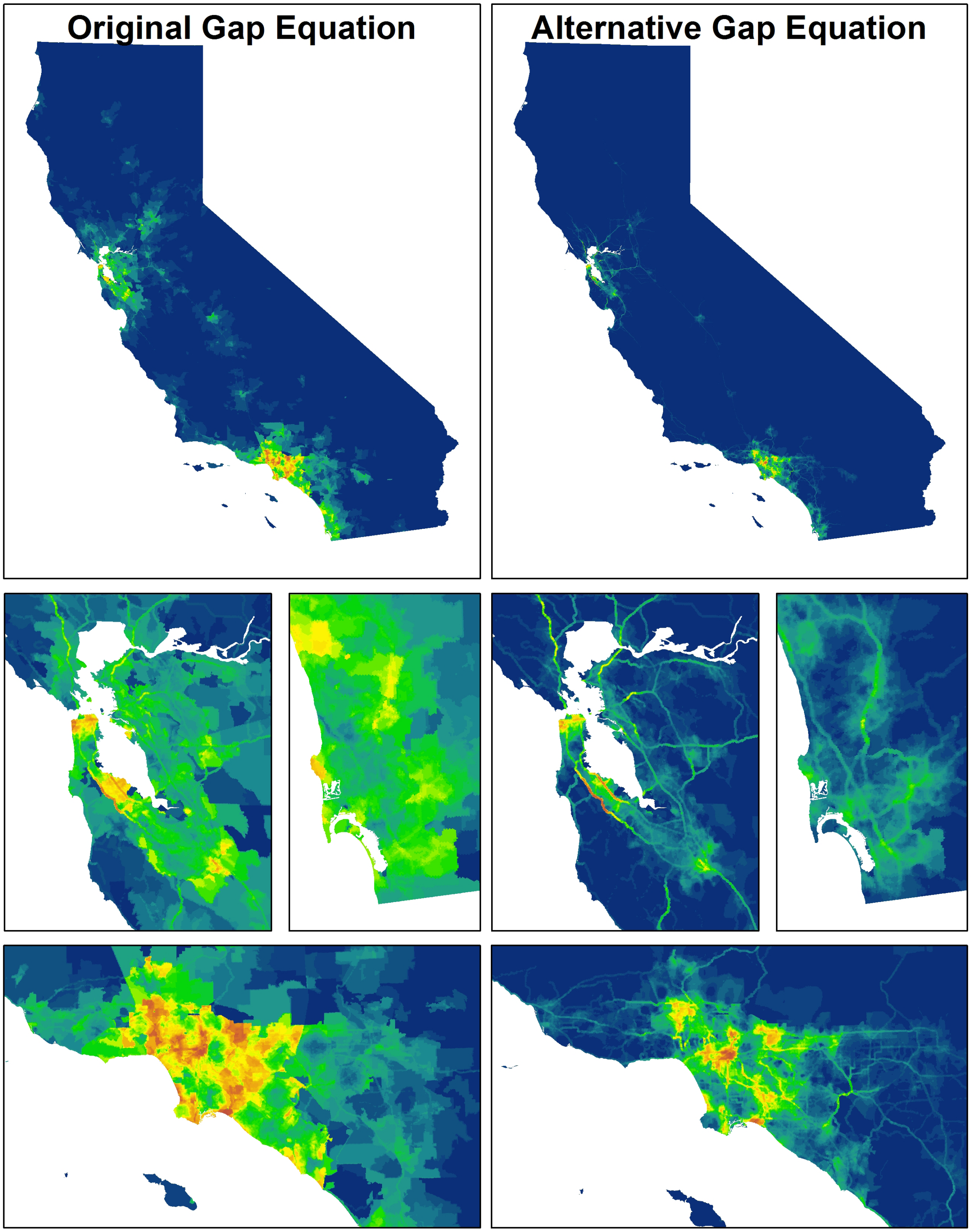
During the course of evaluating the effect of the proposed awards under GFO 15-605, ARB determined that the Potential Coverage factor had a disproportionate effect on the evaluation of coverage gap in certain areas. In its original intent, this factor enabled the coverage gap to consider the potential additional coverage that could be supplied by a new station in essentially any location across the state in addition to the extent of coverage already provided by the existing hydrogen fueling station network. The factor was based on calculating the population encapsulated within a 15-minute extent of multiple evaluation seed points across the state, as in the local capacity estimation tool. The factor is therefore a population density factor, with the additional consideration that convenient access to a hydrogen station is counted only within a 15-minute coverage extent. In the original implementation of the CHIT 2015 Release, Potential and Existing coverage were weighted equally. Under this weighting, coverage gap in certain areas with a combination of high population density and high market indicators remained uncharacteristically independent of the number of additional stations placed locally.

Based on this observation, ARB performed a sensitivity analysis of changes in coverage gap with various balances in weighting between existing and potential coverage factors. Through this analysis, ARB found that the population density-based potential coverage factor would need to have an extremely low weight in order for additional stations to have the expected impact on coverage gap and identification of need for a further additional station. Therefore, an alternative formulation for the coverage gap was developed. Acknowledging the high correlation to population density, the factor may be utilized as a scalar multiple in the predictive market evaluation, rather than as an additive factor in evaluation of local coverage. Results of the alternative coverage formulation (shown below) are compared in Figure 17 to the original coverage gap formulation. In Figure 17, all other factors have been given the same weight between original and alternative formulations.

CHIT 2017 Release (Alternative Formulation):

Let
Coverage Gap = Coverage * ((1-p) * Market + p * Traffic),
Coverage= Existing,
Market= (((1-r) * (x * Financial + y * P/HEV + z * Education) + r * Registrations) * Auto Manufacturer Survey) * Potential, and
Financial= u * Income + v * MSRP + w * Luxury,
with the following requirements on scaling factors:
$x + y + z = 1$,
$u + v + w = 1$,
$0 \leq p \leq 1$, and
$0 \leq r \leq 1$.

Figure 17: Comparison of Coverage Gap Equations Available in Updated 2017 Release Version of CHIT



Based on the results in Figure 17, high-scoring areas (a high score implies greater gap between market and coverage and thus greater need for additional coverage) in the alternative formulation cover a smaller area and are less dispersed throughout the state. In addition, even with the same weight, the traffic intensity factor clearly has a larger impact in the alternative formulation for coverage gap. These can be desirable features in results, depending on the intent. However, ARB found that coverage gap in this formulation did not lend itself well to determination of priority areas. In particular, the prominence of high-traffic areas causes priority areas to be defined as limited, narrow stretches of land along highly-travelled highways. Such limited definition of a priority area offers little flexibility for designing future funding programs. Additionally, consideration of traffic is a controlling factor in many areas under this formulation, which ARB does not deem appropriate given the simulation nature of the data. For this reason, ARB has maintained the original formulation of coverage gap for this Annual Assessment, as it had done for evaluations in GFO 15-605, but will continue to evaluate options in future evaluations.

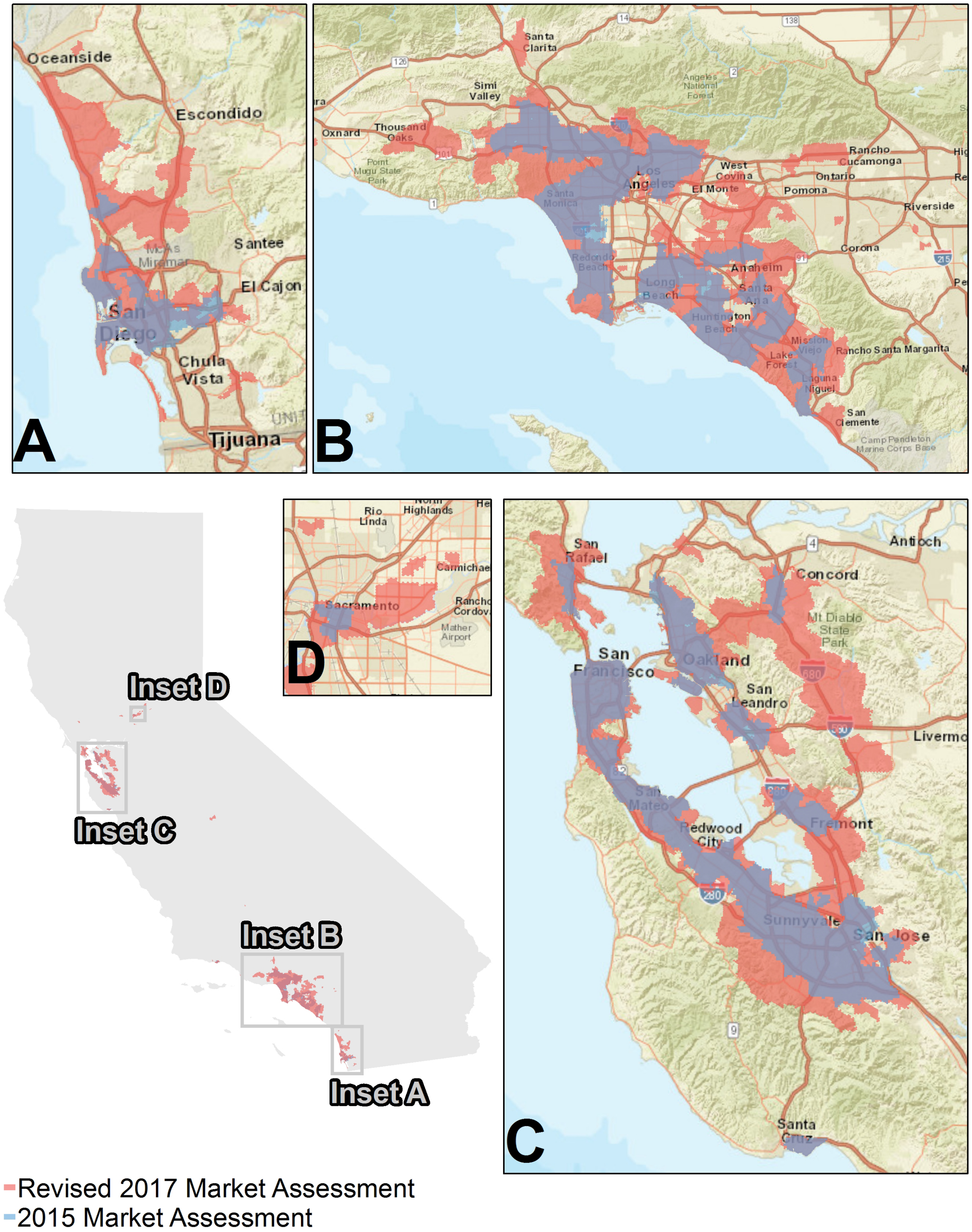
Various Process and Tool Improvements

In addition to the major revisions mentioned above, several minor improvements and new capabilities will be available with the 2017 release of CHIT:

- Implementation of a hexagonal analysis grid for improved fidelity of geographical representation and data management
- US Census American Community Survey-Based input layers have been updated to the latest available version (2015 vintage 5-year estimates)
- DMV 5-year registration data layers have been updated to 2012-2016
- All input and output data layers have been migrated to the NAD 1983 Teale-Albers projected coordinate system, in keeping with new ARB standards
- Default settings for several tools have been re-tuned, and default input and output file specifications for tools have been revised so users can more easily replicate ARB's analysis immediately from the download package
- Revised the underlying math of the Priority Area identification tools to increase the use of built-in ArcGIS statistical analysis capabilities
- New tools to directly run sub-processes that are part of larger tools:
    - A new tool allows users to quickly recalculate the coverage gap with new input data weights without needing to also re-perform all the spatial alignment of the input data layers
    - A new tool allows users to add a single new station to the network and calculate the effect on the coverage gap in an already existing coverage gap layer

These changes, along with several of the others mentioned in the prior sections have an impact on the underlying assessment of the FCEV first adopter market's highest-strength locations. Figure 18 provides a comparison of the highest-ranked market areas identified in the 2015 and 2017 analyses. There is significant overlap between the two assessments, but in general, the high-market areas identified by the new analysis cover much broader areas than in the previous analysis. Updated demographic and DMV indicator data, tuning of indicator weightings, and the updated priority area identification tool had the largest impact on this change. In addition to this change in the market evaluation, the coverage gap has become more sensitive to the inclusion of new fueling stations in the network.

Figure 18: Comparison of High-Scoring Market Areas Identified in 2015 and 2017 CHIT Analyses



Suggested Station Counts and Locations for Future State Co-Funding

Based on the Priority Area definitions displayed in Figure 14 and the projected 2020 statewide population of 13,400 FCEVs on California's roadways, ARB determined that the numbers of stations needed in each priority area are as indicated in Table 3. As discussed previously, the order of priority is a coverage-based assessment; it does not account for the timing of new capacity needed. For this reason, San Francisco is the third-highest priority, though it is not projected to require a new station by 2020 in order to meet capacity needs. Additionally, ARB recommends flexibility should be enacted as necessary for determining priority between areas; the table is presented in order but ARB does not intend strict adherence to the order. As in previous Annual Evaluations, the priority areas are divided into a first and second priority, based on the coverage gap evaluation and projected pace of growth in capacity need.

Table 3: Priority Area Station Recommendations Determined by CHIT, based on 13,400 FCEVs in 2020 (City Names in the Description Correspond to the Highest Coverage Gap within a Priority Area)

	Priority Areas	Description	Number of Stations
First Priority	1 (Region A)	Downtown Los Angeles - West Hollywood - Glendale - Northridge - Calabasas - Pacific Palisades	5
	1 (Region B)	Long Beach - Arcadia - West Covina - Claremont - Cerritos - Downey - Hacienda Heights	
	2	Manhattan Beach - Redondo Beach -Torrance - San Pedro	1
	3	San Francisco	0
	4	San Mateo - Foster City - Belmont - San Carlos	2
	5	South San Jose	1
	6	Santa Clarita	1
	7	North Tustin	1
	8	Dana Point - Aliso Viejo - Laguna Beach	1
	9	East Yorba Linda - East Anaheim	1
	10	La Jolla	1
	11	San Clemente	1
Second Priority	12	Alameda	1
	13	Sacramento (Downtown to East Sacramento)	1
	14	Sunland -Tujunga	1
	15	Ladera Ranch - Eastern Mission Viejo - Rancho Santa Margarita	1
	16	East San Jose	1
	17	Carlsbad - Encinitas	1
	18	Mira Mesa - Carmel Mountain Ranch - Rancho Bernardo	1

In addition to these core areas, the Energy Commission should consider co-funding additional connector and destination stations to continue to enhance the full functionality of the network. CHIT does not make determinations for these types of stations; however, the OEM Group of the CaFCP has provided a list of locations that represent their collective priorities. Core market areas, connectors, and destinations are provided in the list. ARB's analysis of the list is provided in Appendix D. This list can be referenced for destination and connector location suggestions and to gain further insights into auto manufacturers' understanding of FCEV and hydrogen fueling market viability in addition to CHIT evaluations.

CVRP Response Data and Implications for CHIT

Through the California Clean Vehicle Rebate Project, consumers who purchase or lease new Battery Electric Vehicles (BEVs), Plug-In Hybrid Electric Vehicles (PHEVs), or FCEVs may be eligible for a rebate. As part of the program, rebate recipients are invited to respond to a number of on-line surveys; completion of the surveys is strictly voluntary. Because of the early stage of commercial deployment, FCEV drivers have so far only been asked to respond to the Consumer Survey, which is administered on an ongoing basis following approval of their rebate. For FCEV drivers, this survey focuses on consumer perceptions and decision-making involved in the purchase or lease of their vehicle. Follow-up surveys are anticipated for future distribution to learn about consumer behavior and perceptions once they have had additional experience incorporating the vehicle into their daily lives.

Many of the questions asked in the Consumer Survey can help inform ARB's development of the CHIT market assessment and provide a means to test some of the tool's fundamental assumptions about consumer behavior and desirability of hydrogen fueling station locations. The following is a review of information gathered from the first release of CVRP FCEV survey data and its possible implication for future implementations of CHIT. The data cover survey responses through January 31, 2017. The total number of FCEV survey respondents was 202, though the number of respondents to any individual question may be less. With this number of respondents, ARB does not yet feel it is appropriate to make changes to its CHIT calculations, but it is important to report the early findings and continue to assess how they may change with a more significant participation in the survey.

At a fundamental level, CHIT's FCEV first adopter market estimation attempts to find areas with local demographic data that indicate agreement with motivating factors in FCEV early adopters' purchase decisions. Questions in the Consumer Survey can provide insight into the appropriate metrics and values to implement in CHIT for these indicators. Figure 19 provides fundamental insight, showing the reported benefits that respondents felt primarily motivated their purchase decision for an FCEV. The factor cited the most often as the most important was reducing environmental impacts. Nearly twice as many respondents chose this over the next-highest factors of High Occupancy Vehicle lane access and overall money savings, which may have been interpreted as savings on total cost of ownership. The focus on environmental benefit is in agreement with ARB's understanding of the FCEV first adopter market.

Figure 19: FCEV First Adopter Perceptions of Ownership Benefits

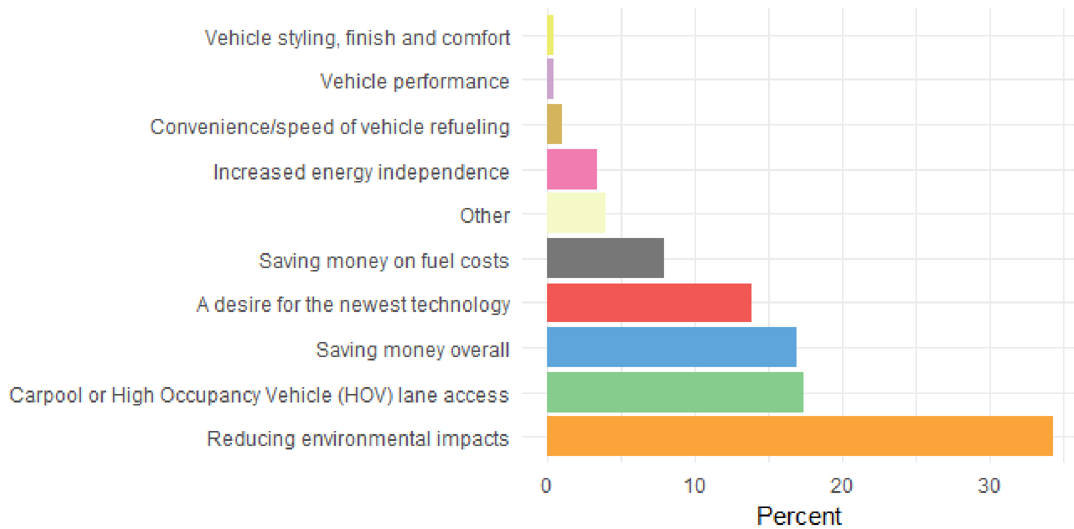
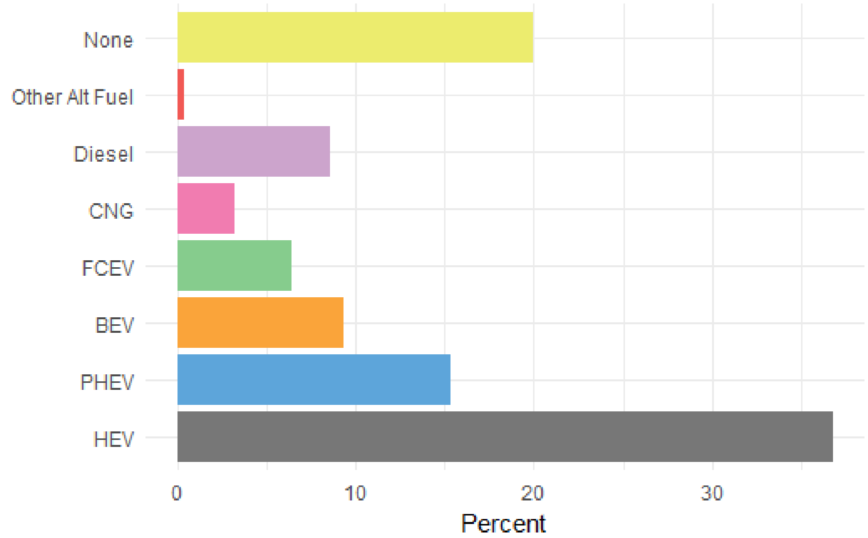


Figure 20: Past Alternative Fuel Vehicle Ownership Among FCEV First Adopters



CHIT relies on historical data for first registrations of hybrid electric vehicles (HEVs) and PHEVs as a demographic indicator for potential consumers who are looking for both environmental benefits and convenient fueling, since HEVs and PHEVs do not require changes to consumer fueling behavior in the way that BEVs might. Responses in Figure 19 seem somewhat at odds with this assumption, given the lower priority for convenience and speed of fueling. However, Figure 20 shows that FCEV first adopters had substantially higher rates of past adoption of HEVs and PHEVs than BEVs. Furthermore, Figure 21 shows that among first adopters whose FCEV purchase was intended to replace another vehicle, gasoline and HEV vehicles were much more commonly replaced than BEV and even PHEV vehicles. Ultimately, the decision to purchase or lease a FCEV was made by these early adopters even with significant cross-shopping of BEV and PHEV technology, as indicated in Figure 22. Taken together, these results seem to indicate that PHEV and HEV past adoption could be a valid indicator of propensity to adopt a FCEV in the current early market, though the motivation may not be as directly tied to convenience and speed of refueling as ARB had first assumed in development of CHIT.

Figure 21: Technology of Replaced Vehicles Among FCEV First Adopters

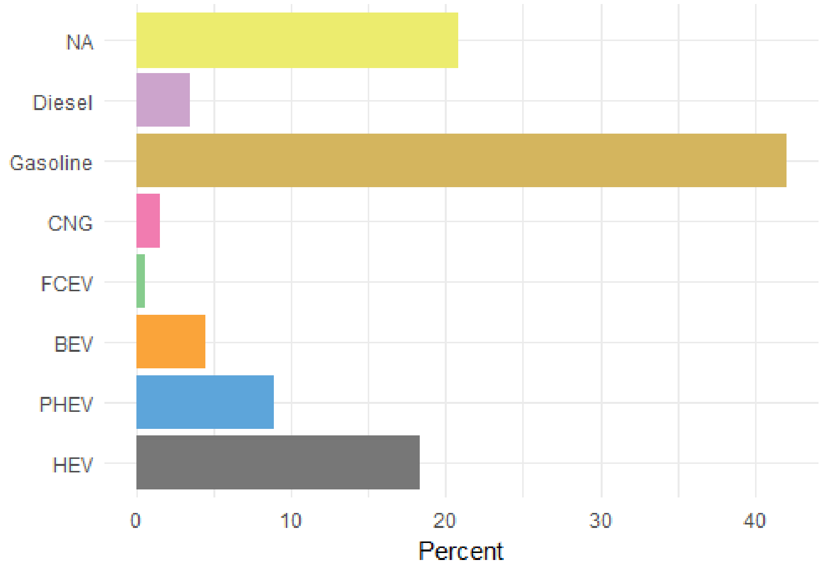
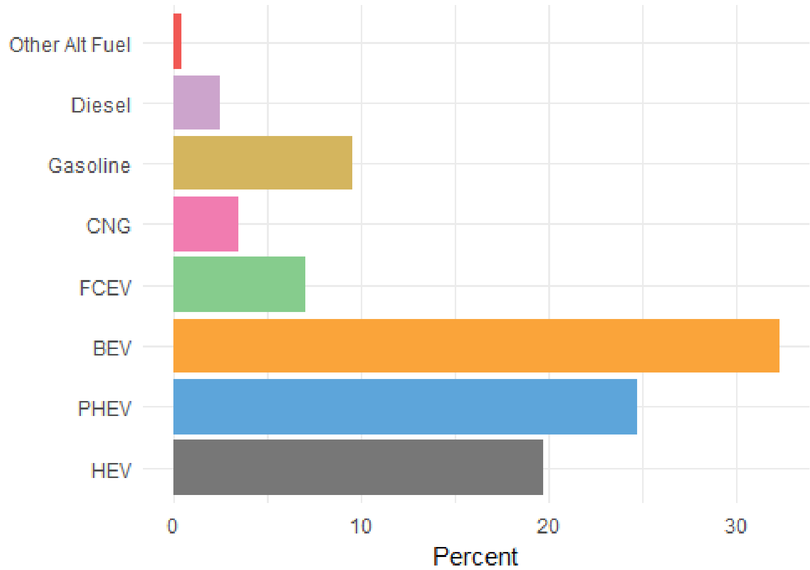


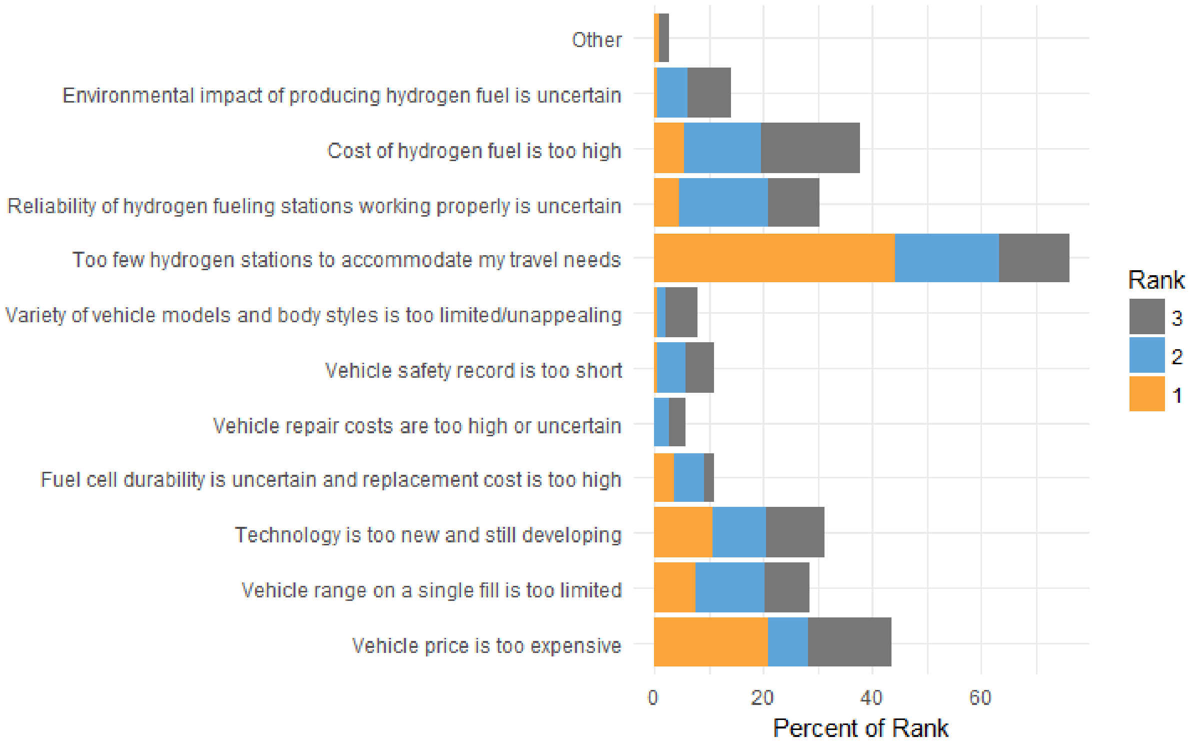
Figure 22: Vehicle Technologies Considered by FCEV First Adopters



When asked to identify and rank their three most important concerns about owning an FCEV, consumers most often indicated the availability of fueling stations as one of their three concerns, as shown in Figure 23. This was also the most common highest-ranked concern amongst consumers. This result is a strong consumer-based indication of the importance of continuing the AB 8 program and ensuring the investments result in successful hydrogen fueling stations as quickly as possible. Vehicle and fuel price were the next most-common concerns, and while each was chosen by roughly the same number of respondents, vehicle price was more often a primary concern than fuel price[10]. Station reliability, vehicle range, and the early development nature of fuel cell technology also stood out as top concerns. Most of these issues are not able to be directly addressed by the State, nor do any of them appear to be necessary to include as a demographic market indicator in CHIT. However, the high rank of fuel price as an overall concern may be an issue that could be addressed through creative structuring of future station funding programs or by reaching market maturity where competition will reduce prices.

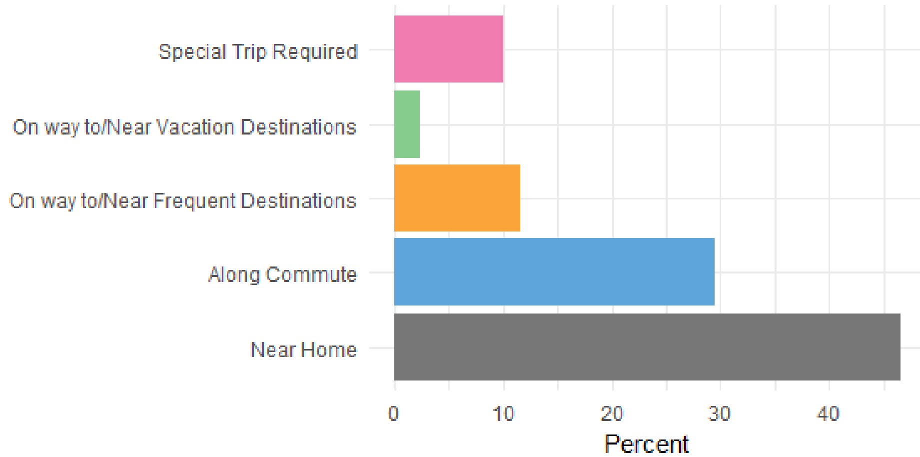
10 Auto manufacturers currently provide up to $15,000 of hydrogen fuel for drivers who purchase or lease a FCEV. Knowledge of this provision may impact the relative perception of vehicle and fuel price as concerning factors.

Figure 23: FCEV First Adopter Perceptions of Ownership Concerns



Insight into concerns over station availability is possible through questions that ask respondents to compare their past gasoline fueling behavior to their current hydrogen fueling behavior. FCEV drivers report regularly using between one and three stations, with two being the median response. Outlier responses between four and seven were also reported. By all measures, these drivers typically used more gasoline stations, which may be more an indication of limited hydrogen fueling availability than changes in driver habits. Respondents reported using between one and seven gasoline stations, with a median response of three and half of respondents indicating between two and four. Outliers for the number of gasoline stations were as high as ten. It is important to note that auto manufacturers currently offer their FCEVs only to drivers who live and/or work in specific areas where there is sufficient hydrogen fueling infrastructure to support vehicle deployment. These data on hydrogen fueling patterns are therefore more optimistic than the full statewide situation, since they do not represent any of the areas where there is no fueling available and therefore no FCEV deployment. By contrast, gasoline fueling is available throughout the state, as are gasoline-powered vehicles. It can therefore be concluded that even in areas with hydrogen fueling availability, the coverage of the network is still behind what consumers have become accustomed to with gasoline.

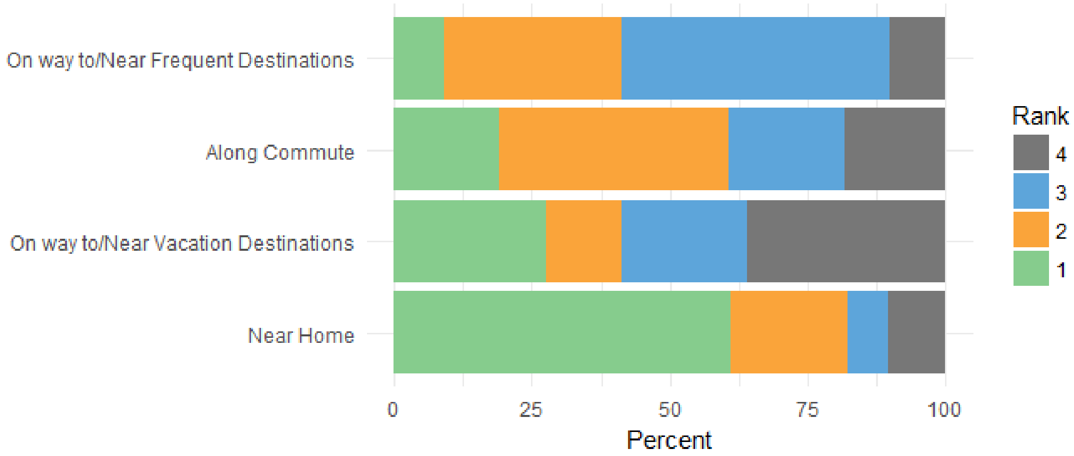
Figure 24: Locations where FCEV First Adopters Currently Fuel



Another fundamental assumption built into CHIT is that FCEV first adopters will be motivated to purchase or lease a vehicle by having a hydrogen fueling station located near their home. That is, coverage should be assessed with respect to convenient fueling choices within range of first adopters' homes. Stakeholders have inquired about other types of locations, such as along common travel routes, as potential locations where first adopters would need fueling availability. To help understand the consumer perception, the survey asked respondents about the location of the station they use the most (Figure 24) and the locations where they would most like to see new stations built (Figure 25). Respondents most often indicated that their most common fueling stop is near their home, while stations along their commute were the second-most common primary station. Stations on the way to or near errands, vacation destinations, and away from all typical driving were the primary station for approximately 25% of respondents. The result of near-home fueling being the most common primary option is in line with the CHIT model as first developed. However, the strong response to primary fueling along a commute route is a good consumer-based indicator of the need to include commuter routing in consideration of placing new stations. This is in line with the discussion above of including traffic intensity data in CHIT evaluations, with a lower relative weighting compared to the near-home demographic indicators.

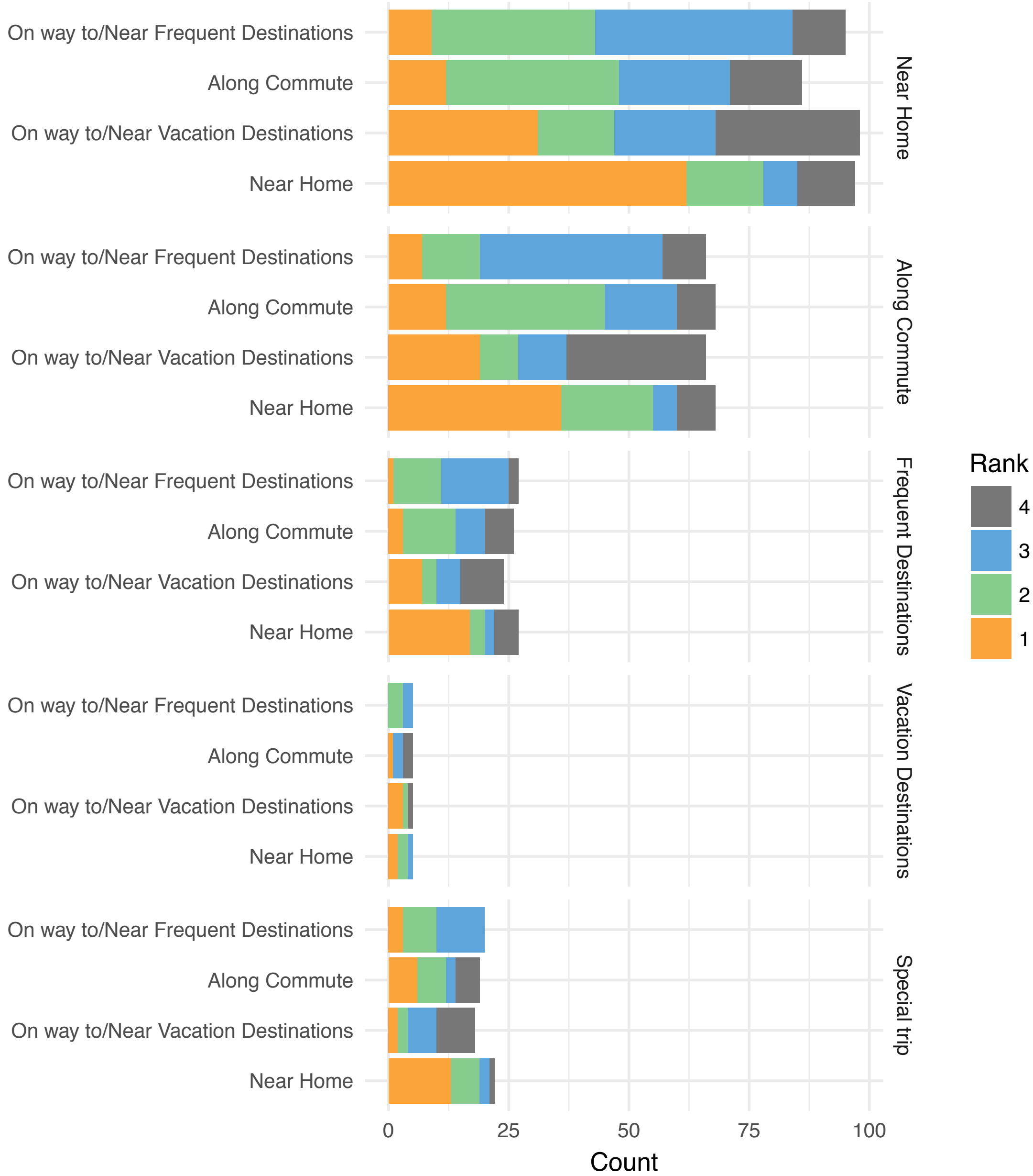
Given the limited number of hydrogen fueling stations currently in the network, stations where respondents currently fuel may not actually be the locations where they want to fuel. Figure 25 shows respondents' ranking of conceptual locations for new stations, when given the options of near home, on the way to or near vacation destinations, along their commute, and on the way to or near other frequent destinations (which may include frequent shopping or errand destinations). Almost 60% of respondents indicated that another station near their home would be the most desirable location for a new station. Although stations along commutes were the second-most used currently, new stations in these locations ranked low in desirability (20%). When looking at first and second choices combined, results shown in Figure 25 more closely resemble those of Figure 24.

Figure 25: Locations where FCEV First Adopters Desire Increased Station Coverage



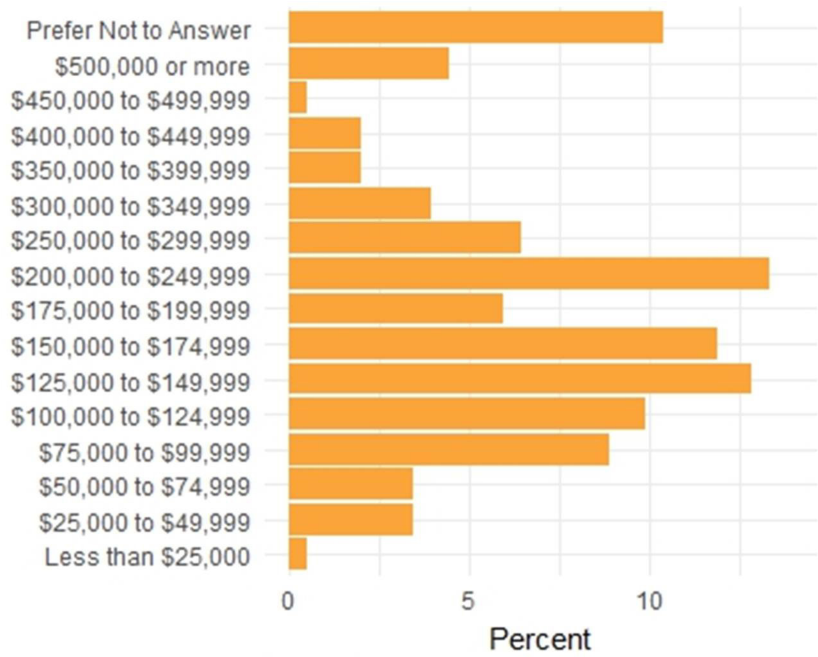
Further evidence of the primary need for fueling stations near the home is shown in Figure 26. In this figure, the responses for where FCEV first adopters fuel most often are shown by the labels on the right. Within each category, responses are further divided by the location where respondents would most like to see a new station, indicated by the labels on the left. In nearly every case, regardless of where the driver currently fuels, their most desired location for a new station is near the home. This also holds true when considering first- and second- ranked choices. A new station along the drivers' commute is similarly fairly universally the second most desired choice. As expected, for those who currently fuel most often along their commute, a new station near the home is more desirable than another along the commute. Taken together, these data are further support for CHIT to prioritize identification of near-home coverage gaps while integrating commuter traffic patterns with a lesser emphasis.

Figure 26: FCEV First Adopters' Most Desired New Station Location Grouped by their Most Used Location



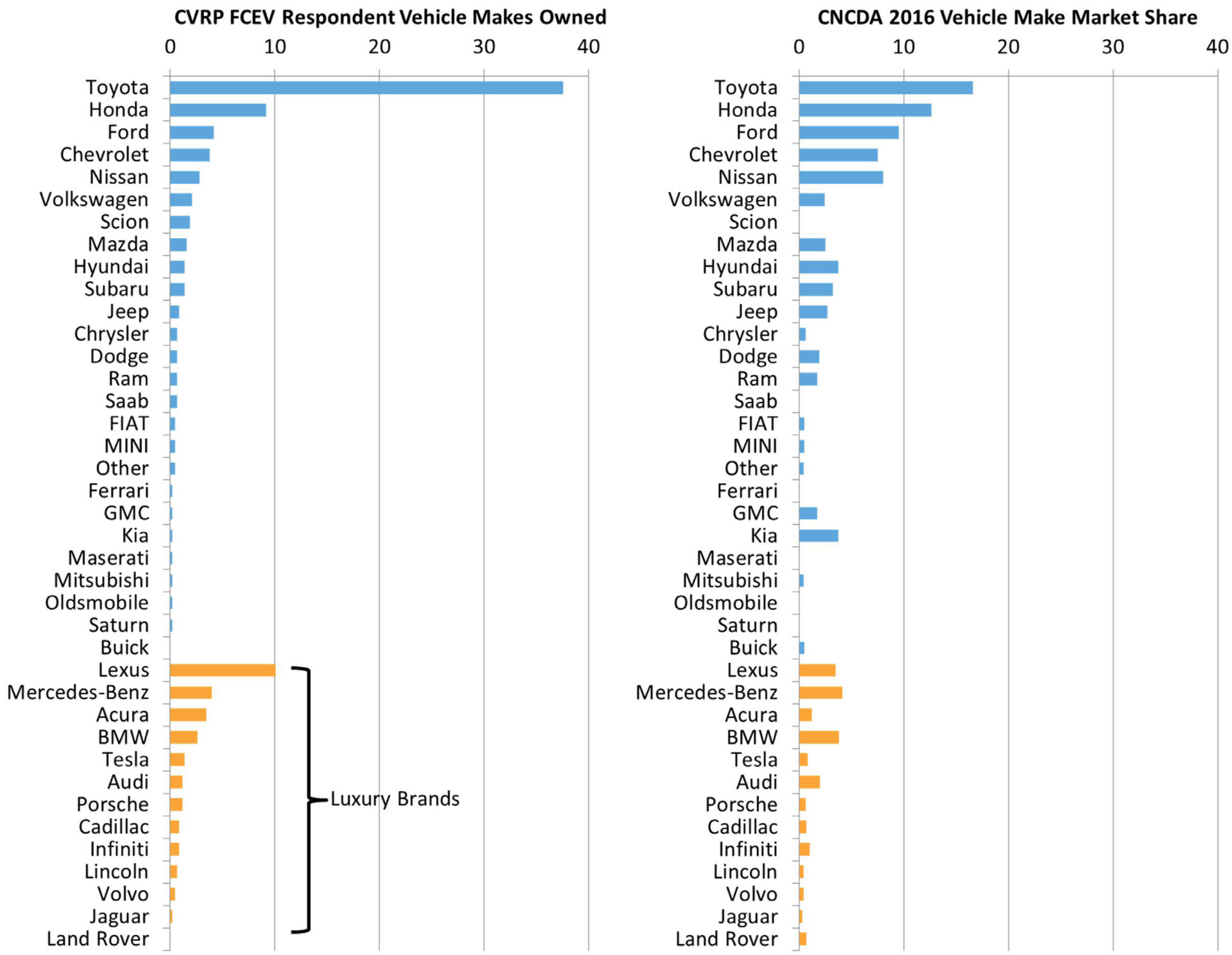
Additional demographic indicators that CHIT relies on for its estimate of the FCEV first adopter market include income, vehicle make preference, and educational attainment. w vw shows the distribution of household income of FCEV first adopters. The peak of the distribution appears to be between $125,000 and $250,000. This is actually a lower income range than CHIT's income factor is based on, and may indicate a need to adjust the income data incorporated in future CHIT evaluations. In addition, based on discussion with auto manufacturers about typical expectations from first adopters and experience with the pre-commercial market, there seemed to be potential for FCEV first adopters to have a strong affinity for luxury vehicle makes. Figure 28 shows the distribution of vehicles owned by survey respondents prior to the purchase or lease of the FCEV, alongside the distribution of the 2016 vehicle market share as provided by the California New Car Dealers Association's (CNCDA) 2016 Q4 Outlook [40]. By comparing the distributions, it does appear that survey respondents had more affinity for luxury brands than the general new car market, though the difference is not large. Survey respondents reported luxury vehicle ownership at a rate of 27.2%, while the 2016 new vehicle market share had a luxury vehicle rate on the order of 19.5%. On the other hand, the popularity of Toyota, a non-luxury brand, was markedly higher among survey respondents than the general new car market. Overall, the data from the survey do not make a strong case for a luxury vehicle preference among FCEV first adopters, but they also do not seem to refute the assumption.

Figure 27: Distribution of Household Income of FCEV First Adopters



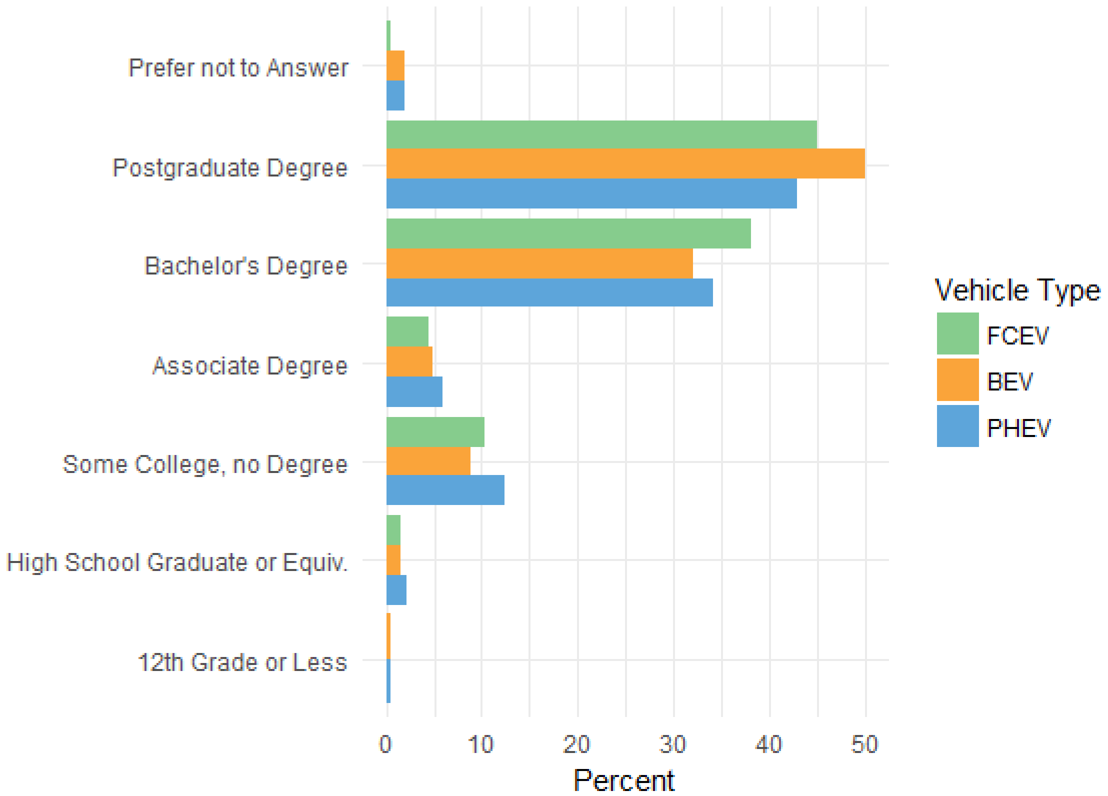
There are some possible explanations for the apparent discrepancies between these CVRP-based findings and the formulation of the related demographic indicators in CHIT. Regarding the significant preference for Toyota vehicles as compared to the slight preference for luxury brands indicated in Figure 28, it is possible that there is an element of brand loyalty affecting the CVRP results. It should be noted that Toyota has had the largest publicly-announced plans for near term FCEV deployment and are currently the only auto manufacturer offering their vehicle both for lease and for sale. The significant preference for Toyota (and Lexus, which is a Toyota brand) in CVRP respondents' past purchases may be skewed if the volumes of Toyota FCEVs sold and leased is significantly greater than other makes.

Figure 28: Distribution of Vehicle Makes in FCEV First Adopter Garages Prior to Purchase and Comparison to 2016 New Vehicle Market Share [40]



Many past works point to relatively affluent, highly educated, socially and environmentally conscious persons as the most likely first adopter of new technologies. However Figure 27 and Figure 28 show there is the possibility that the several government and auto manufacturer incentives (the State cash rebate, the currently-lapsed federal tax credit, several local incentives, and auto manufacturer incentive of free fuel to FCEV buyers and lessees) are generating a shift in the FCEV first adopter market away from the traditional socio-economic definition. The several financial incentives have the potential to change the overall cost-of-ownership considerations for FCEVs as a financially viable option for new car buyers and lessees, and thereby broaden the portion of the population that could be first adopters.

Figure 29: Educational Attainment of CVRP Recipients



Finally, educational attainment was also explored through the CVRP survey, as shown in Figure 29. As with BEV and PHEV respondents, FCEV first adopters have a high degree of educational attainment. The vast majority (~75%) have obtained a bachelors degree or higher, with postgraduate degrees actually outnumbering bachelors by a small amount. This is well in agreement with the use of a postgraduate degree indicator as input data to CHIT.

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.

Assessment and Projections of Hydrogen Fueling Capacity in California

Total hydrogen fueling capacity of 13,620 kg/day in the funded network is expected to be fully available by 2020. Changes described in Chapter III are all accounted for in this projection. As shown in the lower left of Figure 30, the expected addition of eight new stations per year beginning in 2020, each with a fueling capacity of at least 300 kg/day, will provide a minimum projected 2023 fueling network capacity of 23,220 kg/day. The progression of fueling capacity within each county is also displayed in the several charts on the upper portion of Figure 30.

The per-county and statewide balances of hydrogen demand and capacity are presented in Figure 31. For these estimates, demand on a per-county basis is derived from the responses to the auto manufacturer survey augmented by CHIT market assessments whenever necessary. The capacity on a per-county basis is assigned based on location of nearby drivers served, rather than the locations of the stations as in Figure 30. As first described in the 2016 Annual Evaluation, county-based FCEV market share in 2020 and 2023 were utilized as a basis to divide each station's fueling capacity among all counties within a 15 minute drive of the station. This more appropriately considers the capacity of stations that reside just inside the border of one county, but that are likely to serve a much more significant fueling market in an adjacent county.

Compared to the same assessments in the 2016 Annual Evaluation, deficits in hydrogen fueling capacity are now expected to be lower than previously projected. The direct causes of these smaller deficits are the reduction in the overall number of FCEVs indicated by the auto manufacturer survey results and the increase in the assumed capacity of future stations from 180 kg/day to 300 kg/day, based on the results of applications and awards in GFO 15-605. Without any additional stations, only a handful of counties would experience a deficit of hydrogen in 2020, and the overall state hydrogen capacity will have a surplus of 4,360 kg/day. This surplus increases to 6,760 kg/day with the addition of eight 300 kg/day stations. In 2023, without additional stations, nearly all individual counties will have a deficit of hydrogen and the statewide deficit will be 11,800 kg/day. With an additional investment into thirty-two 300 kg/day stations, the statewide deficit in 2023 falls to 2,200 kg/day, approximately equivalent to eight additional stations.

Figure 30: Statewide and County Hydrogen Fueling Capacity, with Averaged New Station Funding Rate of Eight per Year with a 300 kg/day Capacity

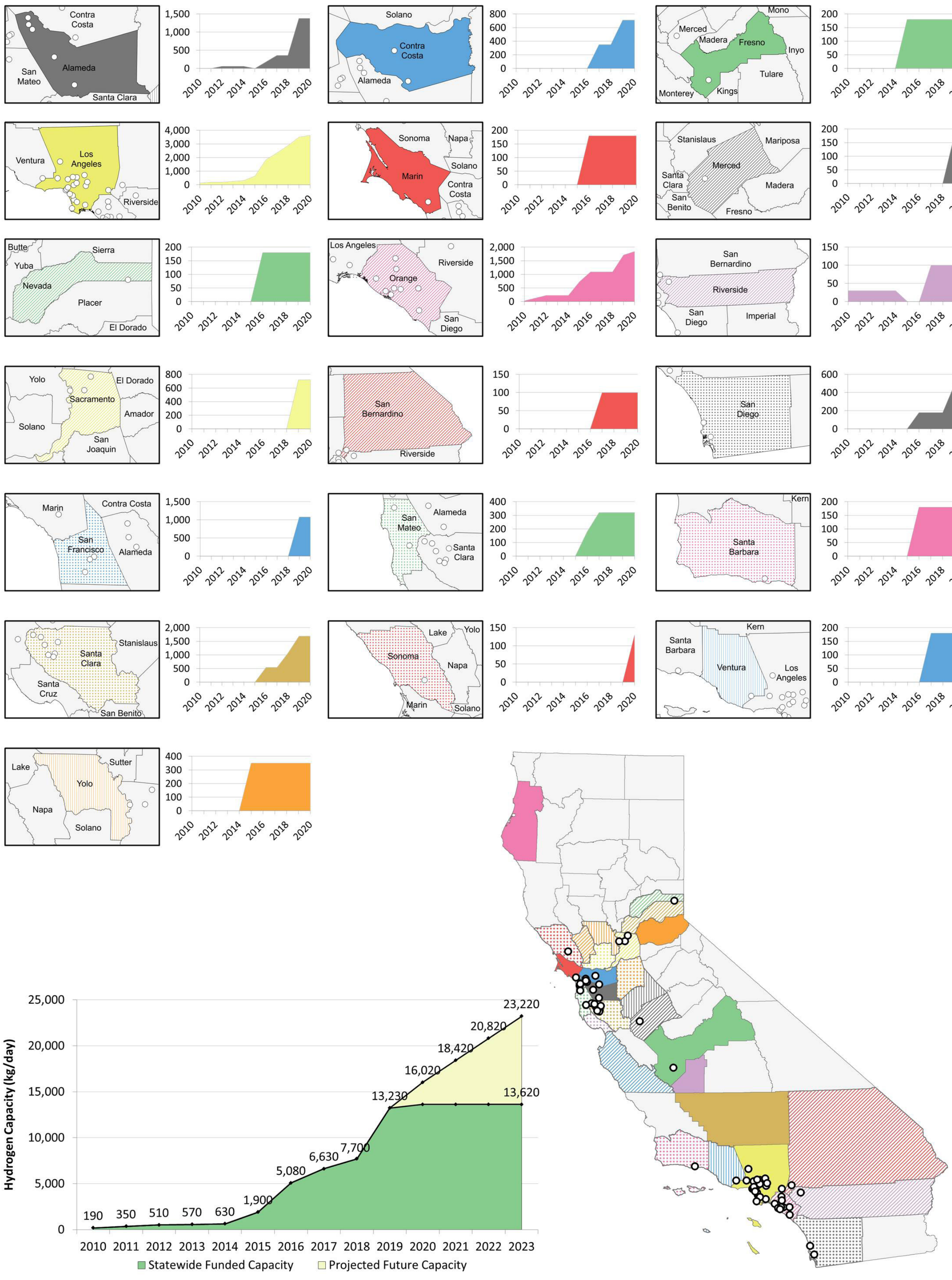
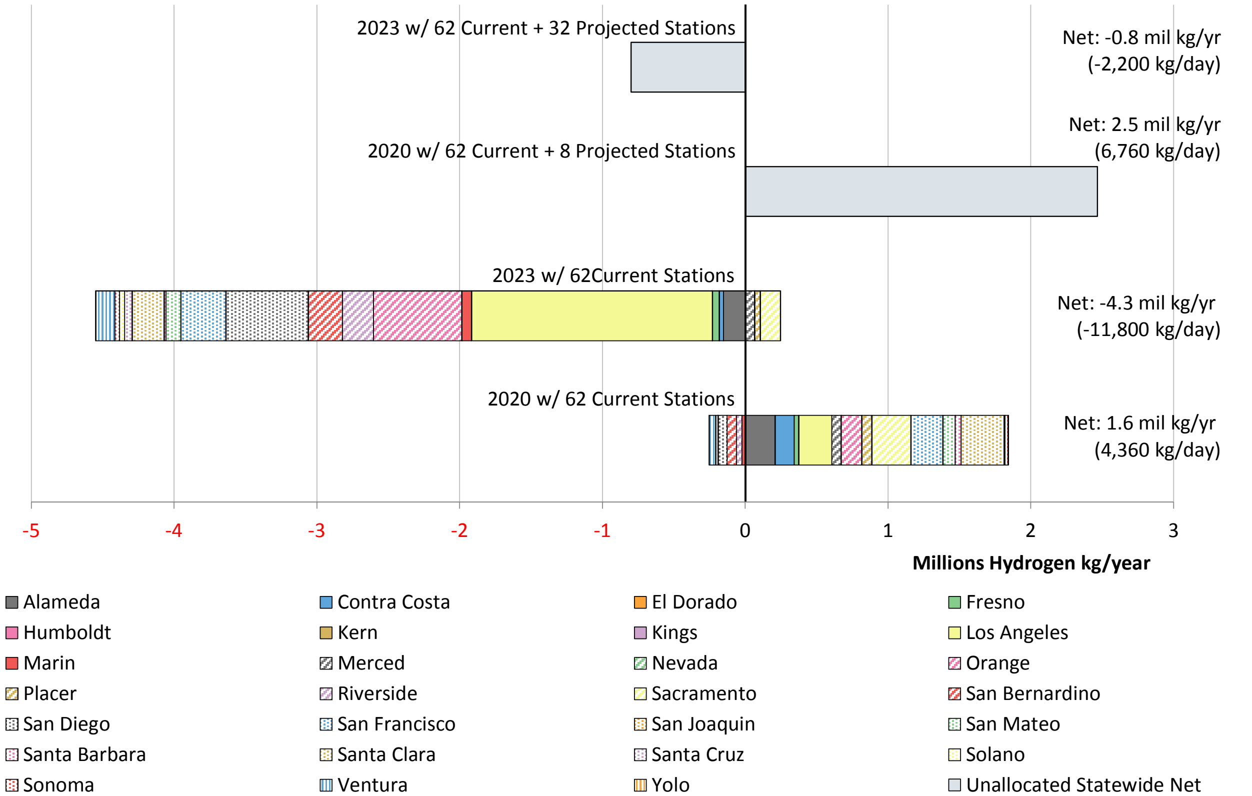
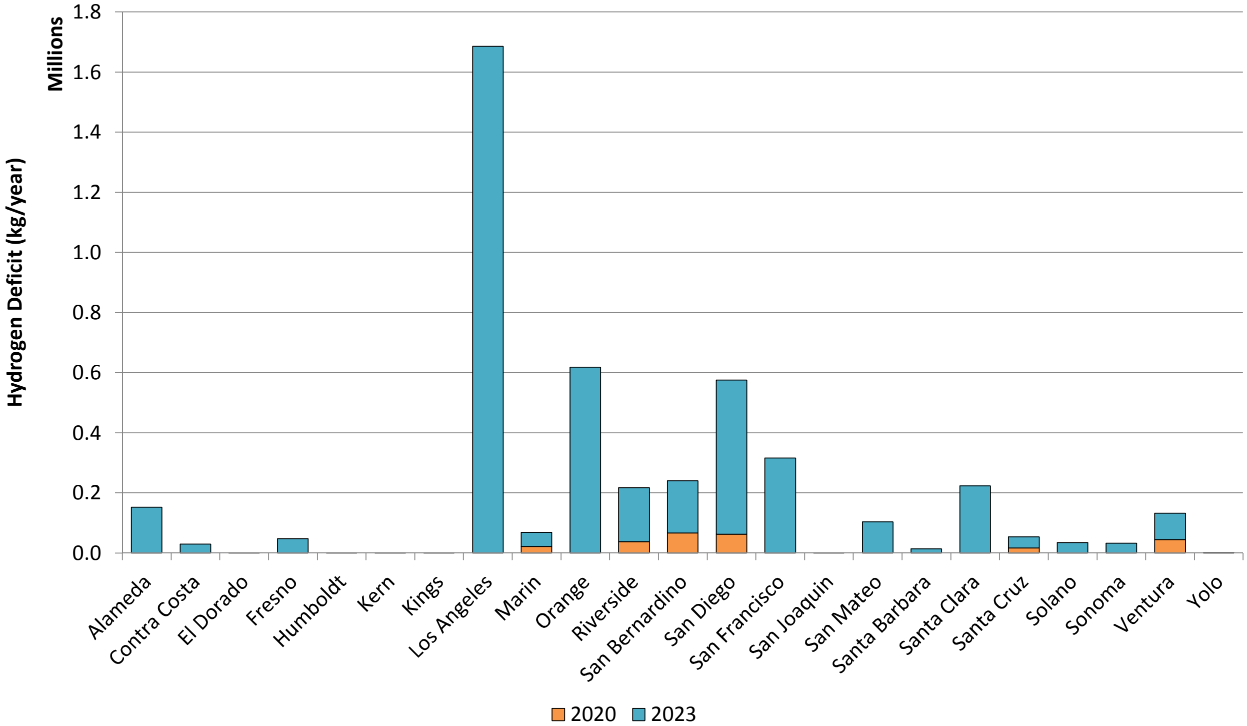


Figure 31: Estimated Balance of Hydrogen Fueling Capacity by County and Statewide in 2020 and 2023



As shown in Figure 32, only six counties are expected to have a noticeable deficit of hydrogen fueling capacity in 2020. In order of largest to smallest deficit, these counties are: San Bernardino, San Diego, Ventura, Riverside, Marin, and Santa Cruz. However, the largest deficit, in San Bernardino, is approximately 180 kg/day. With only a slight increase beyond 300 kg/day in the average fueling capacity of the next set of funded stations, these deficits could easily be addressed. In 2023, the largest deficits in order from largest to smallest will be in Los Angeles, Orange, San Diego, and San Francisco counties. Santa Clara, San Bernardino, and Riverside also stand out as a second tier of priority in terms of need for new capacity. Without continued AB 8 investment, these deficits represent approximately 22 new 300 kg/day stations' worth of fueling capacity. As with previous years, the capacity analysis at the state and county levels shows a clear need for continued funding through at least 2023.

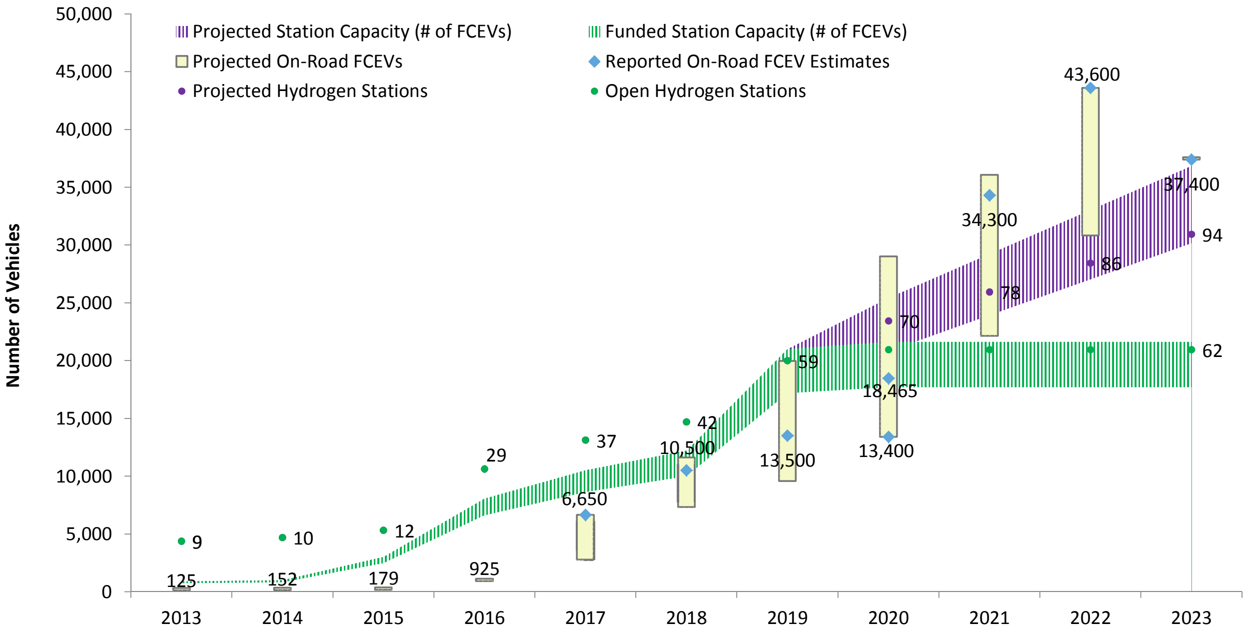
Figure 32: County-Based Hydrogen Fueling Deficit in 2020 and 2023 with 62 Currently Funded Stations



Fueling capacity of the funded and projected future hydrogen fueling network is compared to current expectations for on-the-road FCEVs in Figure 33. As in Figure 4, the range of all on-the-road projections for FCEVs since 2014 are indicated by a solid bar; reported projections at the end of the mandatory and optional survey periods are indicated by blue diamond symbols. The green shaded area indicates the potential number of FCEVs that could be fueled by the funded network of stations, with an assumption of 0.7 kg/day average fuel consumption per FCEV. The purple shaded area indicates the increased number of vehicles that could be supported with continued funding of eight 300 kg/day stations each year from 2020 to 2023. Beginning in 2020, both the funded and projected hydrogen fueling capacity is exceeded by the largest potential demand from vehicles indicated on the annual auto manufacturer surveys. However, the demand from the most recent 2020 estimate of 13,400 FCEVs in 2020 is exceeded by the funded station capacity.

In 2021, the minimum demand is projected to be very close to the anticipated capacity range of the hydrogen fueling network, assuming continued investment. In 2022, the minimum fueling demand approaches the upper limit of the projected network fueling capacity. By 2023, the single estimate for on-the-road FCEV demand exceeds the upper limit of the projected hydrogen fueling network capacity. Taken together, these trends indicate that as in previous years' analyses, continued funding of hydrogen fueling stations is necessary. The expected gap between fueling capacity and demand has shifted from 2020 to 2021, but a significant gap will continue to develop over time if funding is not maintained. In order to maintain fueling capacity that leads demand and enables additional FCEV deployment in the future, the rate of statewide capacity growth will need to accelerate beyond the business-as-usual assumption. Increasing the number of stations funded per year and/or funding stations with larger fueling capacities are the most direct changes that could have a significant impact on the State's efforts to ensure sufficient hydrogen fueling availability as the FCEV market develops.

Figure 33: Projected Hydrogen Demand and Fueling Capacity, Given Business as Usual Assumptions in State Incentive Programs



Alternative Financing Mechanisms to Accelerate Future Station Funding Rates

The above analysis demonstrates a clear need to accelerate hydrogen fueling station deployment in order to keep pace with projected demand. The current process of grant funding is necessarily time-intensive due to the requirements of encumbering funds on a fiscal year basis ($20 million per year), developing a solicitation, preparing applications, reviewing applications, and awarding and contracting grants. The long timeline required for this funding structure may not allow the necessary flexibility to accelerate overall station deployment. As a secondary effect, it also has the potential to create uncertainty for station developers and financial partners. The Energy Commission is actively investigating alternative funding mechanisms to enable network-wide acceleration of growth; the ARB has begun parallel preliminary exploration of additional concepts.

While the hydrogen fueling market as a whole is still in its early stages of development, there are local markets in early adopter locations across the state with enough funded hydrogen fueling infrastructure to potentially allow transition to a more highly-leveraged and efficient funding mechanism locally. Localized transitions away from grant funding to other options may ultimately prove more beneficial in rapidly establishing a long-term competitive market than continued grant funding alone. In addition to the overall objective of funding more stations on a faster schedule, stakeholder input is currently being sought to advise on methods of meeting the following goals through new funding mechanisms, including those presented here and others under consideration by the Energy Commission or developed through a public workshop process:

- Leveraging complementary investment and funding opportunities within the State
- Lowering perceived risk for private investors
- Increasing the private funds leveraged per State dollar invested
- Maintaining a more constant availability of State funds
- Incentivizing renewable hydrogen throughput
- Building hydrogen fueling demand

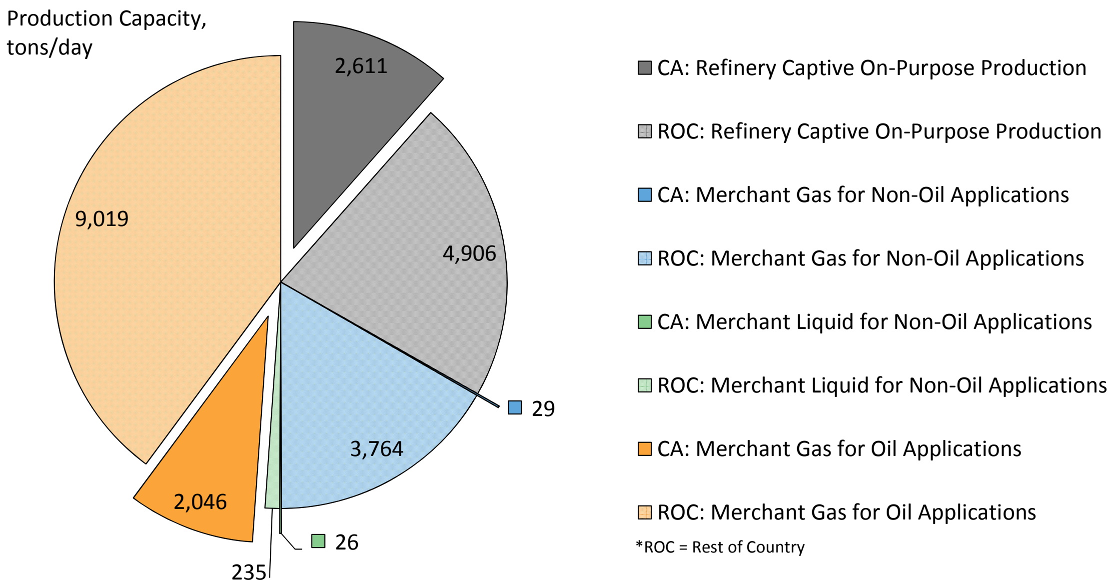
- Supporting the development of more competitive market dynamics in areas with sufficient grant-funded and/or private development
- Maintaining grant funding options in situations where they are more appropriate (like destination and connector stations or establishing the first station(s) in a new market)

ARB and the Energy Commission have begun the fact-finding stage of a new project to understand the requirements and possible trajectories towards a self-sufficient fueling industry. ARB recommends that the findings of that study should inform any adopted changes for future funding. In addition, ARB has performed preliminary analyses of some concepts that may be mutually attractive to the Energy Commission (by enabling more stations to be funded per dollar of State funds through greater leveraging of private money) and station developers (by providing funds in a manner that are designed more specifically for the needs of the current early market phase and are designed to attract more private capital). These concepts are presented in Appendix E along with a discussion and exploration of the trade-offs between key parameters in the design of these funding mechanisms. The discussion in Appendix E is preliminary and does not represent any guarantee of future funding program design through the Energy Commission.

Exploration of Needs for New Hydrogen Production Capacity in California

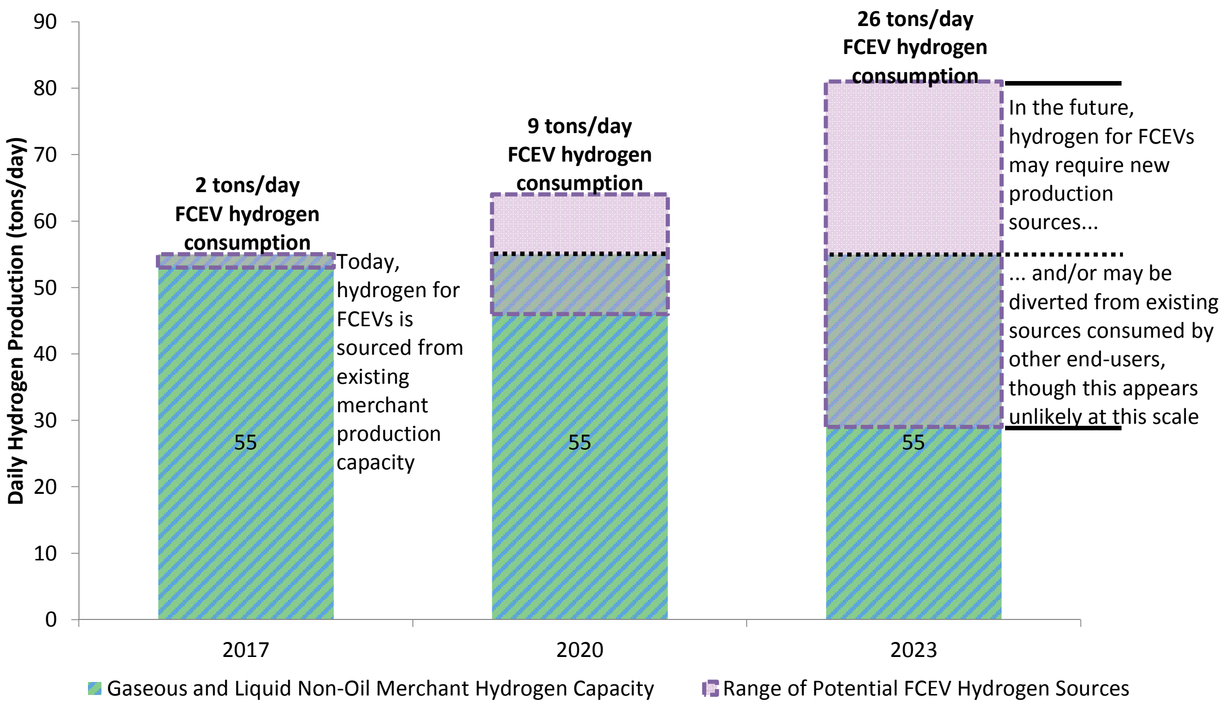
This and prior Annual Evaluations have noted that a successful FCEV market launch could generate enough hydrogen demand in the future to overwhelm expected local and statewide dispensing capacity under business-as-usual assumptions of station network growth. However, it is quickly becoming apparent that there is also the potential for a future gap in hydrogen production capacity, especially in-state production capacity. Data collected by the Pacific Northwest National Laboratory indicates that the hydrogen production capacity in California and the United States is large but most is generated for use in petroleum refining processes, either on-site or through a captured portion of the merchant hydrogen market [33]. As shown in Figure 34, captive, on-purpose production at refineries and merchant gaseous hydrogen ultimately used in oil refining represent 4,700 and 18,600 tons/day of daily production in California and the United States, respectively. These amounts dwarf the merchant liquid and gaseous production for purposes other than oil refining. In California, there are only 26 tons/day of liquid and 29 tons/day of gaseous merchant hydrogen sold for purposes other than oil refining [33].

Figure 34: Daily Hydrogen Production Capacity and Use in California and the United States [33]



These limited production capacities can present a challenge to future FCEV deployment plans. Figure 35 illustrates the potential scale of the coming challenge, by comparing the total of California's existing non-oil merchant hydrogen production capacity to projected hydrogen consumption by FCEVs. Currently, hydrogen fueling stations source their product from existing production capacity. Sources may actually be merchant production facilities for oil and non-oil markets, since the demand for FCEV fueling is currently a minor part of the overall hydrogen market. However, as the hydrogen demand for FCEVs becomes more significant, this may overcome the marginal excess production capacity available at these facilities. It is possible that commercial agreements could be made to allow hydrogen fuel for FCEVs to be sourced from existing facilities, requiring production capacity to be diverted from other industries that are currently supplied by those facilities. This scenario is demonstrated in Figure 35 by the lower bound of the portion of FCEV demand overlapping the current production capacity. However, this scenario is unlikely based on current understanding of the industry. Thus, it is likely that new production capacity will need to be developed; the upper bound of demand shown above production capacity in Figure 35 illustrates a scenario when all of future FCEV hydrogen is sourced from new production facilities. Ultimately, the mix of hydrogen sources for FCEVs could be anywhere between these extremes, as shown by the shaded region.

Figure 35: Comparison of Projected Statewide Hydrogen Demand to Current In-State Non-Oil Merchant Hydrogen Production Capacity[11]



11 ARB has limited its analysis to merchant hydrogen sources without assumption that captive, on-purpose production within the oil industry could be redirected to transport applications. This is because of two primary reasons: 1) hydrogen demand in oil refining has been increasing and is projected to continue increasing as regulations like LCFS demand increasingly cleaner-burning petroleum fuel products, and 2) hydrogen for transport applications requires significantly higher purity than the hydrogen typically generated for oil refining purposes; redirection of this hydrogen to transport would require additional investment in purification technologies on a large scale. Additionally, ARB is aware that some of the merchant hydrogen facilities marked as serving oil refining in the Pacific Northwest National Laboratory dataset currently supply California's hydrogen fueling stations. However, the amounts of hydrogen delivered from these production facilities to FCEV fueling stations are extremely small compared to their capacities (<<1%). ARB anticipates that the vast majority of these facilities' operations are for oil refining purposes as indicated in the dataset and will not be viable sources to support a larger hydrogen fueling market. Finally, Figure 35 shows no growth in in-state merchant hydrogen production through 2023. Growth may occur during this period, though ARB is not aware of current plans to do so, and feedback from industry stakeholders indicates project development timelines of up to 5 years once the need for a new hydrogen production facility is identified.

Figure 35 further demonstrates that the expected 2023 demand from light-duty FCEVs alone is equivalent to nearly half of the non-oil, merchant, gaseous and liquid hydrogen production capacity in the state (and roughly equal to either one individually, according to Figure 34). This will occur at a time when it is not yet expected that the demand from other industries, especially the oil refining industry, will sufficiently reduce to allow significant redirection of the hydrogen to direct transportation fuel use. If growth in other transportation sectors, such as medium- and heavy-duty vehicles, occurs during the same period, demand could even approach or exceed all of the current in-state production capability. With transportation fuel hydrogen consumption potentially representing such a large amount compared to the total of existing production capacity, there is a clear need to begin developing strategies to ensure future hydrogen demand can be met with sufficient production capacity growth.

It is critically important to ensure that future additional hydrogen production capacity is developed in-state. California's fuel and energy regulations such as SB 1505 and LCFS ensure a higher implementation of renewable, low-GHG, and low criteria pollutant resources in the hydrogen production lifecycle than if the fuel were to be produced in another state. Emissions associated with hydrogen transportation alone can represent a significant portion of well-to-wheel greenhouse gas and criteria pollutant emissions. This is especially true for gaseous transportation over long distances, which would require more vehicle-miles to transport the same amount of hydrogen as liquid hydrogen. There is also additional cost associated with longer-distance fuel transport, which can ultimately be passed on to the hydrogen consumer. Thus, in order to continue ensuring hydrogen meets and even exceeds the State's environmental goals and FCEV drivers' expectations of environmental benefits and costs, strategies should focus heavily on in-state production capacity and renewable production methods in particular. The Energy Commission has begun an effort to explore co-funding such a renewable hydrogen production facility in-State; ARB finds that this is a timely and necessary development and should continue to be pursued [31]. Additional State funding resources available to current and future hydrogen producers include the sales and use tax exemption and energy bond financing programs through the California Alternative Energy and Advanced Transportation Financing Authority and the California Lending for Energy and Environmental Needs program from the state's Infrastructure Bank [36].

Hydrogen Fueling Station Performance Standards and Technology

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

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

Hydrogen fueling stations are rapidly evolving in capabilities and design with each successive set of grant awards issued through AB 8 funding programs. As station technology continues to mature and greater numbers of FCEVs are deployed on California's roadways, it is important to ensure that new stations continue to meet customer expectations of the retail fueling experience. Greater numbers of FCEVs on-the-road will require not only greater numbers of stations, but also stations with greater fueling capacity, increased capabilities for reliably meeting performance criteria, and greater capacity for fueling multiple vehicles at once than hydrogen fueling stations funded to date. Today's network already exhibits the need for station designs with these improved capabilities. Some stations awarded funding as recently as 2014 have reported dispensing the full station's capacity of fuel in a single high-use day. Stations and FCEV drivers have also reported long lines for fueling during peak hours at some of the more heavily utilized stations. ARB recommends the following guidelines for expectations of station technical capabilities in future State-funded programs in order to anticipate future needs of FCEV drivers. Further discussion for those interested in participation with the HyStEP[12] program is provided in Appendix G.

Defining an Open-Retail Station

While a hydrogen fueling station is considered operational for grant agreement purposes once it has demonstrated the technical capability to fuel a single vehicle, an Open-Retail station meets several additional technical and performance requirements required to provide the full retail sale experience customers expect. Open-Retail stations demonstrate this capability through a series of performance validation steps, including California Department of Food and Agriculture (CDFA) Division of Measurement Standards (DMS) testing for dispensing meter accuracy, HyStEP confirmation of the station's ability to meet industry-standard fueling protocols, and separate testing of point-of-sale capabilities and hydrogen quality. The current process from Operational to Open-Retail is illustrated in Figure 36[13].

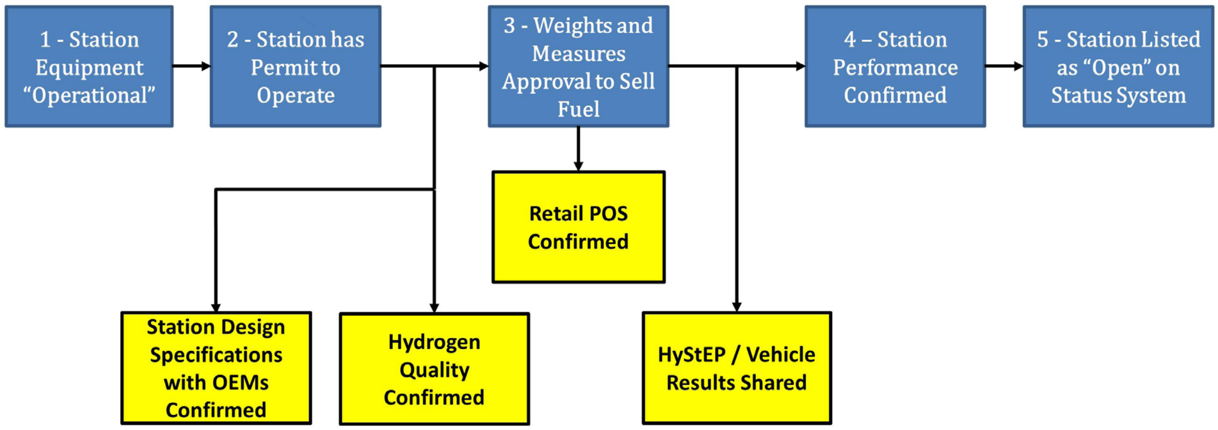
California's State co-funded hydrogen fueling network is approaching the point of being comprised entirely of Open-Retail stations. The Energy Commission's GFO 15-605 significantly

12 The HyStEP device was designed and built by Sandia National Laboratories, the National Renewable Energy Laboratory, and Powertech Labs with funding provided by the DOE Fuel Cell Technology Office's H2FIRSTprogram.

13 Appendix F provides more complete definitions of these and other station status definitions.

advanced this expectation by requiring that all funded stations have a plan for becoming an Open-Retail station within 180 days of meeting the agreement requirements for achieving operational status. Going forward, Open-Retail stations should remain the expectation for all State co-funded stations. ARB recommends that the Energy Commission consider shortening the allowable time for making the transition from Operational to Open-Retail to as low as 90 days.

Figure 36: Process Flow for Hydrogen Fueling Stations to Achieve Open Status[14]



Hydrogen Station Performance Confirmation

Confirmation of station performance in California has been enabled by the multi-year efforts of the HyStEP program and device implementation, designed to streamline confirmation of hydrogen dispensers' ability to conform to the SAE J2601 fueling protocol. Prior to the introduction of HyStEP, individual auto manufacturers had to separately schedule time with the station developer to test the performance of the station. Often, several testing visits would be required of each auto manufacturer, and scheduling conflicts were likely to occur. The result was an exceptionally long testing period required for station performance confirmation. With HyStEP or a similar device, the ultimate goal is that an independent party separate from the auto manufacturers assesses a station's performance and provides confirmation with a single week's worth of testing, as shown in Figure 37. In the interim, HyStEP is currently used as a first independent test of station performance, with confirmation determined collaboratively with the station developer and auto manufacturers who may also perform their own independent testing after reviewing ARB's report of findings made through the HyStEP device. Report review may result in one of several outcomes, as shown in Figure 38; if a determination is made that the station does not demonstrate compliance with SAE J2601, then the station developer is responsible for making adjustments to their equipment and scheduling a follow-up test. If no follow-up tests are required, the total process currently requires two weeks in most cases.

14 OEM stands for Original Equipment Manufacturer and in this context is synonymous with auto manufacturers. POS stands for Point of Sale.

Figure 37: Current Station Confirmation Process vs. Future Process with HyStEP[15]

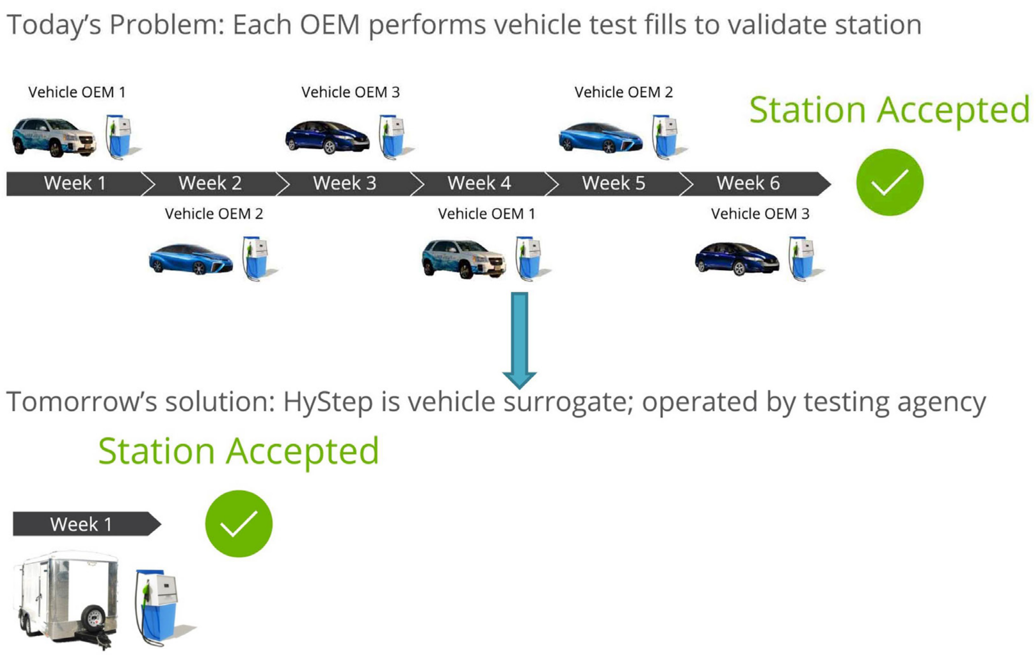
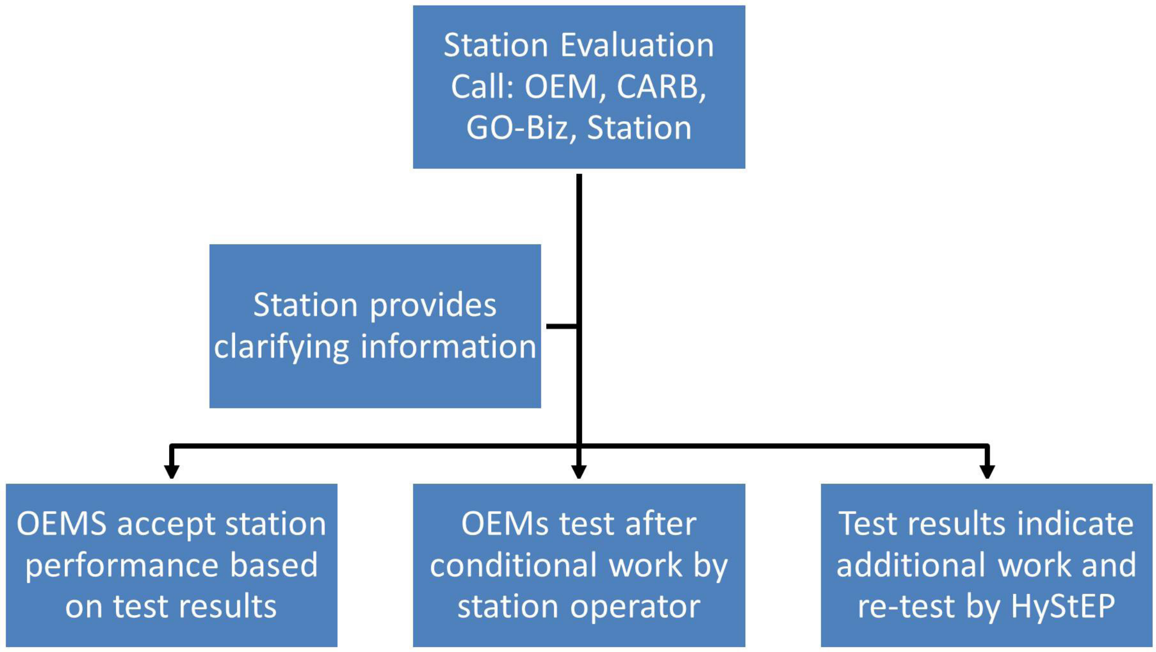


Figure 38: Collaborative HyStEP Evaluation Process



15 Reproduced with permission of Terry Johnson from Sandia National Laboratories; originally created by Terry Johnson, Pacific Northwest National Lab, and the H2Tools program (https://h2tools.org/)

The HyStEP device is trailer mounted and features three 76L Type IV tanks (3.1 kg hydrogen capacity each, at 70MPa). The two images in Figure 39 show the HyStEP device in use and several of its main components. The device includes Infrared Data Association (IrDA) communications, electronics, pressure and temperature transducers, nitrogen supply panel, hydrogen and fire sensors, a data acquisition unit, and a Compressed Gas Association-style collapsible vent stack. The device and post processing software are designed to analyze a fill using the CSA HGV4.3 test procedures. The device collects temperature, pressure, and mass flow rate data to help assess whether a dispenser is capable of following the requirements of the table-based approach in the SAE J2601-2014 fueling protocol. This protocol defines pre-calculated boundaries for safe pressure ramp rate of an FCEV's hydrogen fuel tank during a single fill event. Limits of the tank pressure ramp account for ambient temperature, the pre-cooled hydrogen temperature, and the initial fill state of the tank. Based on these parameters, an average pressure ramp rate and pressure bounds are specified by cross-referencing a set of lookup tables in SAE J2601. Dispensers compliant with the standard are able to maintain a pressure ramp rate sufficiently close to this pre-calculated average ramp rate without diverging outside of the pressure bounds.

Figure 39: HyStEP Device[16]

On June 2, 2016, the California Fuel Cell Partnership (CaFCP) OEM (auto manufacturer) Advisory Group submitted a letter to ARB and the HyStEP Stakeholder Partners (U.S. Department of Energy, CDFA DMS, South Coast Air Quality Management District, and the Energy Commission) in support of deploying HyStEP to address the critical need to test, validate, and open stations [46]. That industry support continues today, with anticipation for the program to continue evolving in scale and capability, and the potential for a third party (possibly a private entity such as a Nationally Recognized Testing Laboratory) to become involved in station performance confirmation testing.

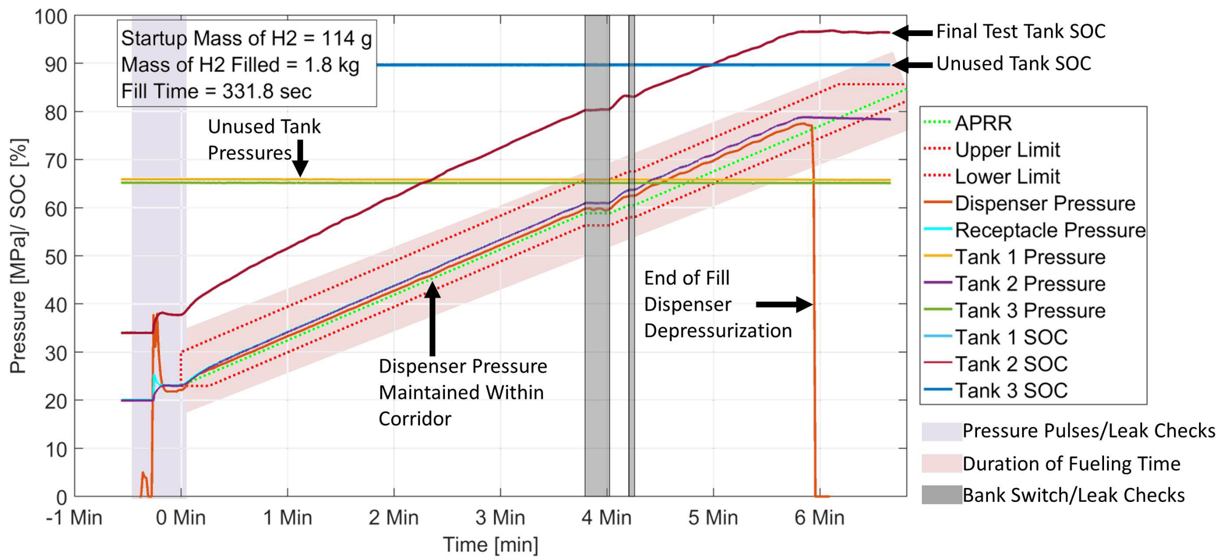
As shown in Figure 36, HyStEP is typically deployed after Hydrogen Quality Testing and Dispenser Type Certification have been successfully achieved. Certain requirements must be met before HyStEP can be deployed to a station; prior to testing, ARB staff sends a checklist to the station developer to help ensure these conditions are met. Given the limited availability of the single HyStEP device, ARB consults with a station confirmation group to determine HyStEP deployment priorities based on station readiness, the potential network effect of stations, and auto manufacturer resources[17]. Whenever possible, ARB clusters consecutive tests in northern California or southern California to minimize travel time.

16 The image on the left shows the device next to a dispenser during testing. The three storage tanks are visible at the bottom of the trailer. The image on the right shows the operator panel, which includes analog gauges, touchscreen, vent regulators, emergency shutdown device, audio/visual alarm, receptacle, and nozzle.

17 The station confirmation group consists of ARB, GO-Biz, the Energy Commission, and auto manufacturers.

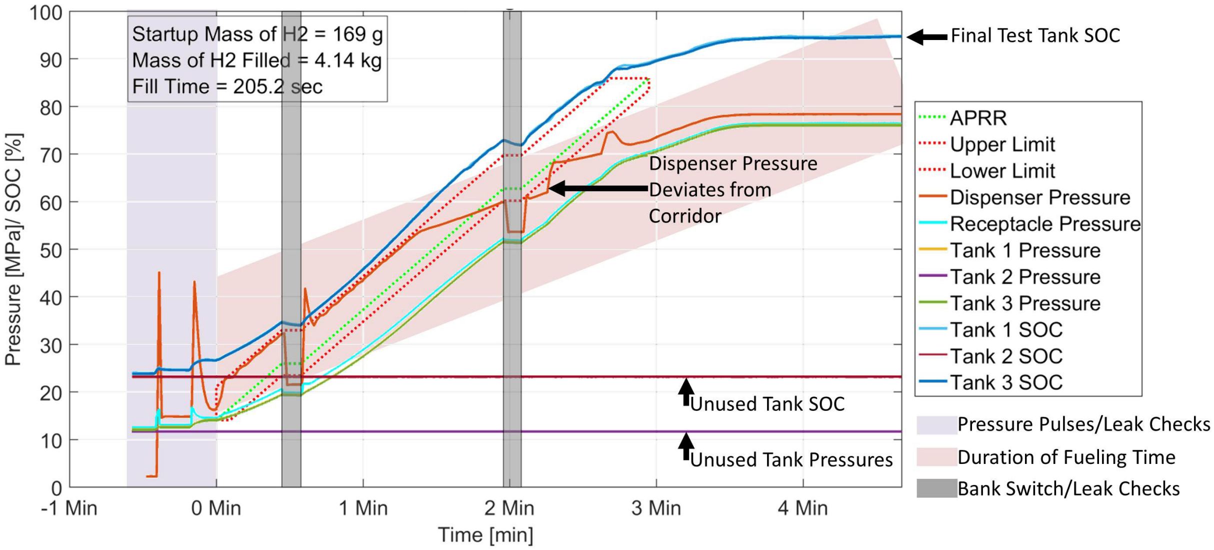
One of the key metrics for determining compliance with SAE J2601-2014 is demonstration that the station's dispenser can maintain a safe pressure ramp rate (of the FCEV's onboard tank), within a corridor of acceptable values. Upper and lower limits of the corridor and the nominal average ramp rate are determined by several variables, including initial tank pressure and temperature, ambient temperature, hydrogen dispensing temperature, and others. HyStEP data collection and evaluation provides graphical confirmation of this capability, similar to Figure 40. Several annotations not typically included in HyStEP reports have been added to the figure for illustrative demonstration. Fill performance graphs like Figure 40 are useful guides for determining compliance with the fueling protocol, but are subject to interpretation and must be informed by additional observations during testing and knowledge of the station design. For example, all fuelings typically begin with a series of pressure pulses and leak checks to gauge initial fill pressure and filling hose integrity, shown by the dispenser pressure (brown line) spikes in the purple shaded region of the figure. The exact duration of these pulses as calculated by the dispenser may require additional information provided by the station operator.

Figure 40: Sample Passing HyStEP Pressure Data



After these checks, filling begins (indicated by the red shaded area), which should nominally follow a calculated average pressure ramp rate (lime green dashed line). For a successful fill, the dispenser pressure must stay within the pressure corridor (upper and lower limits are shown by red dashed lines). The fill in Figure 40 is an example of a dispenser with passing pressure control, as the dispenser pressure always stays within the pressure corridor. Note that in all HyStEP outputs, all three tanks' pressure and state of charge are graphed, though in this example only one of the three tanks was required. Also, some of the fill time is utilized for mid-fill leak checks and/or hydrogen supply storage tank bank switching.

Figure 41: Sample Divergent HyStEP Pressure Data



Several issues may cause a determination that a dispenser is unable to perform according to expectations set in SAE J2601-2014. An example of a test that diverges from J2601 specification is shown in Figure 41. It is important to remember that a single divergent test may not ultimately result in a final determination of a station being unable to meet the protocol standards. Station equipment fine-tuning and re-tests often occur throughout the course of a full week of HyStEP testing, and data are collected and analyzed for all deviating and passed tests. In this example, the deviation occurs around the two-minute mark when the dispenser's pressure falls below the lower limit and is not able to re-enter the pressure corridor for the entire remainder of the fill. A fill with a pressure curve as shown in Figure 41 either indicates a temperature fallback has occurred or a leak has occurred somewhere in the dispensing system. Temperature fallbacks occur when the dispenser temperature cannot maintain the fill within the necessary temperature corridor, and a new (higher) temperature protocol is then implemented, which generally requires a slower pressure ramp rate.

An annotated example of a successful test fill's temperature data is provided in Figure 42. As with pressure data, temperatures are always provided for all three HyStEP tanks, whether or not they are used. Key features of passing temperature performance include dispensed hydrogen temperature entering the required temperature corridor within 30 seconds of start of fueling, the dispensed hydrogen temperature remaining within the corridor for the entire duration of the fill, and the mass flowrate not exceeding a maximum 60 grams per second. By contrast, Figure 43 displays a case where dispensed hydrogen temperature exceeded the allowable upper limit of the corridor early in the fill and was not able to re-enter the corridor. Additionally, the mass flow rate temporarily spiked above the 60 g/sec limit. Temperature performance similar to that shown in Figure 43 indicates a divergent fill.

Figure 42: Sample Passing HyStEP Temperature Data

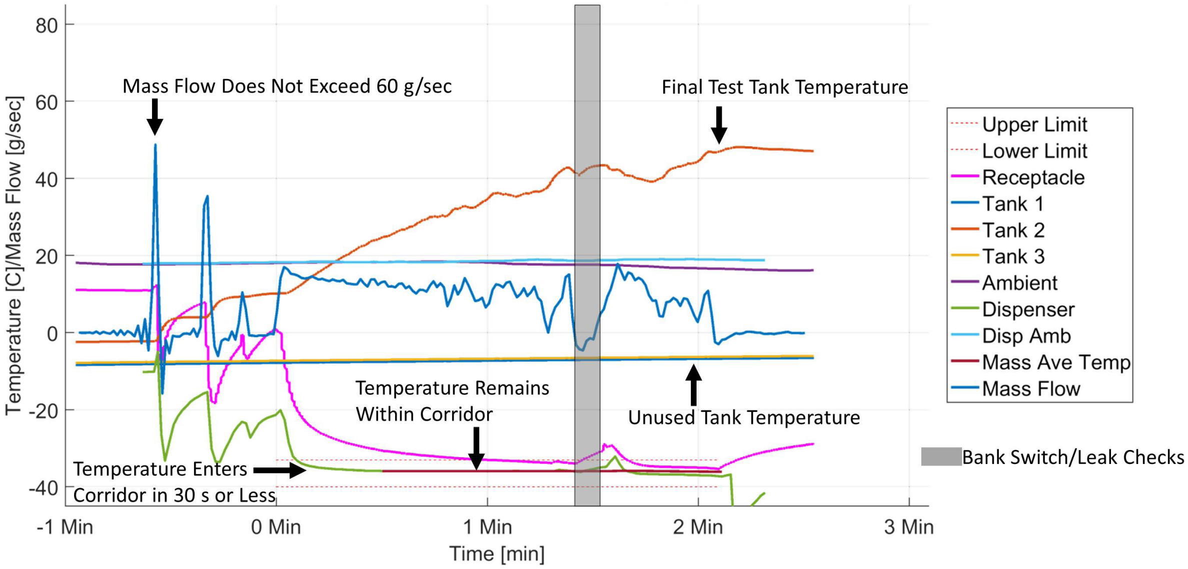
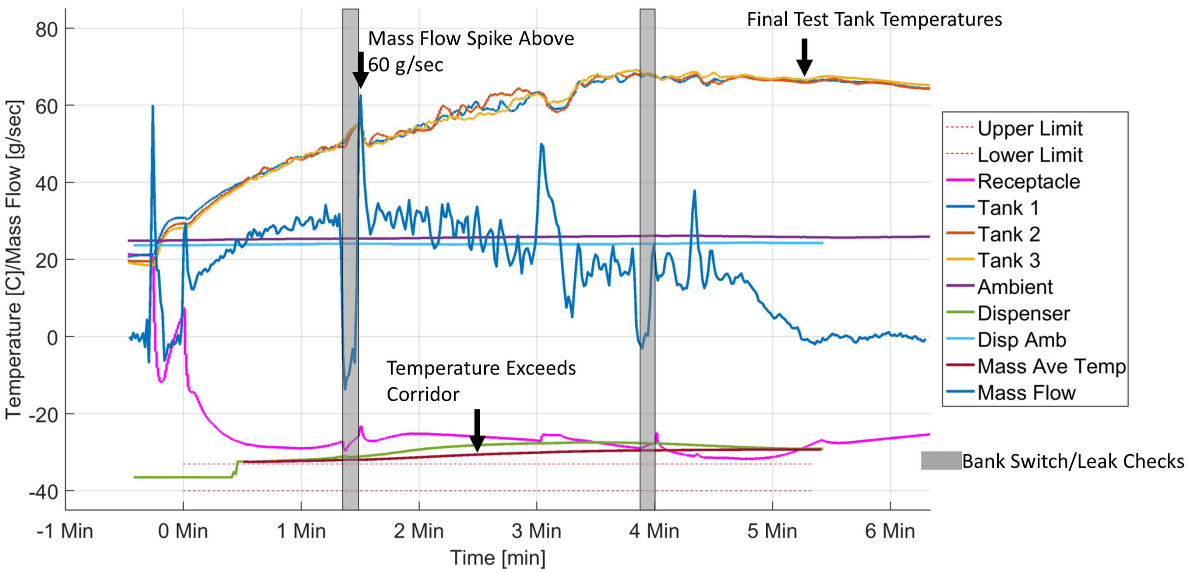


Figure 43: Sample Divergent HyStEP Temperature Data



HyStEP is the first device developed to implement testing according to CSA HGV 4.3. The current software is only designed to evaluate station performance according to the 2014 version of the SAE J2601 fueling protocol and CSA HGV 4.3 test method. Additional post processing modifications will be needed to evaluate stations under different fueling protocols. Development of standards and test procedures is most effective when integrating insights gained from field experience. Both the SAE J2601 fueling protocol and CSA HGV 4.3 test procedure are continuing to be modified, and ARB is participating to ensure recommendations and clarifications based on field experience will be implemented to streamline the field testing and analysis processes. ARB anticipates continuing this active participation as standard revisions continue into the future.

Going forward, ARB anticipates three main activities related to HyStEP. The first major activity will focus on participation in standards and testing procedure updates. Observations from the HyStEP field testing reveal that procedures outlined in standards and codes can be interpreted or evaluated several ways. This is typically a result of unintended ambiguity in the language of the standard. This ambiguity needs to be eliminated in order to ensure station fueling protocol requirements remain clearly definable and interpreted by all parties. Other test procedures are challenging and sometimes not possible to perform in the field during a station performance validation test. Definition of Factory Acceptance Tests is anticipated for a future version of CSA HGV 4.3, which would include methods to perform tests in the laboratory or factory that are difficult or inefficient to complete in the field, among other tests. Station Acceptance Tests would be simultaneously delineated and would likely be an abbreviated set of the tests completed in the field today. Additionally, HyStEP or a similar device could also be utilized for analyzing other fueling protocols, such as J2601-2 (Gaseous Hydrogen Powered Heavy Duty Vehicles), J2601-3 (Gaseous Hydrogen Powered Industrial Trucks [Fork lifts]) or J2601-4 (Under development-Gaseous Powered Devices Ambient Temperature or Orifice Fill). These additional protocols would need post processing software modifications for HyStEP or a similar device in order to enable evaluation of station performance for these specialized applications.

The second main activity will be the ongoing testing of hydrogen fueling stations currently in development. Based on the expected timeline of station development presented in Appendix B, ARB anticipates HyStEP or a similar device could be used to test approximately 32 more stations through 2020. As discussed previously, station readiness, location, and availability of the HyStEP device will play a large role in the ultimate order of station testing. In addition, construction delays are common and often unpredictable, leading to large modifications of the planned HyStEP schedule. Finally, ARB anticipates participating in development of a formalized State or third-party confirmation/certification process. While there is a clear need to make advances toward such a process, its definition and structure are still largely undetermined. The following concepts are currently under consideration and early discussions have begun among industry partners. Additional options beyond those listed below may be introduced as a formal process is further developed:

- Develop a formalized HyStEP station certification process
- Incorporate CSA HGV 4.3 into NFPA 2, which is expected to undergo revision in 2020.
- Develop a third-party testing and certification process

Performance and Design Standards

Several codes and standards committees have been working in earnest over several years to develop science-based standards for hydrogen station design and operation, based on expert guidance. These codes and standards ensure that hydrogen station operations provide, safe, fast, and reliable fueling to all customers. The following set of standards comprises recommended references that all future station developers and operators should be required to adhere to:

- NFPA 2-2016: General guidelines for safe generation, storage, and handling of hydrogen; requirements can affect station design considerations
- SAE J2601-2016: Fueling protocol that ensures safe, fast fills are provided to customers
- SAE J2600-2012: Design requirements for fueling connections, including the nozzle
- SAE J2719-2011: Standards for hydrogen fuel quality for FCEVs
- SAE J2799-2014: Design requirements for interfacing with FCEV fueling receptacle, including communications standards
- CSA HGV 4.3-2014: Test method to validate conformance to SAE J2601.

As newer versions of these standards are finalized, they should be incorporated into future station funding requirements.

With regard to J2601, the 2016 revision introduced the full specification of the formula-based approach (also called the MC Method) for a dispenser's fueling protocol. The formula-based approach relies more heavily on real-time, dynamic data from the fueling to enable the dispenser to adjust fueling rate based on real-time conditions rather than potentially more stringent assumptions used to define fueling corridors in the table-based approach. Monitored parameters include ambient temperature, dispenser pressure, and tank temperature. Since the approach describes methods of altering dispenser performance in response to the dynamics of the fueling operation, it may prove to be a more flexible protocol and allow dispenser designs to more easily, reliably, and consistently meet fueling performance expectations and be more customer-friendly. Prior versions of the standard included finalized specification of only the table-based approach tested by HyStEP, and included updates to the formula-based approach's technical development as an appendix. In the newest version, the formula-based approach is included in the main part of the standard, implying it should be a valid option for station developers going forward.

Although CSA HGV 4.3-2014 does not currently include test methods to validate a dispenser's conformance to the formula-based approach, it is anticipated that the next version (potentially to be released in late 2017 or early 2018) will address this gap. ARB therefore recommends that future State co-funded stations should be allowed to choose the most appropriate approach for their design, whether table-based or formula-based. Additional post-processing software modification may be needed for the HyStEP (or similar) device to address the new formula-based approach while maintaining the ability to test the table-based approach. ARB is actively participating in the standards update and providing feedback based on the experiences gained in the field.

Ensuring Consistent Hydrogen Quality

Hydrogen delivered to fuel tanks onboard FCEVs must be of high purity. Contaminants in the hydrogen fuel can have the potential to degrade performance and durability of the fuel cell stack, or potentially completely block the electrochemical activity of the cells. Depending on the contaminant, the impacts may or may not be reversible, but any loss in performance or availability of the vehicle represents a significant cost to the driver, fuel provider, and/or the auto manufacturer. Ensuring dispensed hydrogen quality is therefore one of the primary concerns of hydrogen fueling station operations. The requirements of GFO 15-605 included testing for dispensed hydrogen quality prior to declaring a station operational, once every three months thereafter, and any time a maintenance operation occurs that has the potential to introduce contaminants. This testing is usually completed by the station operator sending a sample to a private laboratory to complete a full-spectrum test for contaminants per SAE J2719, listed in Table 4. In addition, CDFA DMS has recently begun its hydrogen station fuel quality testing program, which includes random sampling and testing in response to any public complaints the agency may receive. The combination of these efforts appears to be working well, and it is recommended that they be continued in the foreseeable future.

Table 4: Hydrogen Contaminant Species per SAE J2719

Impurity Source	Typical Contaminant
Air	N2, NOx, (NO, NO2), SOx (SO2, SO3), NH3, O3
Reformate hydrogen	CO, CO2, H2S, NH3, CH4
Bipolar metal plates (end plates)	Fe3+, Ni2+, Cu2+, Cr3+
Membranes (Nafion)	Na+, Ca2+
Sealing gasket	Si
Coolants, DI water	Si,Al, S, K, Fe, Cu, Cl, V, Cr
Battlefield pollutants	SO2, NO2, CO, propane, benzene
Compresors	Oils

In addition to regular testing of dispensed hydrogen quality, continuous in-line testing may be recommended for certain applications where hydrogen is generated or purified on-site. In-line testing would sample hydrogen at some point along the dispensing and/or production stream, depending on station design, component costs, and component capabilities. Given the limits of field service, an inline device would likely not be capable of sensing the full suite of potential contaminants that are included in regular quality testing. Instead, an in-line device would likely test for the presence of one or a few “canary” species that indicate a problem may exist with the purity of the hydrogen supply, in real time. This would allow station operation staff to shut down the hydrogen system on-site before contaminants are dispensed to a driver’s vehicle. Currently, there is limited availability of off-the-shelf sensing devices that station developers could incorporate into their designs. Additional research and product development are necessary to produce a product with sufficient technical performance, cost, and flexibility for system integration in the field. Due to the limited nature of available solutions, ARB recommends that in-line testing devices not be required at all stations, though they should be strongly encouraged or incentivized at stations with on-site production or purification.

Dispensing Meter Accuracy and the California Type Evaluation Program (CTEP)

As with any transportation fuel sold in a retail setting, DMS performs testing of hydrogen dispensers installed in California in order to ensure that they accurately meter and report dispensed amounts of hydrogen. Accurate metering protects the consumer from over-paying for fuel they did not receive, the fuel retailer from under-billing for fuel dispensed, and ensures that all suppliers are fairly competing with equivalent expectations of the fuel dispensing process. DMS achieves this by utilizing the Hydrogen Field Standard (HFS), a device developed by the National Renewable Energy Laboratory (NREL) that is able to accurately assess the amount of fuel dispensed in the field at a fully constructed and operational hydrogen fueling station. Dispensers are required to adhere to the requirements of National Institute of Standards and Technology (NIST) Handbook 44, Section 3.39. This standard has also been adopted into California Code of Regulations Title 4, Division 9 with expanded specification of four accuracy classes for certification, shown in Table 5. The more lenient classes are scheduled to sunset over time, allowing equipment manufacturers needed research and product development time to design components that can meet the most stringent tolerances.

The program includes two major aspects: type certification and verification testing of individual dispensers. Type certification occurs the first time a new dispenser design is installed in California. With this first dispenser, DMS will use the HFS to determine compliance with the accuracy classes of NIST Handbook 44 and issue a type certification for the most stringent accuracy class to which the dispenser demonstrates compliance. To date, the four dispenser designs listed in Table 6 have received a type certification at the 5% accuracy class (note that 5743a-15 is an update to 5743-15). Once a dispenser design is type-certified, additional copies of that dispenser may be installed at additional locations across the state with an abbreviated testing schedule. This testing may be completed by DMS or a Registered Service Agent (RSA; may be a local agency or a private company), provided that notification is given to the local weights and measures official and the official witnesses the testing if it is completed by an RSA. These repeat installations must verify that the dispensers meet the acceptance tolerance for the accuracy class issued during type evaluation. Verification of metering accuracy to the type evaluation allows issuance of a seal indicating the station is approved for retail sale of hydrogen. Every year, dispensers must then also demonstrate the ability to meet the maintenance tolerances listed in Table 5.

Table 5: Summary of CTEP Hydrogen Dispenser Accuracy Class Testing

Testing of Accuracy Classes and Tolerances for Hydrogen Gas-Measuring Devices (Two devices were re-tested after modifications)				
Accuracy Class	Number of Hydrogen Gas Measuring Devices Tested	Acceptance Tolerance	Maintenance Tolerance	Number of Devices in Compliance[3]
2	12	1.5%	2.0%	0
3.0[1]	12	2.0%	3.0%	0
5.0[1]	12	4.0%	5.0%	6
10.0[2]	12	5.0%	10.0%	8
1 The tolerance values for Accuracy Classes 3.0 and 5.0 hydrogen gas-measuring devices are applicable to devices installed prior to January 1, 2020. 2 The tolerance values for Accuracy Class 10.0 hydrogen gas-measuring devices are applicable to devices installed prior to January 1, 2018. 3 Devices that meet Accuracy Class 5.0 also meet Accuracy Class 10.0. Total Devices in Compliance is not the sum of both Classes.				Total Devices in Compliance 8

Table 6: Dispensers Currently Listed with Type Certification through CTEP[18]

Certificate Number	Company	Models	Effective Date
5743-15	Bennett Pump Company	H10	6/10/2015
5743a-15	Bennett Pump Company	H10	12/22/2015
5741-15	CSULA	112892	4/29/2015
5778-16	Equilon Enterprises LLC dba Shell Oil Products	RHM08 Mass Flow Sensor, RHE08 Mass Flow Transmitter	2/22/2016
5774-15	Quantum Fuel Systems Technologies Worldwide	113892	11/25/2015

This CTEP program for hydrogen fuel dispensers has enabled California to be a leader in retail sale of hydrogen. In addition, the implementation of the expanded accuracy classes (3%, 5%, and 10%) was first developed in California in recognition of the limitations of current dispensing equipment. The work of the program was instrumental in the expansion of specifications in NIST Handbook 44 to include a 7% accuracy class (5% acceptance, 7% maintenance tolerances). This will provide flexibility for dispensers installed in any state that references the national standard provided by Handbook 44. Thus, this program has demonstrated far-reaching success and should continue to be a part of the requirements for future hydrogen fueling stations.

Fueling Pressure

Based on the known plans for auto manufacturers' current and future FCEV deployments, ARB recommends that future station funding is primarily for light-duty H70 (i.e. 70MPa, 700 bar, 10,000 psi) fueling, as was the focus of GFO 15-605. Inclusion of H35 for fueling applications beyond light duty passenger vehicles may be included at future stations, but not at the expense of the retail experience designed for light-duty H70 fueling.

Point of Sale

In GFO 15-605, the Energy Commission implemented a requirement for the accepted payment methods at hydrogen fueling dispensers. This requirement was modeled after industry input, which specified the range of credit and fleet cars that should be accepted by State co-funded stations [47]. Discussions with industry indicate that these recommendations are still appropriate,

18 All certificates issued to date have been for the 5% accuracy class

and future stations co-funded by the State should meet the same requirements for payment methods.

Station Availability

Over the past year, multiple stakeholders working through the CaFCP have clarified definitions and metrics for various terms related to measuring and ensuring the likelihood that customers will be able to fuel at Open-Retail stations throughout the day. The following definitions have been suggested, per industry consensus [48]:

Uptime: In most cases, the portion of a 24-hour day that a station is operational. Hours when a station is not operational because of a malfunction or work that takes it offline count against the station uptime. Hours when the station must close due to local regulations do not count against the station uptime.

Example: Local regulations limit station operations to between 6am and 10pm. The total potential uptime is then 16 hours. On a given day, the station is taken offline for scheduled maintenance that requires two hours of work. That day, the station's uptime is 14 hours.

Availability: The ratio (expressed as a percentage) of uptime to total potential operational time accounting for local regulations.

Example: The above station is operational on the maintenance day for 14 of 16 total potential hours. On that day, the station's availability is 87.5%.

Reliability: Currently, a more qualitative representation of not only the availability to fuel, but also the ability of the station equipment to provide fueling performance as expected. For example, reliability could include consideration of how often the station unexpectedly terminates fueling, provides an incorrect receipt, or requires multiple attempts to initiate fueling, among other concerns. Fundamentally, reliability is then a statistical measure of a station's full performance capability. Although stations are currently outfitted to provide high-level station status information through the CaFCP's Station Operational Status System (SOSS), the data collected are currently only sufficient to describe uptime and availability. Appropriate sensor and data processing equipment to characterize reliability may currently be too great a cost to incorporate, but future stations may be able to provide such detailed data if needed.

All stations should implement design and operations practices that maximize availability and reliability to the maximum degree possible. Drivers are likely used to high degrees of availability based on their experience with conventional gasoline vehicles, and hydrogen stations will need to replicate this experience as nearly as possible. Today's Open-Retail stations are often capable of achieving high availability (95%+) on individual days, though long-term availability and reliability remain unknowns at the current time due to limited in-operation data. As with stations previously built with State co-funding, ARB recommends that all stations in the future be required to participate in the CaFCP's SOSS program. This program allows station uptime and availability to be reliably characterized and communicated to FCEV drivers through several outlets, including the mobile SOSS website[19], the CaFCP station map, and auto manufacturers' proprietary in-car applications.

The Energy Commission may also find it advantageous to tie station availability to disbursement of operations and maintenance funds through its future funding programs. Release of funds could be contingent upon stations meeting a time-averaged minimum availability metric (for example, 95% average over the most recent 3-month period). A more flexible option could be to require that all stations that fall below a minimum acceptable average availability (for example, 80%) would need to provide a record of active engagement in finding solutions to rectify low availability before continuing funds disbursement. Alternatively, the disbursement amount

19 https://m.cafcp.org

could be pro-rated based on the station's availability compared to a benchmark expectation. For example, a station that receives a $100,000 operations and maintenance grant and has a 1-year availability of 90% compared to a 95% benchmark would receive $95,000 instead. ARB recommends that the appropriate station availability metric expectations for these options should be developed after careful consideration of observed station availability for the currently Open-Retail stations. This review should be completed in cooperation with the CaFCP.

Signage

Several of the stations awarded under GFO 15-605 proposed placement of the hydrogen dispenser in-line with the existing gasoline dispensers at the host site. This places them under the same canopy as all other fueling that currently occurs at the station. This design decision enhances the customer perception of retail hydrogen fueling as an equivalent experience to conventional gasoline. At the same time, it accentuates the need for clear signage on-site to direct hydrogen and gasoline customers to the appropriate dispenser for their vehicle. In addition, station operators have reported gaining several insights over the past few years regarding effective techniques for communicating proper hydrogen dispenser use to FCEV customers. The Energy Commission currently requires station developers and operators to incorporate appropriate educational signage at the station site and encourages developers to engage with local officials to establish pathfinding and directional signage to the station. ARB recommends that the scope of on-site signage requirements be expanded to include communication of hydrogen dispenser location and fueling process in a manner that provides flexibility for developers to design the most appropriate solution for their station while providing the greatest enhancement possible to the customers' fueling experience.

Evolution of Station Design

The proposed stations and selected awards in GFO 15-605 made clear that station designs in 2017 continue the evolution of station capabilities that PON 13-607 represented in 2014. Designs with multiple dispensers, redundancy in the Compression-Storage-Dispensing (CSD) subsystems, simultaneous fills, and improved back-to-back fill capability signal that station designs are being built to more closely match the expected customer needs than most stations built in the past. At the same time, the analyses through the Annual Evaluations continue to show that projected throughput capacity will be exceeded by demand shortly after 2020, assuming business-as-usual growth of network capacity. These signals indicate that industry feels the market will support larger and more capable stations; network development would need to take full advantage of such an opportunity in order to maintain success of the California network.

Beyond these motivating factors, ARB has also maintained active dialogue with industry stakeholder members from the CaFCP in order to understand the industry's collective recommendations for station specifications, as well as concepts for future funding. Central to many of the recommendations is an underlying recognition that California's hydrogen fueling and FCEV markets have made the transition from the "pre-commercial" to "early commercial" phase. This transition implies greater and more well-defined station capacity across the network, the need for improved technical capabilities, and a quicker network deployment rate. Previously, CaFCP also included recommendations in their 2015 letter to the Energy Commission in response to the hydrogen solicitation concepts that would eventually become GFO 15-605 [47]. The earlier letter further referenced H2 Mobility and Nexant technical documents to convey technical performance specifications that stakeholders suggested for California's stations [49], [50].

ARB has considered these various reference materials, including the awards in GFO 15-605, and its own analyses and developed a set of recommendations for future station capacity and performance requirements that should meet industry and consumer expectations. These recommendations have been developed in the context of a network with varying station classifications, as first presented by ARB in its 2014 Annual Evaluation. In recognition of the insights gained over the past few years for various station uses and needs depending on the intent and the local fueling market's development status, ARB also expanded the number and clarified the intent of different station classifications. Table 7 provides ARB's latest recommendations for station capacity, while Table 8 provides recommendations for station technical performance. Capacity specifications in Table 7 are more detailed than ARB's previous recommendations, following the prior works' suggestions to recognize the relationship between rated capacity and station fueling performance. Thus, capacities for 24-hour, 12-hour, 3-hour peak, and 1-hour peak throughput are specified. Performance capabilities in Table 8 address minimum number of fueling positions, simultaneous fueling capability, and back-to-back fueling requirements.

Based on the current status of California's fueling network, coverage in general still remains a priority for development. However, the fueling market in some areas currently has more plans for development than in others. Because of these differences in market development plans, a more nuanced approach that has varying requirements based on local development may be necessary in future funding opportunities. For core market coverage, ARB has defined three types of stations intended for daily use, primarily to support local FCEV commuters.

The first station classification addresses opportunities across California to begin focusing on local capacity growth. Example markets may be the western end of Los Angeles (including Santa Monica, West Hollywood, and nearby cities) and the southern portion of the San Francisco Bay Area (including San Jose and surrounding cities). In these markets, large (by today's standards) stations of 600 kg/day 24-hour capacity and high technical capability should be prioritized. ARB suggests that this focus on capacity growth may be pursued as early as the next funding opportunity from the Energy Commission. Because the initial fueling markets in these areas are well developed, technical capabilities of new stations must correspondingly be required to support rapid growth of local FCEV adoption. ARB therefore recommends that these stations have the highest technical capability, with two or more fueling positions per station, simultaneous fueling, independent CSD or other design features to assure on-site redundancy and improved availability, and the most stringent back-to-back capabilities.

In other areas with an established local fueling network, there may still be a need for coverage to be the greater priority. For this reason, ARB recommends that these stations have a minimum 300 kg/day 24-hour capacity to enable the potential for greater numbers of these lower cost stations to be funded at a time. However, anticipating near-term rapid market growth, technical capabilities for these stations should still be high with added flexibility allowable on a case-by-case basis. Finally, in some core market areas, a new station would still be among the first few to establish local fueling. In these cases, ARB recommends the 24-hour capacity is still at least 300 kg/day in recognition of the current state-of-the-art and anticipation of future drivers' needs, but performance specifications can be somewhat relaxed, especially back-to-back fueling.

Finally, the design of the station network must deliver an ownership experience to FCEV drivers that is fully equivalent to conventional vehicle drivers. This necessitates network development that enables long-distance and destination travel via FCEV. The Coalinga and Santa Nella stations are examples of the former, while the Truckee and Santa Barbara stations are examples of the latter. For these stations, capacity must be more carefully considered. In general, high-capacity stations may have a more favorable business prospect [36]. However, the key to this improved business prospect is also high utilization (utilization is the ratio of throughput to capacity). At connector and destination stations, throughput is not expected to be consistent on either a weekly or even seasonal basis, and total utilization will likely remain low for several years. For this reason, ARB recommends these stations remain at a smaller 24-hour capacity of 200 kg/day. Additionally, these stations would likely not require more than a single fueling position, unless analysis of a specific site or upgrade project indicates otherwise. More advanced fueling capabilities may be optional or as required on a case-by-case basis.

Table 7: Recommendations for Station Fueling Capacity for Various Station Classifications[20]

Classification	Description	24-hour Throughput	12-hour Throughput	3-hr Peak Total Throughput	Peak Hourly Throughput
Core Market Area, Local Fueling Market Capacity Growth	Multiple local stations established; new capacity has greater priority than coverage	600+	480+	136+	48+
Core Market Area, Local Fueling Market Coverage Growth	Multiple local stations established; redundancy and coverage have greater priority than capacity	300+	240+	68+	24+
Core Market Area, Local Fueling Market Initiation	Among first 3 stations in a local fueling market	300+	240+	68+	24+
Intermittent Connector	Stations intended for long-distance fueling	200+	160+	44+	16+
Intermittent Destination	Stations intended for fueling at vacation locations	200+	160+	44+	16+

Table 8: Recommendations for Station Fueling Performance Capabilities for Various Station Classifications (back-to-back fueling specified for 4-kg fills, all fills should be less than 5 minutes)

Classification	Description	Fueling Positions	Simultaneous Fueling	On-Site Redundancy	Back-to-Back Fueling
Core Market Area, Local Fueling Market Capacity Growth	Multiple local stations established; new capacity has greater priority than coverage	2+	Required	Preferred	3 fills with 3-minute rests between, followed by 5-minute rests for 3 peak hours; <10-minute rest otherwise
Core Market Area, Local Fueling Market Coverage Growth	Multiple local stations established; redundancy and coverage have greater priority than capacity	2+	Required	Preferred	3 fills with 3-minute rest between, followed by 5-minute rests for 3 peak hours; <10-minute rest otherwise
Core Market Area, Local Fueling Market Initiation	Among first 3 stations in a local fueling market	2+	Required	Optional	5-minute rests between fills for peak 3 hours; <10-minute rest otherwise
Intermittent Connector	Stations intended for long-distance fueling	1+	Optional	Optional	5 fills with 10-minute rests between in one peak hour; <20-minute rest otherwise
Intermittent Destination	Stations intended for fueling at vacation locations	1+	Optional	Optional	5 fills with 5-minute rests between in one peak weekend hour; followed by 10-minute rests for 3 peak weekend hours; <20-minute rest otherwise

The one difference ARB projects between connector and destination stations is that destination stations may, at certain times of the year depending on location, experience a pronounced peak fueling demand. For example, this would correspond to drivers who make summer weekend vacations trips to Lake Tahoe and need to all fuel at the beginning of their trip home. Such a peak may also be experienced by a connector station, but may not be as pronounced and may

20 These specifications are intended to be nominal specifications. Stations with capacities above or below the indicated amounts may still serve the purpose described for any given station classification in this table. Consideration of the appropriate capacity for any given station will require informed consideration of several market viability factors and the status of the currently-funded hydrogen station network within the local region.

not occur as many times throughout the year, especially as long-distance travel usually offers multiple fueling opportunities along the trip (as the I-5 route between northern and southern California will soon offer for FCEV drivers). For this reason, ARB recommends that destination stations may need to be able to perform back-to-back fueling more frequently during peak hours than connector stations at the current time.

Mobile Fueling

Feedback provided by CaFCP indicates a preference for advancing requirements for multiple fueling positions at individual hydrogen fueling stations over the incorporation of design provisions and a plan to accommodate a mobile fueler. In the past, it has been hypothesized that one or more mobile fuelers could provide necessary backup performance to Open-Retail stations when they experienced an equipment malfunction or another issue that took the station offline. Such a mobile fueler would ideally be designed for contingency operation with retail dispensing either from its own onboard hydrogen storage or the station's storage. While this has the potential to ensure availability of hydrogen fuel to local customers for a greater amount of time, there are additional considerations that have challenged implementation. One difficulty is designing the station layout, including setback and vehicle circulation requirements, to accommodate the size of a mobile fueler. Another is difficulty in obtaining permits to operate the fueler in a variety of locations. Given the advances that have been observed in station design from GFO 15-605 and the dispenser recommendations presented through Table 8, ARB agrees that future State co-funded stations should not be required to accommodate a mobile fueler.

Carbon Intensities and Resource Consumption

With the addition of the 16 stations funded under GFO 15-605, projections for renewable hydrogen throughput in California have shifted. Notably, the previous funding program (PON 13-607) included a separate funding category for 100% renewable hydrogen stations, and individual grant awardees even outside this category made commitments for 100% renewable implementation. GFO 15-605 did not have a similar category, and applications committed to only the 33% renewable requirement, though applicants typically mentioned a desire to utilize more renewable hydrogen as station economics allowed. Thus, the share of renewable throughput expected from GFO 15-605 is less than previous funding rounds. Figure 44 shows that the new projection is for the hydrogen fueling station network to achieve 37% renewable implementation by 2023. This includes all 62 funded stations and 32 additional future stations assumed to comply with the minimum requirement of 33%. Enforcement of SB 1505's 33% requirement on stations without State funding would begin in 2020, when throughput is projected to exceed 3.5 million kg/year. This projection is based on the lesser of demand and capacity in each year, and only accounts for light-duty vehicle hydrogen throughput.

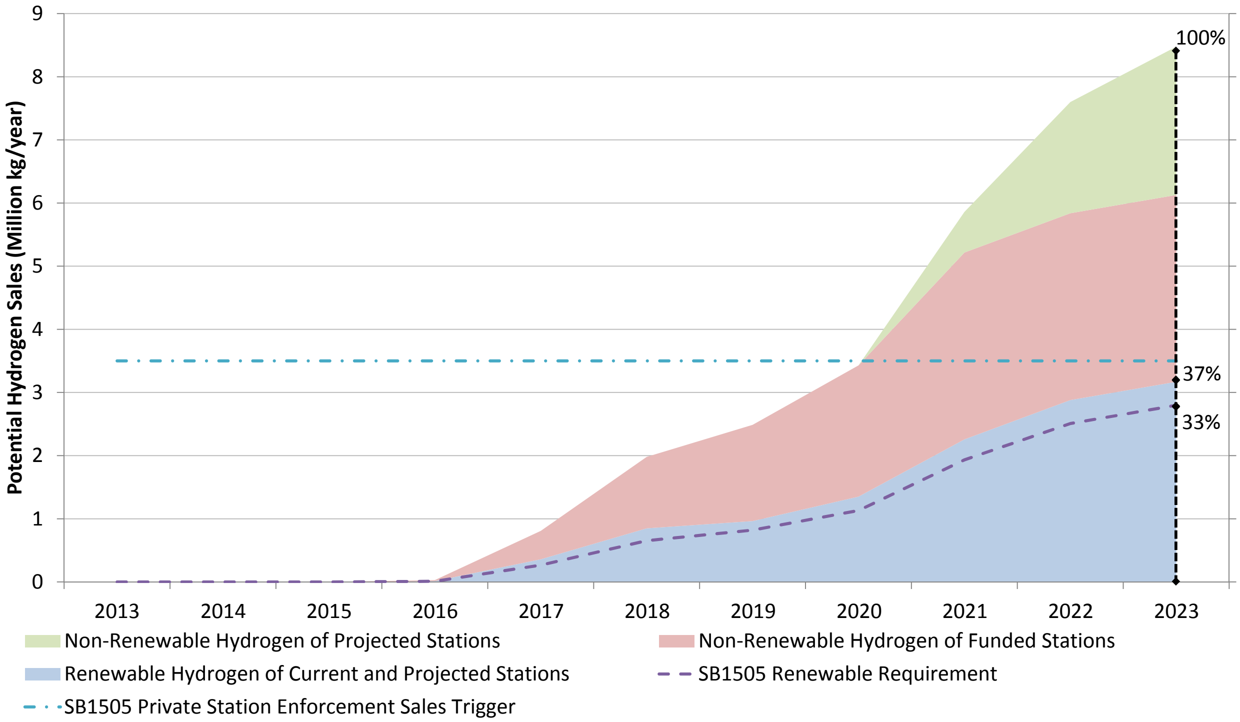
In the future, the LCFS program may become a driver for increased implementation of renewable and low-GHG hydrogen in California's fueling network. On December 5, 2016, staff of the ARB hosted a public workgroup meeting to discuss proposed concepts for changes to encourage greater participation of the hydrogen fuel industry in the LCFS program. An associated discussion paper was also made available for stakeholder and public comment[21] [51]. Major concepts include:

- Hydrogen will become a required regulated party once the SB 1505 threshold of 3.5 million kilograms sold in a year is reached in order to monitor compliance with the greenhouse gas emission and renewable energy resource requirements of SB 1505
- The point of regulation will need to be clarified. Staff proposed that station operators would be designated as the first-in-line credit generators, but are considering feedback and proposals on the topic
- Updated fuel pathways for the Lookup Table method of determining

21 Workgroup meeting materials covering the potential changes to hydrogen as a regulated fuel under LCFS can be reviewed at: https://www.arb.ca.gov/fuels/lcfs/lcfs_meetings/lcfs_meetings_2016.htm

the carbon intensity of hydrogen production
- Improved clarity in the definition of qualifying renewable electricity assets used in the production of renewable hydrogen
- Improved clarity on the treatment of renewable natural gas as a process or feedstock gas in the production of renewable hydrogen
- Various reporting and verification updates, including harmonization of reporting requirements with NREL templates already in-use to meet reporting requirements of Energy Commission-funded stations, and potential exemption from third-party verification requirements

Figure 44: Evaluation of Compliance with SB 1505 Renewables Requirement and Trigger for Enforcement of the Requirement on Stations without State Co-funding



Various stakeholders have in several contexts expressed interest in the potential for LCFS credit generation to play an important role in the economic viability of hydrogen fueling stations. Table 9 shows prospective LCFS credit values per kilogram of hydrogen dispensed, for all certified production pathways currently active in the program (Lookup Table pathways are not shown). A credit value of $100 per credit was assumed for these calculations. ARB's most recent monthly average trading price report indicated an average price of $93 per credit in May 2017; over the lifetime of the program, the monthly average has been as high as $122 per credit. In the 2016 Joint Agency Staff Report, LCFS credit values of $0.22 - $0.62 per kilogram were assumed for four station designs representative of the stations funded to-date. Even with these lower LCFS credit value assumptions, three of the four stations were found to have a profitability index (a measure of the potential revenue per dollar of investment) greater than one. If station developers are able to take advantage of greater LCFS credit values like those shown in Table 9, then future station projects may prove to be even more favorable business ventures.

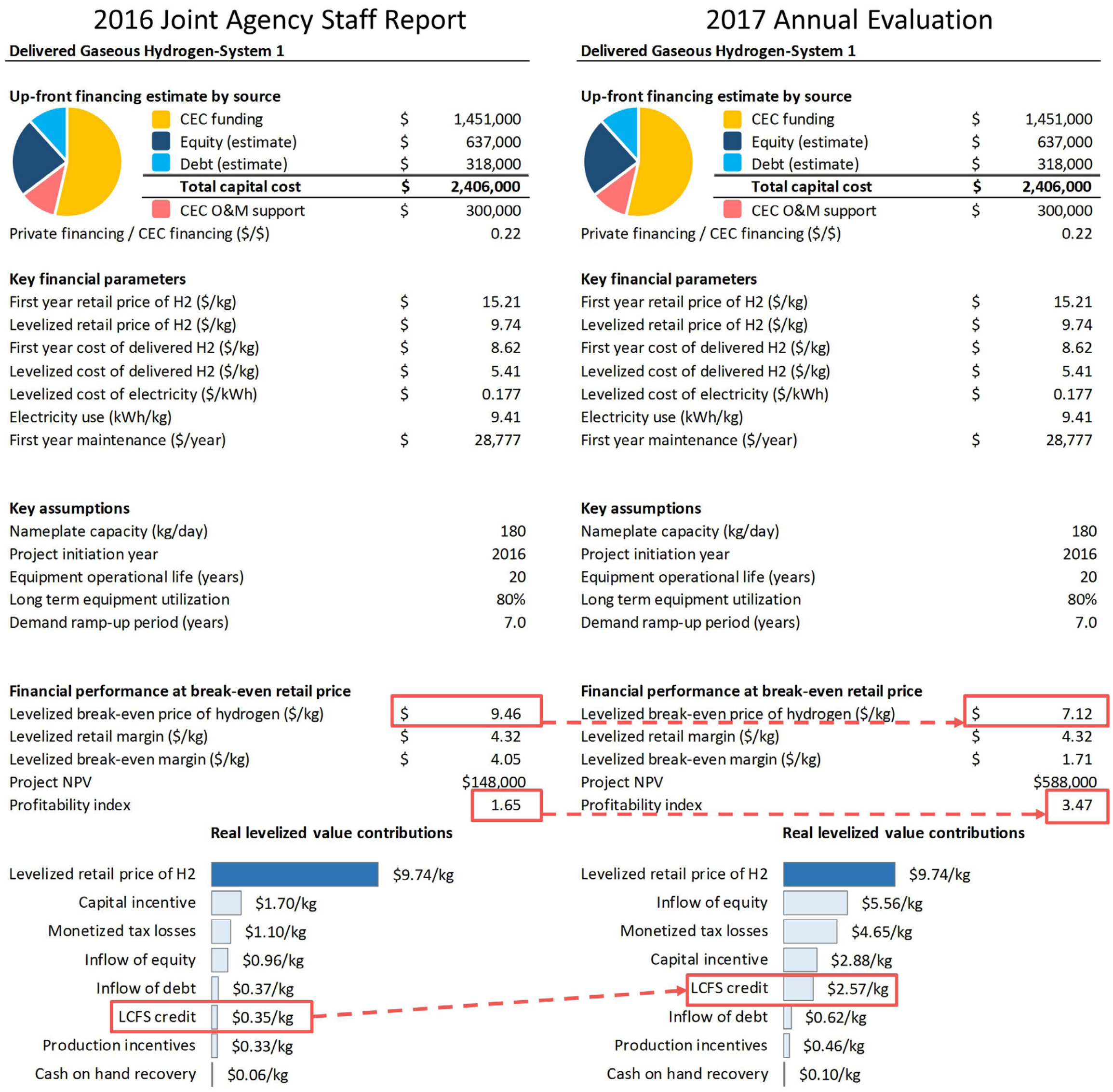
Table 9: Prospective LCFS Credit Values for Certified Hydrogen Pathways

			Assumed Value per Credit: $100
Fuel Pathway	Applicant	Carbon Intensity (gCO2/MJ)	LCFS Value ($/kg)
HYGLF200L	Lyten	-32.36	$3.50
HYGFLF200L	Lyten	15.29	$2.12
HYGLF201L	Lyten	-46.91	$3.92
HYGFLF201L	Lyten	29.84	$1.70
HYGE200L	Alameda-Contra Costa Transit District	0	$2.57

As an example, NREL provided ARB with revised financial assessments of the four station types presented in the 2016 Joint Agency Staff Report [36]. The example shown in Figure 45 compares the station financial performance metrics between a low ($0.35/kg) and high ($2.57/kg) LCFS credit value. The high credit value is based on the zero-carbon HYGE200L electrolysis pathway shown in Table 9. This value was chosen to showcase the potential LCFS revenue available to station operators that sell hydrogen with zero lifecycle emissions of greenhouse gases; additionally, this is a mid-range value for pathways currently registered in the LCFS program. In this example, the profitability index of the station increases from 1.65 to 3.47, indicating a much more favorable business case for the potential station developer and operator.

At the same time, the customer could potentially see a benefit, as the break-even price (at the pump) of hydrogen is reduced from $9.46 to $7.12 per kilogram, assuming the station operator passes the savings on to the customer. The potential reduction in break-even price is actually slightly more than the increase in LCFS credit between the two cases shown. Break-even price in this context is the price the station operator would need to sell their hydrogen in order to achieve the assumed internal rate of return, accounting for all the details of costs and financing for the station. Further evaluations for all four station types presented in the 2016 Joint Agency Staff Report are provided in Table 10. The increased LCFS revenues improve station operator and FCEV drivers' prospects in all cases; however, stations with a smaller rated capacity and on-site hydrogen generation via electrolysis remain a difficult prospect even considering increased LCFS revenue. All stations have been evaluated with a credit value of $2.57/kg for demonstration purposes only; a zero-carbon lifecycle production method may or may not ultimately be achievable for a particular station type and the assumed LCFS credit value of $100 per credit may change over time.

Figure 45: Sample Improvement in Financial Assessment for Stations Dispensing Hydrogen with High LCFS Credit Value [52]



Delivered Gaseous Hydrogen-System 1

	2016 Joint Agency Staff Report	2017 Annual Evaluation
Up-front financing estimate by source		
CEC funding	$ 1,451,000	$ 1,451,000
Equity (estimate)	$ 637,000	$ 637,000
Debt (estimate)	$ 318,000	$ 318,000
Total capital cost	**$ 2,406,000**	**$ 2,406,000**
CEC O&M support	$ 300,000	$ 300,000
Private financing / CEC financing ($/$)	0.22	0.22
Key financial parameters		
First year retail price of H2 ($/kg)	$ 15.21	$ 15.21
Levelized retail price of H2 ($/kg)	$ 9.74	$ 9.74
First year cost of delivered H2 ($/kg)	$ 8.62	$ 8.62
Levelized cost of delivered H2 ($/kg)	$ 5.41	$ 5.41
Levelized cost of electricity ($/kWh)	$ 0.177	$ 0.177
Electricity use (kWh/kg)	9.41	9.41
First year maintenance ($/year)	$ 28,777	$ 28,777
Key assumptions		
Nameplate capacity (kg/day)	180	180
Project initiation year	2016	2016
Equipment operational life (years)	20	20
Long term equipment utilization	80%	80%
Demand ramp-up period (years)	7.0	7.0
Financial performance at break-even retail price		
Levelized break-even price of hydrogen ($/kg)	$ 9.46	$ 7.12
Levelized retail margin ($/kg)	$ 4.32	$ 4.32
Levelized break-even margin ($/kg)	$ 4.05	$ 1.71
Project NPV	$148,000	$588,000
Profitability index	1.65	3.47

Real levelized value contributions (2016 Joint Agency Staff Report)

Levelized retail price of H2	$9.74/kg
Capital incentive	$1.70/kg
Monetized tax losses	$1.10/kg
Inflow of equity	$0.96/kg
Inflow of debt	$0.37/kg
LCFS credit	$0.35/kg
Production incentives	$0.33/kg
Cash on hand recovery	$0.06/kg

Real levelized value contributions (2017 Annual Evaluation)

Levelized retail price of H2	$9.74/kg
Inflow of equity	$5.56/kg
Monetized tax losses	$4.65/kg
Capital incentive	$2.88/kg
LCFS credit	$2.57/kg
Inflow of debt	$0.62/kg
Production incentives	$0.46/kg
Cash on hand recovery	$0.10/kg

Table 10: Demonstration of LCFS Credit Value Impacts on Station Business Cases and Consumer Hydrogen Prices [52]

			Profitability Index, Break-Even H2 Price @LCFS Credit Value	
Station Type	Description	Total Capital Cost	2016 Joint Agency Staff Report	2017 Annual Evaluation
System 1	180 kg/day, Gaseous Delivered	$2,406,000	1.65, $9.45 @ $0.35/kg	3.47, $7.12 @ $2.57/kg
System 2	350 kg/day, Liquid Delivered	$2,803,000	5.19, $7.85 @ $0.22/kg	10.48, $5.38 @ $2.57/kg
System 3	130 kg/day, On-Site Electrolysis	$2,920,000	-3.36, $19.78 @ $0.62/kg	-2.40, $17.73 @ $2.57/kg
System 4	180 kg/day, Gaseous Delivered	$2,406,000	7.71, $6.54 @ $0.35/kg	13.37, $4.20 @ $2.57/kg

Conclusions and Recommendations

AB 8 Requirements: Provide evaluation and recommendations to the Energy Commission to inform future funding programs

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

As in previous Annual Evaluations, ARB finds that significant progress in California's hydrogen fueling network has occurred in the past year, and there are no signs that the State should reduce its pace. In fact, there are clear messages developing that indicate a need to capitalize on this momentum and accelerate the development of the fueling network in the remaining years of AB 8. Over the past three years, accomplishments of the AB 8 program and associated State and industry efforts have resulted in the successful transition from a fully pre-commercial market to an early commercial market for FCEVs and hydrogen fueling. For this reason, ARB continues to recommend that the State utilize all funding available to the AB 8 program in the coming years. Furthermore, ARB recommends that serious consideration be given to the possibility of identifying and implementing a new funding structure under AB 8 that takes advantage of the successful transition to an early market phase and has the express goal of accelerating station deployment. This may be achieved through programs that enable greater leveraging of private capital, that provide more assurance of future funds to potential private investors, and/or that address high operational costs brought on by the cost of procuring hydrogen, especially renewably-sourced hydrogen that is a high priority for FCEV customers.

Continued delays in select station development schedules have exacerbated the previously-reported one-year delay in projected FCEV deployment that had been limited only to the short-term. As some of these delays have not been resolved, FCEV deployment plans have correspondingly been shifted further into the future again, and now affect vehicle release plans for the next six years. In spite of this near-term shift in planning, auto manufacturers have provided repeated reassurances that deployment plans can be accelerated in the future with corresponding acceleration of the fueling network development. This is in agreement with the foundational principles of AB 8; vehicle and station deployments are significantly interdependent and should be appropriately coordinated (with station deployment leading vehicles) to ensure sustained success of both efforts.

Based on the developments of the past year and new insights from public-private partnerships and conversations with stakeholders, ARB makes the following set of recommendations:

- Acceleration of station development, both at the programmatic level of AB 8 as well as the individual station level, needs to be one of the highest priorities in the coming years. Dependable station development leads to dependable and robust FCEV deployment, which has the potential to significantly contribute to the State's climate change and air quality goals. Acceleration of station network deployment will likely require collaborative effort between the State and the hydrogen station developers, as neither entity has full control over all aspects of the ultimate network development pace. This type of collaboration is already a major portion of the State's AB 8-related efforts, so a renewed focus on pace of network deployment is the only addition that ARB recommends at this time.

- New fueling stations proposed for award under GFO 15-605 will significantly advance the customer experience at California's hydrogen fueling network. ARB recommends that these advancements continue to be incentivized by Energy Commission funding. As was done in GFO 15-605, minimum station capacity for future funding should be increased for stations serving high-priority first adopter markets. A new minimum capacity of at least 300 kg/day for most future stations is recommended. In addition, increased emphasis should be placed on technical capabilities and design features that enable enhanced customer experiences. This may include strategies to increase station reliability, greater numbers of fueling positions, point of sale improvements, and seamless integration of hydrogen fueling into other fueling options already existing at the station.
- With the addition of several new stations in the San Francisco Bay Area, first adopter markets across Los Angeles and Orange Counties are once again the highest priority for increased coverage and capacity development. More development is still required in the San Francisco Bay Area, but the needs are currently limited to more targeted communities in the region.
- The Energy Commission has already commenced the exploration of funding an in-state hydrogen production facility, with an emphasis on renewable hydrogen implementation. Comparing ARB's projections of expected hydrogen throughput for light-duty vehicles to the current hydrogen production capacity in the state shows that there will be a need for significant new production capacity in the near future. FCEV customers and auto manufacturers (who are responding to customer needs) emphasize a desire for renewably-sourced hydrogen. Thus, ARB supports the Energy Commission's ongoing work towards a solicitation for a renewable hydrogen production facility in California.
- The State of California has gained a great deal of unique experience with real-world performance of hydrogen equipment and fueling protocols. Through the HyStEP program, ARB has not only helped several developers prepare their stations for retail hydrogen sales, but has also identified gaps in clarity and usability of existing codes and standards. As a one-of-a-kind program within the United States and potentially worldwide, the State of California needs to capitalize on this knowledge by becoming more active in codes and standards development.

These five recommendations acknowledge the rapidly changing landscape of the hydrogen fueling and FCEV markets in California. A great deal of progress has been made through the AB 8 program in recent years, and stakeholders expect the momentum from such successes to be utilized to accelerate future advances. While this is by no means a simple task, it is an appropriate expectation for two co-dependent industries expecting to make the transition from a nascent, limited commercial presence to a mass-market deployment within roughly the next five years. Establishing the current state of the market has proven California's ability to achieve unprecedented successes within the industry, and ARB expects that a transition in goals of State programs should prove equally as successful. New challenges will appear, but so will new opportunities. Thanks to the progress so far, California stands uniquely prepared with appropriate tools at-hand to make the necessary transition. As in previous years, ARB anticipates extensive coordination with the Energy Commission, its other partner agencies at the state and local level, and private industry to ensure collaborative success in this endeavor.

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Appendix A: AB 8 Excerpt

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.

Appendix B: Station Status Summary

List of Known and Projected Hydrogen Fueling Station Status (2010-2020), as of June 23, 2017

Station Name	Street Address	Open Date	Capacity (kg/day)	County	Notes
Burbank	145 W Verdugo Rd	2010, Q1	100	Los Angeles	
Thousand Palms	32505 Harry Oliver Trail	2010, Q1	30	Riverside	
UC Irvine	19172 Jamboree Rd	2010, Q1	30	Orange	
West LA #1	11576 Santa Monica Blvd	2010, Q1	30	Los Angeles	
Torrance	2051 W 190th St	2011, Q2	60	Los Angeles	
Fountain Valley	10844 Ellis Ave	2011, Q3	100	Orange	100% Renewable
Emeryville	1152 45th St	2012, Q2	60	Alameda	100% Renewable
Newport Beach	1600 Jamboree Rd	2012, Q3	100	Orange	
Harbor City	25800 S Western Ave	2013, Q2	60	Los Angeles	
CSULA	5151 State University Dr	2014, Q2	60	Los Angeles	100% Renewable
West Sacramento	1515 S River Rd	2015, Q2	350	Yolo	
Diamond Bar	21865 E Copley Dr	2015, Q3	180	Los Angeles	
Coalinga	24505 W Dorris Ave	2015, Q4	180	Fresno	
San Juan Capistrano	26572 Junipero Serra Rd	2015, Q4	350	Orange	
UC Irvine	19172 Jamboree Rd	2015, Q4	150 add'l	Orange	Capacity Upgrade
West LA #2	11261 Santa Monica Blvd	2015, Q4	180	Los Angeles	
Costa Mesa	2050 Harbor Blvd	2016, Q1	180	Orange	
La Cañada-Flintridge	550 Foothill Blvd	2016, Q1	180	Los Angeles	
Lake Forest	20731 Lake Forest Dr	2016, Q1	180	Orange	
Long Beach	3401 Long Beach Blvd	2016, Q1	180	Los Angeles	
San Jose	2101 North First St	2016, Q1	180	Santa Clara	
Santa Monica #1	1819 Cloverfield Blvd	2016, Q1	180	Los Angeles	
Saratoga	12600 Saratoga Ave	2016, Q1	180	Santa Clara	
South San Francisco	248 S Airport Blvd	2016, Q1	180	San Mateo	
Campbell	2855 Winchester Blvd	2016, Q2	180	Santa Clara	
Fairfax	7751 Beverly Blvd	2016, Q2	180	Los Angeles	
Hayward	391 West A St	2016, Q2	180	Alameda	
Santa Barbara	150 S La Cumbre Rd	2016, Q2	180	Santa Barbara	
Mill Valley	570 Redwood Hwy	2016, Q3	180	Marin	
Truckee	12105 Donner Pass Rd	2016, Q3	180	Nevada	
Playa Del Rey	8126 Lincoln Blvd	2016, Q3	180	Los Angeles	100% Renewable
Anaheim	3731 E La Palma Ave	2016, Q4	100	Orange	
Hollywood	5700 Hollywood Blvd	2016, Q4	180	Los Angeles	100% Renewable
Woodland Hills	5314 Topanga Canyon Blvd	2016, Q4	180	Los Angeles	

Station Name	Street Address	Open Date	Capacity (kg/day)	County	Notes
Del Mar	3060 Carmel Valley Rd	2016, Q4	180	San Diego	
Riverside	8095 Lincoln Ave	2017, Q1	100	Riverside	
Lawndale	15606 Inglewood Ave	2017, Q2	180	Los Angeles	
South Pasadena	1200 Fair Oaks Ave	2017, Q2	180	Los Angeles	
Fremont	41700 Grimmer Blvd	2017, Q3	180	Alameda	Moved from former Redwood City
Ontario	1850 Holt Blvd	2017, Q3	100	San Bernardino	100% Renewable
San Ramon	2451 Bishop Dr	2017, Q3	350	Contra Costa	
Torrance	2051 W 190th St	2017, Q3	140 add'l	Los Angeles	Capacity Upgrade
Thousand Oaks	3102 Thousand Oaks Blvd	2017, Q4	180	Ventura	Moved from former Laguna Niguel
Woodside	17287 Skyline Blvd	2017, Q4	140	San Mateo	
LAX	10400 Aviation Dr	2018, Q1	180	Los Angeles	
Palo Alto	3601 El Camino Real	2018, Q1	180	Santa Clara	
Rancho Palos Verdes	28103 Hawthorne Blvd	2018, Q1	180	Los Angeles	Moved from former Redondo Beach
Santa Clarita	24551 Lyons Ave	2018, Q1	180	Los Angeles	Moved from former Irvine North
Burbank	145 W Verdugo Rd	2018, Q4	100	Los Angeles	Upgrade to Open-Retail
Mountain View	830 Leong Dr	2018, Q4	350	Santa Clara	
Berkeley	1250 University Ave	2019, Q1	360	Alameda	New Award
Campbell #2	337 E Hamilton Ave	2019, Q1	310	Santa Clara	New Award
Citrus Heights	6141 Greenback Ln	2019, Q1	360	Sacramento	New Award
Huntington Beach	16001 Beach Blvd	2019,Q1	310	Orange	New Award
Irvine	5333 University Dr	2019, Q1	310	Orange	New Award
Oakland	350 Grand Ave	2019, Q1	310	Alameda	New Award
Sacramento	3510 Fair Oaks Blvd	2019, Q1	360	Sacramento	New Award
San Diego	5494 Mission Center Rd	2019, Q1	310	San Diego	New Award
San Francisco #1	551 Third St	2019, Q1	360	San Francisco	New Award
San Francisco #2	3550 Mission St	2019, Q1	360	San Francisco	New Award
San Francisco #3	1201 Harrison St	2019, Q1	360	San Francisco	New Award
Santa Monica #2	1866 Lincoln Blvd	2019, Q1	310	Los Angeles	New Award
Santa Nella	12754 State Hwy 33	2019, Q1	180	Merced	New Award
Sherman Oaks	14478 Ventura Blvd	2019, Q1	310	Los Angeles	New Award
Sunnyvale	1296 Sunnyvale Saratoga Rd	2019, Q1	310	Santa Clara	New Award
Walnut Creek	2900 N Main St	2019, Q1	360	Contra Costa	New Award
Emeryville	1152 45th St	2019, Q2	290 add'l	Alameda	Moved from former Oakland Airport
North Hollywood	5957 Vineland Ave	2020, Q3	130	Los Angeles	Moved from former Pacific Palisades; 100% Renewable

Station Name	Street Address	Close Date	Capacity Removed (kg/day)	County	Notes
Orange	1914 East Chapman Ave	2020, Q3	130	Orange	100% Renewable
Rohnert Park	5060 Redwood Dr	2020, Q3	130	Sonoma	100% Renewable
Thousand Palms	32505 Harry Oliver Trail	2015, Q1	-30	Riverside	Non-Retail; Limited 35Mpa Service
West LA #1	11576 Santa Monica Blvd	2015, Q1	-30	Los Angeles	Decommissioned
Fountain Valley	10844 Ellis Ave	2016, Q2	-100	Orange	Decommissioned
Harbor City	25800 S Western Ave	2016, Q4	-60	Los Angeles	Decommissioned
Station Name	**Street Address**		**Capacity (kg/day)**	**County**	**Notes**
Chino	12610 East End Ave	Station No Longer Included Due to Anticipated Fund Liquidation	100	San Bernardino	100% Renewable
Encinitas	310 Encinitas Blvd		180	San Diego	Moved from former Mission Viejo
Los Altos	2300 Homestead Blvd		350	Santa Clara	

Appendix C: Auto Manufacturer Survey Material

Guidance [as of February 2017] for Projected Hydrogen Station Status*, Calendar Years 2016-2017

Alameda County	Capacity: 1090 kg/day Future Upgraded Capacity: 1380 kg/day	
Station Name	**Open Year**	**Capacity (kg/day)**
Berkeley- 1250 University Ave	New Award- 2018 or later	360
Emeryville- 1152 45th St[1]	2012	60
Emeryville Upgrade	2018	350
Fremont- 41700 Grimmer Blvd	2017	180
Hayward- 391 West A St	2016	180
Oakland- 350 Grand Ave	New Award- 2018 or later	310
Contra Costa County	**Capacity: 710 kg/day**	
Station Name	**Open Year**	**Capacity (kg/day)**
San Ramon- 2451 Bishop Dr	2017	350
Walnut Creek- 2900 N Main St	New Award- 2018 or later	360
Fresno County	**Capacity: 180 kg/day**	
Station Name	**Open Year**	**Capacity (kg/day)**
Coalinga- 24505 W Dorris Ave	2015	180
Los Angeles County	**Capacity: 3490 kg/day Future Upgraded Capacity: 3630 kg/day**	
Station Name	**Open Year**	**Capacity (kg/day)**
Burbank- 145 W Verdugo Ave1	2010	100
Burbank Upgrade	2017	100
CSULA- 5151 State University Dr	2018	60
Diamond Bar- 21865 E Copley Dr	2015	180
Fairfax- 7751 Beverly Blvd	2016	180
Hollywood- 5700 Hollywood Blvd	2016	180
La Canada-Flintridge- 550 Foothill Blvd	2016	180
Lawndale- 15606 Inglewood Ave	2017	180
LAX- 10400 Aviation Blvd	2017	180
Long Beach- 3401 Long Beach Blvd	2016	180
North Hollywood- 5957 Vineland Ave	Post-2018	130
Playa Del Rey- 8126 Lincoln Blvd	2016	180
Rancho Palos Verdes- 28103 Hawthorne Blvd	2017	180
Santa Clarita- 24551 Lyons Ave	2017	180
Santa Monica- 1819 Cloverfield Blvd	2016	180
Santa Monica #2- 1866 Lincoln Blvd	New Award- 2018 or later	310
Sherman Oaks- 14478 Ventura Blvd	New Award- 2018 or later	310

South Pasadena- 1200 Fair Oaks Ave	2017	180
Torrance- 2051 W 190th St1	2011	60
Torrance Upgrade	2017	200
West LA- 11261 Santa Monica Blvd	2015	180
Woodland Hills- 5314 Topanga Canyon Blvd	2016	180
Marin County		**Capacity: 180 kg/day**
Station Name	**Open Year**	**Capacity (kg/day)**
Mill Valley- 570 Redwood Highway	2016	180
Merced County		**Capacity: 180 kg/day**
Station Name	**Open Year**	**Capacity (kg/day)**
Santa Nella- 12754 State Hwy 33	New Award- 2018 or later	180
Nevada County		**Capacity: 180 kg/day**
Station Name	**Open Year**	**Capacity (kg/day)**
Truckee- 12105 Donner Pass Rd	2016	180
Orange County		**Capacity: 1840 kg/day Future Upgraded Capacity: 2090 kg/day**
Station Name	**Open Year**	**Capacity (kg/day)**
Anaheim- 3731 E La Palma Ave	2016	100
Costa Mesa- 2050 Harbor Blvd	2016	180
Huntington Beach- 16001 Beach Blvd	New Award- 2018 or later	310
Irvine- 5333 University Dr	New Award- 2018 or later	310
Lake Forest- 20731 Lake Forest Dr	2016	180
Newport Beach- 1600 Jamboree Rd1	2012	100
Newport Beach Upgrade	2018	350
Orange- 1914 East Chapman Ave	Post-2018	130
San Juan Capistrano- 26572 Juniper Serra Rd	2015	350
UC Irvine- 19172 Jamboree Rd	2015	180
Riverside County		**Capacity: 100 kg/day**
Station Name	**Open Year**	**Capacity (kg/day)**
Riverside- 8095 Lincoln Ave	2017	100
Sacramento County		**Capacity: 720 kg/day**
Station Name	**Open Year**	**Capacity (kg/day)**
Citrus Heights- 6141 Greenback Lane	New Award- 2018 or later	360
Sacramento- 3510 Fair Oaks Blvd	New Award- 2018 or later	360
San Bernardino County		**Capacity: 200 kg/day**
Station Name	**Open Year**	**Capacity (kg/day)**
Chino- 12600 East End Ave	Post-2018	100
Ontario- 1850 Holt Blvd	2017	100
San Diego County		**Capacity: 670 kg/day**
Station Name	**Open Year**	**Capacity (kg/day)**
Encinitas- 310 Encinitas Blvd	Post-2018	180
Del Mar- 3060 Carmel Valley Rd	2016	180
San Diego- 5494 Mission Center Rd	New Award- 2018 or later	310
San Francisco County		**Capacity: 1080 kg/day**
Station Name	**Open Year**	**Capacity (kg/day)**
San Francisco #1- 551 Third St	New Award- 2018 or later	360
San Francisco #2- 3550 Mission St	New Award- 2018 or later	360

San Francisco #3- 1201 Harrison St	New Award- 2018 or later	360
San Mateo County		**Capacity: 320 kg/day**
Station Name	**Open Year**	**Capacity (kg/day)**
South San Francisco- 248 S Airport Blvd	2016	180
Woodside- 17287 Skyline Blvd	2017	140
Santa Barbara County		**Capacity: 180 kg/day**
Station Name	**Open Year**	**Capacity (kg/day)**
Santa Barbara- 150 S La Cumbre Blvd	2016	180
Santa Clara County		**Capacity: 2040 kg/day**
Station Name	**Open Year**	**Capacity (kg/day)**
Campbell- 2855 Winchester Blvd	2016	180
Campbell #2- 337 E Hamilton Ave	New Award- 2018 or later	310
Los Altos- 2300 Homestead Rd	Post-2018	350
Mountain View- 830 Leong Dr	2018	350
Palo Alto- 3601 El Camino Real	2018	180
San Jose- 2101 N First St	2016	180
Saratoga- 12600 Saratoga Ave	2016	180
Sunnyvale- 1296 Sunnyvale Saratoga Rd	New Award- 2018 or later	310
Sonoma County		**Capacity: 130 kg/day**
Station Name	**Open Year**	**Capacity (kg/day)**
Rohnert Park- 5060 Redwood Dr	Post-2018	130
Ventura County		**Capacity: 180 kg/day**
Station Name	**Open Year**	**Capacity (kg/day)**
Thousand Oaks- 3102 Thousand Oaks Blvd	2017	180
Yolo County		**Capacity: 350 kg/day**
Station Name	**Open Year**	**Capacity (kg/day)**
West Sacramento- 1515 S River Rd	2015	350

* Note: All years referenced herein are calendar years (Jan 1 through Dec 31); unless otherwise noted, Open Year refers Open-Retail status

1 These stations are currently Non-Retail, but expected to receive an upgrade to Open-Retail

Appendix D: CaFCP OEM Group Station Location Letter Analysis

On June 19, 2017, the OEM Group of the CaFCP submitted to ARB a list of priority hydrogen station location recommendations. The list represented the collective view of participating auto manufacturers of the priorities for new hydrogen fueling stations that the State should consider co-funding. The method of developing the collective list does not signify that any particular station is on the priority list of all auto manufacturers, nor does it prioritize the list. Similarly, no individual auto manufacturer's thoughts on any given station are provided through the list and accompanying letter. However, the list and letter provide a full overview of the stations that the auto manufacturer group as a whole consider to be gaps in the current hydrogen fueling network, and provide a vision of a network development path towards the 100 station goalpost in AB 8. The stations provided in the list may be envisioned to have roles supporting an existing or future core market area, acting as a connector, serving destination travel, or a combination of these purposes. With the exception of a few locations, the expected role of each station location was not indicated by the list and letter.

ARB considers the information provided by the OEM Group as a separate set of guidance from its own CHIT-determined evaluation. As of yet, ARB has not devised a method to explicitly include this information into CHIT evaluations. However, it should be acknowledged that the information provided in the list and letter do provide important information, especially given that it represents an aggregation of market research data and customer feedback that ARB is otherwise unable to access. In the future, ARB may be able to develop a method of incorporating this information directly into CHIT. In the meantime, it is important for the Energy Commission and ARB to understand the intent of the locations suggested by the OEM Group and how well the CHIT determinations may reflect these priorities. Table 11 provides ARB's analysis of the locations suggested by the OEM letter and how well these are reflected in the CHIT analysis.

Locations are divided into four groups: those which reside within the priority areas identified by both the 2016 and 2017 analyses, those identified by either one of these analyses, and those not within CHIT-identified priority areas. Each suggested location is then further characterized in terms of its agreement with CHIT, based on summary statistics (maximum and median) of the coverage gap values within the city boundaries of the locations listed and the gap values nearest the specific highways and landmarks associated with each location. Some locations were provided in the letter with an associated address from a previously funded (and later relocated) or proposed station. In these cases, the exact address was also analyzed. The OEM Group letter highlighted these particular locations as a separate group of "market critical" sites.

High agreement indicates that the specific location (with respect to the city and particular landmark) is within a 2017 priority area and within or very near high coverage gap values. Medium agreement indicates the specific location is within a 2017 priority area, but either coverage gap values at the location are mid-range or a high-value area is a short distance away. Limited agreement indicates only partial overlap between the city boundary and the priority area, with low- to-mid values near the particular location.

Table 11: Analysis of OEM Letter Priority Locations

	OEM Letter Location	Related Address from Prior Proposals and Coverage Gap Value (out of 10)	Assessment of Agreement Between CHIT and OEM Letter Location
Within Priority Areas in 2016 and 2017 Analyses	Beverly Hills	9988 Wilshire Blvd., Beverly Hills, CA 90210: Value: 7	Letter and CHIT Show High Agreement.
	Manhattan Beach		Letter and CHIT Show High Agreement.
	Pacific Palisades		Letter and CHIT Show High Agreement.
	Redondo Beach (South)		Letter and CHIT Show High Agreement.
	San Mateo/Foster City (Hwy 101/92)		
	San Mateo		Letter and CHIT Show High Agreement.
	Foster City		Letter and CHIT Show High Agreement.
	Cerritos (Hwy 91/605)		Letter and CHIT Show High Agreement.
	Downey/Norwalk (Hwy 5/605)		
	Downey		Letter and CHIT Show High Agreement.
	Norwalk		Letter and CHIT Show High Agreement.
	Granada Hills (Hwy 405/118)	15544 San Fernando Mission Blvd., Mission Hills, CA 91345; Value: 6	Letter and CHIT Show High Agreement.
	Los Angeles (near Downtown)		Letter and CHIT Show High Agreement.
	Redwood City (Hwy 101)	503 Whipple Avenue, Redwood City, CA 94063; Value: 5	Letter and CHIT Show High Agreement.
	Sacramento		Letter and CHIT Show High Agreement.
	San Jose (Alamitos)	621 Blossom Hill Road, San Jose, CA 95123; Value: 5	Letter and CHIT Show High Agreement.
	Toluca Lake/Burbank (Hwy 134)		
	Toluca Lake		Letter and CHIT Show High Agreement
	Burbank		Letter and CHIT Show High Agreement.
	Irvine North (Hwy 5/ Culver/133)		Letter and CHIT Show Medium Agreement.
	Laguna Niguel/Aliso Viejo		
	Laguna Niguel		Letter and CHIT Show Medium Agreement.
	Aliso Viejo	22952 Pacific Park Drive, Aliso Viejo CA 92656; Value: 4	Letter and CHIT Show Medium Agreement.
	Brea (Hwy 57)		Letter and CHIT Show Medium Agreement.
	La Jolla		Letter and CHIT Show Medium Agreement.
	Garden Grove / Orange (Hwy 22/5)		
	Garden Grove		Letter and CHIT Show Limitied Agreement.
	Orange		Letter and CHIT Show Limitied Agreement.
	Newport Beach	2201 East Coast Highway, Newport Beach, CA 92660; Value: 3	Letter and CHIT Show Limitied Agreement.

	OEM Letter Location	Related Address from Prior Proposals and Coverage Gap Value (out of 10)	Assessment of Agreement Between CHIT and OEM Letter Location
Within Priority Areas in 2017	Calabasas (Hwy 101)	24025 Calabasas Road, Calabasas, CA 91302; Value: 4	Letter and CHIT Show High Agreement.
	San Diego/Carlsbad-Oceanside (Hwy 5)		
	Carlsbad		Letter and CHIT Show High Agreement.
	Rancho Bernardo (Hwy 15)		Letter and CHIT Show High Agreement.
	Baldwin Park/W. Covina (Hwy 10/605)		
	Baldwin Park		Letter and CHIT Show Medium Agreement.
	West Covina		Letter and CHIT Show Medium Agreement.
	Rancho Santa Margarita (Hwy 241)		Letter and CHIT Show Medium Agreement.
	San Diego/Carlsbad-Oceanside (Hwy 5)		
	Oceanside		Letter and CHIT Show Medium Agreement.
Within Priority Areas in 2016	Cupertino (Hwy 85/280/DeAnza)		Saratoga and New Sunnyvale Stations Provide Nearby Coverage.
	San Diego/Airport (Hwy 5)	3580 Sports Arena Blvd., San Diego, CA 92110; Value: 2	New San Diego Station Provides Coverage. May Become Higher Relative Priority with Further Development.
	Walnut Creek (Hwy 680/24)		New Walnut Creek Station Provides Coverage.
	Monterey		Letter Denotes as Connector for Central Coast.
	Santa Cruz (PCH/Hwy 17)		ARB Postulates Part of Central Coast Connectors Suggested in Letter.

	OEM Letter Location	Related Address from Prior Proposals and Coverage Gap Value (out of 10)	Assessment of Agreement Between CHIT and OEM Letter Location
Not Within a Priority Area. May be due to Existing Coverage or Location Identified for Destination and/or Connector	San Rafael/Corte Madera (Hwy 101)		
	San Rafael		Mill Valley Station Provides Coverage.
	Corte Madera		Mill Valley Station Provides Coverage.
	Corona (Hwy 15/91)		Adjacent to 2017 Priority Area (Eastern Yorba Linda).
	Dublin/Pleasanton (Hwy 580/680)		
	Dublin		Letter and CHIT Show Limitied Agreement.
	Pleasanton		Letter and CHIT Show Limitied Agreement.
	Barstow/Victorville (Hwy 15)		
	Barstow		Not anticipated for Core Market Area. Letter Denotes as Connector to Las Vegas.
	Victorville		Not anticipated for Core Market Area. Letter Denotes as Connector to Las Vegas.
	San Luis Obispo (Hwy 101)		Not anticipated for Core Market Area. Letter Denotes as Connector for Central Coast.
	Wheeler Ridge/Arvin/ Lebec		
	Wheeler Ridge		Not anticipated for Core Market Area. Letter Denotes as Reduncancy for I-5 Connector.
	Arvin		Not anticipated for Core Market Area. Letter Denotes as Reduncancy for I-5 Connector.
	Lebec		Not anticipated for Core Market Area. Letter Denotes as Reduncancy for I-5 Connector.
	Malibu (PCH)		ARB Postulates Part of Central Coast Connectors Suggested in Letter.
	Napa (Hwy 29/Trancas)		ARB Postulates Possible Destination Location.
	Palm Springs/Rancho Mirage		
	Palm Springs		ARB Postulates Possible Destination And/ Or Eventual Connector Locations.
	Rancho Mirage		ARB Postulates Possible Destination And/ Or Eventual Connector Locations.
	Santa Rosa (Hwy 101)		ARB Postulates Part of Central Coast Connectors Suggested in Letter.
	Temecula (Hwy 15)		ARB Posulates Possible Destination Location.
	Ventura (Hwy 101)		ARB Postulates Part of Central Coast Connectors Suggested in Letter.
	Davis (Hwy 5)		
	Folsom		
	Simi Valley (Hwy 118)		
	Vallejo (Hwy 80, 29)		

Twenty-six of the 45 station locations provided by the OEM Group lie within these High to Limited Agreement categories, all of which were included in priority areas in the 2017 Annual Evaluation (some locations were identified with reference to multiple cities; in this case, Table 11 provides an evaluation of each individual city mentioned and the individual cities are listed and indented under the combined location name provided in the OEM letter). Most of these were actually identified in both 2016 and 2017. In addition, a handful of station locations from the OEM Group letter were identified in 2016 but not in the 2017 Annual Evaluation. As noted, this appears to be because of existing coverage in the area, most often provided by a new station awarded in GFO 15-605. Thus, ARB's analysis shows these as high-market areas but the current coverage gap is not among the highest priorities. As coverage is filled out in other areas of the state, these locations may appear as new priorities once again. Other stations identified in 2016 but not 2017 are either explicitly mentioned in the OEM Group letter to be part of a Central Coast Connector Corridor, or ARB interprets the location as serving such a role. The fact that the location has previously been identified through the CHIT core market area evaluation shows that these locations could be dual-purpose in the future as both a connector and initiation point for a future local market.

The final group includes station locations that have not been identified by CHIT as core market areas. For two of these locations (Corona and Dublin/Pleasanton), there may be some limited agreement that mid-range coverage gap values exist in or near the area but the location is not identified by CHIT as among the highest priorities. In another case (San Rafael/Corte Madera), the location is considered covered by the Mill Valley station already in the area. However, in the majority of cases, the station location is either explicitly mentioned in the letter as a destination or connector station, or ARB interprets the location to have this role. These are stations that CHIT is not designed to be able to identify, so the exclusion of these locations from CHIT identification of priority areas is largely to be expected. Finally, there are four locations (Davis, Folsom, Simi Valley, and Vallejo) where the suggested station is likely to serve a core market area that has not been identified by CHIT. ARB will work with auto manufacturers to understand the reasons these areas were identified as high-priority and to explore adjustments to CHIT as deemed necessary. For now, the analysis shown in Table 11 may be used by the Energy Commission to understand and evaluate market viability considerations of particular locations, and how these correlate with CHIT coverage gap evaluations in the area. Suggestions for connector and destination stations to be funded may also be sourced from this table, with additional consideration of market indicators within and outside of CHIT.

Appendix E: Exploration of Alternative Financing Mechanisms

The following are preliminary analyses meant to illustrate the possibilities presented by alternative funding mechanisms for hydrogen fueling stations under AB 8 and are presented as overviews of some options that may prove attractive. More detailed analyses should be completed and other options considered in stakeholder discussions about funding and incentive mechanisms. As with prior hydrogen funding efforts, these should be considered and discussed through the Energy Commission's open and public workshop process. Consideration of alternatives and development of an appropriate funding mechanism may require additional time, but the overall gain in total station deployment rate can outweigh this up-front time burden.

Loan Loss Reserve or Loan Guarantee Program

In a separate program, the Energy Commission is funding a $2 million pilot financing program with the California Pollution Control Financing Authority to administer a loan loss reserve (LLR) fund for electric vehicle charging station loans [41]. The Energy Commission expects to leverage up to $10 million in private sector loans from its $2 million pilot LLR fund. This is a relatively low leverage ratio, which gives added security to private lenders. A similar pilot LLR fund could be put in place for hydrogen refueling station loans. LLR funds provide partial risk coverage for private lenders to cover a pre-specified amount of losses on defaulted or nonpaying loans. Public funds are leveraged by the involvement of the private sector. A similar case can be made for a loan guarantee program where a portion of Alternative and Renewable Fuel and Vehicle Technology Program (ARFVTP) funds would be used to guarantee loans issued by private lenders. LLRs and loan guarantee programs differ in that LLRs guarantee loans only up to a pre-specified amount of losses, whereas loan guarantee programs may potentially guarantee all loan losses [42].

Figure 46: Annual Hydrogen Stations Funded Under a Hybrid LLR and Capital Grant Approach, with an Assumed 20% Leverage Rate

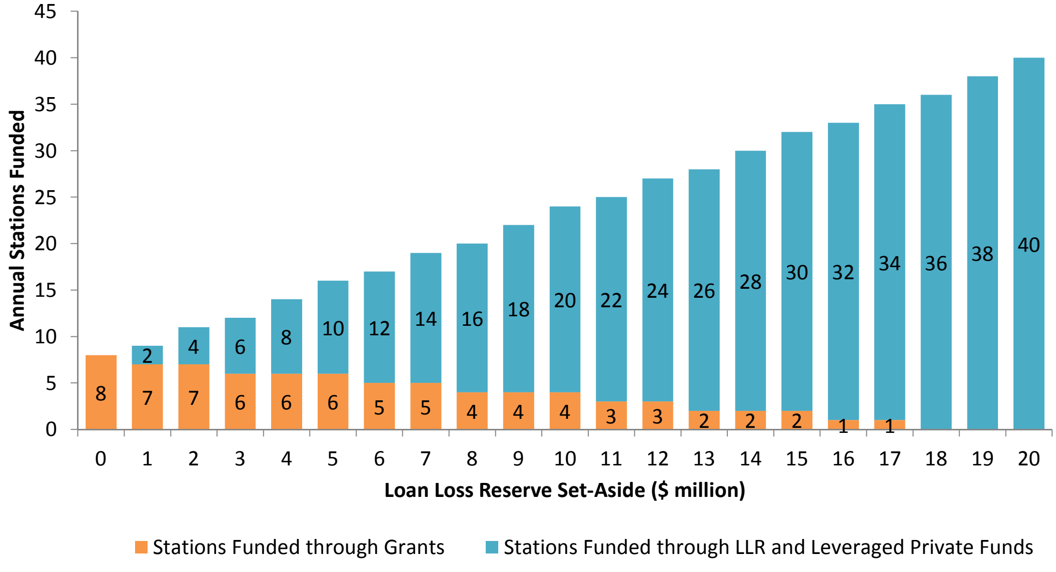


Figure 46 shows the number of stations that could be funded by a hybrid approach; a total of $20 million is assumed available, split between capital grant funding and the indicated LLR set-aside. A 20% leverage rate was assumed for the LLR portion of the funding. Even for small LLR set-asides, the total number of stations funded is increased, and with at least $4 million set aside for the LLR, stations funded through this portion of the program are more numerous than the capital grant-funded stations. This is due to the leverage assumed in the calculations. Such a hybrid approach may be attractive for quickly funding more stations in highly-developed areas with a large anticipated market while simultaneously funding a few select stations in more difficult market locations. For example, with an $8 million LLR set-aside, 16 stations (twice the current rate) could be funded through the LLR portion in markets like Los Angeles and Silicon Valley, where station development and FCEV deployment are currently concentrated. In these areas, station developers may more easily demonstrate a favorable business case and investment proposition to potential investors. An additional four stations could then be funded in connector and/or destination locations, where the business case may not be as favorable and capital grants can help the stations become established in the early years of FCEV deployment. The grant fund portion could also be used to open stations in new markets, enabling more consumers to consider FCEVs as a viable vehicle option.

Figure 47 shows the sensitivity of the total station deployment rate (stations funded per year) to the assumed leverage rate (ratio of public to private funds); the cumulative effect on station deployment is shown in Figure 48. If the leverage rate is 50% or greater, then the hybrid method becomes less attractive, as more than half of stations built must be funded through the LLR program in order to gain an advantage of only a few stations compared to the current capital grant program. The open, public workshop process could help identify the preferred proportion of LLR to grant funds, leverage rate, and other details.

Figure 47: Variation in Stations Funded Under a Hybrid LLR and Capital Grant Approach at Various Leverage Rates

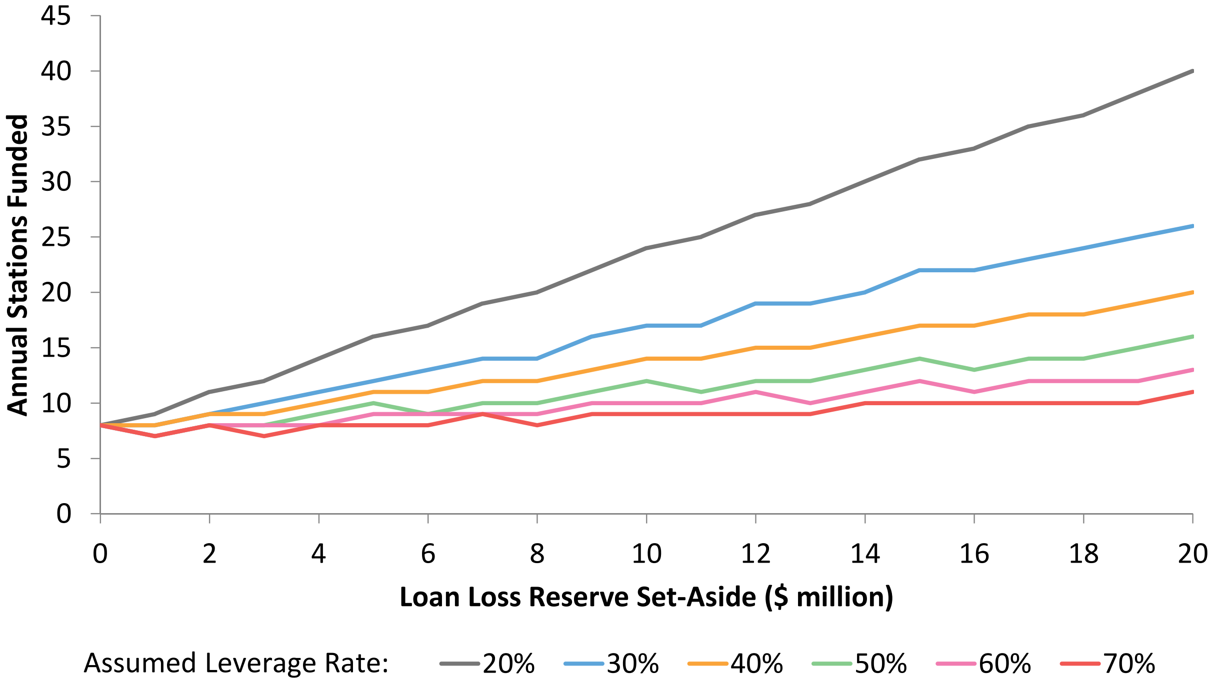
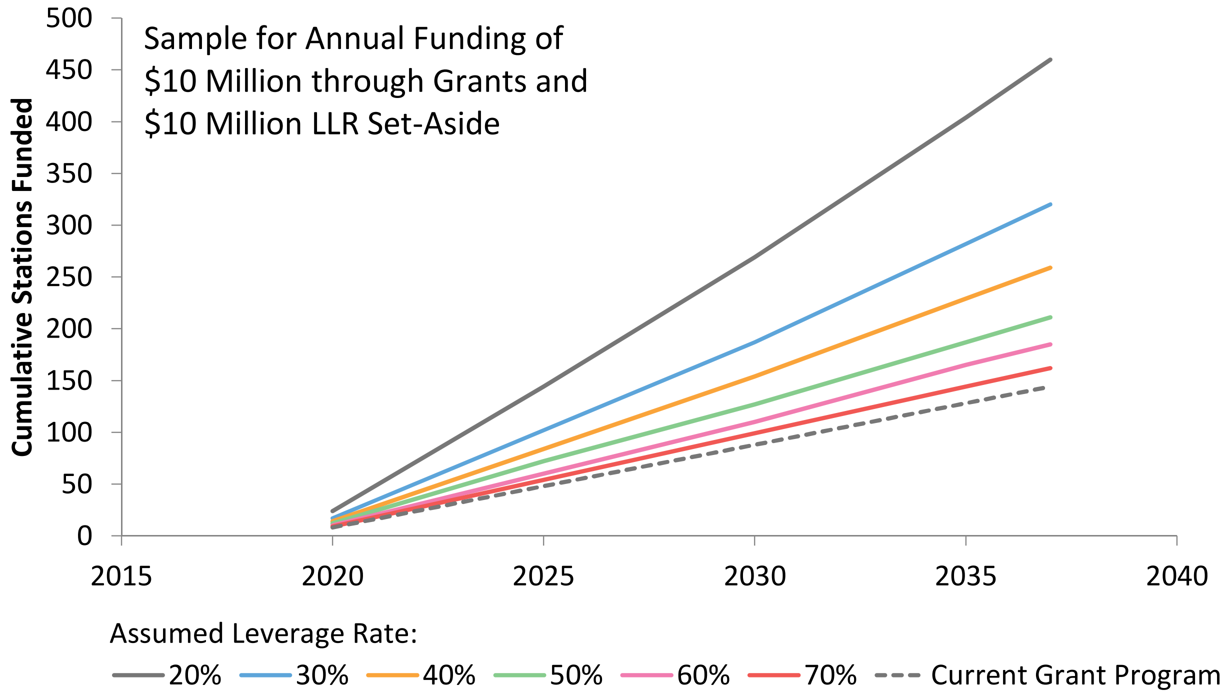


Figure 48: Example Cumulative Station Deployment with a Hybrid LLR and Grant Program for Various LLR Leverage Rates

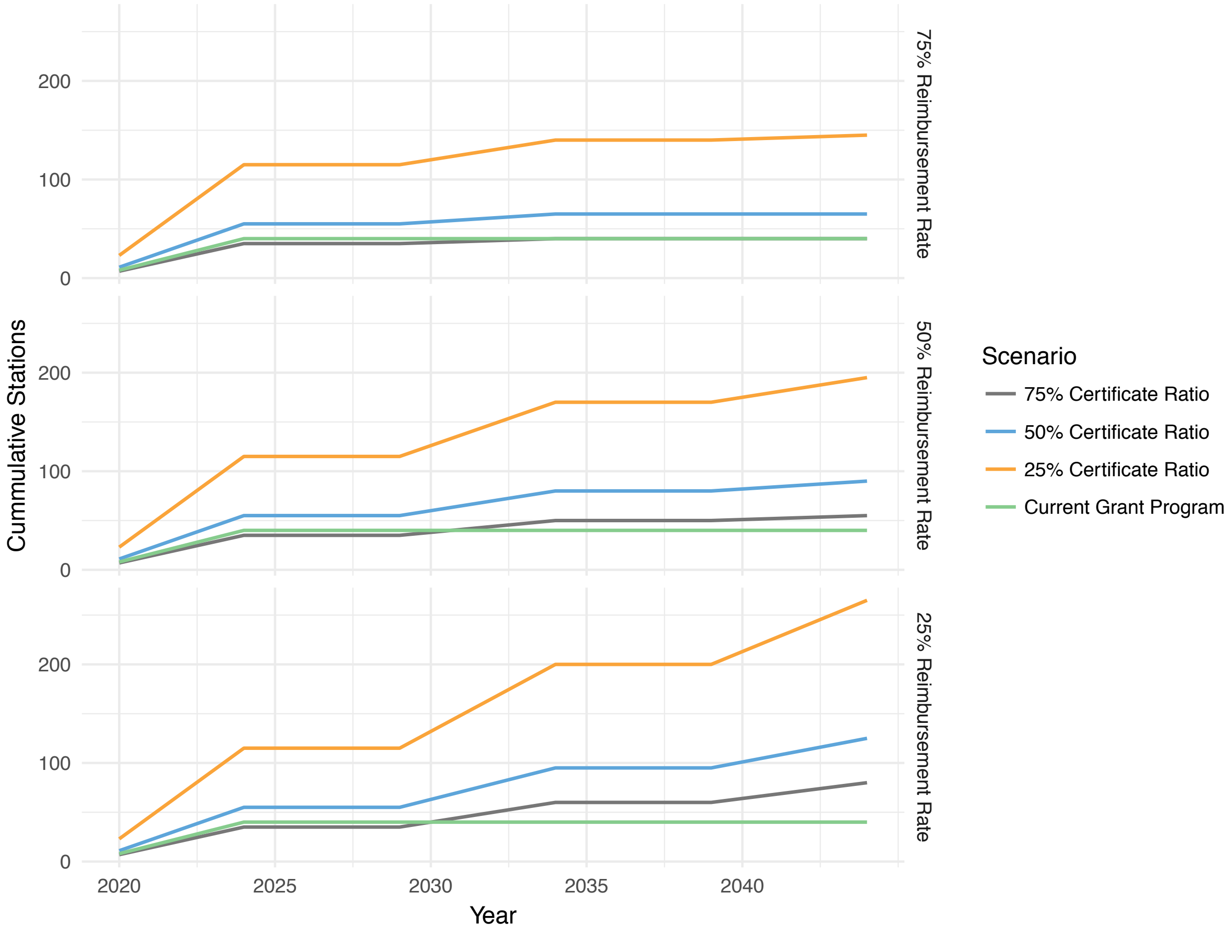


Certificate of Guarantee

Instead of directly funding a portion of station capital expenses, the Energy Commission could issue certificates that guarantee reimbursement for a portion of station capital expenses if the station proves to be poorly utilized after a specified period of time. For example, if the certificate guaranteed 50 percent of station capital expenses, the station developer could use the certificate to secure private investment for the remaining 50 percent of capital expenses. After an agreed maturation period (e.g. 5 or 10 years), the certificate's redeemed value would be based upon the station's utilization rate. If utilization was high, the certificate would have low value. If the utilization was low, the certificate would pay up to a determined rate (e.g. 50%) of capital expenses to the private investor. Funds that were set aside but not ultimately redeemed at the end of the evaluation period would then be available for reinvestment into additional hydrogen stations.

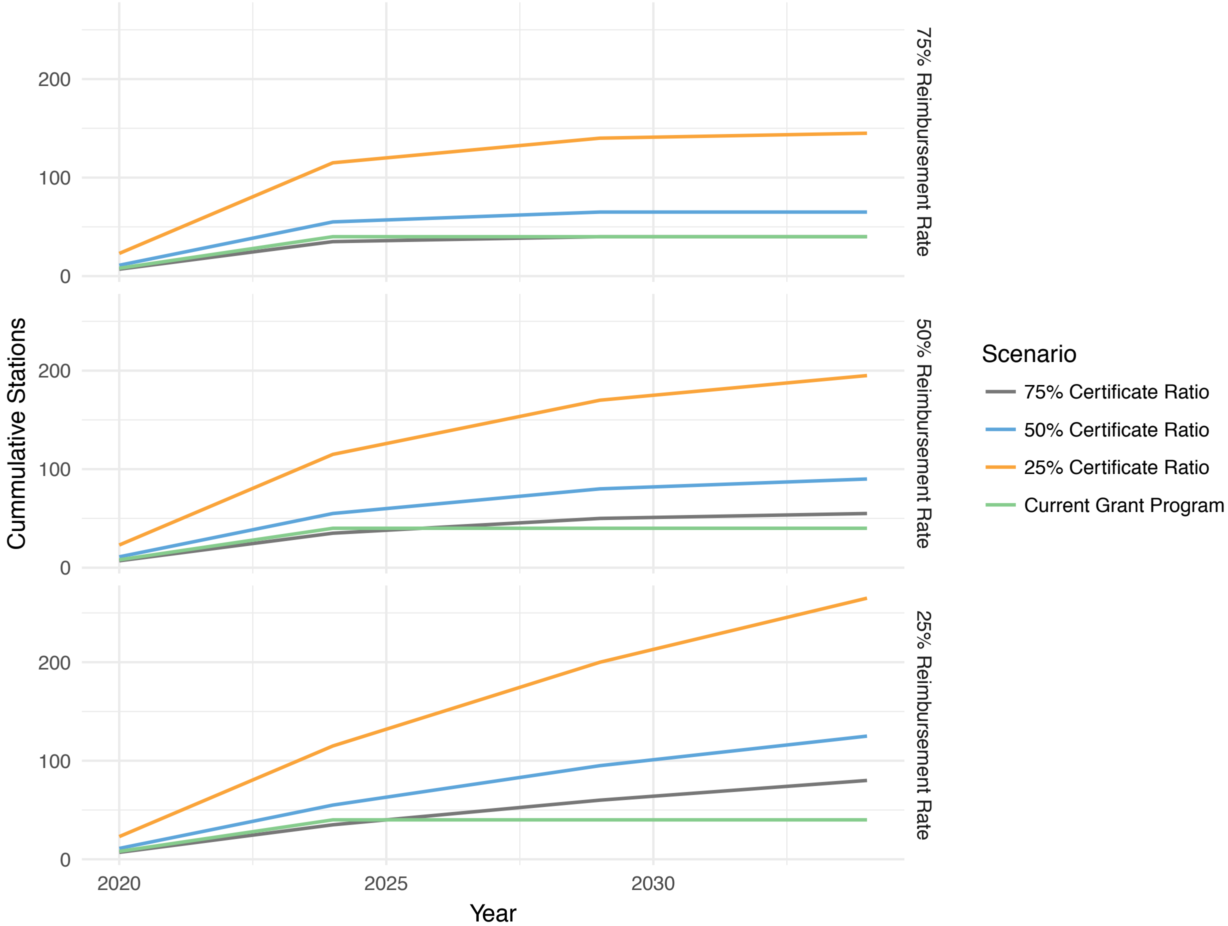
Figure 49 and Figure 50 show the potential future funding schedule for a constant $20 million per year grant program compared to various options within a certificate of guarantee program. Figure 49 assesses programs with a 10-year maturation period; individual lines indicate various levels of funding available through the certification, and the individual charts assess different claimed reimbursement rates at the end of the maturation period. Figure 50 assesses the same scenarios, for a program with a 5-year maturation period, which may be in better agreement with fund disbursement and liquidation requirements. Based on these analyses, a 75% certificate ratio may not be favorable, as it offers little (or in some cases no) advantage in terms of number of funded stations as compared to the current grant program. However, certificate ratios between 25% and 50% may prove attractive to the State in order to help achieve the goal of funding more stations sooner. Of course, the more funds that are reimbursed at the end of the maturation period, the less money that is available for further additional station investment.

Figure 49: Comparison of Station Funding Potential under Capital Grant and Certificate of Guarantee Program Options with a 10-year Maturation Period



With a 5-year maturation period, it may be possible to achieve a faster and more consistent rate of fueling station deployment. Comparison of Figure 49 and Figure 50 demonstrates that for the same assumption of certificate ratio and reimbursement rate, more stations are funded sooner with the shorter maturation period. However, a shorter maturation period represents a riskier proposition for the State. There is less time for the station's demand to grow to the expected throughput and there is a greater chance that stations don't perform well within the maturation period. Thus, either the certificate would have to be made less attractive to the station developer (and ultimately an outside investor) by implementing a lower certificate ratio or the station's reimbursement rate would likely be higher with the shorter maturation period. Either of these scenarios reduces the overall rate of hydrogen station deployment. Further analysis and detailed evaluation would be needed to find the appropriate balance between these factors in the design of a certificate of guarantee program. Discussion in open and public workshops could also help identify the parameters of a certificate of guarantee program that are beneficial to station developers while allowing the Energy Commission to fund a greater number of stations per year.

Figure 50: Comparison of Station Funding Potential under Capital Grant and Certificate of Guarantee Program Options with a 5-year Maturation Period



Direct Investors

Outreach to direct equity investors with an interest in promoting clean energy infrastructure could drive additional investment in hydrogen refueling infrastructure. Some examples of potential direct investors are:

- Breakthrough Energy Coalition (BEC) is a group of high net worth individuals and institutions committed to investing in new energy technologies. BEC investors include Bill Gates, Richard Branson, Jeff Bezos, and the University of California. BEC identifies hydrogen fuel production, ultra-low-cost electricity storage, and next-generation ultra-flexible grid management as areas of interest. BEC sees its role as helping move breakthrough technologies from the research stage through the valley of death to commercial viability [43].
- The University of California Office of the Chief Investment Officer of the Regents (OCIO) is committed to investing in scaling up climate change solutions. The OCIO is building partnerships with the public sector and industry and has established an aligned intermediary with other long-term investors with the goal of accelerating and increasing the flow of private capital into climate infrastructure projects and organizations [44].
- California State Teachers' Retirement System conducts direct equity investment in infrastructure projects [45].

Coordination with LCFS Program to Enable Renewable Fuel Sales Reimbursement

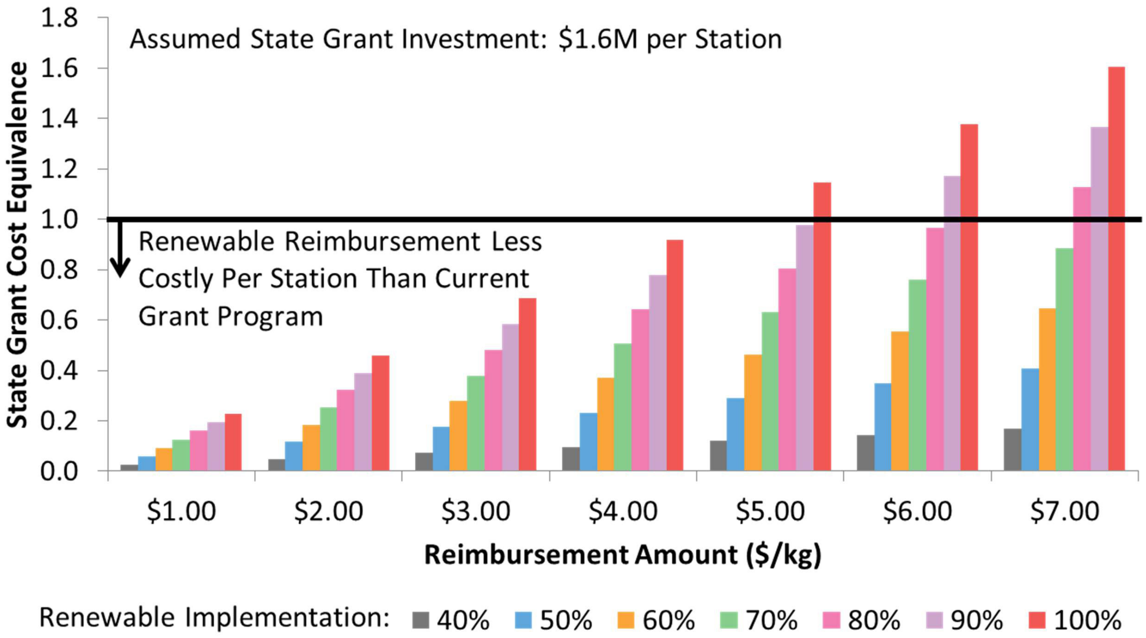
In certain locations across the state, the FCEV and hydrogen fueling markets may be (or may soon become) sufficiently advanced to provide significant assurance of expected throughput to station developers. In these cases, capital expenditure grants that have been instrumental in launching fueling markets across the state may be less necessary as prospects for payback of the initial investment become favorable with increased local station deployment. This presents the opportunity to investigate new station funding structures that take advantage of the local market successes established by existing AB 8 stations. One option may be to more directly promote maximizing air quality and climate improvement through reimbursement of costs incurred to procure and dispense renewable hydrogen above requirements set by SB 1505 and Energy Commission agreements. Under certain assumptions of the reimbursement structure, this type of funding plan may even cost the State less than current grant programs over the lifetime of the agreement, allowing the saved funds to be invested in additional stations. The net effect would be an acceleration of total station deployments.

Such a funding structure would require rigorous verification of dispensed renewable hydrogen quantities at every station funded with this structure. Proposed changes in the Low Carbon Fuel Standard (LCFS) program address ARB's plans for verification of dispensed hydrogen amounts and production resources as regards SB 1505. These proposed changes could be leveraged to enable the Energy Commission to pursue a renewable hydrogen reimbursement program. Open and public workshops may help define methods of harmonizing the necessary reporting for these two programs.

Figure 51 shows a comparison of the cost for 32 new 300 kg/day stations (to achieve 94 funded stations by 2023, shown in Figure 33) between the current grant funding program and a renewable throughput reimbursement. Analysis is shown for two different assumptions of State capital cost per station in a grant program, $1.6 and $2.1 million. For the renewable reimbursement calculations, various amounts of renewable implementation are analyzed, and it is assumed that the Energy Commission may fund each station for 5 years, with 100% utilization at each station. The y-axis is the ratio of State costs under the renewable reimbursement program to the grant funding program; any value less than one (under the black horizontal line) indicates the renewable reimbursement program is less costly to the State and saved funds could be available to fund additional stations.

For modest increases in renewable hydrogen implementation (up to 70% total renewable hydrogen throughput), this brief analysis shows reimbursement amounts up to $7/kg may allow more stations to be funded than a capital grant program. Even a 100% renewable station could be more favorable at a reimbursement rate between $4 and $5/kg. Open and public workshops could help define the acceptable rate of reimbursement to ensure stations remain financially viable and the Energy Commission can make the greatest impact with available funds. Additionally, the potential and need for a hybrid approach (funding individual stations through a mix of capital grants and renewable reimbursement) and individual station/developer caps would need to be addressed through workshop participation.

Figure 51: Cost Equivalence Between Renewable Hydrogen Reimbursement and Capital Grant Programs



Appendix F: Station Status Definition Details

The definition of an **Operational** station is adopted from Energy Commission GFO 15-605 (note that the definition included in previous Energy Commission grant programs like PON 13-607 may have different provisions). The current definition includes the following:

1. Has a hydrogen supply.
2. Has an energized utility connection and source of system power.
3. Has installed all of the hydrogen refueling station/dispenser components identified in the Energy Commission agreement to make the station functional.
4. Has passed a test for hydrogen quality that meets standards and definitions specified in the California Code of Regulations, Title 4 Business Regulations, Division 9 Measurement Standards, Chapter 6 Automotive Products Specifications, Article 8 Specifications for Hydrogen Used in Internal Combustion Engines and Fuel Cells, Sections 4180 and 4180 (i.e., the most recent version of SAE International J2719).
5. Has successfully fueled one FCEV with hydrogen.
6. Dispenses hydrogen at the mandatory H70-T40 (700 bar) and 350 bar (if this optional fueling capability is included in the proposed project).
7. Is open to the public, meaning that no obstructions or obstacles exist to preclude any individual from entering the station premises.
8. Has all of the required state, local, county, and city permits to build and to operate.
9. Meets all of the Minimum Technical Requirements (Section VI) of GFO 15-605.

The definition of **Open-Non-Retail** does not have a prescribed set of conditions, other than that it is a station funded under an early research and/or demonstration grant program (not originally intended to provide retail fueling service) but is nonetheless able to continue providing fueling service to early adopters of FCEVs. Approval for FCEV drivers to fuel at these stations varies according to the individual manufacturer of the vehicle. Some of these stations are expected to be upgraded so they can provide retail service, at which time they will need to demonstrate that all requirements of the Open- Retail definition have been met.

The definition of an **Open-Retail** and all in-progress station statuses are adopted from the GO-Biz effort to define a set of station status definitions with stakeholder consensus across the State agencies and FCEV and hydrogen fueling industries.

Open-Retail stations are defined by:

1. The station passed final inspection by the appropriate Authority Having Jurisdiction (AHJ) and has a permit to operate.
2. The station operator has fully commissioned the station, and has declared it fit to service retail FCEV drivers. This includes the operator's declaration that the station meets appropriate SAE fueling protocol, as required in California.
3. Two auto manufacturers have confirmed that the station meets protocol and fueling interface expectations (including point-of-sale), and their customers can fuel at the station.
4. The dispenser metering performance has been verified, enabling the station to sell hydrogen by the kilogram (pursuant to CCR Title 4, Division 9, Chapter 1).
5. The station is connected to SOSS.

The remainder of the status definitions are as follows:

- **Fully Constructed:** Construction is complete and Station Developer has notified AHJ.
- **Under Construction:** Construction at the site has started and is currently active.
- **Approved to Build:** The station developer has approval from the AHJ to begin construction. Depending on the station developer or individual project, construction may begin immediately or a pre-mobilization effort to select construction crews and deliver equipment may first be necessary.
- **Planning Approval:** The site plan for the station has been approved, which indicates that a hydrogen station can exist on the site, subject to meeting all building, fire, and electrical codes and standards.
- **In Permitting:** The permit application is currently under review by the AHJ planning agency.
- **Finishing Permit Apps:** The station developer is preparing site layout, engineering, and other documents for submittal to the AHJ. This process is often iterative and may actually occur several times throughout the permitting process. In this Annual Evaluation, a station is reported as Finishing Permit Apps if it has not yet submitted this material for the first time (after first submittal, the station is moved to In Permitting, even if new documents are submitted later).
- **Establishing Site Control:** The station developer is actively seeking a new site and/or negotiating a new site lease agreement.

Appendix G: HyStEP Participant Fact-Sheet

Since its introduction a year and a half ago, HyStEP has completed 15 station tests. In some cases, a single station could require multiple visits so the station developer could fine-tune their dispenser's performance to demonstrate compliance with SAE J2601. In addition, station developers that are new entrants to the United States market have utilized HyStEP to help refine and optimize their station. Other than these special cases, HyStEP station testing, analysis, and determination of compliance with SAE J2601 typically requires at least two weeks, one for testing and one for analysis. This effort is typically divided into the tasks shown in Figure 52.

Figure 52: Division of Time and Tasks during a 2-week HyStEP Station Performance Confirmation

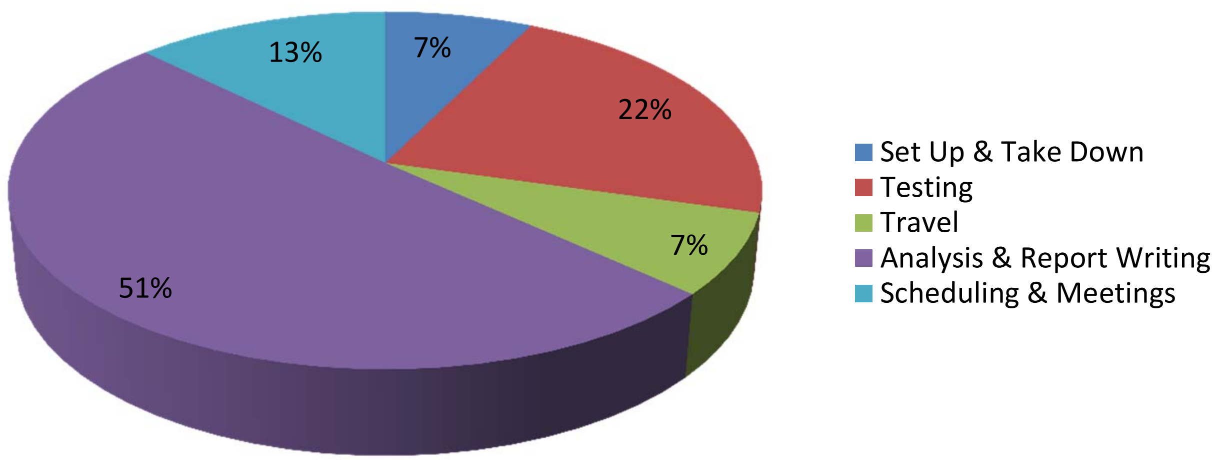


Table 12: Typical HyStEP Testing Matrix[22]

General Fault Tests	Table-Based Communications Tests	Table-Based Fueling Protocol Tests
CHSS+ Capacity Range (w/ Comm)	Abort Signal (3 parts)	Non Com H70 2-4 kg
Ambient Temperature	Halt Signal	Non Com H70 4-7 kg
Minimum Fuel Delivery Temperature	Data Loss Test Then Resumes Fueling	Com H70 2-4 kg
Maximum CHSS+ Gas Temperature	Invalid CRC^ Communication	Com H70 4-7 kg
Minimum CHSS+ Initial Pressure (w/o Comm)	IDDV* - Protocol Identifier	Com H70 7-10 kg
Maximum CHSS+ Initial Pressure	IDDV* – Communications Software Version #	Non Com H35 2-4
Maximum CHSS+ Pressure (w/ Comm)	IDDV* – Tank Volume	Non Com H35 4-6
Maximum State of Charge (w/ Comm)	IDDV* – Receptacle Type	Repeated Table
	IDDV* – Fueling Command	Top-off Fueling
	IDDV* – Fueling Type	High Pressure Capacity
	IDDV* – Measured Pressure	Pre-Cooling Capacity
	IDDV* – Measured Temperature	

HyStEP utilizes CSA HGV 4.3-2014 to evaluate hydrogen fueling stations to determine compliance with the specific requirements in SAE J2601-2014 and J2799-2014 specifications. The CSA HGV 4.3 standard establishes the test method, criteria, and apparatus to evaluate a hydrogen fueling station dispensing system as it relates to achieving the protocols specified in the SAE J2601 and J2799 standards. The testing evaluation applies to dispensers designed to fill vehicle Compressed Hydrogen Storage Systems (CHSS) following the prescribed protocols defined in SAE J2601 that enable rapid fills while conforming to temperature, pressure, and fuel density safety limits. In general, CSA HGV 4.3-2014 contains dispenser and station equipment requirements and is divided into 3 main parts: 1) general fault tests, 2) table-based communications tests, and 3) table-based fueling protocol tests. A standard testing matrix is shown in Table 12. The table-based fueling protocol tests typically require a minimum of 24 fills: 10 non-communication tests, 10 communication tests and 4 additional tests (repeated table, top-off fueling, pre-cooling capacity, and high pressure capacity tests). During a single visit to a station, several of these tests may need to be repeated. While the device is onsite, the station developer or operator may make hardware or software fine-tuning adjustments in order to ensure the test(s) can be completed per the requirements in CSA HGV 4.3-2014. Any issues that are identified throughout this process are typically addressed before the testing week is completed, and are therefore no longer issues by the time the station is declared open. In order to complete the full testing matrix, and accounting for repeated tests, approximately 50 - 60 kilograms of hydrogen may be dispensed to the HyStEP device over a typical testing week.

The HyStEP device is designed to record tank temperature, ambient temperature, and tank pressure every 0.1 seconds and State-of-Charge (SOC) values every 0.5 seconds. During station performance analysis, these data are paired with the dispensing data provided by the station operator on the day of the tests. Dispenser data tests must be formatted uniformly before being analyzed. Data samples need to be provided at least once every second, with the time increment reported at least to the thousandths decimal place. Minimizing time increments is critical to synchronizing start time and leak checks. Required dispensing data includes date and time of fill, time from start of fill, ambient temperature, dispenser temperature and pressure, and mass

22 * IDDV = Invalid Defined Data Value
+CHSS = Compressed Hydrogen Storage System
^CRC = Cyclic Redundancy Check

dispensed. All required reporting units are indicated in Figure 53. The pairing of HyStEP and dispenser data is completed through a MATLAB based executable file that incorporates the CSA HGV 4.3 -2014 testing protocol to determine compliance with SAE J2601-2014 fueling protocol.

Figure 53: Sample Dispenser Data Sheet; Note the Precision of the Increment Delta Timestamp and Units and Precision of Recorded Data

Date/Time	Increment Delta from Beginning of Test (s, 0.001)	Pressure (Mpa)	Ambient Temp (C)	Nozzle Instantaneous Temp (C)	Mass_H2 (g) Dispensed
2017-07-22 01:48:12 PM	0.000	2.12014	13.40000	-22.60000	0.000
2017-07-22 01:48:13 PM	1.440	2.09945	13.40000	-22.60000	0.000
2017-07-22 01:48:14 PM	2.467	2.10980	13.40000	-22.60000	0.000
2017-07-22 01:48:16 PM	3.503	2.13048	13.40000	-22.60000	0.000
2017-07-22 01:48:17 PM	4.527	2.13048	13.40000	-22.60000	0.000
2017-07-22 01:48:18 PM	5.680	60.32568	13.40000	-21.80000	0.000
2017-07-22 01:48:19 PM	6.713	59.53968	13.40000	-33.00000	0.000
2017-07-22 01:48:20 PM	7.857	29.35098	13.40000	-40.10000	74.000
2017-07-22 01:48:21 PM	9.047	29.46475	13.40000	-35.50000	75.000

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