CALIFORNIA
AIR RESOURCES BOARD

2019 Annual Evaluation of Fuel Cell Electric Vehicle Deployment & Hydrogen Fuel Station Network Development

Pursuant to AB 8, Statutes of 2013

arb.ca.gov

July 2019

List of Acronyms

AB 8	Assembly Bill 8 (Perea, Chapter 401, Statutes of 2013)
AHJ	Authority Having Jurisdiction
ARFVTP	Alternative and Renewable Fuel and Vehicle Technology Program
BAU	Business as Usual
BEV	Battery Electric Vehicle
CaFCP	California Fuel Cell Partnership
CAFCR	California Fuel Cell Revolution
CARB	California Air Resources Board
CDFA	California Department of Food and Agriculture
CHAT	California Hydrogen Accounting Tool
CHIT	California Hydrogen Infrastructure Tool
CRADA	Cooperative Research and Development Agreement
CTEP	California Type Evaluation Program
DMS	Division of Measurement Standards
DMV	Department of Motor Vehicles
EO	Executive Order
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
H2FIRST	Hydrogen Fueling Infrastructure Research and Station Technology
H70	Hydrogen at a pressure of 70 megapascal
HGV	Hydrogen Gas Vehicle
HRI	Hydrogen Refueling Infrastructure
HySCapE	Hydrogen Station Capacity Evaluation
HyStEP	Hydrogen Station Equipment Performance
LCFS	Low Carbon Fuel Standard
MIRR	Modified Internal Rate of Return
NIST	National Institute of Standards and Technology
NPV	Net Present Value
NREL	National Renewable Energy Laboratory
PHEV	Plug-In Hybrid Electric Vehicle
PON	Program Opportunity Notice (California Energy Commission's formal communication of a grant program in prior years)
SB 1505	Senate Bill 1505 (Lowenthal, Chapter 877, Statutes of 2006)
SOC	State of Charge
SOSS	Station Operational Status System developed by CaFCP
US DOE	United States Department of Energy
ZEV	Zero Emission Vehicle

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Executive Summary

The past year of growth in California's hydrogen fueling station and Fuel Cell Electric Vehicle (FCEV) markets has progressed similarly to projections reported in the *2018 Annual Evaluation* [1]. In addition, new programs and policies have been developed and initiated to ensure that some of the most ambitious public-private goals are met as projected. The Low Carbon Fuel Standard's (LCFS) Hydrogen Refueling Infrastructure (HRI) credit provisions took effect, predicated on the goal of reaching 200 hydrogen stations by 2025 as described by Governor Brown's Executive Order B-48-18 (EO B-48-18) [2]. The California Energy Commission's (Energy Commission) proposed concepts for the next station funding solicitation were also released, aiming to maximize the benefit of the current Assembly Bill 8 (AB 8; Perea, Chapter 201, Statutes of 2013) program [3]. The next funding solicitation has been proposed to adopt a multi-year, network-focused approach designed to emphasize economic competitiveness and deploy more than the 100 station minimum of AB 8 [4].

> "The four California stations are the first of a series of stations intended by Iwatani for deployment in the western part of the United States. Iwatani is committed to continuously improving the customers' experience and a number of upgrades are planned for the acquired stations. Our multi-year development program is aligned with plans by automakers and the state of California to extend the hydrogen supply chain infrastructure and make fuel cell electric vehicles available to consumers in the expanding U.S. market."
>
> **Mineharu Okamoto**
> President
> Iwatani Corporation of America

The period between June 2018 and June 2019 saw the completion of six additional hydrogen fueling stations and the deployment of over 1,500 FCEVs. These are positive developments demonstrating the continued success of the AB 8 program's funding efforts to date. The next year will be a further demonstration of this success, with as many as 11 additional stations completing construction and opening for retail customer service later this year. All remaining stations are still projected to be completed by the end of 2020, in line with previous expectations.

The past year has also demonstrated continued participation of private industry beyond the AB 8 program. The public-private California Fuel Cell Partnership (CaFCP) published its vision of one thousand stations and one million FCEVs by 2030 in its 2018 *Revolution* document [5]. The members of CaFCP have continued work on translating that vision into enabling goals and actions and may provide further publications in the next year to bring the path of success into clearer focus. Several industry stakeholders have announced multi-million dollar plans for investment in hydrogen fuel infrastructure upstream of the fueling stations themselves. Auto manufacturers have similarly announced significant scale-up of FCEV production capacity in the near future. Developments have also continued in other vehicle markets, with companies like Nikola announcing significant heavy-duty FCEV and infrastructure deployment plans that could represent a major transformation of the market for hydrogen as transportation fuel.

> "As our hydrogen refueling infrastructure continues to grow in California and into the northeastern U.S., we eagerly anticipate the exponential reduction in emissions it will bring, resulting in a cleaner atmosphere for everyone"
>
> **Michael O'Brien**
> Vice President of Product, Corporate & Digital Planning
> Hyundai Motor America

These developments all indicate continuing growth in the hydrogen fuel and FCEV markets in California. However, the goals of EO B-48-18 and the *Revolution* require much more than continuation of the historical rate of growth in FCEVs and hydrogen fueling. Meeting both of these goals requires acceleration in both markets that must initiate within the next few years. The State's efforts are beginning to address this needed shift and attempt to provide an impetus to accelerate market development, especially through new concepts in AB 8 funding and the LCFS HRI program. The California Air Resources Board (CARB) and the Energy Commission are also continuing to develop analysis methods that highlight a path to hydrogen fueling network self-sufficiency, provided FCEV deployment grows commensurately.

> "We, as industry, are ready to invest in hydrogen technology and set up large-scale projects to boost deployment… Multilateral cooperation is essential to tackle the global challenge of climate change by moving towards an energy transition, and the Clean Energy Ministerial Hydrogen Initiative is a great example of collaboration to make this possible."
>
> Benoit Potier
> Hydrogen Council Co-Chair
> Chairman & CEO
> Air Liquide

Based on analysis of the current status and trajectory of FCEV deployment and hydrogen fueling network development, CARB has made the following determinations:

> "We're going to shift from limited production to mass production, reduce the amount of expensive materials like platinum used in FCV components, and make the system more compact and powerful,"
>
> **Yoshikazu Tanka**
> Chief Engineer of the Toyota Mirai

- Today's network of 41[1] open hydrogen fueling stations has established the early fueling market that enabled the launch of the FCEV consumer market in California. Of the 24 funded stations currently under construction, 11 are projected to open later this year. Coverage and capacity provided by the state's hydrogen fueling network will therefore grow substantially in 2019 and should encourage continuing FCEV deployment opportunities.
- Hydrogen fueling station network development continues to be largely on schedule with prior expectations. Ongoing communication efforts between State and private entities have led to more reliable station development projections.
- California's consumer FCEV market has successfully launched and continues to grow, even with roughly two-thirds of the stations originally envisioned as needed to begin vehicle market launch[2]. This is an important achievement and proves that FCEVs and hydrogen are a viable consumer market. Still, State goals call for sustained and even accelerated deployment to build upon this early milestone. Current auto manufacturer-provided projections for on-the-road FCEVs are 26,900 in 2022 and 48,000 in 2025. While these represent continued and steady growth for the period through 2022, growth through 2025 has seemingly been delayed by one year. This delay is counter to the 2025 (200 station) goal of EO B-48-18 and the 2030 (1,000 station and one million FCEV) goals of the Partnership's *Revolution*. CARB's LCFS HRI program and the Energy Commission's grant funding through AB 8 are major steps that should provide certainty to the market for the 2025 200 station goal. Still, in order to

1 For this report, CARB is counting the San Francisco Third Street station as open, although it has not yet begun retail operations. CARB's understanding is the station was preparing to transition to open retail status at the same time that the northern California supply disruption event began. The station is fully constructed and has completed all testing, review, and confirmation steps required of an open retail station. CARB therefore expects that the station will be able to begin retail operations as soon as the supply disruption is resolved, just like the remainder of the open station network.

2 The California Fuel Cell Partnership's 2012 publication *A California Road Map: The Commercialization of Hydrogen Fuel Cell Vehicles* described the need for 68 retail hydrogen fueling stations to enable the launch of the FCEV market [9]. In reality, California's FCEV market began pre-commercial launch in 2015, when only a handful of retail and non-retail stations were available. The transition to the early commercial market was recognized in 2017, when 31 stations (by this time, most were retail stations) were available.

support the ongoing operation of such a large network, FCEV deployments will need to accelerate beyond any pace reported to date. Further delays in initiating such acceleration will only push those goals further into the future. Given that long-term projections have been more significantly altered than near-term projections, CARB does not find a compelling reason for this delay associated with changes over the past year in the expected open dates for the currently funded fueling network.

> "Hydrogen fuel cells work in a lot of situations, like long-distance trucking, where battery-electric doesn't. Batteries can work where fuel cells don't make sense. It's not a one-size-fits-all situation."
>
> "We believe the fuel cell will replace the diesel engine in the next 10 years."
>
> **Trevor Milton**
> CEO of Nikola Motor

> "Hyundai Motor Group, the global pioneer of the commercial production of FCEV, is taking a bold step forward to expedite the realization of a hydrogen society. We will expand our role beyond the automotive transportation sector and play a pivotal role in global society's transition to clean energy by helping make hydrogen an economically viable energy source. We are confident that hydrogen power will transcend the transportation sector and become a leading global economic success."
>
> **Euisun Chung**
> Executive Vice Chairman
> Hyundai Motor Group

- Disruptions in hydrogen supply to California's fueling stations have occurred in the past year as the state's hydrogen fueling network continues to grow. Because California's hydrogen fueling network relies on a limited set of available production and distribution facilities, supply interruptions can have a magnified effect on station operations and ultimately FCEV customers. While the impact can be severe, it is ultimately temporary in nature while stakeholders work to assess and address the root causes of the interruptions. In addition, it is a known challenge that is actively discussed among private and public stakeholders who are working cooperatively to ensure sufficient hydrogen resources can be developed and available to support growth in the state's FCEV fleet. CARB therefore finds that while supply disruptions can significantly impact the current FCEV market, their ultimately temporary nature does not provide sufficient explanation for a change in long-term FCEV deployment.
- The next round of hydrogen fueling station grant funding through the Energy Commission may provide a streamlined location and capacity evaluation process. This process would be enabled by prior location analysis completed by CARB in support of the *Revolution* document and the recent development of the new Hydrogen Station Capacity Estimation (HySCapE[3]) tool [6]. CARB recommends utilizing an area classification system built on the current network status and the features and layout of the projected 2030 network, which would lead applicants to the appropriate size and location of hydrogen fueling stations.
- Bolstered by the requirements of the LCFS HRI credit provisions and the requirements of Energy Commission grant funding eligibility, California's hydrogen fueling network is expected to continue to meet the 33% minimum renewable requirement for Senate Bill 1505 (SB 1505; Lowenthal, Chapter 877, Statutes of 2006) [7]. The currently-funded station network will dispense hydrogen with 39% renewable content sourcing, with the potential for greater renewable implementation in the future if there is significant participation in the LCFS HRI credit program, which requires a 40% renewable implementation.

3 HySCapE is a model used by CARB and the Energy Commission and developed in partnership with the National Renewable Energy Laboratory to provide a standardized method of estimating hydrogen fueling station daily capacity based on limited information about a station's equipment specifications. Further details are provided later in this report.

California's Hydrogen Deployment Strategy

California's hydrogen fueling station network is one of the first in the world to demonstrate the viability of hydrogen fuel sales in a retail environment and the potential that such a network creates for deployment of consumer FCEVs. The strategy for developing this network has evolved through time (from the publication of the California Hydrogen Blueprint Plan [8], to the release of the California Fuel Cell Partnership's first Roadmap [9], and on through the development and implementation of the California Hydrogen Infrastructure Tool to support AB 8 and the Partnership's Revolution vision for 2030 [5].) Each successive version built on the prior plans and incorporated insights gained throughout the years. However, fundamental acknowledgment has remained steady that a set of retail hydrogen fueling stations needs to be established prior to the launch of a consumer FCEV market. This approach was embodied by AB 8, which provided certainty for hydrogen fueling station development.

As stations have developed and vehicles deployed, complementary policies like Operations and Maintenance grants through AB 8 and the new LCFS HRI credit provision have been introduced to maintain momentum and provide a basis for achieving the most ambitious goals. The combination of grant programs through AB 8 and the LCFS HRI credit provision provides station developers with opportunities to receive consistent support for both capital-intensive expenses of establishing a hydrogen fueling station and cash-flow challenges encountered in the early years of FCEV deployment. The combination also appropriately balances early public support to initiate market development with growing private investment as the network matures and individual stations become more successful and realize greater financial health through their own retail fuel sales.

More recently, focus has also turned towards the cross-sectoral challenges and benefits that the State's hydrogen fueling network program can address. The broadest embodiment of this is captured by the United States Department of Energy's H2@Scale program. This initiative aims to resolve technical challenges associated with utilizing hydrogen generated from renewable electricity as a means of balancing an increasingly renewable electricity grid while providing a zero-carbon fuel and industrial process gas across all sectors. Developing a hydrogen-fueled FCEV market introduces an opportunity for a controllable load that will be needed at the times of day when renewable electricity generation outpaces demand. In this situation, the excess renewable electricity needs to be removed from the grid, either by shutting off or disconnecting renewable generation devices or directing the excess energy towards devices that store or convert the energy in a useful form for later use. Electrolyzers with near-instantaneous response time are a promising available technology solution to this challenge; the hydrogen fuel that they can generate represents an economic market driver to generate interest in deploying the technology.

Within transportation more directly, the potential synergies between developing light-duty and medium/heavy-duty hydrogen transportation options have also started to crystallize. The technological challenges of hydrogen powertrains in both sectors have largely been addressed; the greatest barrier that remains is the economics of achieving large-scale production quickly. Because of the greater volume of light-duty vehicles, developing a market for hydrogen-fueled passenger cars (which begins with developing the associated hydrogen fueling network) can help fuel cell production reach large scale faster. Cost savings for fuel cells in light-duty vehicles can directly translate to medium and heavy-duty vehicles, as several manufacturers have already demonstrated by using the same fuel cell stack in vehicles across all of these sectors. Thus, passenger cars, buses, delivery vans, and freight-bearing trucks all have potential for cost reductions based on the growth of the light-duty FCEV market. Similarly, because each medium/heavy-duty vehicle individually consumes much more hydrogen than an individual passenger vehicle, economies of scale for hydrogen production and distribution infrastructure can be more rapidly achieved by growing the market for larger vehicles. This could accelerate the market development of fuel-grade hydrogen towards a more commoditized system like gasoline and benefit all hydrogen-powered vehicles.

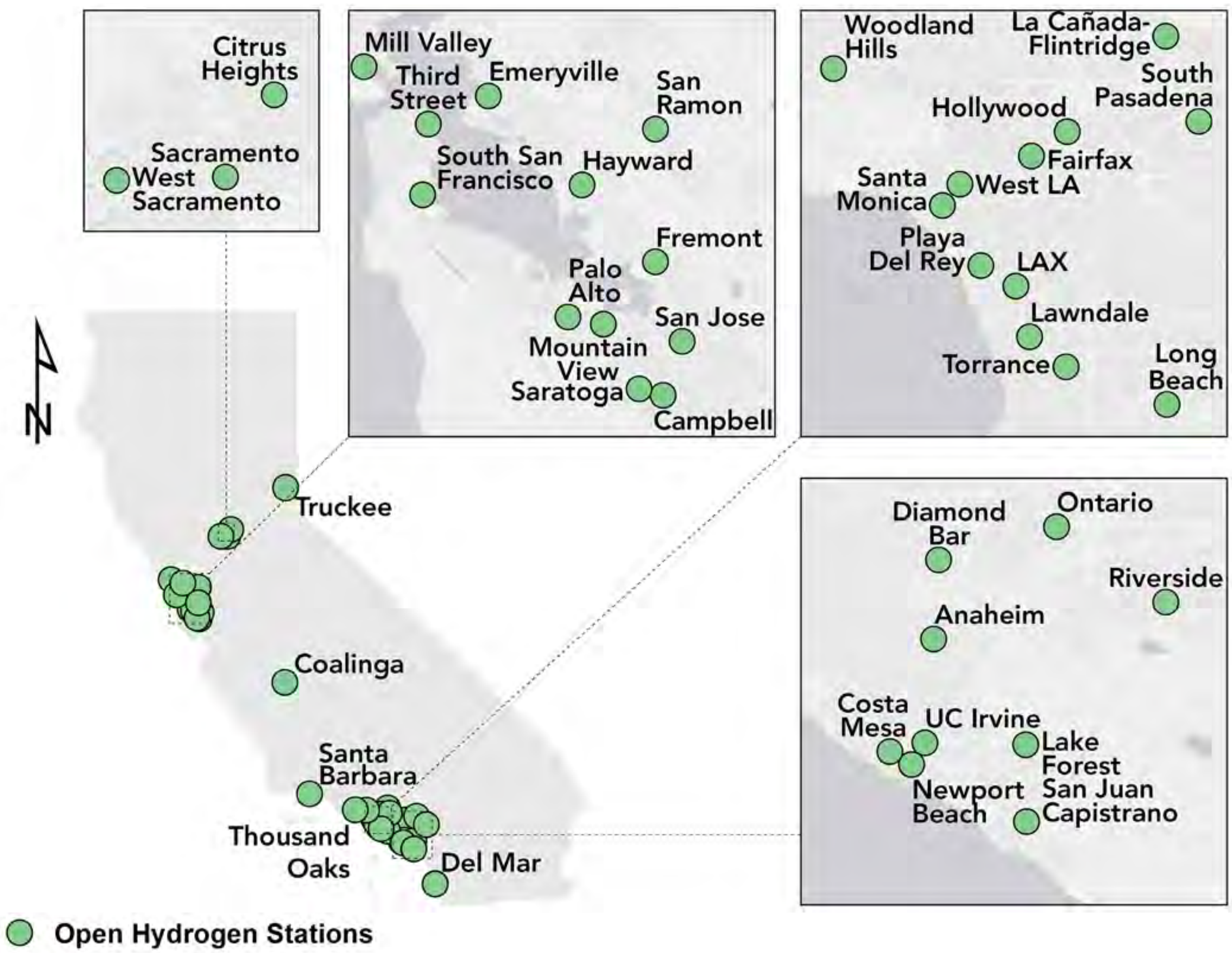
Going forward, it is likely that further insights will be gained through these market-building efforts in California as well as by studying developments that will occur in other nations across the globe. While California has been a leader in showing that consumer FCEV markets can be established with appropriate planning and support, other states and nations with different strategies and programs will provide opportunities to learn and adjust as appropriate. However, given the recent trends of expanding fuel cell powertrains across all vehicle types and the need to address greenhouse gas emissions across all sectors, it appears clear that holistic and integrated planning will become an increasingly fundamental aspect of hydrogen planning and policy in the future.

Findings

Finding 1: Station network development in 2019 has expanded coverage and capacity in core market areas.

As of May 28, 2019, California's hydrogen fueling network consists of 41[4] open retail hydrogen fueling stations, five more than reported at the same time last year (at which time the Burbank station was pre-emptively counted, but is not currently included in open station reporting). The new network additions are located in the east and south San Francisco Bay Area, the city of San Francisco, Sacramento, and the Los Angeles area. These are all markets likely to see the highest concentrations of FCEV first adopters, as determined through California Hydrogen Infrastructure Tool (CHIT) analysis. Figure ES1 displays the locations of all 41 stations, and highlights the newly-established subnetwork of stations in and around Sacramento that will provide FCEV drivers in the area with multiple fueling options, and showcase the network benefit of closely-placed stations that can provide redundant coverage and fueling capacity to the local FCEV population.

Figure ES1: Current Open Hydrogen Fueling Station Network (as of May 28, 2019)

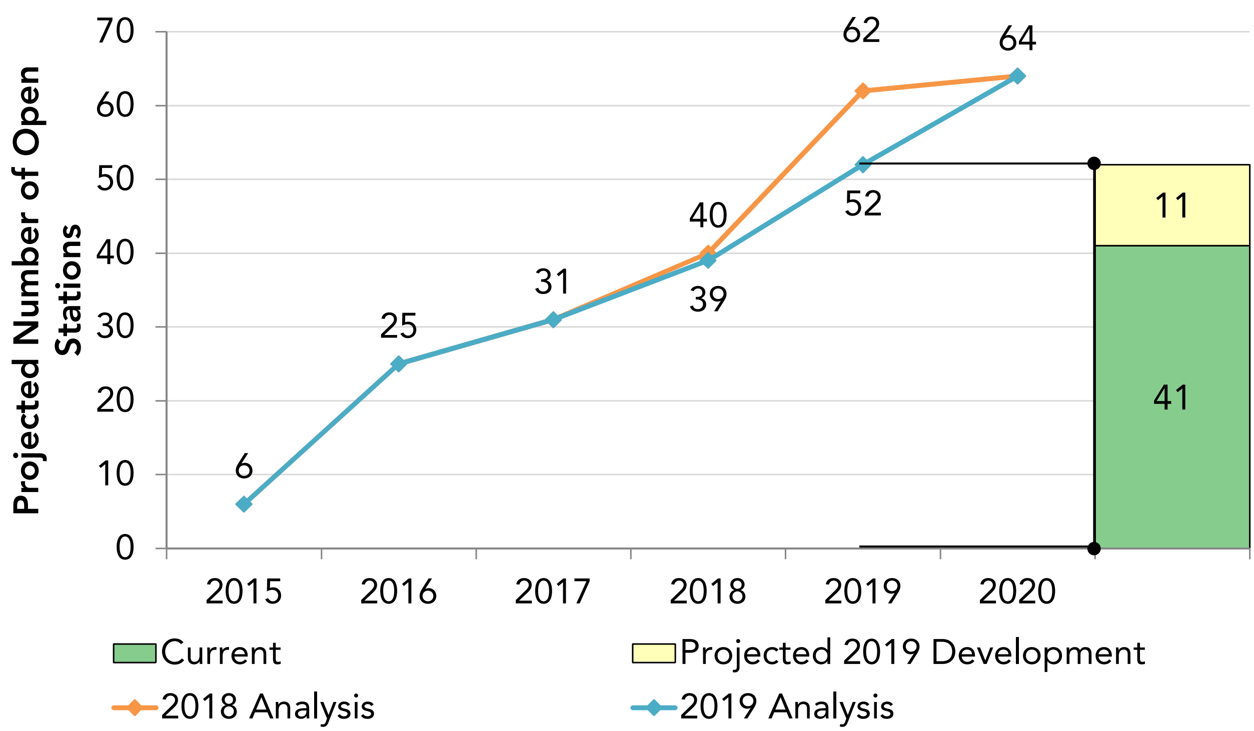


4 For this report, CARB is counting the San Francisco Third Street station as open, although it has not yet begun retail operations. CARB's understanding is the station was preparing to transition to open retail status at the same time that the northern California supply disruption event began. The station is fully constructed and has completed all testing, review, and confirmation steps required of an open retail station. CARB therefore expects that the station will be able to begin retail operations as soon as the supply disruption is resolved, just like the remainder of the open station network.

Finding 2: Station network development through 2018 and early 2019 has continued to remain largely on schedule.

Previous projections had anticipated that 40 hydrogen fueling stations would be available in the network by the end of 2018. By the close of last year, the network had 39 open hydrogen fueling stations. Notably, prior reports preemptively anticipated the Burbank station would open in early 2018, which has not yet happened and explains the one station discrepancy. Still, the progress made in the last year highlights improvements made in communication between industry and State agencies regarding hydrogen station development progress. However, development progress for the future has been adjusted compared to prior estimates, with 52 stations now expected to be open by the end of 2019 compared to 62 as previously reported. While this is reflective of some station development times extending longer than previously expected, many of the stations projected to open in 2020 are estimated to do so in the first half of the year. In addition, other stations have actually opened ahead of the previously-projected schedule, and all 64 funded stations are still projected to open by the end of 2020. In fact, three of the hydrogen stations that have opened since the *2018 Annual Evaluation* were funded only in the most recent grant funding solicitation (GFO 15-605), which first proposed awards only two years ago, on February 17, 2017. This is an encouraging sign that hydrogen fueling station development time is continuing to improve. Thus, while schedules have shifted for the next two years, CARB does not anticipate a long-term network development delay. Figure ES2 displays the progress in the open station network development and highlights the anticipated 11 new stations yet to open in 2019.

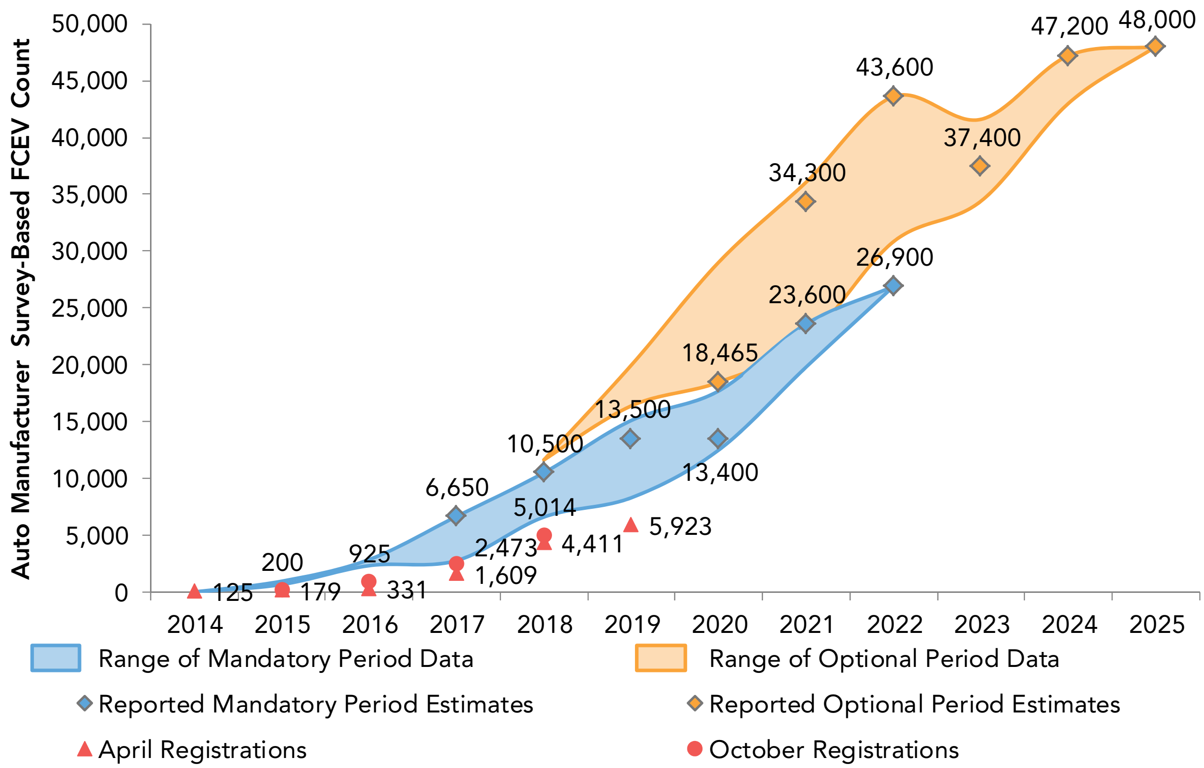
FIGURE ES2: COMPARISON OF STATEWIDE FUNDED STATION PROJECTIONS BETWEEN 2018 AND 2019 ANNUAL EVALUATIONS



Finding 3: Auto manufacturer projections for FCEV deployments do not demonstrate sufficient acceleration to support the FCEV deployment goals of EO B-48-18 and the California Fuel Cell Partnership's *Revolution* document.

California's FCEV fleet currently consists of 5,923 vehicles on the road according to CARB's analysis of the latest Department of Motor Vehicles (DMV) registration records available[5]. This represents growth of 1,500 vehicles from the same time last year; while not as large as the growth between 2017 and 2018, the pace of FCEV deployment is largely sustained and auto manufacturer projections provided through the annual survey indicate that acceleration will occur in the next few years. Updated projections for future on-the-road FCEV fleets informed by the auto manufacturer survey are 26,900 in 2022 and 48,000 in 2025, as shown in Figure ES3. The nearer-term estimates represent a slightly slower pace than prior reports, but still infer significant acceleration in the short term. On the other hand, the projection for 2025 represents another one year delay in reported deployment plans. This one year delay does not appear to be explained by the progress in station network development in the past year; although some individual station open dates have shifted, they represent a small fraction of the funded network and should not initiate vehicle deployment delays so far in the future. Thus, auto manufacturer deployment projections have not yet advanced California's projected FCEV fleet towards the 2030 goal of one million vehicles, as reported in the California Fuel Cell Partnership's *Revolution*. Members of the Partnership acknowledge the difficulty of that goal and the necessary scale of accelerated FCEV deployment needed to meet it. The longer that acceleration of either FCEV or fueling station network market development is delayed, the more difficult it will be for collaborative State and industry efforts to ensure that goals for 2025 and beyond are met on schedule.

Figure ES3: Current and Projected On-Road FCEV Populations and Comparison to Previously Collected and Reported Projections

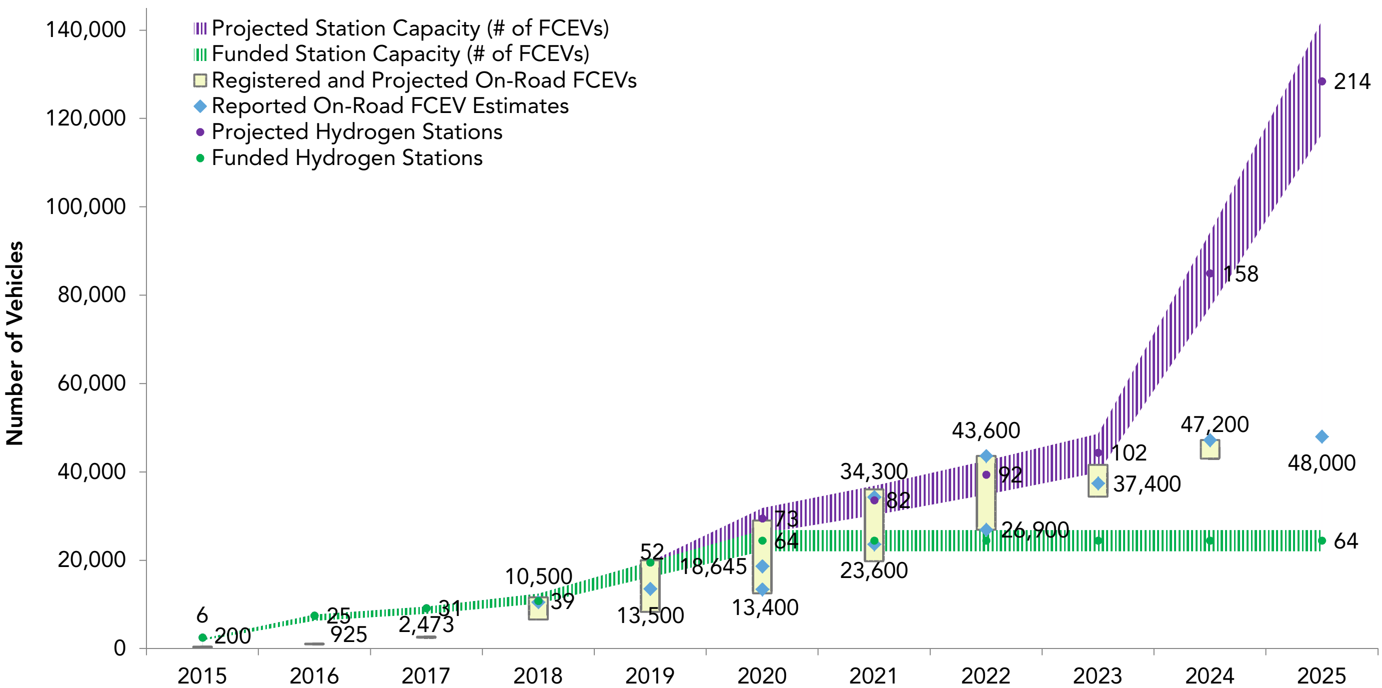


5 Auto manufacturer estimates reported through the California Fuel Cell Partnership provide a similar estimate of 6,830 vehicles through as of June 1, 2019 [56]. DMV data are based on current registration status, while CaFCP data are driven more directly by vehicle sales. These typically have different reporting and processing periods, which may lead to different estimates at times.

Finding 4: A station network of 200 stations per EO B-48-18 provides up to three times the fueling capacity of auto manufacturers' currently projected FCEV deployment plans for 2025.

Through EO B-48-18, CARB and other State agencies are charged with working towards the goal of 200 hydrogen fueling stations by 2025. This goal requires roughly doubling the amount of stations intended to be funded by AB 8, with only one additional year of build time. The AB 8 program and the LCFS HRI credit provision are programmatic efforts to secure that goal for California's future. At least 100 stations will be built by 2024 through the AB 8 program; the LCFS HRI program endeavors to provide the additional support needed to develop the remaining stations to the 200 goal in 2025. However, these programs (especially the HRI credit program) will be strained if FCEV deployment is not sufficient to provide necessary hydrogen demand and therefore economic activity in the hydrogen fueling industry. More vehicles translate to more hydrogen demand and more private interest in continuing the buildout of the hydrogen fueling network. The 48,000 FCEVs projected by 2025 only represent approximately one-third of the fleet that 200 stations may be able to serve at that time, as shown in Figure ES4. While it is widely acknowledged by industry and government groups alike that station development must precede FCEV deployment, such a large gap is likely unsustainable and likely puts the success of the network at risk. Greater FCEV deployments are necessary to realize the 200 station goal of EO B-48-18 on schedule.

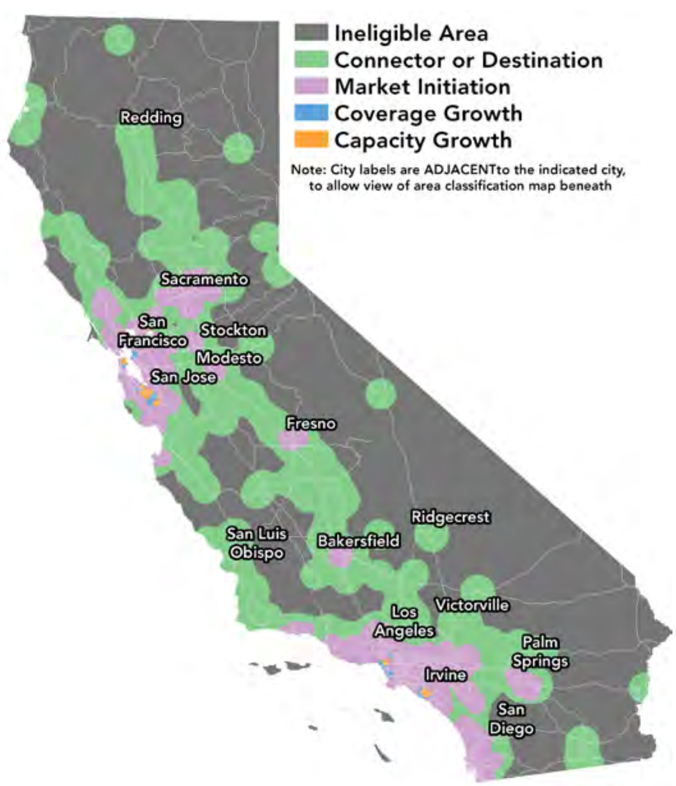
Figure ES4: Projected Hydrogen Demand and Fueling Capacity Under Assumptions of Meeting the Original AB 8 Goals, Followed by Meeting EO B-48-18 Goals



Finding 5: CARB recommends a streamlined station location evaluation for the next round of Energy Commission grant funding. This method can leverage CHIT-led analyses already reported in the 2018 Annual Evaluation and in alignment with the 200 station goal of EO B-48-18.

Past Energy Commission grant solicitation efforts have relied on iterative implementation of CHIT and other tools in order to aid evaluation of proposed hydrogen fueling station location and capacity. This has provided a means to ensure that each successive hydrogen fueling station proposed for award was informed by the State's analysis of hydrogen station needs and accounted for all awards proposed earlier in the grant program. This was critical to ensure that initial stations were appropriately matched to the coverage and capacity needs of the initial FCEV market and efficiently utilized State funds to achieve those goals. During the development of the 1,000 hydrogen fueling station vision reported in the *2018 Annual Evaluation*, CARB leveraged the capabilities of CHIT to identify a suitable network to support the one million FCEV deployment target. CARB recommends that the findings of that effort can now be used as a streamlined tool for performing location-based evaluations in the next Energy Commission grant solicitation. CARB has developed the map shown in Figure ES5, which leads development towards areas aligned with the 2030 1,000 station vision. In addition, local area station needs are classified based on current network development status and the distribution and timing of high-capacity hydrogen fueling stations in the 2030 vision. These classifications inform the target number of simultaneous fueling positions and capacity for proposed stations based on their location. Following this method can reduce the effort required of both applicants and the Energy Commission in the application preparation and evaluation process.

Figure ES5: Recommended Station Location Evaluation Basis[6]

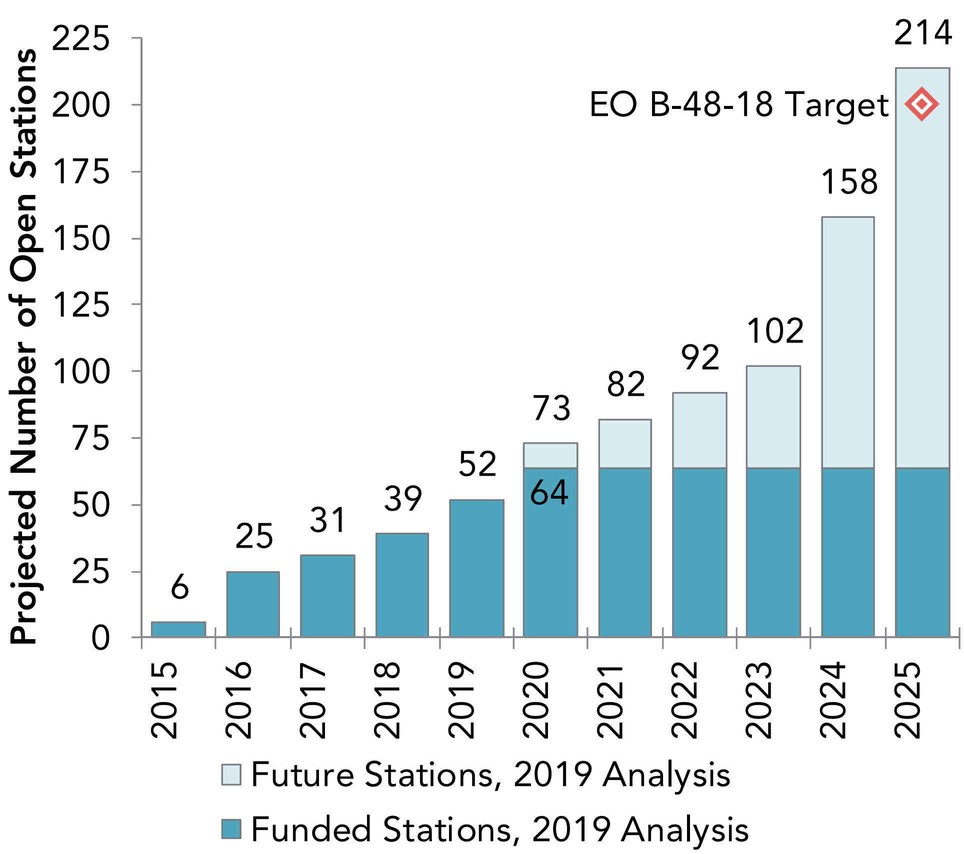


6 **Connector or Destination:** An area with long-term potential for local market development, but will likely serve as a long-distance connector or travel destination in the short-term; **Market Initiation:** An area with high potential for FCEV first adopters, but currently has less than three hydrogen fueling stations open or in construction; **Coverage Growth:** An area with high potential for FCEV first adopters, that has at least three stations open or in construction, and will likely need very large stations further in the future; **Capacity Growth**: Similar to Coverage Growth, but large stations will be needed sooner

Finding 6: California's FCEV market has successfully launched and grown with fewer hydrogen fueling stations than previously thought necessary. This is an important accomplishment, but both infrastructure and vehicle deployments need to continue and significantly accelerate in order to secure State ZEV implementation and emission reduction goals.

California has been the first market in the United States to test the viability of establishing a hydrogen-powered FCEV market. Not only has that viability been proven through the many public and private policies, programs, investments, and real-world development efforts to deploy hydrogen fueling stations and FCEVs, but market establishment has actually occurred with a smaller fueling network than prior expectations. The California Fuel Cell Partnership previously envisioned 68 stations as a minimum requirement to launch an FCEV market [9]. Pre-commercial market launch began in 2015 with a handful of stations available, and today's early commercial FCEV market continues to grow even as the hydrogen network is currently pushing towards the 64 stations originally thought as necessary to simply begin deployment. This is a significant accomplishment that demonstrates that retail customers find value and utility in FCEVs as a zero-emission option for their personal transportation needs. Still, State goals for criteria pollutant and greenhouse gas emission reduction, Zero Emission Vehicle (ZEV) deployment, and the associated necessary fueling infrastructure deployment require continued investment and even an entirely new pace of progress not yet seen in the industry. As shown in Figure ES6, in order to meet the goals of AB 8 and EO B-48-18, a significant number of stations beyond those currently funded must be developed. With the Energy Commission's grant solicitations and the LCFS HRI program as the primary State funding mechanisms available to drive towards these goals, it is plainly evident that the continued expenditure of the full $20 million available per year for light-duty hydrogen fueling stations through AB 8 should continue.

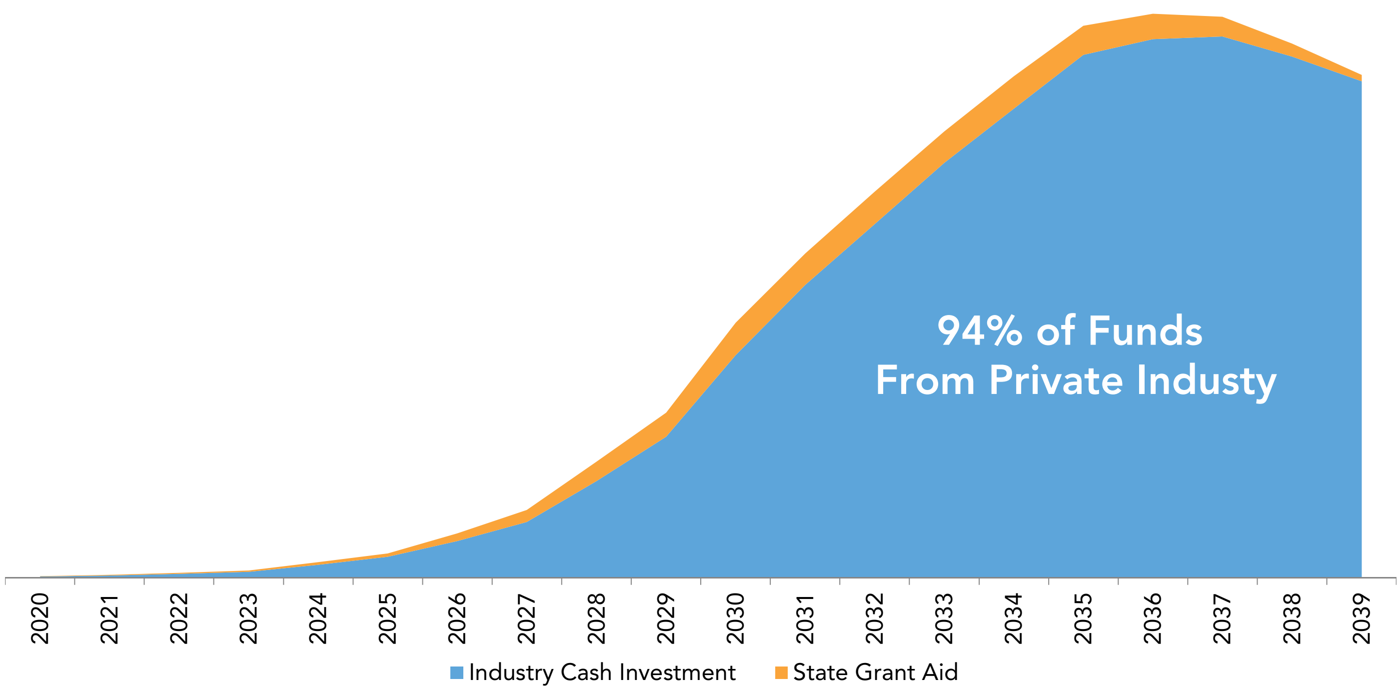
Figure ES6: Projected Station Deployment to Meet AB 8 and EO B-48-18 Goals



Finding 7: CARB and the Energy Commission are continuing to develop a methodology to determine the needs of achieving hydrogen fueling network self-sufficiency.

AB 8 requires CARB and the Energy Commission to consider the cost and timing of developing a hydrogen fueling station network that is financially self-sufficient. The agencies began work in 2016 on a multi-year effort to study this question and develop an analysis capability to evaluate the cost and timing question. In December 2018, results of a survey distributed to hydrogen fueling industry stakeholders were reported and particularly highlighted the findings of minimum design and operation criteria that industry stakeholders have determined lead to a profitable hydrogen fueling station. That analysis and other outside resources have been utilized to develop an analytical framework that investigates the cash flows and financial performance of stations in hypothetical future network development scenarios (See Appendix D for details). Results are currently in draft form, but preliminary evaluations and sensitivity analyses provide some useful insights. Industry-reported difficulties with keeping small (less than 400 kg/day) stations profitable are confirmed, due to the large capital and operating (mostly fuel procurement) costs and the limited opportunity to generate income through fuel sales. The target FCEV rate of deployment has the largest effect on financial evaluations of all parameters investigated so far. Finally, scenarios that evaluate the possibility of State aid to co-fund the hydrogen network to the point of self-sufficiency find that the vast majority of network investments would likely come from private industry, even with extended market-enabling State co-funding, as shown in Figure ES7.

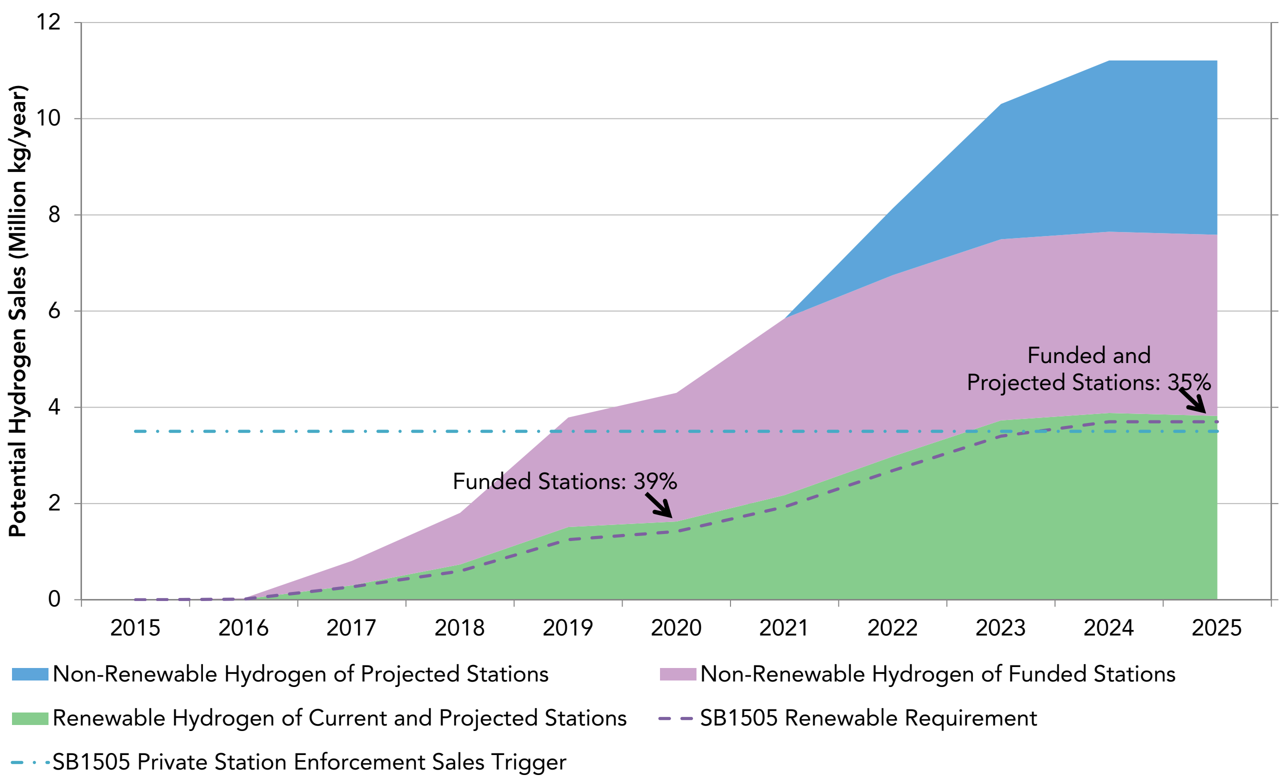
FIGURE ES7: ILLUSTRATIVE DIVISION OF NETWORK FUNDING SOURCES



Finding 8: The open and projected hydrogen fueling network is expected to maintain compliance with the renewable hydrogen requirements of SB 1505. Participation in the Low Carbon Fuel Standard's Hydrogen Refueling Infrastructure credit program will help ensure this compliance.

Compliance with the 33% renewable hydrogen requirement of SB 1505 has largely been assured by the eligibility criteria and the grant agreements developed through the Energy Commission's grant solicitation process. Thanks to these efforts, the funded station network is expected to dispense more than the minimum 33% renewable hydrogen, as shown in Figure ES8. Stations that participate in the Low Carbon Fuel Standard and generate Hydrogen Refueling Infrastructure credits will be further required to dispense hydrogen with a 40% renewable content, providing additional assurance that the network as a whole will meet or exceed the 33% minimum of SB 1505. Based on projected hydrogen throughput, CARB continues to expect that the trigger for enforcing these same requirements on stations without State co-funding will be activated by the end of 2019.

Figure ES8: Evaluation of Compliance with SB 1505 Renewables Requirement and Trigger for Enforcement of the Requirement on Stations without State Co-Funding



Conclusions

The coming year represents great opportunity for the hydrogen fueling market in California. A large number of stations are expected to complete construction and open for retail operations. The LCFS HRI credit program has already begun to approve applications and provide a means to stabilize hydrogen station financial performance in the early market. The upcoming grant solicitation from the Energy Commission has been proposed to provide multi-year funding for successful applicants, enabling long-term and more holistic network-wide planning in application materials. These developments are major strides in fulfilling the goals of EO B-48-18 and the California Fuel Cell Partnership vision- 1,000 hydrogen stations by 2030 and the deployment of one million FCEVs.

There are still many unknowns and much work that must be completed to achieve this vision, both in terms of hydrogen fueling station network development and FCEV deployment. CARB has continued to emphasize the need for development of both of these inter-related industries to be well-coordinated. For the early market, this has meant that station deployment must precede FCEV deployment. As both markets progress in maturity, there will be a need to develop in closer synchronization. CARB must closely watch the developing plans for FCEV deployment in the coming years to ensure that too large of a gap does note persist between planned capacity of the targeted station network and vehicle demand.

Plans have yet to be realized that demonstrate the kind of acceleration, especially in FCEV deployment, needed to meet these challenging goals. The coming year may provide proof of sustainable momentum in network development enabled by the current State support policy and programs. In addition, private industry has announced several additional projects with substantial investment to address challenges in the hydrogen supply chain that do not receive quite as much focus in State programs. These advances may in turn provide necessary assurance for further accelerating FCEV deployment plans in the future.

Photo courtesy of CaFCP

Development of HySCapE

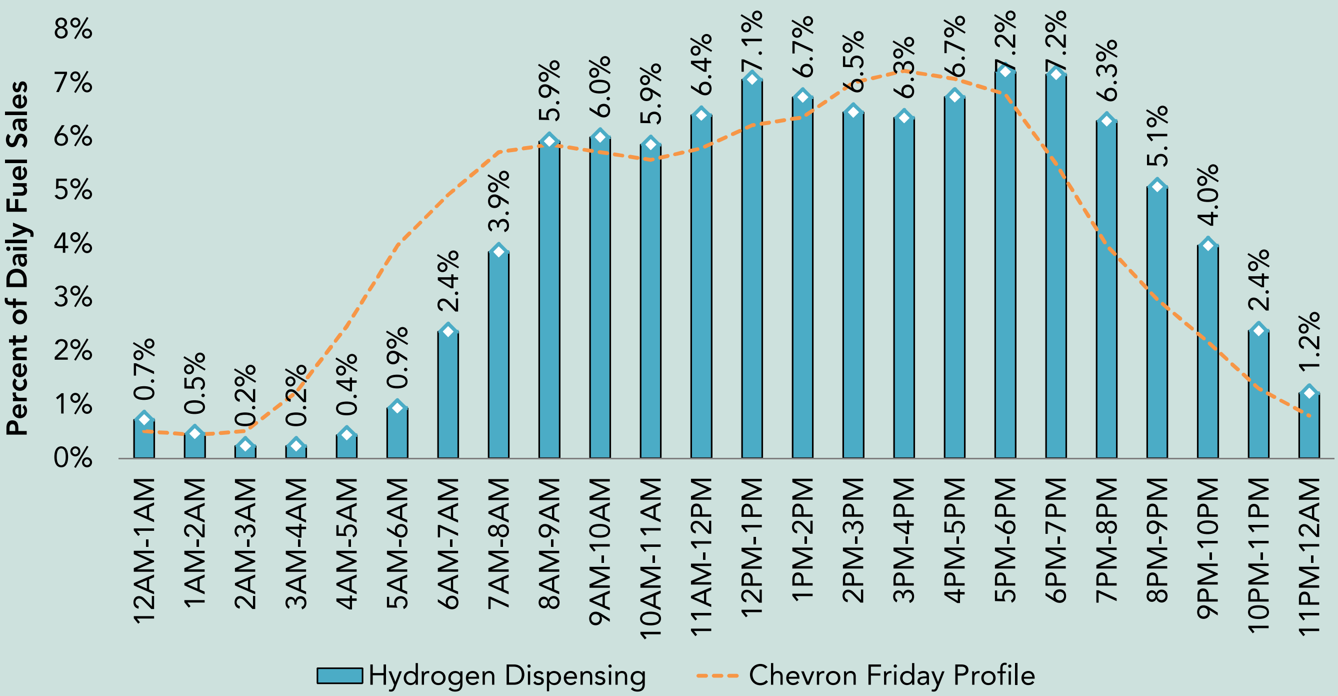
Over the past year, CARB and the Energy Commission have collaborated with researchers at the National Renewable Energy Laboratory (NREL) to develop the HySCapE tool [6]. HySCapE was created with the goal of providing an independent "standard ruler" for ascertaining potential station fueling capacity based on a limited set of known information about station design and equipment specifications. This standard ruler could then be applied during evaluation phases of State funding programs to provide a consistent estimation of individual station capacity. Currently, HySCapE is being utilized by the LCFS program for its HRI credit provisions and has been proposed for use by the Energy Commission for its upcoming grant solicitation.

The HySCapE tool evaluates potential station capacity according to an industry-vetted demand profile, known as the "Chevron Friday Profile." This demand profile was developed through industry-led studies of fueling patterns at operational gasoline stations and provides an estimate of the fueling demand that a station may experience throughout each hour of the day. In reality, this demand profile can vary by day of the week and by season; HySCapE evaluates full 24-hour fueling capacity against the Friday profile, known to be one of the most challenging fueling demand profiles to meet. The chart on the following page shows this standardized demand profile compared to the network average in the current open hydrogen fueling network. While there are differences due to the early development phase of the hydrogen network, NREL researchers have noted that the hydrogen station profiles more closely match the Chevron standard over time.

There are many capacity metrics that may be of interest to State programs, station developers, auto manufacturers, and the general public. For the LCFS and Energy Commission programs, the primary capacity metric is likely to be the 24-hour hydrogen fueling capacity. This metric provides insight on the total maximum potential hydrogen throughput that the station could support in one day. There are additionally two methods currently considered in State programs to assess the 24-hour fueling capacity:

- Capacity rating for a station that starts with a full storage tank, provides fuel throughout the day, but does not receive an additional delivery of hydrogen during the day. This method provides an estimate of the maximum capacity potential of the equipment alone, without regard to station operation strategies. Such a metric is also insightful to understand the capabilities of the station performance when normal hydrogen deliveries may be temporarily constrained.
- Capacity rating for a station that starts with a full storage tank, provides fuel throughout the day, and may receive additional fuel deliveries once or more during the day. This capacity accounts for the operational and logistic strategies that a station operator may employ, as many stations currently in the network do receive midday fuel deliveries on a regular basis. While midday deliveries do provide heightened challenges due to the presence of a delivery truck at the same time as fueling customers, it is not uncommon in the retail fuel industry in general and may be the preferred strategy for some hydrogen station operators. This metric therefore allows for consideration of the full station equipment and operation strategy.

Chevron Friday Gasoline Demand Profile and Network Average Hydrogen Fueling Demand Profile

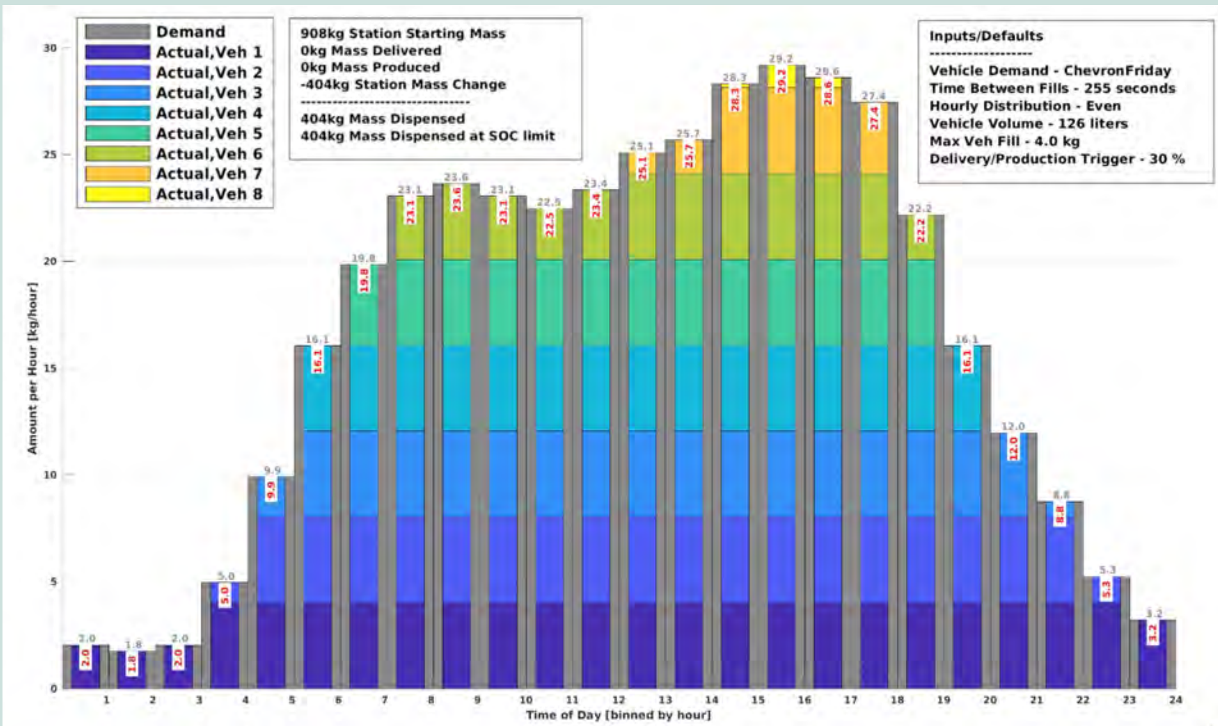


The total demand at the station is scaled in HySCapE according to specified capabilities of the modeled hydrogen equipment, in particular the specified time between fills. The time between fills parameter describes the maximum "rest" time between the end of one fueling event and the beginning of the next, specifically in the peak hour of demand (which is the hour beginning at 3pm in the Chevron Friday profile shown above. A shorter time between fills results in an increased maximum demand. This increased demand incurs further stress on the station equipment, which must maintain high delivery pressures and low delivery temperatures to each successive vehicle throughout the day. Moreover, because this peak occurs in the afternoon, the station must achieve this when it is likely not at full storage capacity and has been under operation for an extended period of time. Thus, fill performance may become limited during peak hours if the station equipment is not designed to meet the expected demand in all hours of the day.

SAE J2601 defines requirements for successful fill performance; one key metric is the ending State of Charge (SOC). SOC is a measure of how full the vehicle's onboard hydrogen tank is at the end of a fill event, given initial and ambient conditions. Utilizing these definitions, HySCapE evaluates stations' ability to not only dispense hydrogen but also its ability to dispense hydrogen at the SOC minimum of 95% and above as specified by SAE J2601. The first figure on the following page demonstrates a station design that meets the full daily demand according to the Chevron Friday Profile and does so with all fills provided meeting the SOC criteria (note that "Mass Dispensed" and "Mass Dispensed at SOC Limit" in the upper left box are equal).

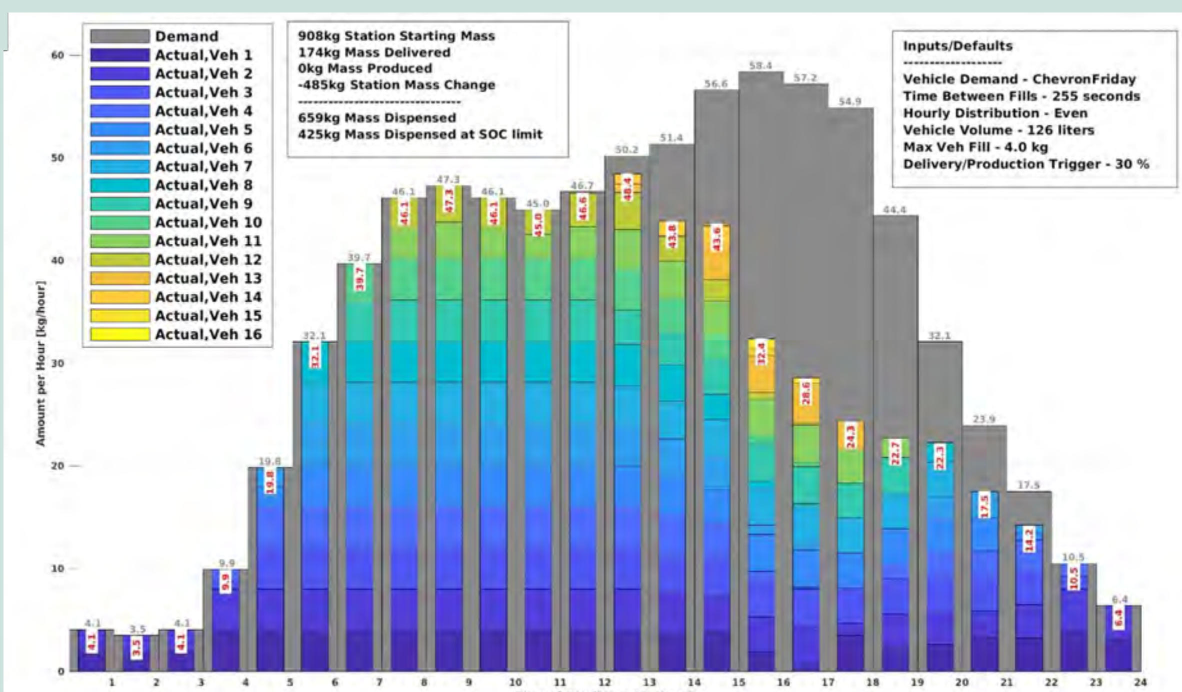
By contrast, the second figure on the following page shows a station that dispenses more hydrogen during the day, but does not meet the fuel demand cycle and does not dispense all of its hydrogen at the SOC minimums. Such a station design would not present a positive customer experience as some customers that arrive after noon would not be able to fuel at all; some of those that do receive fuel would not receive a full tank. Both the LCFS program and the Energy Commission's proposed station grant solicitation aim to provide a customer experience at least on par with gasoline; thus, the performance of the second station example would be unacceptable. Both programs encourage stations like the one in the first station example by only evaluating the mass dispensed at the SOC limit, and in the case of the proposed Energy Commission grant solicitation, requiring that this matches the total mass dispensed. Such a match between the capacity ratings ensures that all customers who arrive at the station will receive fuel and receive a full fill.

Demonstration of A 404 kg/day Station that Meets Full Demand Profile and Provides All Fills Above Minimum State of Charge



Courtesy of NREL

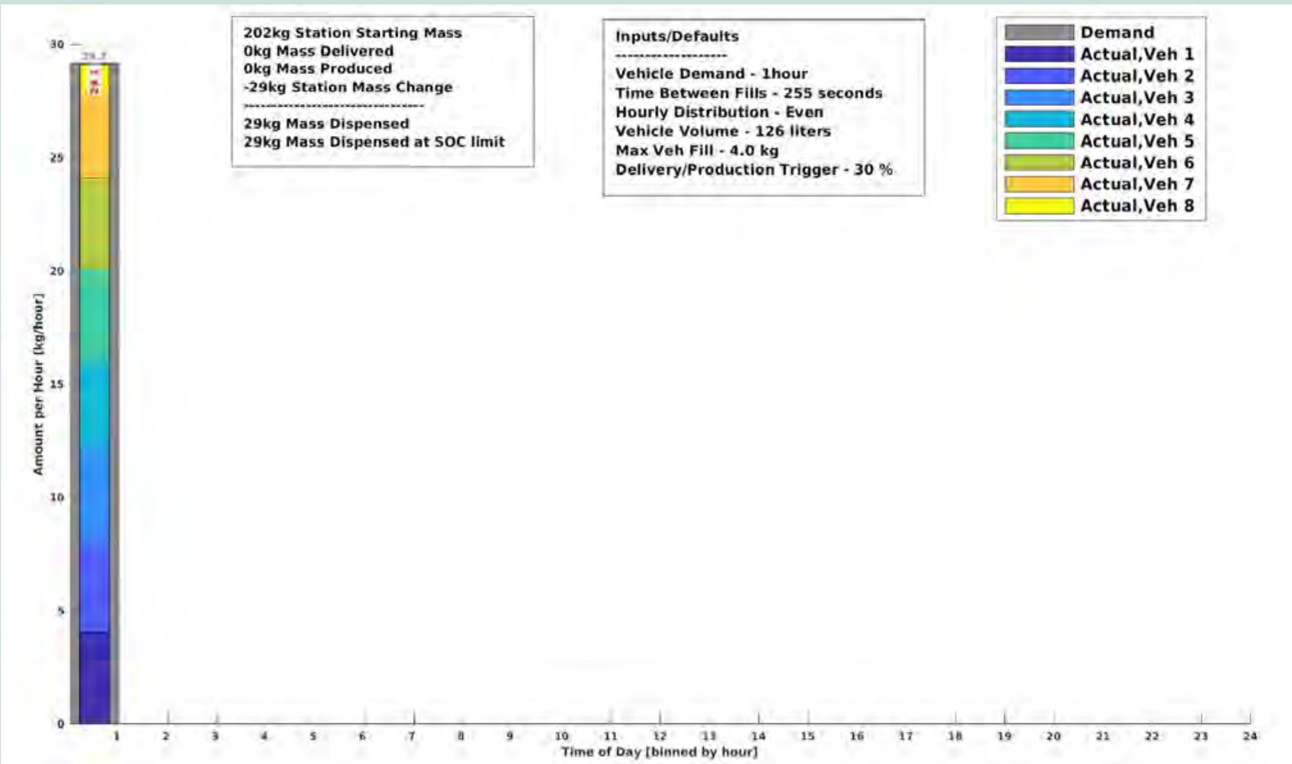
Demonstration of a 425 kg/day Station that Does not Meet Full Demand Profile and Does Not Meet State of Charge Requirements



Courtesy of NREL

Although the mass dispensed at SOC provides assurance of each fill being successful, there is still a need to ensure that individual stations have anticipated meeting a large enough peak demand. As shown on the previous page, this occurs typically during the 3pm hour. One measure of proper peak performance could be to simply evaluate the number of full-SOC fills in this hour from the 24-hour HySCapE evaluation; in the example at the top of the previous page, this is eight full fills (which may be accomplished through multiple dispensers). However, when stations undergo performance testing prior to commencing retail operations, they are typically tested when the station hydrogen storage is full or nearly full and the station has not been operating throughout the day (since it is not yet open to the public). Thus, the maximum one-hour capability of the station considered separately from the demand profile may not be accurately captured by the 24-hour test. For this reason, NREL has also developed a 1-hour capacity estimation, as shown below.

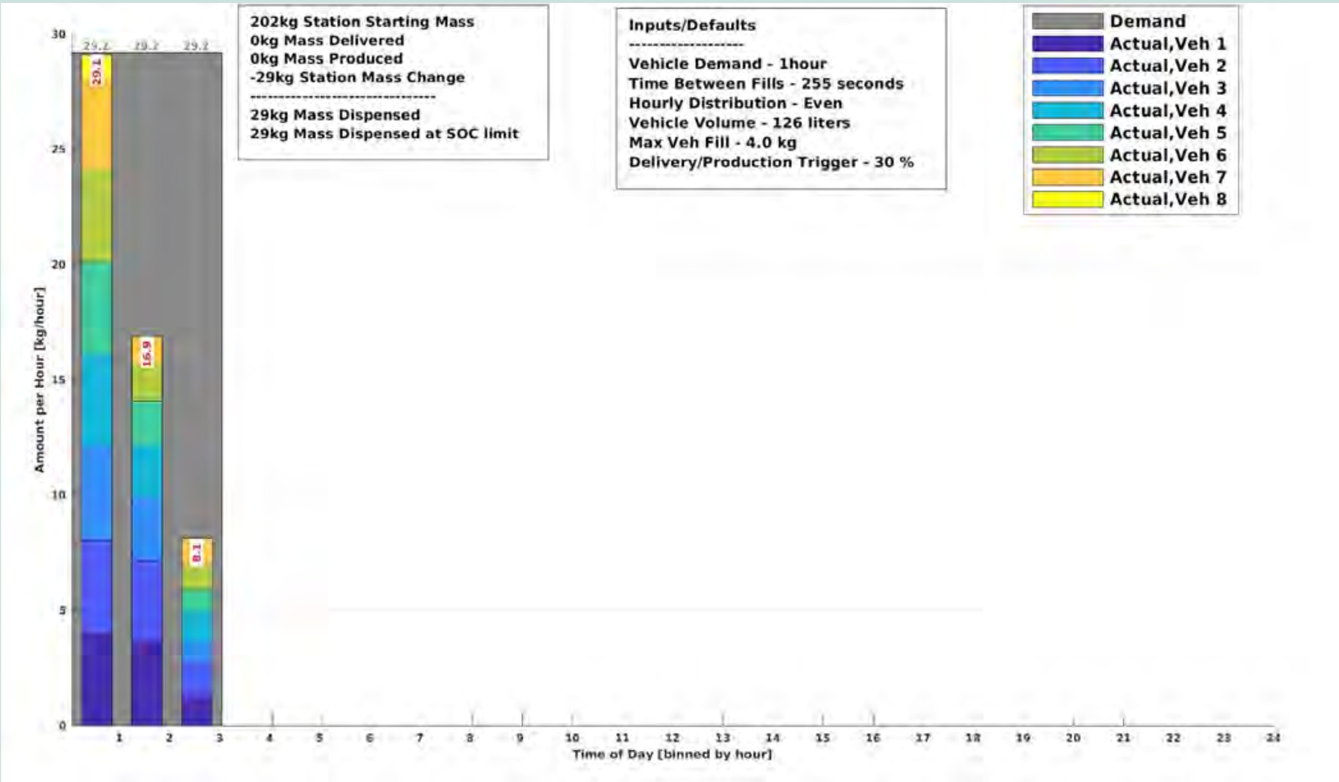
Sample 1-hour HySCapE Evaluation



Courtesy of NREL

The example above indicates that the station design evaluated can provide a maximum of eight fill events meeting the SOC requirements. While the 1-hour evaluation is shown to occur at midnight, the actual time does not matter since it is completed irrespective of the rest of the day's demand profile. Similarly, industry recommendations and publications have endorsed evaluation of a 3-hour profile to capture the dynamics of the more extended 3-hour peak performance. This allows for evaluation of whether the station design has sufficient longevity beyond just the highest peak demand hour, since 2pm though 6pm are all relatively high-demand. The example on the following page demonstrates a 3-hour evaluation for a station that meets all requirements in the peak hour, providing eight fills meeting SOC requirements. However, the following two hours do not meet the projected demand and cannot consistently provide fills of sufficient SOC.

Sample 3-hour HySCapE Evaluation



Courtesy of NREL

CARB and the Energy Commission find that the capabilities offered by the HySCapE tool provide valuable insight into evaluating station performance. In particular, HySCapE is a first-of-its kind, free, public, and transparent tool for evaluating station capacity equivalently across many different design options, including stations with either gaseous or liquid storage onsite. Industry stakeholders are encouraged to familiarize themselves with the HySCapE tool, consulting the online and downloadable versions as well as the reference and guidance material provided by NREL.

Introduction

On May 16, 2019, Akiji Makino, Chairman and CEO of Iwatani Corporation welcomed industry, government, and the general public to the grand re-opening of the West Sacramento hydrogen fueling station. In 2015, the West Sacramento station became the first in the state to achieve retail sales status. Built and then operated by Linde, LLC, the station initiated the development of what is today a network of hydrogen fueling stations spanning much of the state of California and enabling the deployment of approximately 6,000 Fuel Cell Electric Vehicles to everyday consumers. The occasion for the gathering was to re-present the West Sacramento station to the public. As the new owners and operators of the station, Iwatani announced its intention to upgrade and elevate the station to a new role as a flagship for the state, with renewed emphasis on performance and providing a fully retail customer experience.

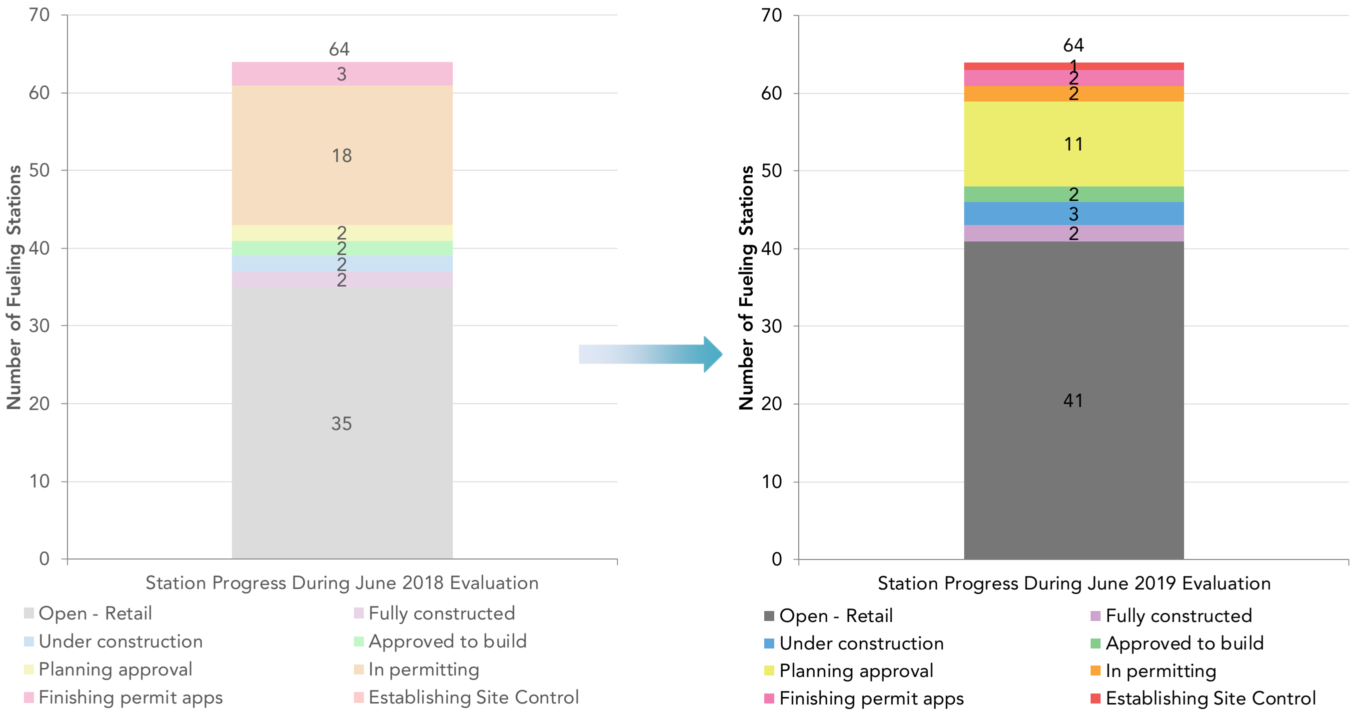
Just as attendees to the event anticipated a bright future for the station, the overall hydrogen fueling network now stands on the brink of substantial developments in the near future. With 41 hydrogen fueling stations currently open and providing retail sales and another 23 funded, the Energy Commission is working to finalize its next competitive station funding grant solicitation. As proposed in the *Draft Solicitation Concepts*, this next solicitation will represent a new way of thinking about station network design and deployment by asking station developers to propose and collaborate with the Energy Commission on multi-year network planning and construction [4]. In addition, the Low Carbon Fuel Standard program began implementing its Hydrogen Refueling Infrastructure credit provision, providing new opportunities for station developers to fund more expansive station networks. These programs combined are key steps to ensuring the State successfully reaches the 100 station goal by 2024 as outlined in AB 8 and the 200 station goal for 2025 as outlined by EO B-48-18.

Per the requirements of AB 8 (see Appendix A), CARB collaborates with industry stakeholders, public-private partnerships, the Energy Commission, and other State and local agencies to track and assess the progress of the hydrogen fueling station network development and FCEV deployment. Annual Evaluations provide CARB's assessments, especially as related to the metrics of station network coverage and capacity and necessary technical specifications for station design, operation, and testing. Through its collaborative work, CARB has also participated in several other analyses that provide a more holistic view of the current status and the future challenges facing network development. These Annual Evaluations provide CARB's latest updates on these efforts.

Station Network Progress

California's hydrogen fueling station network has progressed well over the past year. While a net five additional stations have opened since the publication of the *2018 Annual Evaluation*, a large number of stations have made significant development progress, as shown in Figure 1: Hydrogen Fueling Station Network Status, as of May 9, 2019
(The Lightened Figure on the Left is Reproduced from the 2018 Annual Evaluation;
The Full-Saturation Figure on the Right is the Current Status). While 21 stations were in the permitting or earlier phases of development at this time last year, only 5 stations remain in such an early phase of development. Moreover, some stations that had only begun their development process in June of 2018 have actually become open stations by now and have commenced with retail fuel sales to customers in their markets. An additional two stations have completed construction and should therefore open for retail operations shortly. Fully 11 of the remaining 23 stations currently in development are expected to open by the end of this year. Such a large number of new station openings in California has only happened between December 2015 and December 2016.

Figure 1: Hydrogen Fueling Station Network Status, as of May 9, 2019[7]
(The Lightened Figure on the Left is Reproduced from the *2018 Annual Evaluation*;
The Full-Saturation Figure on the Right is the Current Status)



7 See Appendix E for detailed definitions of all development phases

FCEV and Hydrogen Station Progress across the U.S.

- Industrial gas company and hydrogen station developer Air Liquide, in partnership with Toyota Motor Corporation, has been developing a network of twelve hydrogen stations in the northeast United States to enable launch of FCEVs in the area. On National Hydrogen Day 2018 (October 8, coined by the US Department of Energy for the date's match to hydrogen's atomic weight of 1.008), the company announced that four of the hydrogen stations have completed construction. The stations are location in: Hempstead, New York; Providence, Rhode Island; Mansfield, Massachusetts; and Hartford, Connecticut [43].
- After Colorado adopted California's vehicle emission standards in late 2018, Governor Jared Polis issued an executive order for the state's agencies to develop policies and programs to move the state towards zero emission vehicles and to propose a Zero Emission Vehicle rule [44]. The Order established a State workgroup to develop, coordinate, and implement programs towards this goal.
- Governor Jay Inslee of the state of Washington signed a bill introduced by State Senator Brad Hawkins, which allows public utility districts in the state to produce and sell renewable hydrogen [45]. The bill had passed unanimously in both the State Senate and House. Douglas County Public Utility District has announced plans to generate hydrogen through electrolyzers powered by excess hydroelectric power.

Draft Solicitation Concepts Released

On January 23, 2019, the Energy Commission released the *Draft Solicitation Concepts* for its next grant solicitation for light-duty hydrogen fueling stations. Representing the culmination of a series of workshops in late 2017 and the synthesis of substantial public comment, the *Draft Solicitation Concepts* outlines a hydrogen station grant program unlike any of the previous programs developed by the Energy Commission. The proposed concepts embody feedback presented to both the Energy Commission and CARB that station developers can provide more cost-competitive applications and develop more nuanced station network plans by receiving multi-year, network-oriented support. Whereas previous solicitations have chosen individual stations in sequence to recommend awards, this new concept would choose developers' groups of initial stations and evaluate their multi-year planning and proposed operations strategies. The proposed structure is likely to enable the AB 8 program to support the development of more than the minimum 100 stations described in statute, with the same total funds allowed through the Clean Transportation Program (also known as the Alternative and Renewable Fuel and Vehicle Technology Program, or ARFVTP).

LCFS HRI Update

The Hydrogen Refueling Infrastructure credit provision of the Low Carbon Fuel Standard became effective in Q1 2019. This provision allows eligible hydrogen station operators to apply to generate LCFS credits based on the difference between the station's installed capacity and the actual hydrogen throughput. Stations are eligible to generate these credits for a period of 15 years. In this way, the program provides a consistent and predictable supplementary revenue stream opportunity for station operators. This can help ensure the stations are able to stay open during early years when demand may be low. In addition, it has the potential to achieve other targets of the State's overall hydrogen fueling program, including:

- Deploying more hydrogen stations sooner, and specifically supplementing the AB 8 program to make important advancements toward the 200 station target for 2025 initiated by EO B-48-18
- Deploying stations with larger capacity on average, which could bring stations with greater potential for financial self-sufficiency to California's network
- Increasing the implementation of renewable energy resources for the production, distribution, and dispensing of hydrogen fuel; this is especially true as HRI eligibility requirements include a 40% renewable content provision and LCFS credit generation potential increases as stations sell more hydrogen made from low-carbon resources
- Reducing the sale price of hydrogen to consumers, due to the improved station economics

Aside from the 40% renewable hydrogen provision, these are only potential program outcomes and may not all be achievable together. Over the coming years, CARB will monitor and assess the performance of the program on an ongoing basis and provide transparent reporting. So far, 31 stations (shown in Table 1) have been approved to begin generating HRI credits. All are stations already funded through past Energy Commission grant solicitations, and most are currently open. Assuming an average hydrogen carbon intensity of 75 $gCO2_e$/MJ, and following the credit calculation equation in §95486.2 (a)(5) of the LCFS regulation, the 11,277 kilograms of approved capacity could generate nearly 19,500 LCFS credits per quarter [46]. The LCFS data dashboard cites average credit values around $180 per credit [47]; thus, the 19,500 credits could represent a value stream of $3.5 million per quarter to the approved station network in aggregate. In this illustrative example, if no hydrogen is dispensed at the stations then LFCS credit revenue would be generated completely by the HRI provision. As hydrogen fuel sales increase, the credit generation mechanism shifts away from the HRI provision and to the standard throughput-based mechanism. When fuel sales are equal to the station capacity, no HRI credits will be generated; the program is therefore self-sunsetting for successful stations. In addition, CARB estimates that a total of 55,775 kg/day of capacity were available for HRI crediting in Q2 2019, so the program is currently undersubscribed.

Table 1: Stations Approved to Generate LCFS HRI Credits[8] [48]

Applicant Entity	Station Name	Station Address	City	Number of Dispensing Units	HRI Refueling Capacity (Kg/day)	Effective Date Range for HRI Crediting
First Element Inc.	Truckee	12105 Donner Pass Road	Truckee	1	266	04/01/2019 - 03/31/2034
First Element Inc.	Coalinga	24505 W Dorris Avenue	Coalinga	1	266	04/01/2019 - 03/31/2034
First Element Inc.	Santa Barbara	150 South La Cumbre Road	Santa Barbara	1	266	04/01/2019 - 03/31/2034
First Element Inc.	Thousand Oaks	3102 E Thousand Oaks Boulevard	Thousand Oaks	1	266	04/01/2019 - 03/31/2034
First Element Inc.	Mill Valley	570 Redwood Highway	Mill Valley	1	266	04/01/2019 - 03/31/2034
First Element Inc.	Playa Del Rey	8126 Lincoln Boulevard	Los Angeles	1	266	04/01/2019 - 03/31/2034
First Element Inc.	Hollywood	5700 Hollywood Boulevard	Los Angeles	1	266	04/01/2019 - 03/31/2034
First Element Inc.	Del Mar	3060 Carmel Valley Road	San Diego	1	266	04/01/2019 - 03/31/2034
First Element Inc.	Fremont (Grimmer)	41700 Grimmer Boulevard	Fremont	1	266	04/01/2019 - 03/31/2034
First Element Inc.	Hayward	391 W A Street	Hayward	1	266	04/01/2019 - 03/31/2034
First Element Inc.	South San Francisco (Airport)	248 S Airport Boulevard	South San Francisco	1	266	04/01/2019 - 03/31/2034
First Element Inc.	South Pasadena	1200 Fair Oaks Avenue	South Pasadena	1	206	04/01/2019 - 03/31/2034
First Element Inc.	Campbell (Winchester)	2855 Winchester Boulevard	Campbell	1	266	04/01/2019 - 03/31/2034
First Element Inc.	La Canada Flintridge	550 Foothill Boulevard	La Cañada Flintridge	1	266	04/01/2019 - 03/31/2034
First Element Inc.	Lake Forest	20731 Lake Forest Drive	Lake Forest	1	266	04/01/2019 - 03/31/2034
First Element Inc.	Costa Mesa	2050 Harbor Boulevard	Costa Mesa	1	266	04/01/2019 - 03/31/2034
First Element Inc.	Long Beach	3401 Long Beach Boulevard	Long Beach	1	266	04/01/2019 - 03/31/2034
First Element Inc.	Saratoga	12600 Saratoga Avenue	Saratoga	1	198	04/01/2019 - 03/31/2034
First Element Inc.	San Jose	2101 N 1st Street	San Jose	1	266	04/01/2019 - 03/31/2034
Shell Inc.	3rd Street	551 3rd Street	San Francisco	2	513	04/01/2019 - 03/31/2034
Shell Inc.	Bernal Road	101 Bernal Road	San Jose	2	513	04/01/2019 - 03/31/2034
Shell Inc.	Citrus Heights	6141 Greenback Lane	Citrus Heights	2	513	04/01/2019 - 03/31/2034
Shell Inc.	Fair Oaks	3510 Fair Oaks Boulevard	Sacramento	2	513	04/01/2019 - 03/31/2034
Shell Inc.	Harrison	1201 Harrison Street	San Francisco	2	513	04/01/2019 - 03/31/2034
Shell Inc.	Mission Street	3550 Mission Street	San Francisco	2	513	04/01/2019 - 03/31/2034
Shell Inc.	University Berkeley	1250 University Avenue	Berkeley	2	513	04/01/2019 - 03/31/2034
Air Liquide Hydrogen Energy US LLC	LAX	10400 Aviation Boulevard	Los Angeles	1	200	04/01/2019 - 03/31/2034

8 "Number of Dispensing Units" in LCFS HRI program reporting is taken as an equivalent term to number of fueling positions used elsewhere in this report. Station capacities are determined on a 24-hour basis through the use of HySCapE and accounting for one additional mid-day delivery. Station capacity is also dependent on the operating hours of the station. Thus, capacities in Table 1 may differ from Appendix B (which are nominally 12-hour capacities) and may differ between stations with the same equipment installed at various locations.

Applicant Entity	Station Name	Station Address	City	Number of Dispensing Units	HRI Refueling Capacity (Kg/day)	Effective Date Range for HRI Crediting
First Element Inc.	Sherman Oaks	14478 Ventura Boulevard	Sherman Oaks	2	808	07/01/2019 - 06/30/2034
First Element Inc.	Oakland	350 Grand Avenue	Oakland	2	808	07/01/2019 - 06/30/2034
First Element Inc.	Studio City	3780 Cahuenga Boulevard	Studio City	2	808	07/01/2019 - 06/30/2034
Air Liquide Hydrogen Energy US LLC	Palo Alto	3601 Camino De Real Street	Palo Alto	1	136	07/01/2019 - 06/30/2034
			Total	**41**	**11,277**	

Photo courtesy of CaFCP

Location & Number of Fuel Cell Electric Vehicles

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

CARB 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

CARB relies on two primary data sources for current and future projections of on-road FCEV counts, as defined by the requirements of AB 8. The first data set is current vehicle registrations, provided by the Department of Motor Vehicles. CARB receives periodic updates of the then-current status of all vehicles in the DMV's registration status database. CARB filters these data to count only FCEVs that are current on their registration status and registered to valid ZIP codes within the state of California. In addition, CARB annually distributes a survey to auto manufacturers that asks for future FCEV production volumes (as well as Plug-In Hybrid Electric Vehicle (PHEV) and Battery Electric Vehicle (BEV) projections) and related technical specifications for vehicles of all three technology types. Auto manufacturers are required to provide responses for the current model year and the next three model years. For this 2019 survey, years 2019 through 2022 are therefore mandatory reporting years. In addition, CARB requests information for the next three model years (2023 to 2025 for the latest survey) on a voluntary basis. Not all auto manufacturers present the same responsiveness to optional period data in all survey years.

In addition, CARB has employed various methods to gather as much information as possible about the expected geographic distribution of the FCEVs in the auto manufacturer survey responses. CARB has found varying degrees of success with gaining insight through this more detailed information request. However, both the 2017 and *2018 Annual Evaluation* presented evidence that auto manufacturers have provided data largely in agreement with estimates provided by CARB's California Hydrogen Infrastructure Tool (see next chapter for more detail). For the 2019 auto manufacturer survey, CARB therefore did not ask manufacturers for additional geographic detail and only asked for a single statewide vehicle deployment value for each model in each future model year. In the survey materials, CARB indicated that the scenario shown in the CaFCP's *Revolution* document and further detailed in the 2018 *Annual Evaluation* would be assumed as the basis to distribute future vehicle deployments geographically for this analysis. Thus, auto manufacturers were provided with a map and list of open and funded stations' then-current historical and projected open dates (provided in Appendix C) and were advised that CARB would reference the station distribution from the CaFCP *Revolution* document in its analyses (respondents were provided links to both the *Revolution* and the 2018 Annual Evaluation).

Analysis of DMV Registrations and Auto Manufacturer Survey Responses

CARB stores and tracks each year's current FCEV registration and future deployment projection data in its Microsoft Access-based California Hydrogen Accounting Tool (CHAT). CHAT also has capabilities to combine DMV registrations and auto manufacturer projections into future expectations of on-the-road FCEVs. On-the-road FCEV projections in CHAT also account for vehicle attrition rates similar to the agency's transportation emissions model, EMFAC. All vehicles are assumed to fall out of the on-road fleet (due to accidents, malfunctions, and other causes) according to an exponential decay with a 15-year half-life. For example, a fleet of 100 new FCEVs deployed today would be expected to shrink to 50 after 15 years and 25 after 30 years.

In addition, CARB performs some adjustment of auto manufacturer survey responses prior to transferring the data to CHAT. The first is the geographic distribution of vehicles outlined above. CARB distributed projected vehicles to individual counties according to the progression of hydrogen station capacity from funded AB 8 stations and future projected stations in the *Revolution* scenario. Table 2: County-Based Relative Allocation of Station Capacity and Future FCEV Deployment outlines the proportion of vehicles allocated to each county based on the year of deployment, according to this method. As noted in the *2018 Annual Evaluation*, new stations in this scenario are expected to continue to be focused in the markets that are currently receiving the most development through the AB 8 program (such as Los Angeles and Orange Counties and the counties of the San Francisco Bay Area) until the year 2023. After this point, the scenario anticipates broader development of the network into other high-potential markets outside these early core markets.

Table 2: County-Based Relative Allocation of Station Capacity and Future FCEV Deployment

County	2019	2020	2021	2022	2023	2024	2025
Alameda	11.64%	7.85%	6.78%	5.87%	5.13%	2.65%	1.75%
Butte	0.00%	0.00%	0.00%	0.00%	0.00%	1.35%	0.89%
Colusa	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Contra Costa	2.59%	4.25%	3.67%	3.18%	2.78%	1.43%	1.95%
El Dorado	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.22%
Fresno	1.33%	0.90%	0.78%	0.67%	0.59%	1.48%	0.98%
Glenn	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Humboldt	0.00%	0.00%	0.00%	0.00%	0.00%	1.18%	0.78%
Imperial	0.00%	0.00%	0.00%	0.00%	0.00%	0.93%	0.61%
Inyo	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Kern	0.00%	0.00%	0.00%	0.00%	0.00%	1.35%	2.29%
Kings	0.00%	0.00%	0.00%	0.00%	0.00%	0.59%	0.78%
Lake	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Lassen	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Los Angeles	36.17%	33.90%	35.33%	36.75%	34.08%	24.65%	20.23%
Madera	0.00%	0.00%	0.00%	0.00%	1.14%	0.59%	0.39%
Marin	1.33%	0.90%	0.78%	0.67%	0.59%	0.30%	0.87%
Mendocino	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.22%
Merced	1.33%	0.90%	0.78%	0.67%	0.59%	1.48%	0.98%
Monterey	0.00%	0.00%	0.00%	1.31%	1.14%	1.60%	2.12%
Napa	0.00%	0.00%	0.00%	1.31%	1.14%	0.59%	0.78%
Nevada	1.33%	0.90%	0.78%	0.67%	0.59%	0.89%	0.59%
Orange	8.08%	11.45%	11.40%	9.87%	8.63%	5.96%	4.96%
Placer	0.00%	0.00%	0.00%	0.00%	1.14%	1.18%	1.17%
Riverside	0.74%	0.50%	0.43%	1.68%	1.47%	6.40%	12.50%
Sacramento	5.34%	3.60%	4.62%	4.00%	3.50%	2.81%	4.88%
San Benito	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.39%
San Bernardino	1.48%	1.00%	0.86%	0.75%	1.80%	3.29%	3.24%
San Diego	1.33%	3.40%	4.45%	3.85%	4.02%	5.44%	5.33%
San Francisco	8.01%	7.15%	7.69%	6.65%	7.78%	4.01%	2.66%
San Joaquin	0.00%	0.00%	0.00%	0.00%	0.00%	4.04%	3.35%
San Luis Obispo	0.00%	0.00%	0.00%	0.00%	4.58%	2.36%	1.95%

County	2019	2020	2021	2022	2023	2024	2025
San Mateo	6.08%	5.85%	6.57%	5.68%	4.97%	2.56%	1.70%
Santa Barbara	1.33%	0.90%	0.78%	0.67%	0.59%	1.65%	1.48%
Santa Clara	7.93%	13.90%	12.01%	11.70%	10.23%	5.27%	6.23%
Santa Cruz	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Shasta	0.00%	0.00%	0.00%	0.00%	0.00%	1.01%	0.89%
Siskiyou	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Solano	0.00%	0.00%	0.00%	0.00%	0.00%	0.59%	2.06%
Sonoma	0.00%	0.00%	0.00%	2.06%	1.80%	2.53%	1.67%
Stanislaus	0.00%	0.00%	0.00%	0.00%	0.00%	3.03%	2.68%
Sutter	0.00%	0.00%	0.00%	0.00%	0.00%	0.59%	0.39%
Tehama	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Tulare	0.00%	0.00%	0.00%	0.00%	0.00%	1.18%	1.56%
Tuolumne	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.22%
Ventura	1.33%	0.90%	0.78%	0.67%	0.59%	2.83%	2.77%
Yolo	2.59%	1.75%	1.51%	1.31%	1.14%	2.19%	1.45%
Yuba	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

In addition, CARB translated model year to year of deployment by assuming that 1/3 of the vehicles of a given model year would be deployed in the prior calendar year and the remaining 2/3 in the calendar year matching the model year. This is consistent with prior Annual Evaluations and is based on observations of the overall automobile market in prior years.

The resulting current and projected on-the-road FCEV estimates are provided in Figure 2: Comparison of On-The-Road Vehicle Counts in 2014-2019 Annual Evaluations. CARB estimates that as of April 4, 2019 there are 5,923 FCEVs with a current and active registration status in California[9]. The most recent auto manufacturer survey results indicate an on-the-road FCEV population of 26,900 in 2022 and 48,000 in 2025. While the near-term projections present positive steady growth compared to prior survey responses, the long-term projections indicate an unexpected slowing of vehicle deployment or a continued persistence of a 1-year delay in projected vehicle deployment.

This behavior is particularly unexpected for the 2019 survey, given the large number of seemingly high-impact developments over the course of the past year. As discussed in the *2018 Annual Evaluation*, the members of the CaFCP developed and published a vision for one million FCEVs on the road as soon as 2030. This is a vision that requires significant acceleration in vehicle deployment conceivably within the timeframe of the 2019 annual survey. The HRI credit provision of the LCFS was adopted, providing a way to secure hydrogen fueling station success even in early years of low throughput and a means for the State to provide a funding mechanism to secure the goal of 200 stations by 2025 in Executive Order B-48-18. Several hydrogen production and distribution companies made announcements of significant investments to improve existing hydrogen supply chain facilities or develop new facilities to serve California's transportation market. The Energy Commission's *Draft Solicitation Concepts* presented an attempt by the State to design a grant solicitation that supports lower-cost and larger-scale station deployment per industry-stated needs. Some auto manufacturers have even made announcements of large expansions of their FCEV production facilities. All the while, the funded hydrogen station network's development proceeded largely on schedule (see next chapter).

9 Auto manufacturer estimates reported through the California Fuel Cell Partnership provide a similar estimate of 6,830 vehicles as of June 1, 2019 [56]. DMV data are based on current registration status, while CaFCP data are driven more directly by vehicle sales. These typically have different reporting and processing periods, which may lead to different estimates at times.

The past year has included some events that have emphasized challenges in the state's hydrogen supply and distribution infrastructure system upstream of hydrogen fueling stations. The hydrogen fueling station network in California is currently supplied by a limited number of facilities operated by a limited number of separate entities. This presents a situation in which temporary supply interruptions can have a magnified effect on station operations and ultimately FCEV customers.

When incidents occur that remove part of the existing supply network (such as trucks that deliver hydrogen to fueling stations, facilities that fill those trucks with hydrogen, or other upstream assets), there is limited availability of contingency or backup equipment and hydrogen supply to mitigate the impact to customers. Disruptions have occurred multiple times in the past year and have resulted in severely reduced hydrogen availability for up to several weeks at a time. While the impact can be severe, it is ultimately temporary in nature and private stakeholders that are typically competitors in this market have worked cooperatively to provide any relief available in these situations. In addition, supply constraints are a known challenge that is actively discussed among private and public stakeholders who are working cooperatively to determine the scope of needed industry development to support desired growth in the state's FCEV fleet. Therefore, these temporary disruptions also do not seem to provide sufficient explanation for a change in long-term FCEV deployment projections.

In short, while prior Annual Evaluations noted an apparent one-year delay in FCEV deployment projections and found reasonable explanations in the events of the prior year, it is difficult to find similar explanations for the FCEV deployment projections in the current analysis. Based on the myriad positive developments in the past year, CARB cannot find that a long-term one-year delay in FCEV deployment is caused by any action related to hydrogen infrastructure plans or observed development. Auto manufacturers' responses in the 2019 survey therefore either indicate that infrastructure forces are not as impactful as previously expected, other factors outside of infrastructure are having an outsize impact on manufacturers' expected FCEV deployment, auto manufacturers are turning priorities in their deployment plans to other regions of the world, or other consideration(s) led to the vehicle deployment responses in this year's survey.

Figure 2: Comparison of On-The-Road Vehicle Counts in 2014-2019 Annual Evaluations

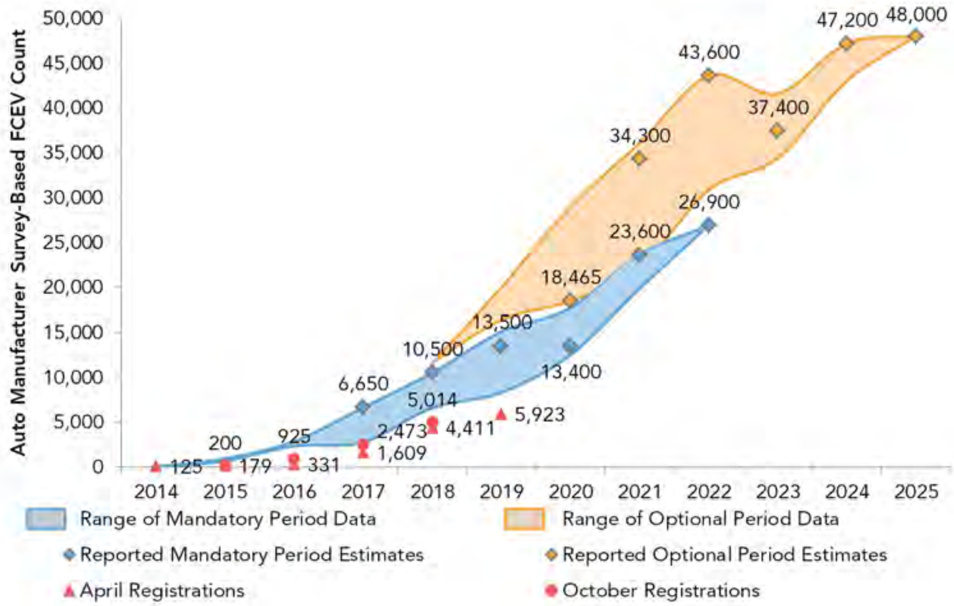


Figure 3: Distribution of Current FCEV Registrations as of April 4, 2019

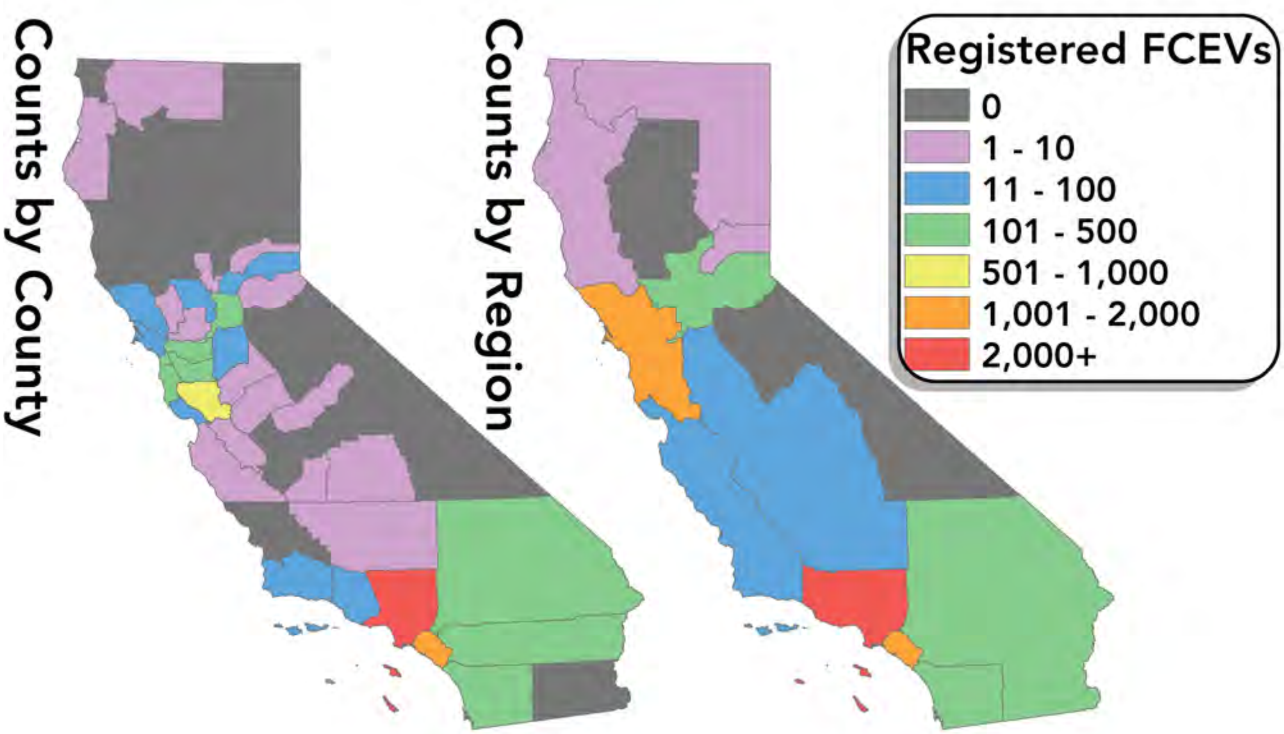
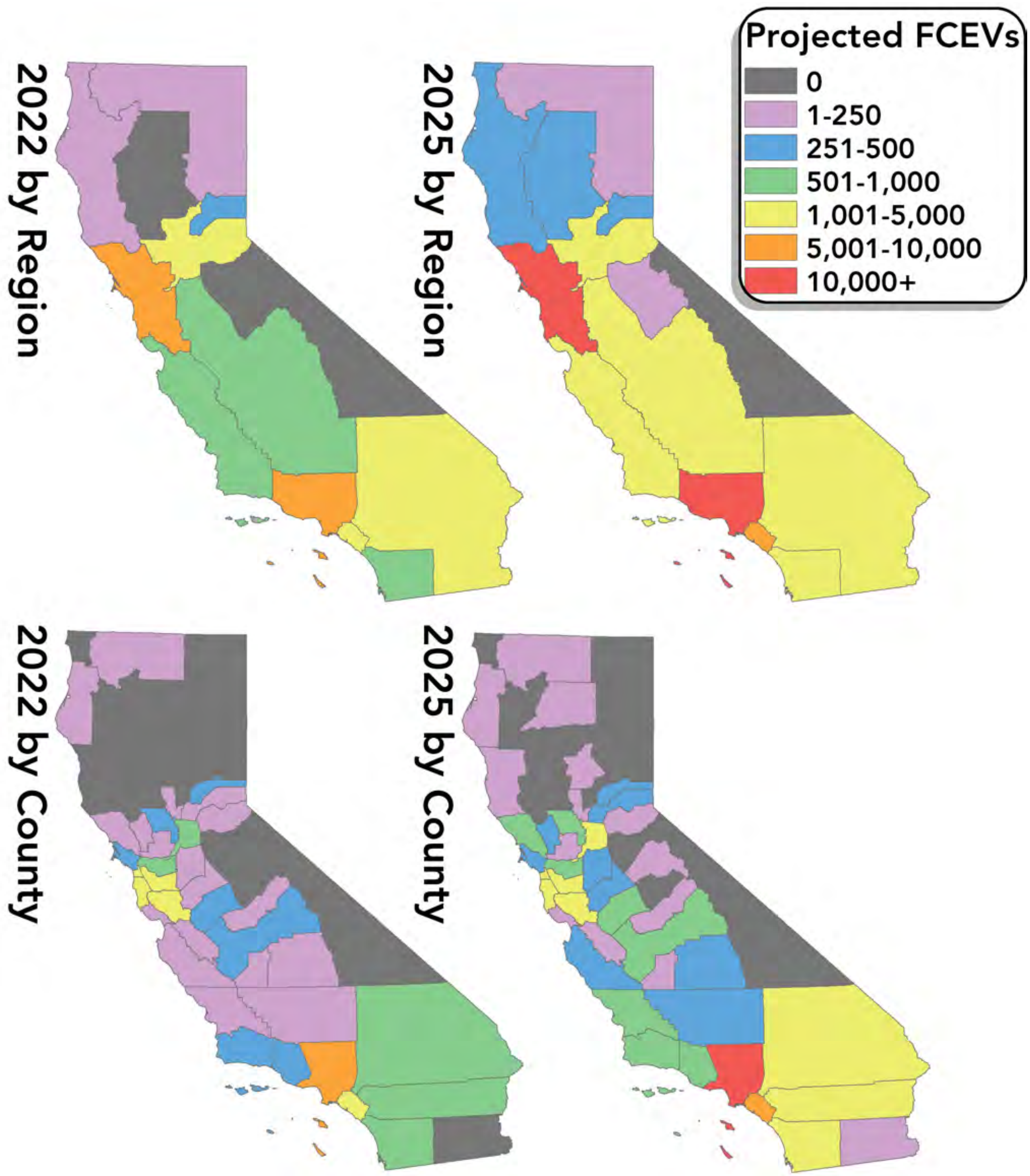


Figure 3: Distribution of Current FCEV Registrations as of April 4, 2019 shows that the highest concentration of FCEVs in today's fleet is in Los Angeles and Orange counties, with significant vehicle deployment also in other southern California counties, around the San Francisco Bay area, and in Sacramento and surrounding counties. Some vehicles are also registered in counties seemingly remote from the retail hydrogen fueling network and the core high-market areas. In the more distant areas like the northwest of the state, these vehicles may be fueling through the use of privately installed and operated hydrogen fueling stations. In other cases, the vehicles may be fueling through a combination of long-distance driving to retail stations and/or private stations.

Figure 4: Geographic Distribution of Future On-The-Road FCEVs



Estimated geographic distributions of FCEVs in 2022 and 2025 are shown in Figure 4: Geographic Distribution of Future On-The-Road FCEVs, with resolution provided both by county and analysis region (described in Table 3 and displayed in Figure 5: Map of Analysis Regions Used in this Evaluation). The Greater Los Angeles area is expected to remain the focal point for FCEV deployment through 2025, with the County of Los Angeles continuing to lead. The San Francisco Bay Area, Orange County, Sacramento, Riverside, San Bernardino, and San Diego counties are also expected to remain focal points for deployment through 2025. However, through 2022 and into 2025, other counties with markets that are currently smaller begin to receive a greater portion of the vehicle deployment and by 2025, several counties along the central coast and in the San Joaquin Valley are projected to see significantly accelerated FCEV deployment. In fact, most regions of the state would see FCEV deployment by 2025, with only the High Sierra and North Interior regions receiving zero or extremely limited FCEV deployments by this time.

Table 3: Definitions of Analysis Regions Used in this Evaluation

Analysis Region	Constituent Counties
Central Coast Range	Monterey, San Benito, San Luis Obispo, Santa Barbara, Santa Cruz
Greater Los Angeles	Los Angeles, Ventura
High Sierra	Alpine, Inyo, Mono
Inland Deserts	Imperial, Riverside, San Bernardino
North Central Valley	Butte, Colusa, Glenn, Shasta, Tehama
North Coastal Region	Del Norte, Humboldt, Lake, Mendocino, Trinity
North Interior Region	Lassen, Modoc, Plumas, Siskiyou
Orange Country	Orange
Sacramento Region	El Dorado, Placer, Sacramento, Sutter, Yolo, Yuba
San Diego County	San Diego
San Francisco Bay Area	Alameda, Contra Costa, Marin, Napa, San Francisco, San Mateo, Santa Clara, Solano, Sonoma
San Joaquin Valley	Fresno, Kern, Kings, Madera, Merced, San Joaquin, Stanislaus, Tulare
Sierra Foothills	Amador, Calaveras, Mariposa, Tuolumne
Sierra Nevada	Nevada, Sierra

Figure 5: Map of Analysis Regions Used in this Evaluation

Northeast and Zero Emission Vehicle States Optional Survey

Since 2017, CARB has included an additional optional portion of the annual auto manufacturer survey. This portion seeks to gain information about the potential FCEV deployment in states other than California that have either adopted CARB's low- and zero-emission vehicle regulations for light-duty vehicles or have been active in multi-state ZEV collaborations. While California currently has the largest hydrogen fueling network and the longest-running funding program, progress has been made in other states in recent years. The state of Connecticut has offered funding for stations through an open grant solicitation process [49]. The state of New York currently offers rebates to municipalities that install ZEV fueling infrastructure, including hydrogen stations [50]. As reported in the *2018 Annual Evaluation*, automotive parts supplier Servco has installed a station on their property in Hawaii to support a local fleet of Mirai vehicles and intends to make the station able to provide retail service to the public [51]. Finally, Air Liquide and Toyota have been collaborating on the development of a network of 12 hydrogen fueling stations in multiple states in the Northeast [43].

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Based on California's experience, these station developments should enable local FCEV deployments. To understand the full current and potential future scale of FCEV deployment domestically and to holistically support the expansion of FCEV use, CARB has asked for projected vehicle deployments in several of these states. As in previous years of the survey, too few responses were provided at the resolution of individual states for CARB to provide detailed reporting. Auto manufacturer expectations for vehicle deployment for the other states included in the survey remains in the hundreds of vehicles. Auto manufacturers again emphasized uncertainty surrounding the potential path of hydrogen station network development as a key factor preventing the conveyance of more concrete information.

Fuel Cell Electric Vehicle and Transportation Hydrogen Market Growth

- In May 2018, Toyota Motor Corporation announced planned expansion of its FCEV production capabilities from 3,000 per year to 30,000 per year after 2020 [11]. In a similar announcement released in December of 2018, Hyundai Motor Group revealed its "FCEV Vision 2030 [12]." This vision includes major investment of $6.7 billion to develop production capacity of 700,000 fuel cell stacks per year for a variety of platforms, including automobiles, drones, ships, locomotives, forklifts, and stationary power generation. Of these, 500,000 per year are planned to be dedicated to passenger and commercial vehicles. The plan's first milestone will be the opening of a new production facility with capacity of 40,000 units per year, set to begin operations by 2022.
- The fuel cell propulsion system of the Hyundai NEXO was named one of the top 10 engines of 2019 by Wards Auto [13]. Wards Auto noted that "the NEXO is a zero-emissions EV [Electric Vehicle] that offers the same range, performance and refueling time as a conventional ICE [Internal Combustion Engine] powertrain right now, not five years from now. It must be recognized." The NEXO propulsion system joins the Honda Clarity Fuel Cell (2018) [14] and the Hyundai Tucson Fuel Cell (2015) [15] as prior fuel cell winners of the award.
- Audi has announced that it will increase investments in fuel cell technology, and announced that it will develop a prototype in 2019, launch a market-ready model in 2021, and potentially take the step to large-scale production in the second half of the 2020 decade [16]. Exact dates are yet to be confirmed. The announcements noted that a pathway to full electric mobility will require both battery and fuel cell electric vehicles, with Audi specifically finding that limited availability of raw materials for battery production is one reason to pursue a multi-technology strategy.
- Air Liquide announced intent to develop the first "world scale" liquid hydrogen production facility dedicated to hydrogen energy markets, with construction beginning in 2019 [17]. The $150 million production facility will be located in the western United States, produce 30 tons per day of liquid hydrogen (the company equates this to 30,000 FCEVs worth of fuel demand), and directly support the FCEV market in California through a long-term agreement with FirstElement Fuel. FirstElement is constructing and operates the largest number of hydrogen fueling stations in California's current open and funded hydrogen fueling network. At the same time, Air Liquide announced a plan for equity investment in FirstElement Fuel to enable robust hydrogen fueling infrastructure deployment in California.
- Air Products and Chemicals, Inc., an industrial gas company that supplies hydrogen to California's current fueling stations and other customers, announced plans to build its second liquid hydrogen production facility in California [18]. The facility is expected to begin operations in 2021 and is intended to address growing demand from the transportation and other hydrogen-consuming industries.
- United Hydrogen, a merchant hydrogen production company, recently opened a new liquid hydrogen production facility in Charleston, Tennessee with a production capacity of 10 tons per day [19]. The facility began operations in March, and like the Air Liquide and Air Products facilities, has identified California's hydrogen transportation fuel market as one of its primary customers.

Location & Number of Hydrogen Fueling Stations

AB 8 Requirements: Evaluation of hydrogen fueling station network coverage

CARB 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

In the year since publication of the *2018 Annual Evaluation*, the open hydrogen fueling network has grown by six stations: Citrus Heights, Emeryville, LAX, Palo Alto, Sacramento, and San Francisco Third Street[10]. (This represents a net growth of five stations, as the Burbank station is not yet considered open, as was previously reported). Four stations have had replacements proposed and three of these have been approved by the Energy Commission:

- The station previously proposed for award in Huntington Beach has been approved to be replaced by a station in Fountain Valley (this was reflected in the analysis and reporting of the *December 2018 Joint Agency Staff Report* [52])
- The station previously proposed for award in Walnut Creek has been approved at an Energy Commission Business Meeting to be replaced by a station on Bernal Road in San Jose
- The station previously proposed for award in Irvine has been proposed to be replaced by a station in Concord
- The station previously proposed for award in Santa Monica on Lincoln Blvd has been approved to be replaced by a station in Culver City

In addition, some individual stations' projected open dates have been updated as development progress became clearer throughout the year. The updated history and projections of open stations in each county and statewide are presented in Figure 6: End of Year Open Station Projections by County and Statewide (as of June 1, 2019). Compared to the projections provided in the previous Annual Evaluation, it is clear that ten stations will now open in 2020 rather than 2019. On the individual county level, Contra Costa, San Bernardino, and San Diego counties will have their second station open one year later than previously expected. In addition, the connector station at Santa Nella in Merced county will be completed one year later than previously reported. The updated projections for individual stations' open dates are further detailed in Figure 7.

Since 2015, CARB has relied on the implentation of CHIT to prepare assessments of coverage and capacity provided by the open and funded hydrogen fueling network and to compare this to the needs of the registered and projected FCEV fleet. The tool has been developed in the ArcGIS environment and is available for download and use by any interested party with access to the software. Coverage evaluations in CARB's implementation of CHIT provide a method for accounting for the fueling station coverage provided to California's communities as affected by the travel time required to reach a station and the availability of single or multiple stations within a given distance. In CARB's evaluations, coverage is assumed to be limited to a 15-minute drive around any given station, with greater coverage provided by nearer stations and more stations serving a given area.

10 For this report, CARB is counting the San Francisco Third Street station as open, although it has not yet begun retail operations. CARB's understanding is the station was preparing to transition to open retail status at the same time that the northern California supply disruption event began. The station is fully constructed and has completed all testing, review, and confirmation steps required of an open retail station. CARB therefore expects that the station will be able to begin retail operations as soon as the supply disruption is resolved, just like the remainder of the open station network.

Figure 6: End of Year Open Station Projections by County and Statewide (as of June 1, 2019)

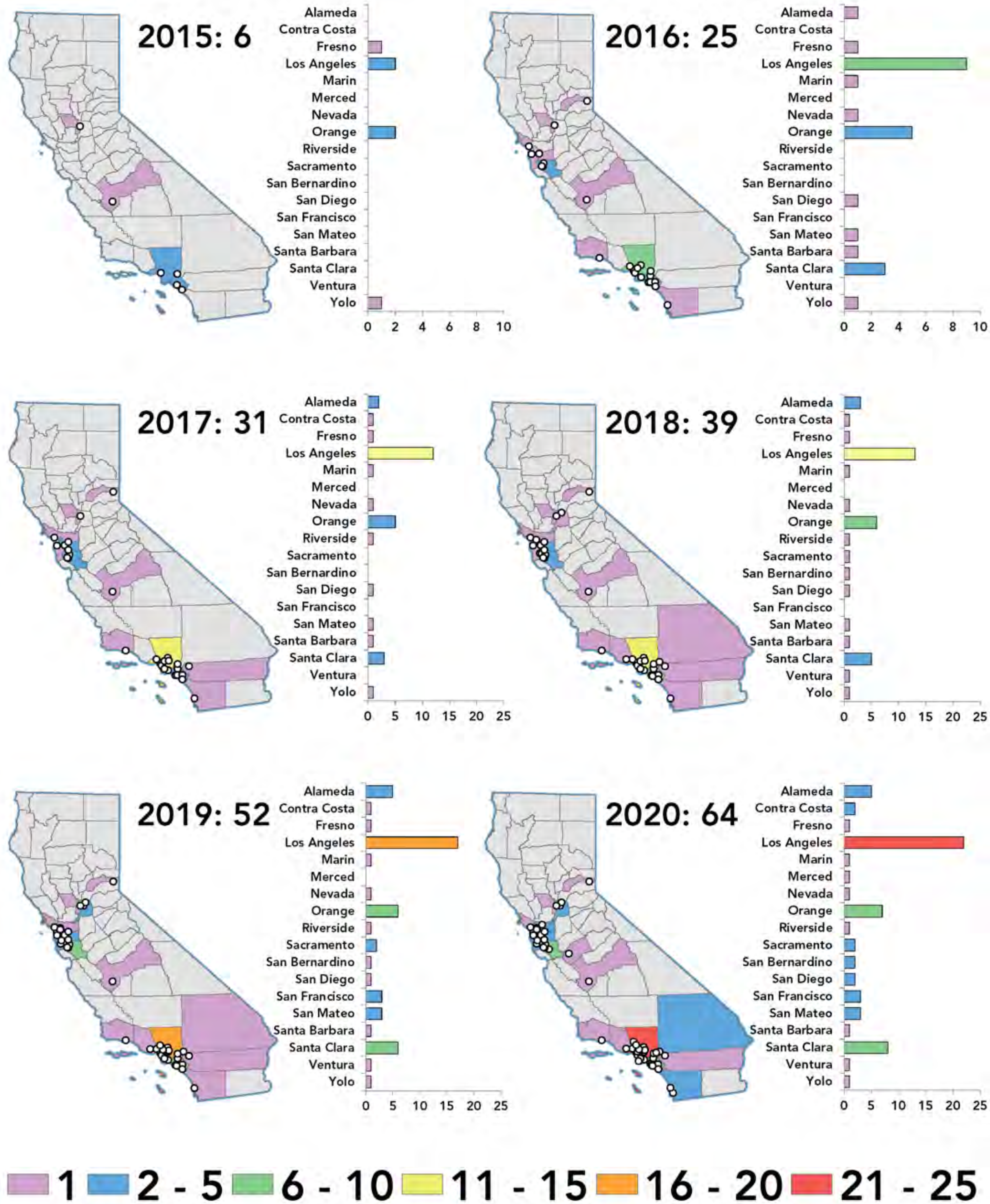


Figure 7: History and Projections for Open and Funded Hydrogen Station Network

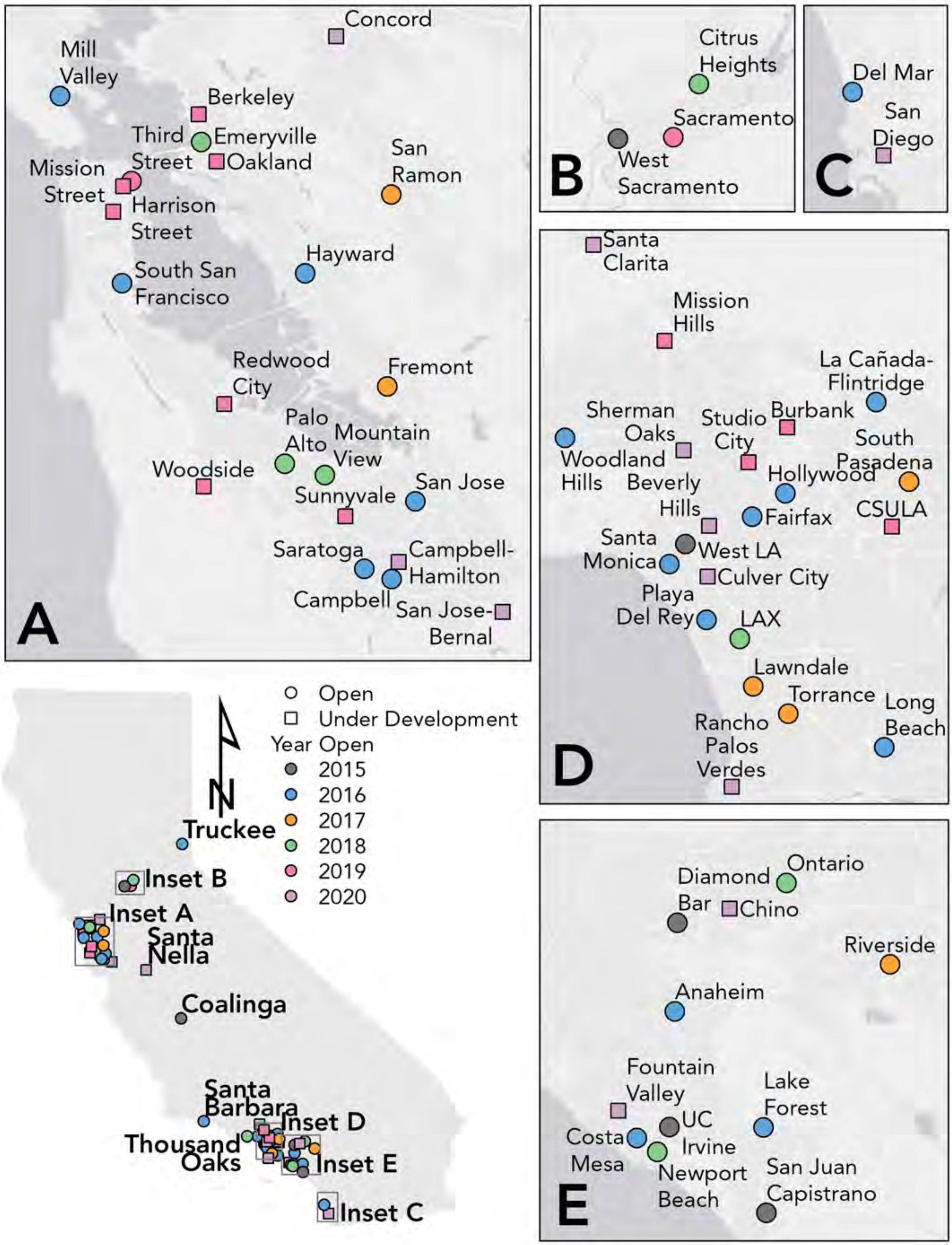
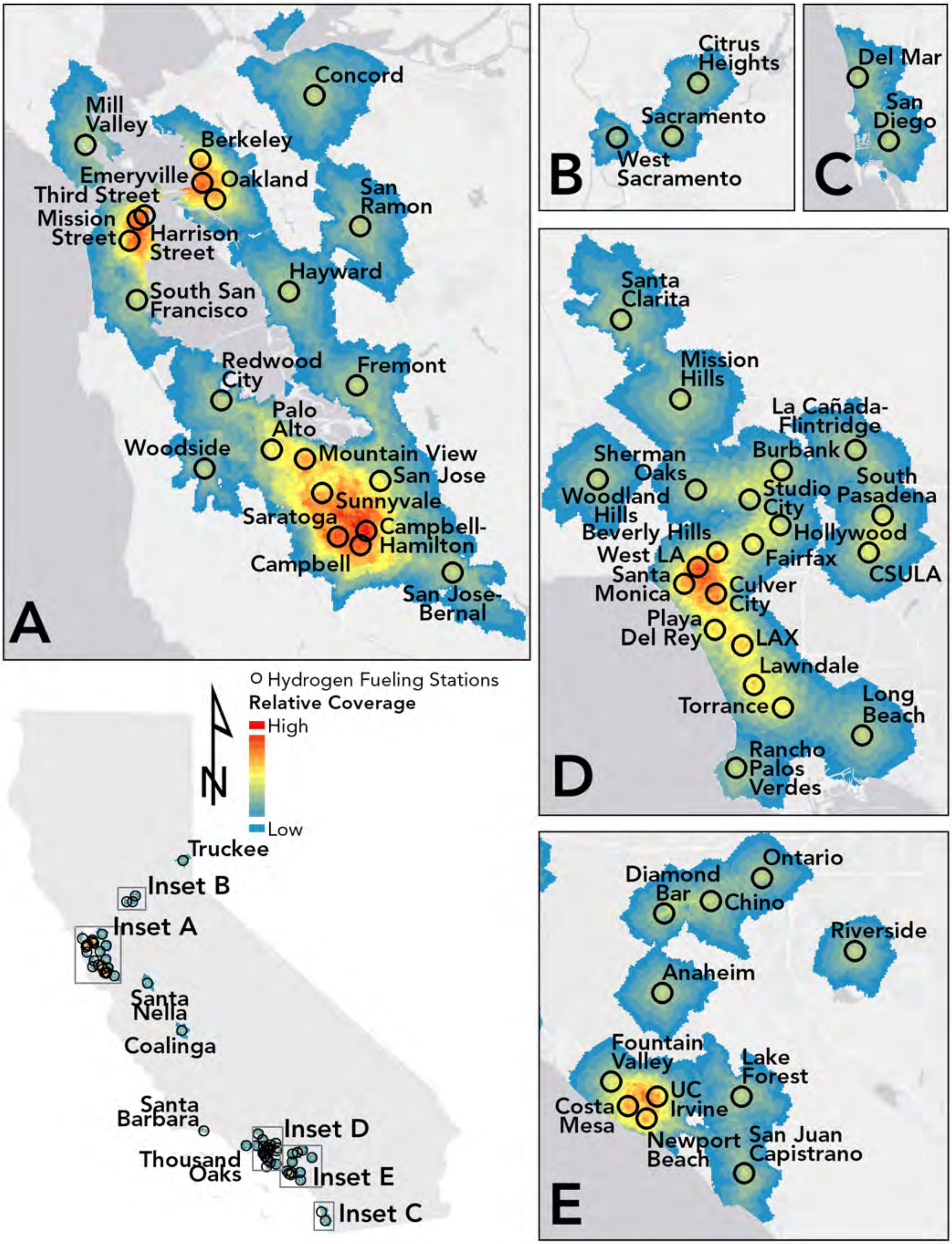


Figure 8: Assessment of Coverage Provided by Open and Funded Hydrogen Station Network



Implications for the network coverage due to changes in the funded station network are apparent in Figure 8: Assessment of Coverage Provided by Open and Funded Hydrogen Station Network. Coverage previously provided near Walnut Creek has shifted northward to the newly-proposed Concord location, though the coverage still slightly overlaps with the San Ramon station. This provides continuous fueling opportunity within 15 minutes for drivers and communities along I-680 between Dublin and Benicia. Coverage on the southern end of the San Francisco Bay area has extended further southward with the addition of the San Jose station on Bernal Road. Concentrated and overlapping coverage in West LA has extended to the southeast due to the Culver City station. The reach of coverage in Orange County has hardly changed, but there has been a decrease in intensity between UC Irvine and Lake Forest due to the proposed move of the Irvine station to Concord. The move from Huntington Beach to Fountain Valley is short and therefore does not have a great impact.

Disadvantaged Communities

Due to the small degree of changes in coverage provided by the open and funded hydrogen fueling network, CARB finds that hydrogen network coverage provided to Disadvantaged Communities remains largely unchanged since the analysis presented in the *2018 Annual Evaluation*. Namely, the previous Annual Evaluation found that while approximately 1% of the Disadvantaged Community population lived in the same census tract as an open or planned hydrogen fueling station, approximately 35% of the Disadvantaged Community population lives within the 15-minute extent of coverage provided by the network.

Trends of Station Deployment Rates

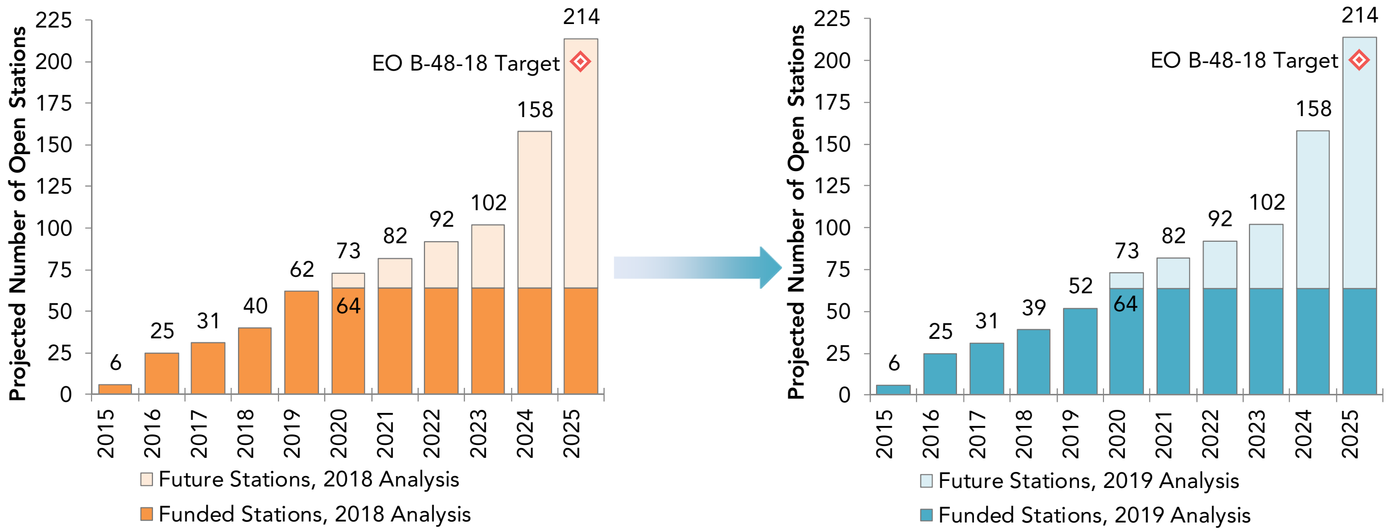
As shown in Figure 9: Comparison of Statewide Station Projections Between 2018 and 2019 Annual Evaluations, CARB analyses continue to expect that all 64 funded stations will become open by the end of 2020, similar to prior analyses. Although the numbers of stations that did open in 2018 and are currently expected for 2019 are fewer than reported last year, all stations remain on a schedule that should enable retail operations to commence in 2020 at the latest. Based on ongoing collaborative effort with industry stakeholders, CARB also expects future station deployment to follow a trajectory that accomplishes the goal of at least 200 stations by 2025, per Executive Order B-48-18.

The pace of deployment for these future stations is largely unknown, but the projections used in the current and previous Annual Evaluations adopt the deployment scenario developed for the California Fuel Cell Partnership's *Revolution* document. In this scenario, stations are built through the remainder of AB 8 at the previously-calculated pace of 9 to 10 stations per year, based on the estimated number of stations that can be funded with each annual allocation of $20 million. Afterwards, stations are built at a pace to enable FCEV deployments to accelerate and achieve the goal of one million FCEVs on the road in 2030. This station deployment rate slightly exceeds the Executive Order target, with 214 stations open and serving retail customers in 2025. In addition, the *2018 Joint Agency Staff Report* anticipates that future station funding through AB 8 could actually result in a slightly larger network in 2022 and 2023 than assumed for this Annual Evaluation. Based in part on proposed amounts of grant funds available to stations in the next station funding solicitation, the *2018 Joint Agency Staff Report* anticipated 110 stations could be open by 2024 through AB 8 (compared to 102 in this Annual Evaluation).

Global Announcements of FCEV Commitments

- Fuel cell electric vehicles and hydrogen fuel have recently received significant focus in China's automobile market [30] [31] [32]. Multiple important achievements have been accomplished in prior years: China established a 2030 goal of one million FCEVs on the road in 2015, has established its first twelve hydrogen fueling stations, and reportedly spent an estimated $12B on government support for fuel cell technologies. However, recent developments point towards significant acceleration to come in the near future. Two particular events highlight this shift: 1) On March 15, the national government announced a proposal to promote the development and construction of hydrogen fueling stations for hydrogen vehicles, and 2) Wan Gang (a former Audi executive and former Science and Technology Minister, current Vice Chairman of China's national policy advisory board, and considered the father of China's electric vehicle movement) provided an interview in which he publicly stated the need to advance the commercialization of hydrogen and fuel cell vehicles and look to establishing a hydrogen society. To this end, Wan Gang mentioned government resources would therefore be committed and described potential demonstrations of a hydrogen ecosystem in selected trial regions. In addition, the national government has set targets of 100,000 FCEVs within the next five to six years and 30,000 annual clean vehicle deployments in 30 cities each year from 2019 onward (mostly FCEV and most likely beginning with public transportation applications). At the same time, manufacturers have taken steps to meet these targets; notably, a production plant with an annual capacity of 160,000 FCEVs is currently being built and is expected to be operational by 2024.
- Several announcements related to hydrogen and fuel cell transportation in South Korea have also been made in the past year. The country has announced changes to regulations to ease production and distribution of hydrogen-powered buses, with an associated goal of deploying 1,000 of the vehicles by 2022 [33]. In addition, the government announced the establishment of HyNet, a special purpose corporation formed by the partnership of 13 companies in the hydrogen industry with the goal of building the country's first 100 hydrogen fueling stations by 2022 [34]. Finally, South Korea has also announced a goal of shifting all commercial vehicles in the country to hydrogen-powered fuel cell vehicles by 2035 and a goal of beginning to commercialize hydrogen-powered trains after 2025 [35].
- During the 2019 G20 Ministerial Meeting on Energy Transitions and Global Environment for Sustainable Growth, leaders from the United States, European Union, and Japan signed a statement signifying their intent for continued cooperation in hydrogen and fuel cell technologies [36]. The agreement emphasizes the broad impact that hydrogen can potentially have in developing sustainable energy systems across industries and economic sectors and the intent to develop a future Memorandum of Cooperation with other partnering countries. The agreement specifically mentions affordable and reliable hydrogen, including potential cooperation to address: infrastructure; regulations, codes, and standards; hydrogen safety; reduction of greenhouse gas and other emissions; and communication and outreach.
- The Canadian province of British Columbia has begun development and deployment of a retail hydrogen fueling station network, built and operated by hydrogen technology company HTEC. The first of eight planned stations was opened last year in Vancouver [37]. In addition, two stations recently received funding from both the federal and provincial governments [38].
- Six companies in the hydrogen and fuel cell industry have formed the consortium H2Bus, committed to deploying 1,000 hydrogen-powered fuel cell buses and associated fueling infrastructure throughout Europe [39]. The group characterizes their goal as providing the "most cost-effective truly zero-emission option available" and quotes target costs of €375,000 capital cost for each bus and hydrogen prices that translate to service costs of €0.30 per kilometer.

Figure 9: Comparison of Statewide Station Projections Between 2018 and 2019 Annual Evaluations



It is important to note that at some point in the next 5 years, the station deployment rate will need to significantly accelerate in order to meet the goals of EO B-48-18 and the Partnership's *Revolution*. Ongoing development of the next hydrogen station grant solicitation through the Energy Commission and the recent adoption of the HRI provision in the LCFS Program should prove to be powerful enablers of such a shift. Thus, the assumed pace of 9 to 10 stations per year through the end of AB 8 may be surpassed. However, these will need to be coupled with accelerating FCEV deployment in order to guarantee the intended 2025 objectives are met. In addition, it is too early to determine whether additional support tools will be needed to meet the 200 or 1,000 station goals as projected and achieving additional goals (such as lowering the price of hydrogen at the pump and/or increasing the renewable content) may also require additional support mechanisms.

The acceleration of future station deployment shown in Figure 9: Comparison of Statewide Station Projections Between 2018 and 2019
Annual Evaluations is not currently matched by the FCEV deployment rates indicated by auto

Global Announcements of FCEV Commitments (continued)

- Toyota of Europe and Italian fuel company Eni have announced a partnership to investigate accelerating the deployment of hydrogen and FCEVs in Italy [40]. The partnership will begin with a hydrogen fueling station deployed at one of Eni's facilities in San Donato and the delivery of ten Mirai vehicles for demonstration. The companies plan further deployment throughout Italy based on successful demonstration at this test site.
- Delivery company DHL Express and vehicle manufacturer StreetScooter announced a collaboration to deploy 100 hydrogen-powered panel vans in Germany, beginning in 2020 [41]. The vehicles are expected to have a 500 kilometer range (more than 300 miles), with a maximum payload over 800 kg (approximately 1,800 pounds).
- The world's first hydrogen-powered fuel cell passenger train began commercial operations in the German state of Lower Saxony in September of 2018 [42]. Two Coradia iLint trains, built by rail manufacturer Alstom, have been deployed into commercial service over 100 kilometers (62 miles) of passenger rail lines. The trains can reach speeds of 140 kilometers per hour (87 miles per hour) and have a range of 1,000 kilometers (620 miles).

manufacturers through the confidential survey process. Most notably, the 64 currently-funded stations provide enough fuel for approximately 24,200 FCEVs. Achieving the auto manufacturers' 48,000 FCEV projection by 2025 with 214 stations in the network requires all future stations to only have an average capacity of approximately 110 kg/day. This is well below the current network average and far below the expected and observed trend toward larger stations that individually support much larger fleets of FCEVs and present more attractive and potentially self-reliant business opportunities. Given these considerations, there is a clear need for auto manufacturers' FCEV deployment plans in California to accelerate in the near term so that goals for 2025 and beyond can be achieved.

Suggested Station Counts and Locations for Future State Co-Funding

Current recommendations for future hydrogen station co-funding through AB 8 are based on the continued implementation of CHIT. Introduced in 2015 and updated in 2017, CHIT is a geospatial analysis tool built in the ArcGIS environment. CHIT provides methods for assessing the relative need for new hydrogen fueling stations across the state, accounting for the open and funded hydrogen fueling network. The fundamental steps of CHIT analyses are shown in Figure 10: CHIT Evaluation Process Comparing Market and Coverage Assessments to Determine Coverage Gaps and Capacity Need. The major steps of analysis include:

1. **Market and Commuter Traffic Assessment:** Assess the relative strength of the FCEV first adopter market across the state according to various observational and modeled demographic and vehicle market indicators as well as 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 10: CHIT Evaluation Process Comparing Market and Coverage Assessments to Determine Coverage Gaps and Capacity Need

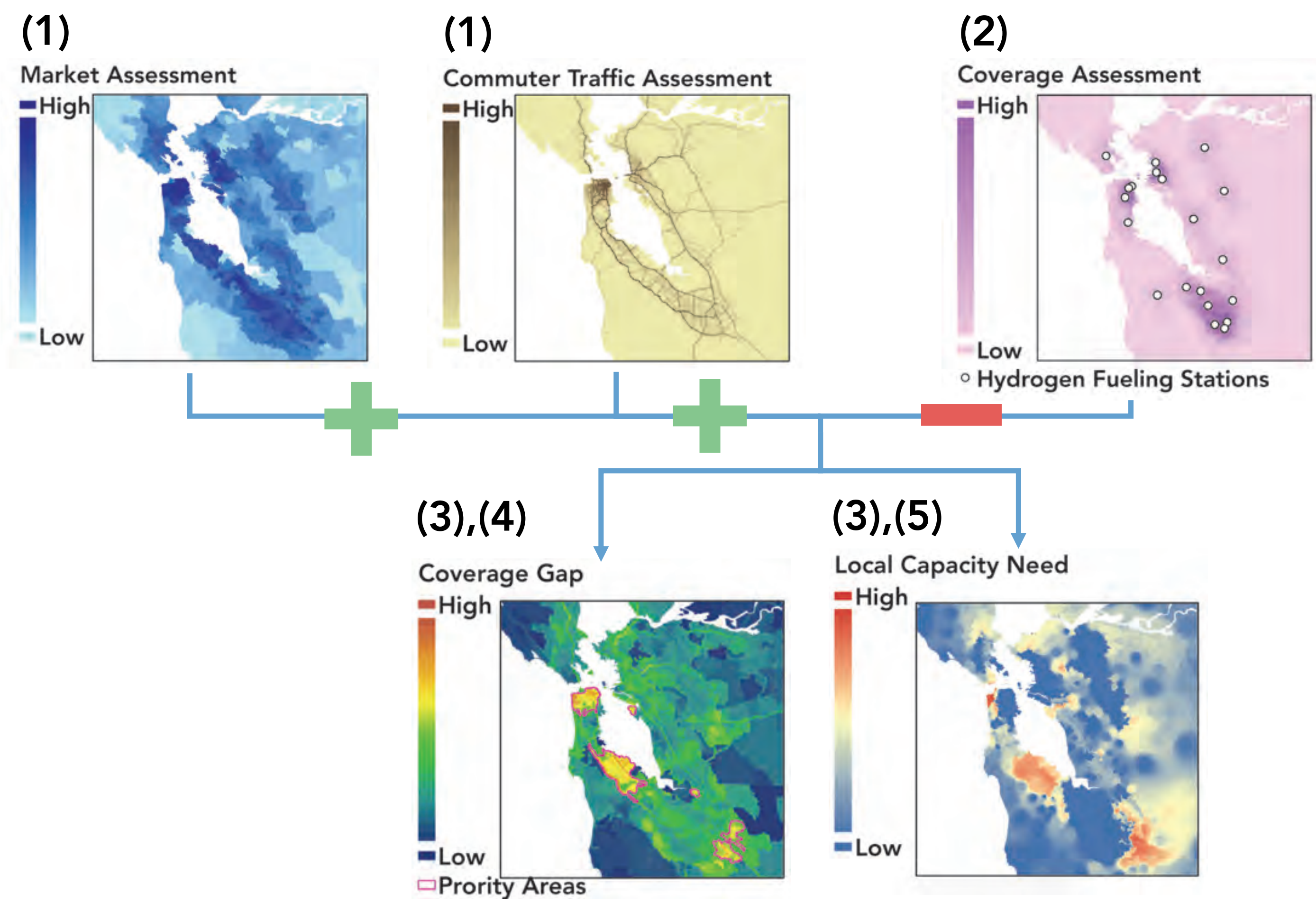
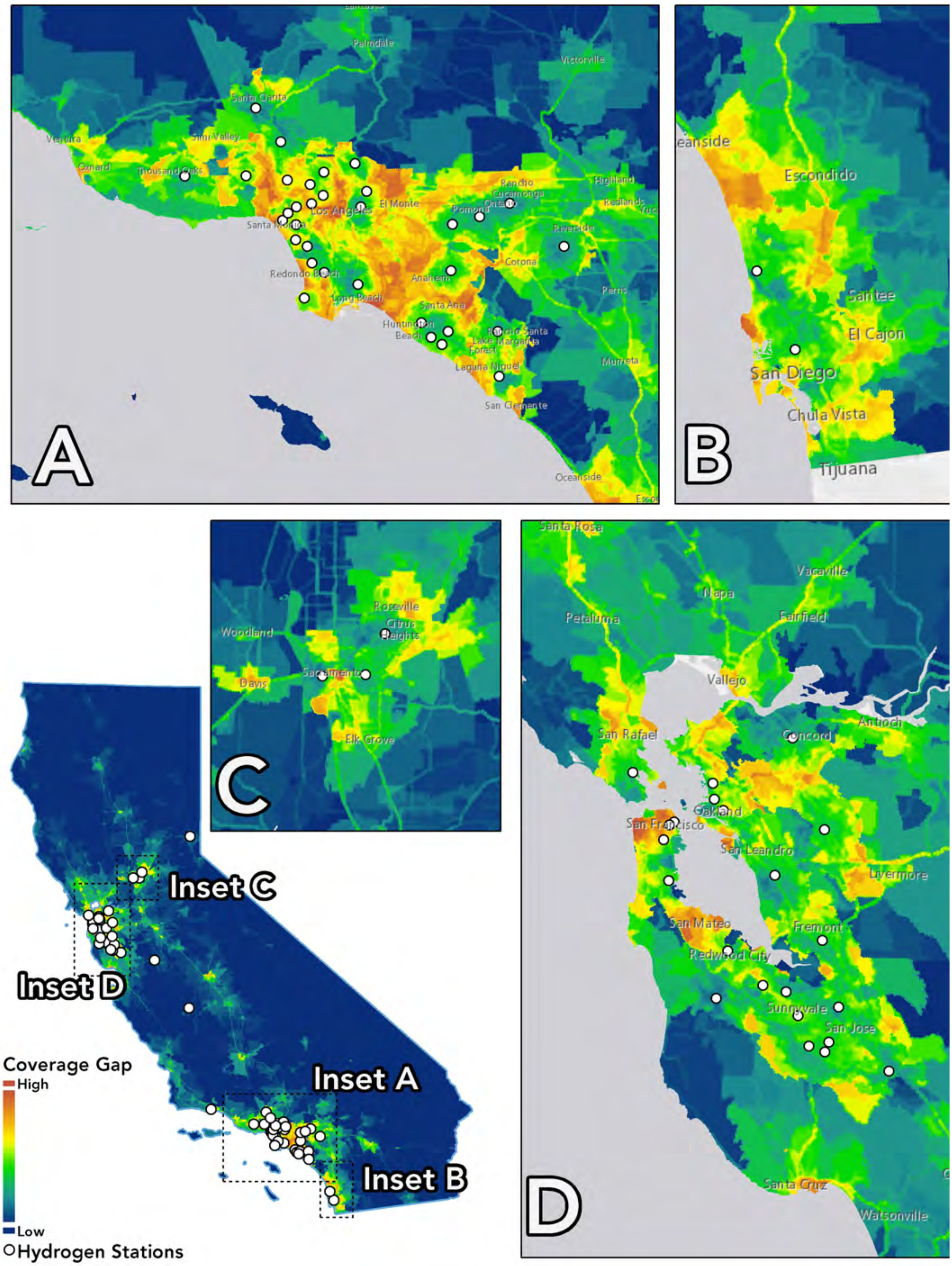


Figure 11: Coverage Gap Analysis, as of June 1, 2019 shows the results of coverage gap analysis, accounting for the current station network status and coverage shown in Figure 7 and Figure 8: Assessment of Coverage Provided by Open and Funded Hydrogen Station Network. The currently open and funded station network has been successful in providing coverage to some of the largest potential FCEV first adopter markets in the state. Even with this progress, many of the greatest needs for additional hydrogen fueling stations exist in pockets of these high-priority markets that do not yet have coverage commensurate with the strength of the local FCEV market. In some cases (such as in the Sacramento area and San Diego), these gaps are simply because the funded station network's coverage does not yet reach all the communities with high concentration of potential first adopters, and a single additional station in these communities may be sufficient for some time. In other cases (such as West Los Angeles), there are several stations already in the network that provide multiple fueling options, but the concentration of potential first adopters in the area could still require additional local stations to enhance the overlapping coverage. Finally, there are also significant needs in important connector and destination areas, such as along the CA-99 corridor (particularly in Fresno) and near Santa Cruz.

Figure 11: Coverage Gap Analysis, as of June 1, 2019



In addition to current network analysis capabilities, the *2018 Annual Evaluation* introduced a new iterative simulation framework CARB developed that leverages the functions of CHIT to project potential hydrogen network deployment. This framework was utilized to generate the scenario depicted in the California Fuel Cell Partnership's *Revolution* document, and aided in the design of a deployment trajectory enabling a 1,000 station network by 2030. This process also relies on assumptions of future station technology implementation (primarily the pace of individual station capacity growth) and station deployment rates. Station locations in the analysis are then determined using the same coverage and capacity need metrics common to all CHIT analyses. These projected locations were then translated into a map of potential hydrogen station density in 2030.

As shown in Figure 12, the results of both the current CHIT analysis (which focuses more closely on the current network status and the most immediate coverage and capacity needs) and the long-term 2030 scenario have been leveraged to provide location and capacity recommendations for the next station funding program. A statewide overview is provided in Figure 13: Recommended Eligible Areas for Hydrogen Fueling Station Funding
and Classification of Target Design Capacity, with greater detail provided in Figure 14: Geographic Detail for Recommended Hydrogen Fueling Station Funding and Classification of Target Design Capacity. Recommended eligible areas for station funding encompass all areas of the 2030 projected network, including core market, connector, destination, and emerging market areas. Recommendations for the target station design capacity are based on the current development status, projected local market metrics (including station density, capacity, and timing), and the overall market evaluation determined through CHIT.

Four area classifications are suggested (not counting ineligible areas).

1. **Capacity Growth:** Capacity Growth areas are defined by three criteria:
   - The area is one of the 11 largest (in terms of first adopter metrics) contiguous market areas as identified through the market assessment functions of CHIT (see Figure 16: Largest Potential Markets (Outlined in Pink) as Determined through CHIT Market Evaluation for a depiction of these core areas).
   - The area currently has three or more (open or funded) hydrogen fueling stations providing coverage to current and potential local drivers.
   - The scenario analysis in support of the CaFCP's Revolution document finds that larger stations (above 600 kg/day capacity) should be first deployed in these areas.
2. **Coverage Growth:** Coverage Growth areas are defined similarly to Capacity Growth areas, except that the largest stations in the 2030 analysis are projected to come to these neighborhoods further in the future.
3. **Market Initiation:** Market Initiation areas are also those within the 11 largest contiguous market areas; however, these neighborhoods do not yet meet the threshold of at least three open or funded hydrogen fueling stations providing coverage.
4. **Connector and Destination:** Connector and destination stations are located in the remainder of all eligible areas outside of the core markets.

With the definitions provided above, Capacity Growth, Coverage Growth, and Market Initiation are not static classifications (however, the Ineligible Areas would remain fixed; no area would change from Ineligible to one of the eligible classifications or vice-versa). A neighborhood or community that is currently provided coverage by only two open stations would be considered Market Initiation. However, if a third station is funded that provides coverage to that same community then its classification would no longer be Market Initiation. Instead, it would move into either Coverage Growth or Capacity Growth, based on the determinations in the future projected station development scenario. Figure 15: Long-Term Geographic Distribution of Capacity and Coverage Growth Areas highlights the geographic distribution of coverage and capacity growth areas in a long-term scenario in which all markets have progressed beyond the three-station initiation phase. This provides a potential long-term roadmap to anticipate the eventual needs within key markets of the state that may be temporarily masked by the market initiation needs.

Figure 12: Process of Utilizing Current CHIT Analyses and Future Scenario Analyses to Develop Recommendations for Locations to Provide Continued Hydrogen Fueling Station Funding

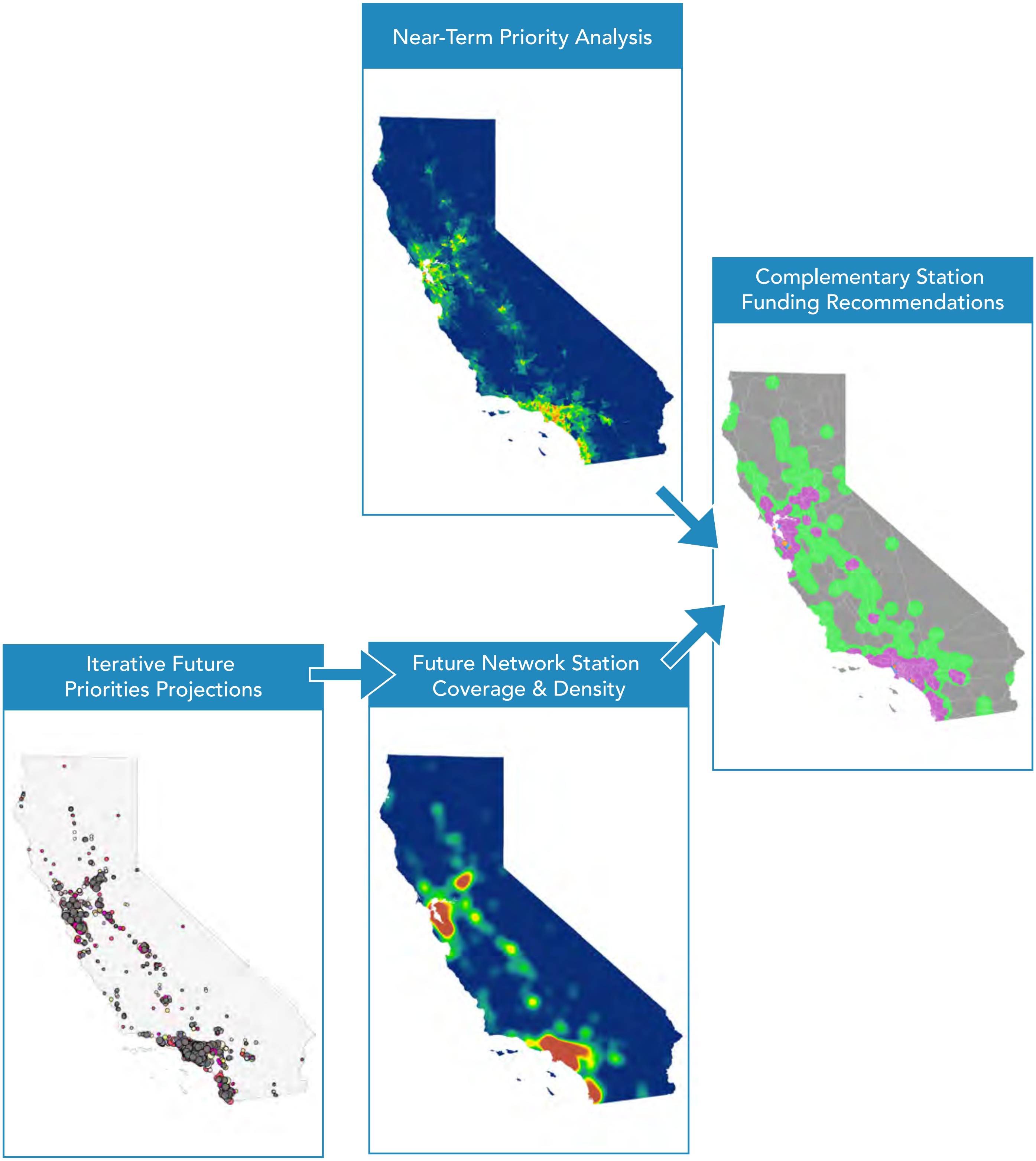


Figure 13: Recommended Eligible Areas for Hydrogen Fueling Station Funding and Classification of Target Design Capacity

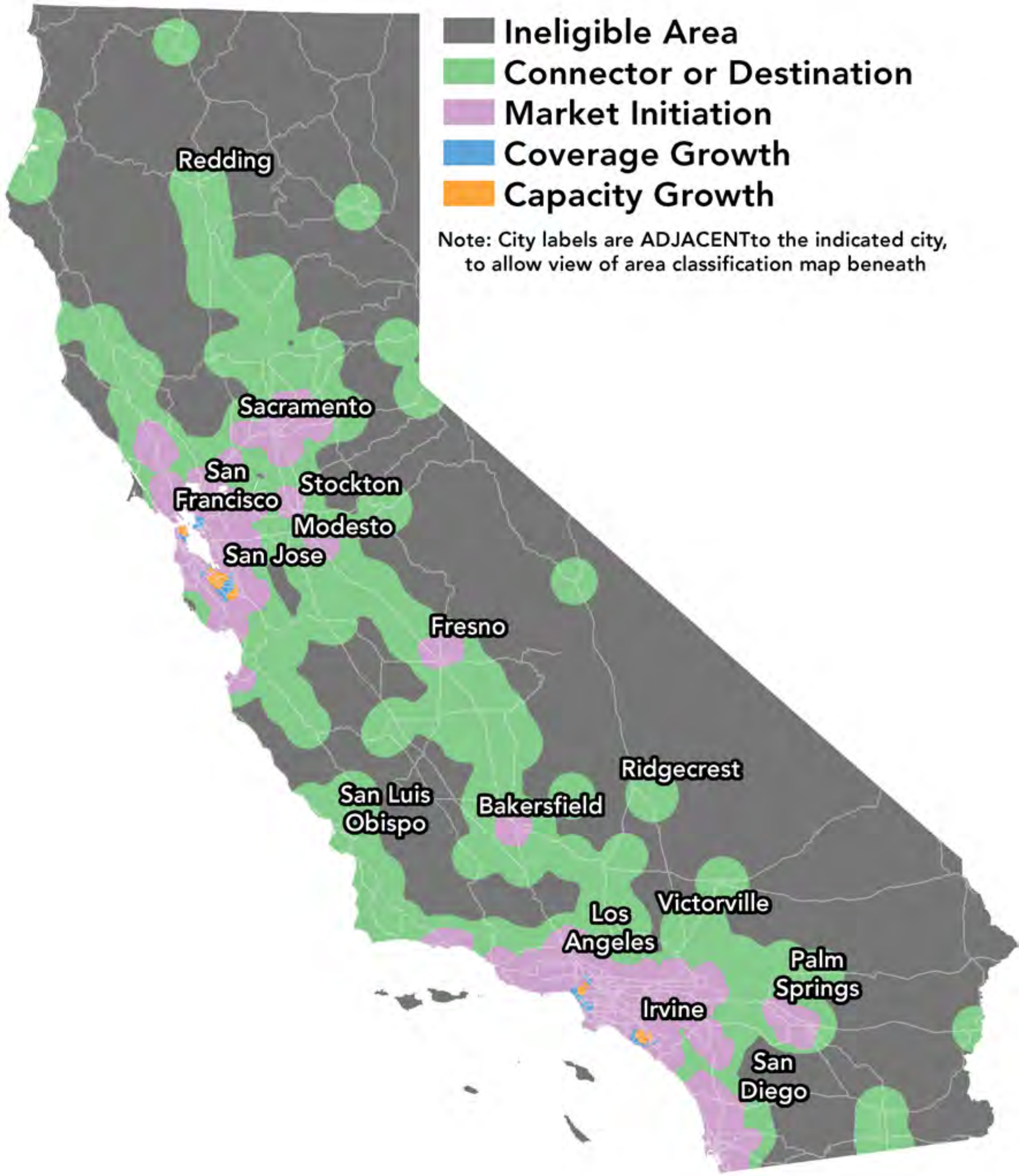


Figure 14: Geographic Detail for Recommended Hydrogen Fueling Station Funding and Classification of Target Design Capacity

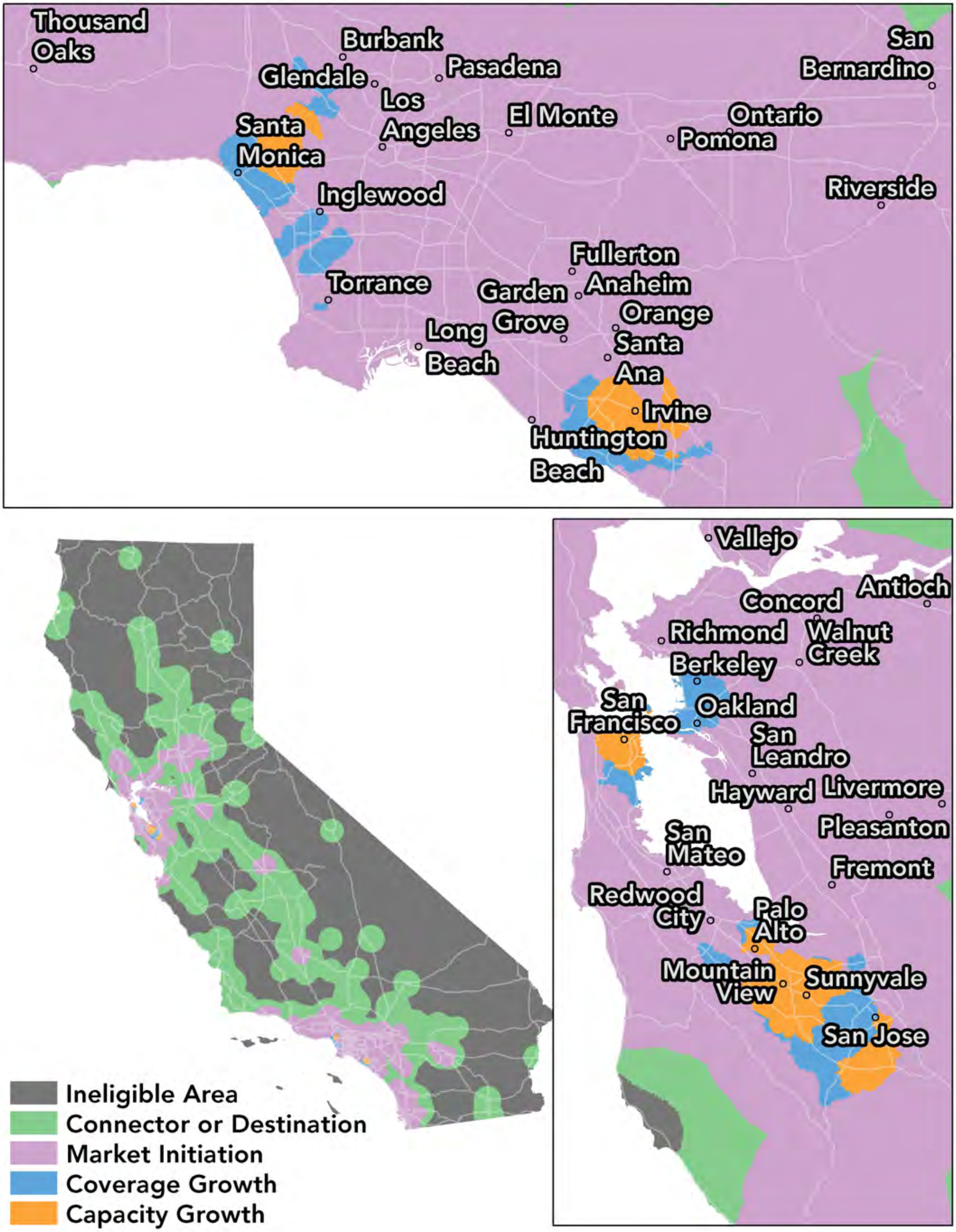


Figure 15: Long-Term Geographic Distribution of Capacity and Coverage Growth Areas

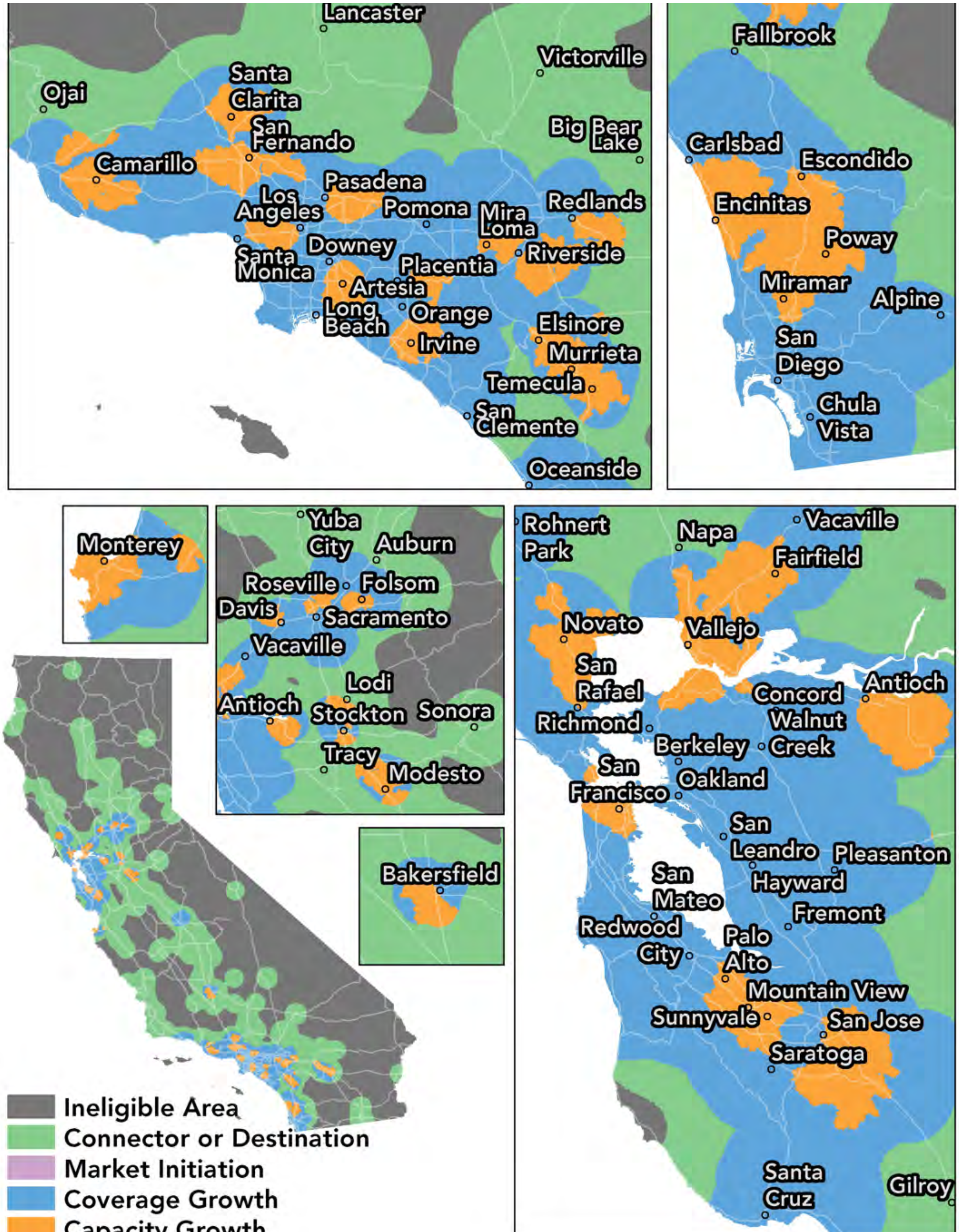
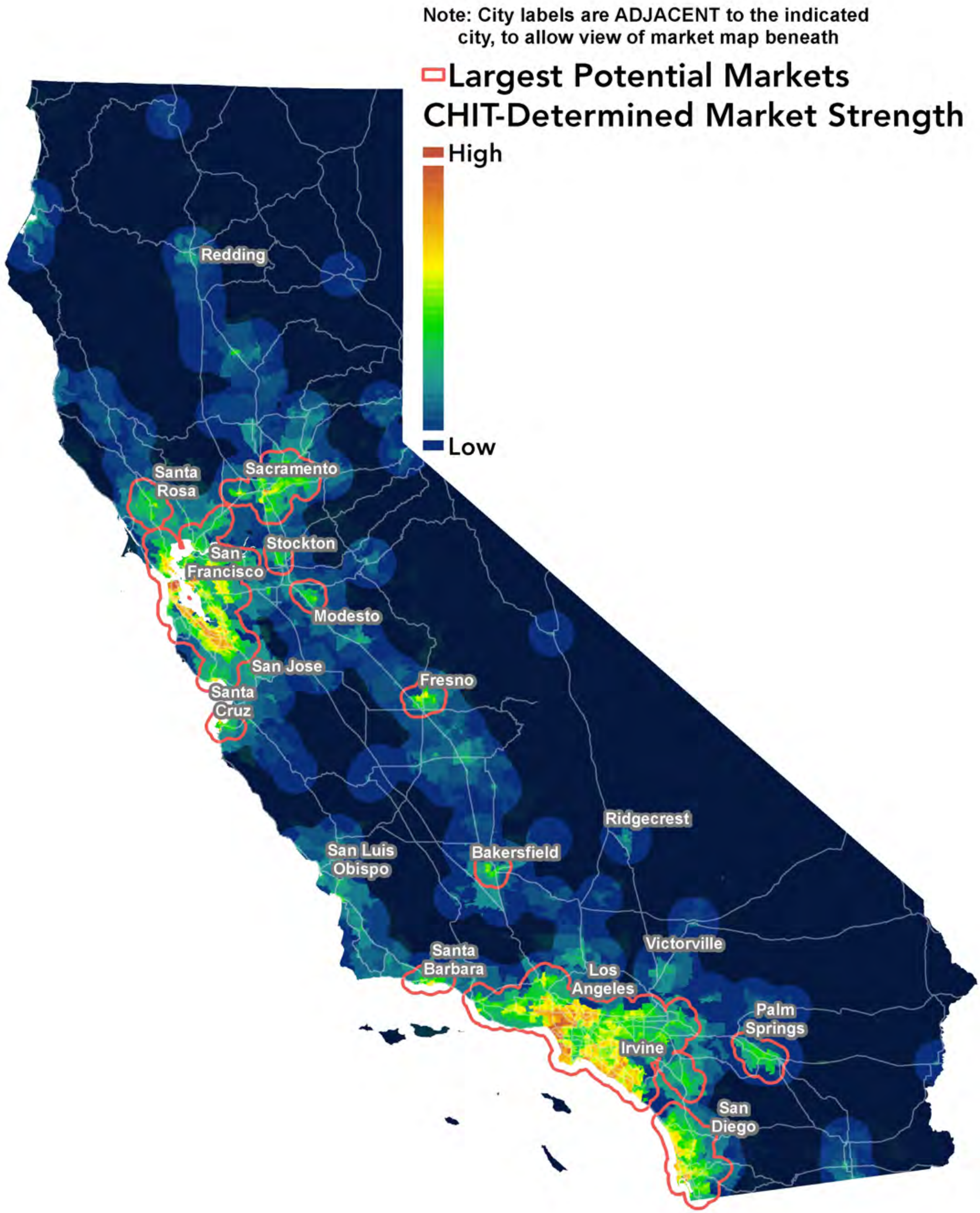


Figure 16: Largest Potential Markets (Outlined in Pink) as Determined through CHIT Market Evaluation



Area classifications are envisioned to provide guidance for the station archetype that would be most appropriate for future funding. Based on comments received from industry throughout the past year, and considering insights provided by the development and implementation of the new HySCapE tool, CARB has developed station design recommendations built on minimum numbers of fueling positions, which translate directly into minimum required station capacities.

While the HySCapE tool provides a means to evaluate capacity of varying station designs according to a standardized methodology, various station capacities for the same station design can be determined based on assumptions of station operation and interpretation of HySCapE output. In order to avoid this added variability, CARB has developed the station capacity recommendations for various Area Classifications with the assumption that they are determined through HySCapE with stations simulated to only receive a hydrogen delivery at the beginning of the day, and that the capacity rating per dispenser must be achieved such that all fills in the day are complete fills with an ending State of Charge (SOC) of 95% or more. SOC is a measure of how full the vehicle's onboard hydrogen tank is at the end of a fill event, given initial and ambient conditions. These requirements ensure that the station capacity rating is most influenced by the equipment performance capabilities and the station design, rather than the logistics of hydrogen delivery to the station. This also happens to provide station capacity evaluations that are well in agreement with the 12-hour capacity reporting that has been utilized for all stations funded to date through the AB 8 program. For the next station funding solicitation, CARB therefore recommends the minimum station design metrics shown in Table 4: Recommended Station Design Capacity Requirements by Area Classification.

Table 4: Recommended Station Design Capacity Requirements by Area Classification

Area Classification	Minimum Number of Fueling Positions	Minimum Capacity per Fueling Position (kg/day)	Minimum Station Capacity (kg/day)
Capacity Growth	3	225	675
Coverage Growth	2		450
Market Initiation	2		450
Connector or Destination	1		225

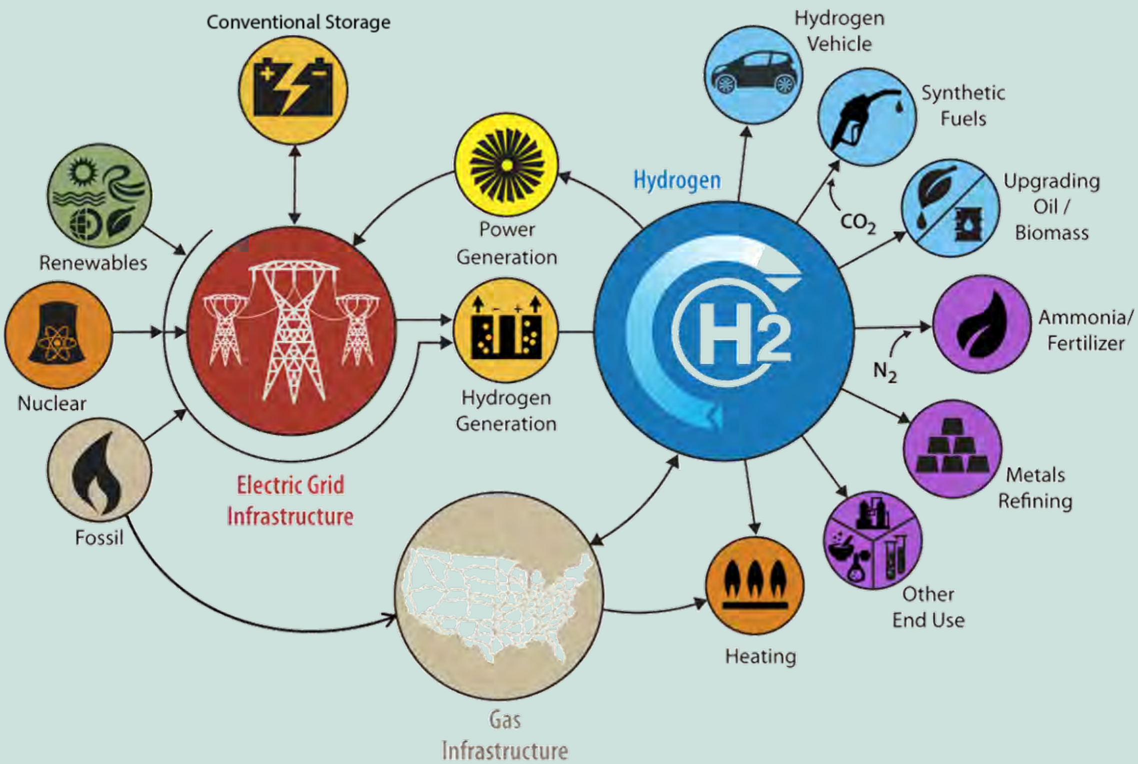
Capacity requirements for Coverage Growth and Market Initiation are identical. Earlier development of CARB's recommendations suggested that stations in the Market Initiation area may not be required to have as advanced back-to-back filling capability as the Coverage Growth stations. However, through continued coordination with the Energy Commission and industry stakeholders, there does not seem to be a need for such a distinction. In fact, if new stations developed today are meant to catalyze the acceleration necessary to enable a goal of 1,000 stations by 2030, then allowing for smaller station deployment in areas with high growth potential could be detrimental to longer-term goals. Still, CARB finds it important to clearly communicate the difference between Market Initiation and Coverage Growth areas to indicate the differences in expected backup coverage, customer expectations, and competitive market conditions that may exist in these different areas.

Finally, area classifications in Table 4: Recommended Station Design Capacity Requirements by Area Classification (and in a similar table in the Energy Commission's most recent *Draft Solicitation Concepts*), indicate that the capacity requirements are minimums. However, CARB and the Energy Commission anticipate that station developers may find compelling reasons through their own analysis to argue that a different station design may be more appropriate than the requirements based on Table 4: Recommended Station Design Capacity Requirements by Area Classification and Figure 13: Recommended Eligible Areas for Hydrogen Fueling Station Funding and Classification of Target Design Capacity. In order to offer flexibility to station developers, CARB recommends that station designers be allowed to increase or decrease their fueling position count by one (or be provided an equivalent flexibility). This helps limit both over- and under-build based on the State's best available information of local station development need.

H2@Scale CRADA: California Hydrogen Infrastructure Research Consortium

In 2016, the Fuel Cell Technology Office of the United States Department of Energy (US DOE) introduced the concept H2@Scale, a multi-year research program designed to analyze and develop technology and information solutions for the establishment of a nationwide integrated hydrogen energy system [10]. This hydrogen energy system is envisioned to interact with both the (increasingly renewable) electricity grid and the natural gas pipeline and transportation system. Several points of hydrogen consumption would exist throughout the system, including hydrogen as transportation fuel, industry process gas, ammonia resource, synthetic fuels resource, and others. In addition, production of hydrogen is focused on renewable resources, thereby providing the greatest GHG and air quality benefits to the transportation fuel industry while also enabling and supporting greater renewable resource implementation. H2@Scale touches on energy generation, transformation, storage, transport, and consumption in a holistic system, as shown below.

Visualization of H2@Scale Concept [10]



In support of this effort, the US DOE released a solicitation for proposals under Cooperative Research and Development Agreements (CRADA), with the aim of developing research and development projects through the National Laboratories that address the challenges identified for H2@Scale. One of the awarded projects was the California Hydrogen Infrastructure Research Consortium, a cooperation between CARB, the Energy Commission, the Governor's Office of Business and Economic Development, the South Coast Air Quality Management District, the United States Department of Energy, and the National Renewable Energy Laboratory. The Consortium seeks to address early market development challenges experienced in California in particular.

The Consortium consists of six tasks to be completed over a 12- to 24-month period:

- **Data Collection and Analysis:** Hydrogen fueling stations funded through the Energy Commission's AB 8 efforts are currently required to report operational data to NREL for up to 3 years. NREL utilizes these data to develop publicly-available aggregated analyses of station performance, providing insights into metrics such as station utilization, station maintenance and failure analysis, fueling profile and customer behavior analysis, and others. This task will build from the existing data collection and analysis capabilities to continue providing insights and develop new analyses to refine ongoing station development programs.

- **Medium and Heavy-Duty Fueling:** Over the past few years, there has been noticeable momentum in the development of hydrogen fueling and powertrains for medium and heavy-duty vehicles. At the same time, there are still unresolved questions, especially concerning hydrogen fueling infrastructure for these vehicles. This task will seek to answer unknowns about the benefits of hydrogen and fuel cell application to these vehicles and fueling performance needs and characterization.
- **Hydrogen Contaminant Detector:** Currently, the purity of hydrogen fuel delivered to retail customers is analyzed on a periodic basis by the California Department of Food and Agriculture's Division of Measurement Standards (CDFA DMS). This provides a significant amount of certainty to fueling customers that they will not receive fuel with impurities that could affect longevity and performance of the onboard fuel cell stack. However, there is still a need for a device that could be installed along the path of hydrogen flow at fueling stations and enable real-time detection of contamination events. Such a field device cannot be as sensitive or as comprehensive as the laboratory testing that currently takes place, but could still provide on-the-spot notice to station operators of serious contamination issues. This task will provide validation of proposed in-line detector performance technology and designs.
- **Nozzle Freeze-Lock Evaluation:** Hydrogen fuel dispensed to vehicles must be chilled to -40C in order to enable fast refilling times while also preserving the lifetime of the tanks onboard FCEVs. This presents a technical challenge as the cold temperatures of the flowing hydrogen fuel may create the propensity for the nozzle to become temporarily frozen to a vehicle's filling valve. When this occurs, customers may have to wait a period of time (up to minutes) to allow the nozzle to thaw and loosen from the valve. This task will create an environmentally-controlled experimental test facility at NREL to identify the conditions that lead to nozzle freeze-lock and validate proposed designs' ability to avoid this issue under a variety of ambient conditions.
- **Hydrogen Integration:** A key aspect of the H2@Scale concept is the integration of hydrogen as an energy resource, fuel, and process material across industries. In particular, the value of hydrogen as an energy storage medium that enables greater renewable implementation is a key feature of the concept. While technical feasibility of devices such as hydrogen-producing electrolyzers to fill this role has been demonstrated through prior and ongoing works, there is still a need to translate these technical evaluations into scenario analyses and case studies that demonstrate the benefits of such a hydrogen system to California's energy sector and other industries within California. This task will assess these benefits and provide needed insight for policy and decision-makers in California.
- **Technical Assistance:** This task will provide National Laboratory technical expertise to address additional analysis and research questions that arise through California's hydrogen fueling network deployment experience

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.

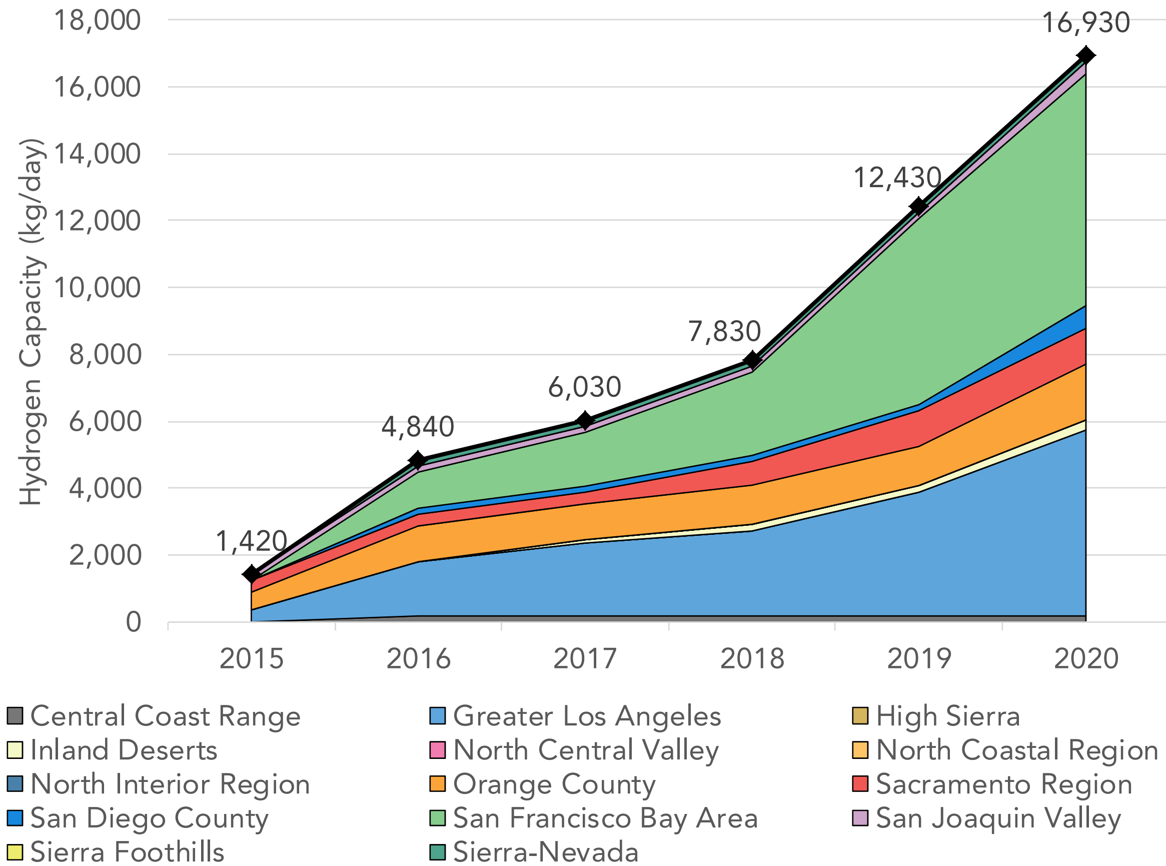
CARB Actions: Determine statewide and regional capacity of hydrogen supply. Translate statewide and regional vehicle counts of Chapter II to hydrogen demand. Determine balance between capacity and demand as guideline for additional amount of capacity required.

Assessment and Projections of Hydrogen Fueling Capacity in California

The history and projections of open hydrogen fueling capacity for all stations funded to date through the AB 8 program are shown in Figure 17. Capacities are aggregated by analysis region for legibility and ease of comparison to projections of capacity deployment further in the future. As mentioned, while individual station open dates have shifted since the previous Annual Evaluation, all stations and their associated capacities are expected to be available by the end of 2020. The currently-funded network does span a significant portion of the state, though the Greater Los Angeles and San Francisco Bay Area regions currently have the most open and funded capacity. The Sacramento Region and Orange County have the next largest capacities.

Photo courtesy of CaFCP

Figure 17: Historical and Projected Hydrogen Fueling Capacity of 64 Funded Stations Aggregated by Region[11]



Station capacities are reported in this Annual Evaluation consistent with prior Annual Evaluations and Joint Agency Staff Reports. That is, they represent the "nameplate" 12-hour capacity as reported by the station developers and operators themselves. Typically, these have been interpreted to represent capacities during the busiest 12 hours of the day, encompassing both the morning and the afternoon peak. Other programs at CARB and the Energy Commission may report or assess different capacity values for the same stations. This is because they represent different bases of evaluation. For example, stations receiving HRI credits in the LCFS program are evaluated based on a 24-hour period, with an additional delivery of hydrogen allowed in the capacity evaluation. In the Energy Commission's most recent *Draft Solicitation Concepts*, a 24-hour capacity rating without the second delivery but with additional specifications for consecutive fill timing was referenced.

Although these several evaluation bases can lead to multiple values of capacity for the same station, they are all equally valid within the context of their intended applications. For reporting purposes in Annual Evaluations, it is important that all stations are reported on the same basis. With its use of a 24-hour basis and allowing additional deliveries, the basis used for the LCFS HRI program may represent more of the theoretical maximum capacity of a station allowing for typical station operation practices. However, not all stations in the network have yet applied to receive credits under this provision; thus, not all station capacities are currently known on this basis. Similarly, the basis proposed by the Energy Commission's *Draft Solicitation Concepts* has not yet been applied to any stations already in the funded and open network. Due to these limitations, CARB has chosen to maintain the 12-hour peak-to-peak capacity rating reported by station developers and operators. This basis will be re-evaluated in the future as more station developers

11 Some historical data have been corrected due to errors found in a similar figure of the *2018 Annual Evaluation* and updates to some station capacities

and operators report station capacities according to standardized HySCapE methods though the LCFS and Energy Commission programs.

The potential regional development of hydrogen capacity in future years is displayed in Figure 18: Geographical Distribution of Future Hydrogen Station Fueling Capacity. In the figure, more saturated bars show the capacity of the stations currently open and funded through the AB 8 program, while adjacent lightened bars show the projected additional capacity provided in each region, following the network development scenario described in the *2018 Annual Evaluation* and the Partnership's *Revolution* document. This scenario also assures that the goal of EO B-48-18, to open 200 stations by 2025, can be achieved and provides hydrogen fueling capacity for more than 125,000 FCEVs. Over time, the 64 currently funded and open stations become a diminishing portion of the overall network capacity, though still play significant roles through 2025, especially in the Greater Los Angeles and San Francisco Bay Area regions. Projected station capacities begin to enter the market in 2020 for this scenario; this is likely earlier than will actually occur, given that the next station funding grant solicitation is currently in development.

In addition, Figure 18: Geographical Distribution of Future Hydrogen Station Fueling Capacity makes clear the geographic expansion of projected hydrogen fueling network development over time. The Greater Los Angeles and San Francisco Bay Area regions continue to receive network development focus through 2021. However, beginning in 2022, other regions begin to accelerate their growth rate and increase in prominence. In particular, the Central Coast Range, the Inland Deserts, and the San Joaquin Valley regions are projected to have significant expansion starting in the years 2023-2024. Orange County, Sacramento, and San Diego County regions are all currently significant contributors to statewide capacity, second only to Greater Los Angeles and the San Francisco Bay Area. Through 2025, their capacity expansion is relatively constant, though there is some contraction of the Orange County region's share of total capacity. Finally, the North Central Valley and North Coastal regions are emerging markets in 2024 and 2025, indicating significant geographic dispersion of the projected hydrogen fueling network.

Figure 18: Geographical Distribution of Future Hydrogen Station Fueling Capacity

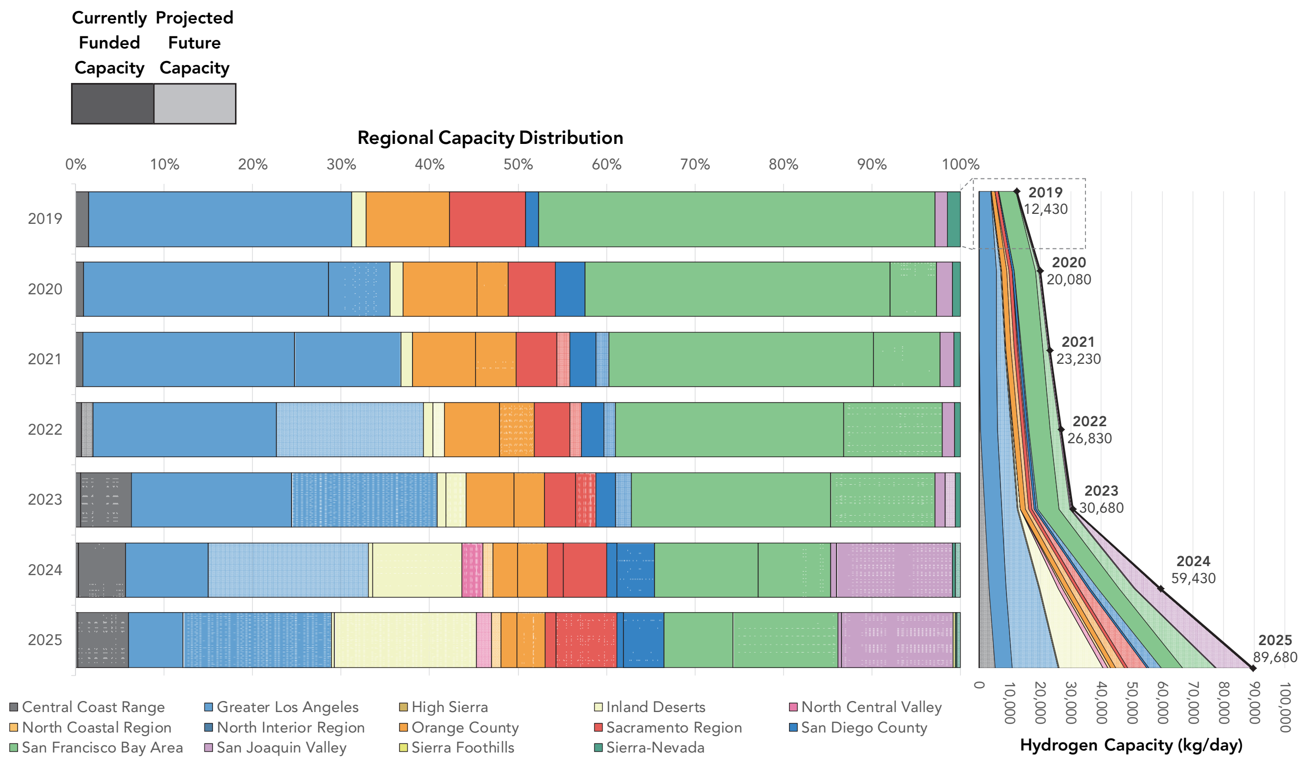
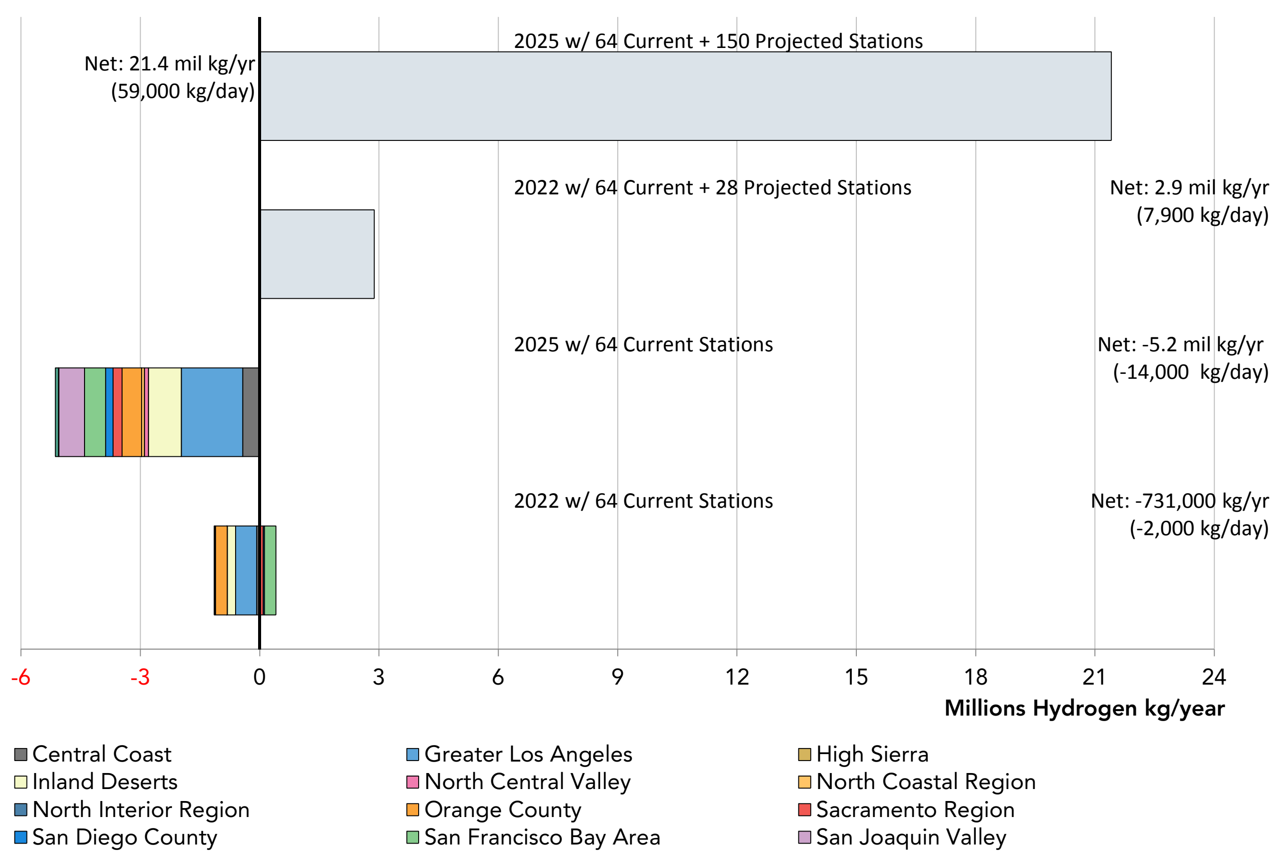


Figure 19: Projected Regional and Statewide Hydrogen Fueling Capacity Balance without Spatial Allocation of Future Stations



Comparison of the statewide and regional hydrogen fueling capacities shown in Figure 18: Geographical Distribution of Future Hydrogen Station Fueling Capacity to the projected on-road FCEV fleet shown in Figure 4: Geographic Distribution of Future On-The-Road FCEVs provides insights for future balances of hydrogen supply and demand. Figure 19: Projected Regional and Statewide Hydrogen Fueling Capacity Balance without Spatial Allocation of Future Stations provides analysis of this balance for the current 64 funded and open stations on a regional basis and provides statewide analysis that additionally accounts for the projected future station deployment (without assuming the locations match the *Revolution* scenario). The results clearly indicate that continued funding of new stations beyond the current 64 is necessary. By 2022, the only regions that are projected to have sufficient hydrogen fueling capacity are Sacramento, San Diego, and the San Francisco Bay Area. Even in these regions, the balance is positive by only a slim margin of one to two stations' worth of capacity. By 2025, all regions exhibit a deficit of hydrogen fueling capacity if additional station funding was not provided. However, if stations continue to be deployed as assumed for this Annual Evaluation, then sufficient hydrogen fueling capacity can be assured on a statewide basis through 2022 and 2025. Figure 20: Projected Hydrogen Fueling Capacity Deficits by County highlights the counties that will require focused station deployment in the next three and six years, while Figure 21: Current Capacity Gap Evaluation for Estimated 2025 FCEV Population presents the spatial distribution of current capacity needs.

Figure 20: Projected Hydrogen Fueling Capacity Deficits by County

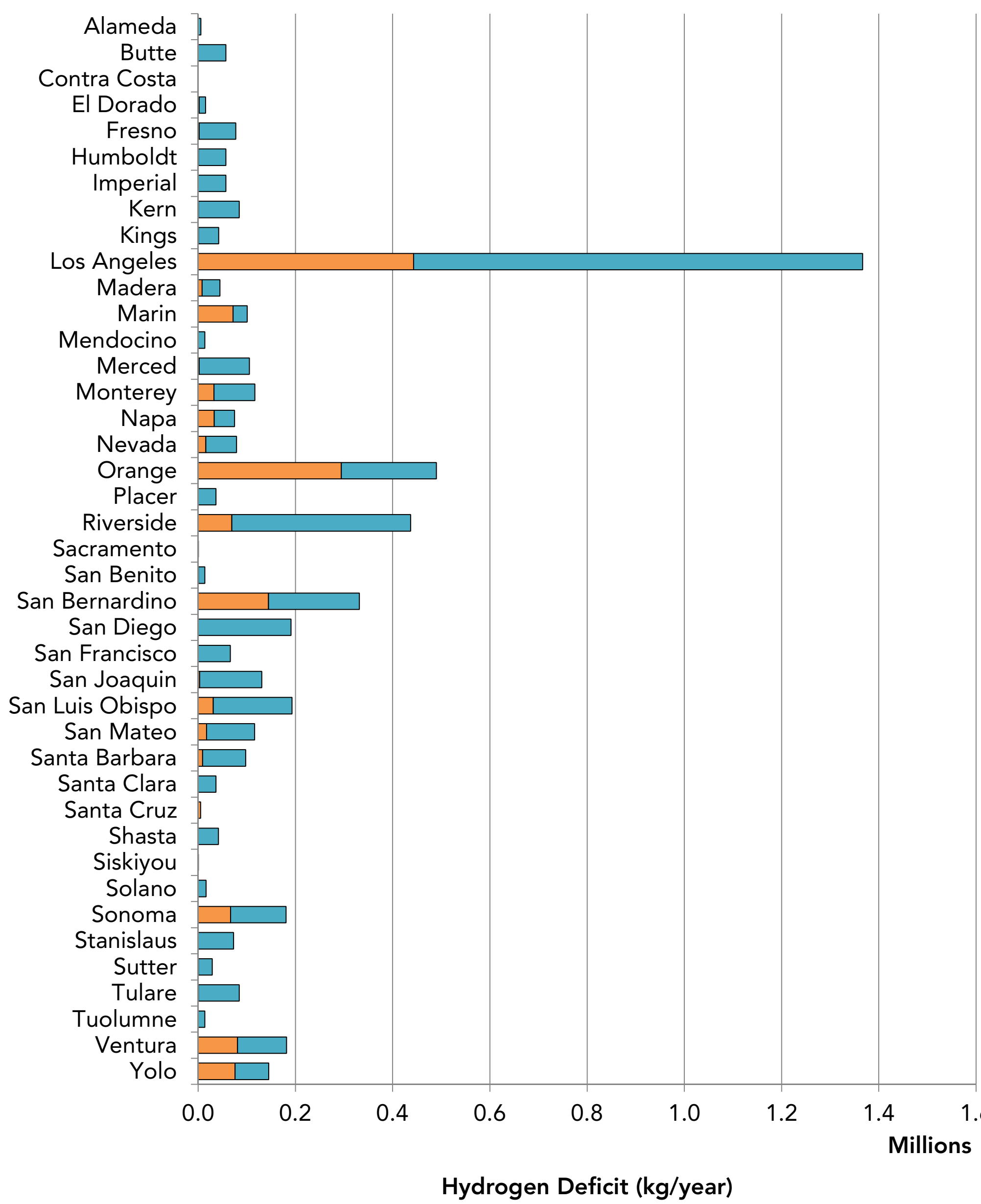


Figure 21: Current Capacity Gap Evaluation for Estimated 2025 FCEV Population

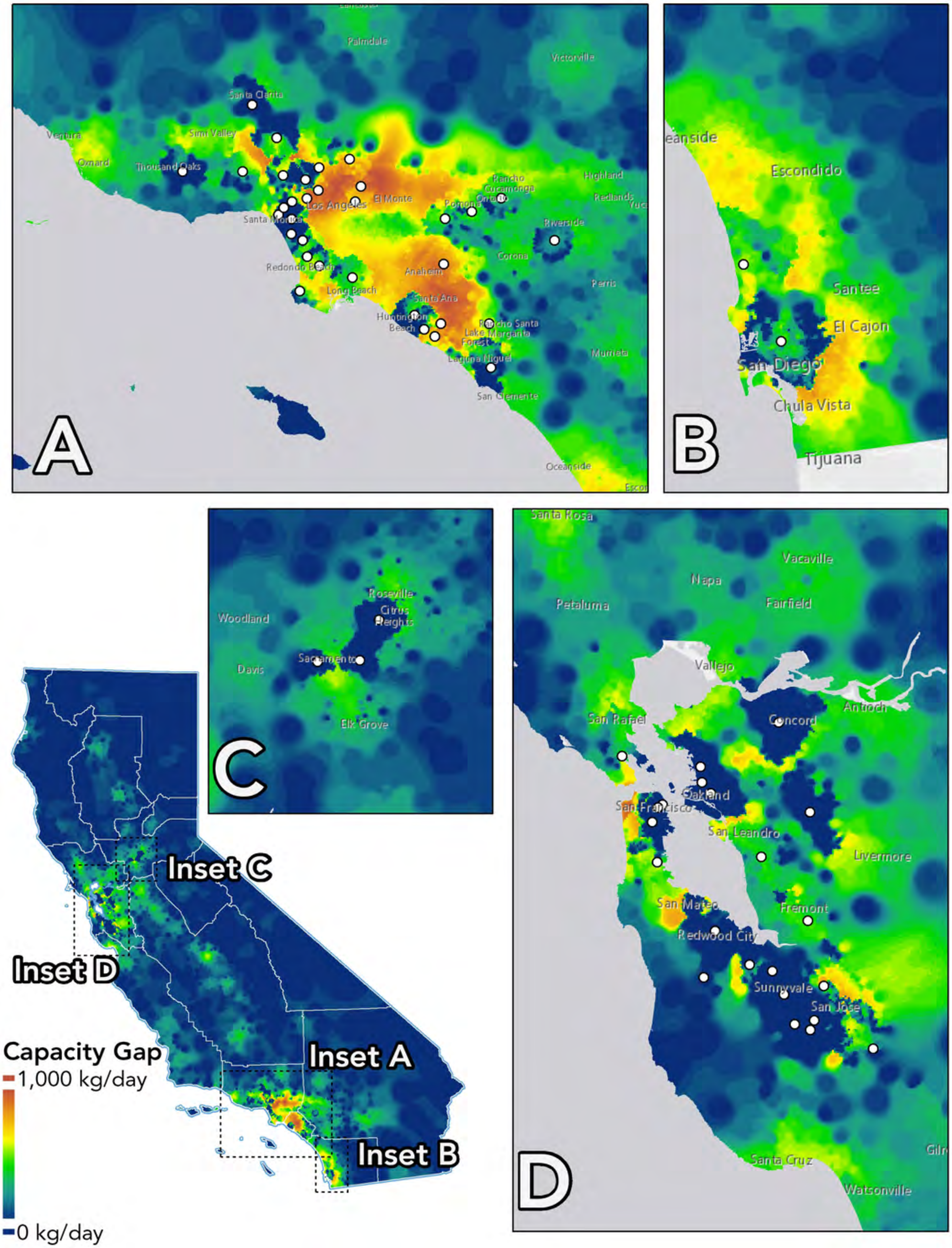


Figure 22: Projected Regional and Statewide Hydrogen Fueling Capacity Balance with Future Station Locations Following Revolution Scenario provides an assessment of the regional balance that would occur if the future projected stations were spatially allocated. In this scenario, there is the possibility that the Inland Desert region would have demand exceed capacity by approximately 235 kg/day, or one station's worth (well within the margin of uncertainty). Otherwise, the individual regions' supply and demand are well-balanced. By 2025, the state as a whole and the individual regions can develop hydrogen fueling capacity well in excess of the projected demand. This could be a positive and industry-accelerating situation, as station capacity would exceed demand by 60 metric tons per day, eliminating any concerns that fueling station availability as a whole would be insufficient.

However, such a large margin is also difficult to sustain, as it indicates that station developers and operators would not have very high utilization of their stations. While the network average utilization rate would be 70% in 2022, it would fall to 35% in 2025. It is therefore clear that in order to support the station coverage and capacity expansion envisioned by EO B-48-18, the auto manufacturers must significantly accelerate their plans for deploying FCEVs in the California market. This point is underscored by Figure 23: Comparison of Projected Vehicle Deployment and Network Nameplate Fueling Capacity and Figure 24: Comparison of Projected Vehicle Deployment and Potential Usable (80% of Nameplate) Fueling Capacity, which show a widening gap between the numbers of vehicles that could be supported by the projected station network and the thus-far stated plans of the auto manufacturers as reported through the annual survey. By 2025, this gap is as large as 70,000-100,000 FCEVs, evaluating the network capacity on a 12-hour nameplate basis. Even an assessment that accounts for potential limitations due to queuing and customer satisfaction (which have been reported to show that an 80% utilization rate is optimal), the gap is still as large as 50,000-70,000 FCEVs. Auto manufacturer plans for FCEV deployment must therefore double or even triple in order for hydrogen demand to support the desired deployment of 200 hydrogen fueling stations by 2025.

Figure 22: Projected Regional and Statewide Hydrogen Fueling Capacity Balance with Future Station Locations Following *Revolution* Scenario

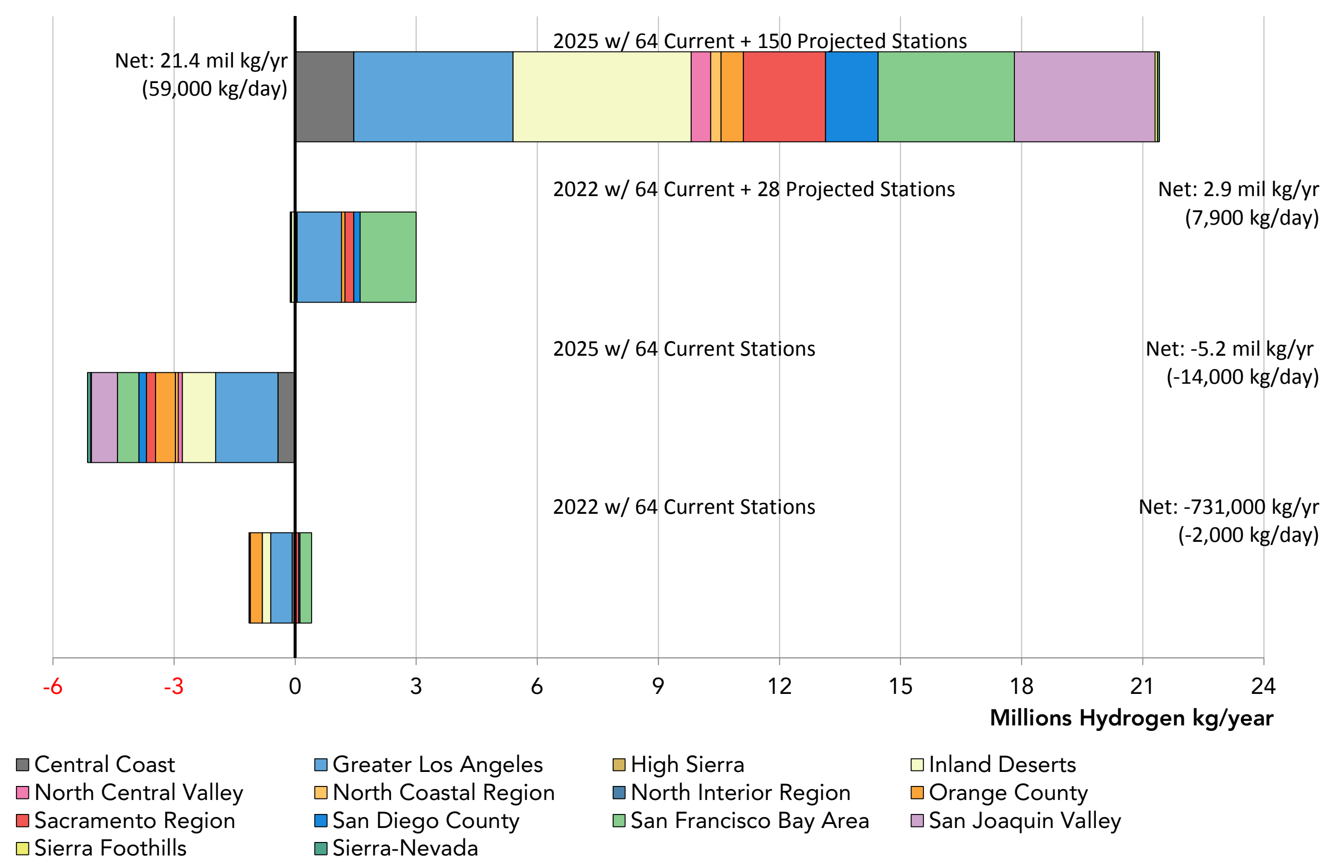


Figure 23: Comparison of Projected Vehicle Deployment and Network Nameplate Fueling Capacity

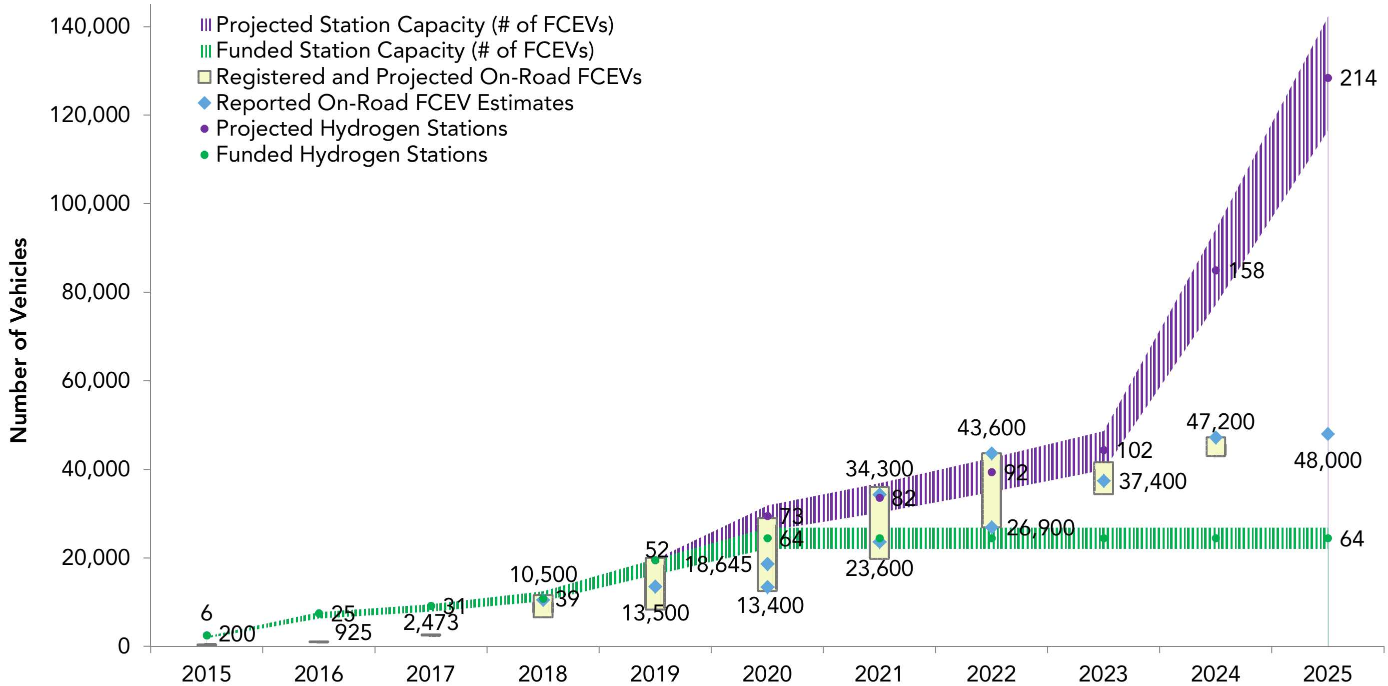
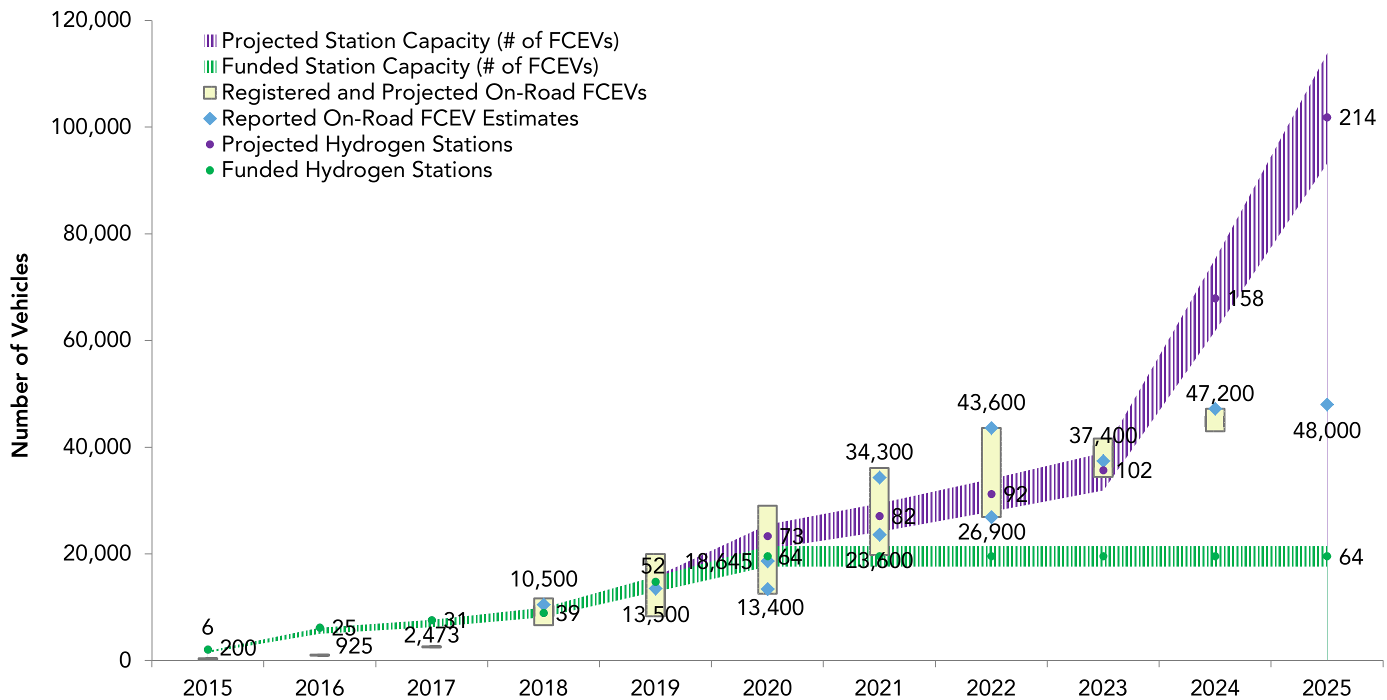


Figure 24: Comparison of Projected Vehicle Deployment and Potential Usable (80% of Nameplate) Fueling Capacity



Hydrogen Fueling Station Performance Standards and Technology

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

CARB 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.

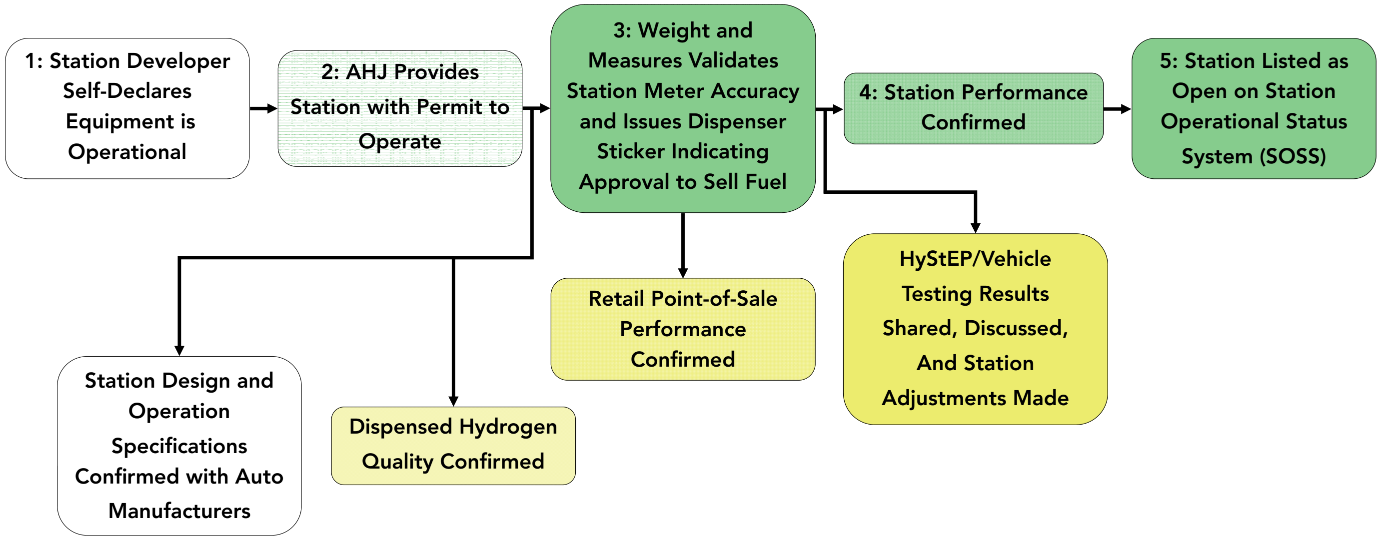
California's retail hydrogen fueling stations have consistently been expected to meet the latest and highest standards available in design, safety, performance, and consumer experience. The goal of widespread FCEV deployment requires interactions between hydrogen customers and the fueling stations that closely match the expectations held for gasoline fueling. This in turn requires that hydrogen stations are built and operated according to rigorous standards that enable such positive experiences to become the norm for FCEV drivers. Because hydrogen is a recent entrant to the retail transportation fuel market, some of these standards and practices are continuously updated and refined. The transition from pre-commercial to early commercial retail markets in California has provided opportunities to develop new insights and provide feedback for these ongoing developments. Stations funded under future Energy Commission programs should continue to be held to the latest standards and expectations.

Retail Station Performance

CARB recommends that previously-reported definitions for retail hydrogen fueling stations continue to be implemented in future Energy Commission grant solicitations. A retail hydrogen fueling station is able to provide hydrogen fuel to any customer in the general public with a light-duty FCEV in a manner that is fast, safe, and reliable. Customers in the retail environment should not have any access restrictions imposed and should be able to fuel using their preferred and industry-standard payment method during all operating hours of the host site. Customers can expect to regularly achieve a full tank (greater than 95% SOC) in a single fueling event that lasts a total of three to five minutes. Access to amenities, including appropriate lighting and signage, and the availability of restrooms and convenience stores should be as common as and on par with experiences at conventional retail fueling stations.

Achieving these goals in a timely manner requires implementation of appropriate design, construction, and operation of the station as well as thorough coordination between the station developer and operator, the site host, local authorities having jurisdiction (AHJs), State agencies, and other industry stakeholders. Currently, a series of five main steps ensure that a station is able to meet all retail operation expectations before it is declared open and able to sell hydrogen to the general public, as outlined in Figure 25: Process Flow for Hydrogen Fueling Stations to Achieve Open Status. These steps occur once the hydrogen station has been fully constructed and all electric and other utility connections have been completed.

Figure 25: Process Flow for Hydrogen Fueling Stations to Achieve Open Status



The primary codes and standards, along with the most recent publication date, that station developers in the next grant funding program should follow include:

- NFPA 2-2016: Fundamental safeguards for safe generation, storage, and handling of hydrogen; requirements can affect station design considerations
- CSA HGV 4.9-2016: Design, installation, operation, and maintenance standards for hydrogen fueling stations, based on United States and international codes and standards. Several component-specific standards are also incorporated into these requirements.
- SAE J2601-2016: Industry standard fueling protocol that ensures safe, fast fills are provided to customers
- SAE J2719-2015: Standards for hydrogen fuel quality for FCEVs
- SAE J2799-2014: Design requirements for interfacing with FCEV fueling receptacle, including communications standards
- ANSI/CSA HGV 4.3-2016: Test method to validate conformance to SAE J2601

Hydrogen Station Performance Confirmation

All light duty FCEVs sold in California are designed to fuel using the SAE J2601 fueling protocol. An SAE industry work group comprised of auto makers and station developers designed the protocol to adjust for ambient temperature and vehicle conditions in order to safely fill vehicles as quickly as possible. To achieve a quick fill without overheating the vehicle tank, the station pre-cools the hydrogen gas before dispensing into the vehicle. The vast majority of fueling is done with active communication between the vehicle and station so that the station can adjust or terminate fueling if process limits are reached. Fueling without communications can also be done if communication has failed, but with more conservative performance targets to account for uncertainty of vehicle conditions.

It is in the interest of all parties involved to ensure stations correctly implement the fueling protocol. To that end, a test procedure (ANSI/CSA HGV 4.3) was developed for protocol verification. The test procedure is currently structured to be performed on stations that have already been constructed and are operational. In the future, the test procedure scope may expand to account for type testing done in the factory.

Today, testing to verify station performance according to ANSI/CSA HGV 4.3 is primarily completed through the implementation of the Hydrogen Station Equipment Performance (HyStEP) program.

The program utilizes the HyStEP device[12], a trailer-mounted system that emulates a FCEV and provides data capture and diagnostic capabilities to implement the methods of ANSI/CSA HGV 4.3 and analyze the station's performance against the filling protocol in SAE J2601. In addition, individual auto manufacturers will often perform stress tests of the hydrogen fueling station to analyze its back-to-back fueling performance and assess how well the station will perform during peak demand hours. In some cases when the hydrogen fueling station may be of a repeat design that already exists in multiple locations in the network or when the HyStEP device may be unavailable, auto manufacturers may also perform their own ANSI/CSA HGV 4.3 test. At other times, the auto manufacturers may individually decide to perform abbreviated stress tests or choose not to perform them for similar reasons.

Evolving the HyStEP Program to Meet the Expected Needs of Accelerating Station Network Development

The fueling verification process is still evolving into a universally accepted industry norm, so the potential for conflicting interpretations and the need for oversight and conflict resolution is a concern. Fueling FCEVs using the SAE J2601 fueling protocol is relatively new, so the protocol and test procedure continue to be refined, incorporating new field observations into the development of new and improved methods. However, the fueling verification process goes beyond the scope of the test procedure: it includes setting requirements on who can test stations, when stations must be tested, and who has oversight over testing. Currently, there is no requirement in the California fire code to verify stations comply with the fueling protocol. However, that may change as the fire code is updated. Even so, the fire code is implemented by local authorities, which could lead to inconsistent implementation of the fueling protocol verification process.

CARB staff continue to evaluate the need for a regulation that requires the SAE J2601 fueling protocol for light duty publicly accessible fueling stations and defines the fueling protocol verification process. In November 2018, CARB staff held a public scoping workshop to solicit feedback from stakeholders and the public about this issue. Representatives from FCEV automakers, station equipment manufacturers, station developers, testing organizations, state agencies, local agencies, and a member for the public were in attendance. CARB staff presented on the potential need for a regulation, and a number of industry stakeholders presented their vision for fueling protocol verification. There was a general consensus that some centralized oversight is needed over the process. One concept that industry supports is the development of CARB approved third party test organizations. CARB staff will continue to develop regulatory concepts.

Ensuring Consistent Hydrogen Quality

Delivery of high-purity hydrogen to FCEV customers is a priority in order to ensure long useful life of FCEVs and help the technology achieve widespread adoption. The fuel cells that power FCEVs are sensitive to several contaminant species that may enter the fuel supply stream from a variety of sources at different points in the fuel life cycle. Some contaminants cause temporary or reversible reductions in output power. Others can cause longer-lasting or permanent damage and may even render one or more cells in the stack inoperable if exposure lasts long enough or is at high enough concentration.

The SAE J2719 standard outlines the typical contaminant species that may enter the hydrogen transportation fuel system, their typical sources, and recommended maximum allowable concentrations for the FCEV application. Typical species and their sources cited by the standard are displayed in Table 5: Hydrogen Contaminant Species per SAE J2719. The California Department of Food and Agriculture's Division of Measurement Standards (CDFA DMS) operates a program that helps ensure hydrogen sold at California's retail stations meets these standards. Dispensed

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.

hydrogen quality is tested several times a year over the course of a station's lifetime. The program tests hydrogen before a station opens for retail sales, any time a service or maintenance operation may introduce impurities into the system, in response to any customer complaints, and according to a randomized spot-check schedule. Overall, stations can therefore typically be tested as often as every six months, if not more frequently.

While the fuel for these tests is dispensed in the field at operating hydrogen fueling stations, the dispensed hydrogen itself must be transported to a laboratory facility for analysis. The wide range of species and the required sensitivities for many of the potential contaminants are too restrictive to enable comprehensive direct field analysis of hydrogen quality. Combined with the testing performed by hydrogen suppliers that occurs at the point of production and/or distribution, this program largely ensures high-quality hydrogen is regularly dispensed at California's fueling stations. However, there does remain the possibility that some contamination events could be missed. For this reason, CARB, the United States Department of Energy, the National Renewable Energy Laboratory, the Energy Commission, South Coast Air Quality Management District, and the Governor's Office of Business and Economic Development, have been cooperating on the development of a device that could be installed in the field in-line with the fueling dispenser and provide real-time warnings of high contaminant concentrations. Such a device would rely on testing for a limited set of contaminants whose presence in the fuel stream indicates a significant contamination risk. Such a device is intended to provide an early warning to station operators who could stop fueling operations in real-time whenever the device provides a warning.

Table 5: Hydrogen Contaminant Species per SAE J2719

Impurity Source	Typical Contaminant
Air	N_2, NO_x (NO, NO_2), SO_x (SO_2, SO_3), NH_3, O_3
Reformate hydrogen	CO, CO_2, H_2S, NH_3, CH_4
Bipolar metal plates (end plates)	Fe_3^+, Ni_2^+, Cu_2^+, Cr_3^+
Membranes (Nafion)	Na^+, Ca_2^+
Sealing gasket	Si
Coolants, DI water	Si, Al, S, K, Fe, Cu, Cl, V, Cr
Battlefield pollutants	SO_2, NO_2, CO, propane, benzene
Compressors	Oils

Dispensing Meter Accuracy and the California Type Evaluation Program

In addition to hydrogen quality, CDFA DMS also administers the California Type Evaluation Program (CTEP). CTEP is a program that ensures metering accuracy across a variety of devices and applications, with a scope much broader than hydrogen or even fuel sales alone. Within CTEP, hydrogen fueling dispensers are required to meet standards of accuracy for the metering of dispensed fuel. Ensuring meter accuracy provides a fair retail environment, where customers only pay for what they purchase and retailers are compensated fully for what they sell. In California, there are currently four accuracy classes to which hydrogen fueling dispensers may be certified and the accuracy class is posted publicly on the dispenser, similar to conventional fuel dispensers.

The structure of four accuracy classes shown in Table 6: Summary of CTEP Hydrogen Dispenser Accuracy Class Testing, was developed in California based on observations during early station development that no meters existed that could meet the 2.0 accuracy class, which was the only accuracy class available at the time. Therefore, CDFA DMS developed a four-class system with looser tolerances that progressively expire over time. This provided industry time to develop more accurate meters without delaying the early station deployment. As shown in Table 6: Summary of CTEP Hydrogen Dispenser Accuracy Class Testing,, most of today's network has been tested to accuracy class 5.0, with only a few stations listed as class 10.0. The 10.0 class has already expired; while no new stations can be installed that meet this lower-tolerance class, the existing stations can continue to operate as tested. In addition, the 5.0 and 3.0 accuracy classes are set to similarly expire at the end of this year.

CDFA DMS has begun a process to harmonize the system shown in Table 6: Summary of CTEP Hydrogen Dispenser Accuracy Class Testing, with the system currently adopted by the National Institute of Standards and Technology (NIST), shown in Table 8: Proposed Revised Accuracy Class System for California. The system recommended by NIST was developed with consultation and observations from the experience in California and staff of CDFA DMS, and includes a single 7% accuracy class. The new proposed California system, shown in Table 8: Proposed Revised Accuracy Class System for California, incorporates this accuracy class, keeps legacy classes in place for stations already using them, and removes the more restrictive 2% and 3% accuracy classes. Thus, it represents a balanced approach informed by real-world experience and provides an opportunity for California's type evaluation program to be in agreement with the nationally-recognized standards recommendation. The new system should not present difficulties to future station development, as most stations already in operation in California have been tested to the more stringent 5.0 accuracy class. A list of all hydrogen dispenser designs currently listed in the CTEP program is provided in Table 9: Dispensers Currently Listed with Type Certification through CTEP.

Table 6: Summary of CTEP Hydrogen Dispenser Accuracy Class Testing

Testing of Accuracy Classes and Tolerances for Hydrogen Gas-Measuring Devices			
Accuracy Class	Acceptance Tolerance	Maintenance Tolerance	Number of Devices in Compliance
2	1.50%	2.00%	0
3.0[13]	2.00%	3.00%	0
5.0[13]	4.00%	5.00%	36
10.0[14]	5.00%	10.00%	3
		Total Devices in Compliance	**39**

Table 7: NIST Handbook 44 Accuracy Classes

Accuracy Class	Applications or Commodity Being Measured	Acceptance Tolerance	Maintenance Tolerance
7.0	Hydrogen gas as a vehicle fuel	5.0%	7.0%

Table 8: Proposed Revised Accuracy Class System for California

Accuracy Classes and Tolerances for Hydrogen Gas-Measuring Devices		
Accuracy Class	Acceptance Tolerance	Maintenance Tolerance
5.0	4.0%	5.0%
7.0	5.0%	7.0%
10.0[15]	5.0%	10.0%

13 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.

14 The tolerance values for Accuracy Class 10.0 hydrogen gas-measuring devices are applicable to devices installed prior to January 1, 2018.

15 The tolerance values for Accuracy Class 10.0 hydrogen gas-measuring devices are applicable to devices installed prior to January 1, 2018.

Table 9: Dispensers Currently Listed with Type Certification through CTEP[16]

Certificate Number	Company Name	Models	Effective Date
5824-18	Air Liquide Advance Technologies U.S. LLC	US-Gen I	1/22/18
5743a-15	Bennett Pump Company	H10	12/22/15
5741-15	CSULA	112892	4/29/15
5778-16	Equilon Enterprises LLC dba Shell Oil Products	RHM08 Mass Flow Sensor, RHE08 Mass Flow Transmitter	2/22/16
5774a-18 (replaces 5774-15)	Quantum Fuel Systems LLC	118586	2/14/18
5774-15	Quantum Fuel Systems Technologies Worldwide	113892	11/25/15

Renewable Content of California's Hydrogen Fueling Network

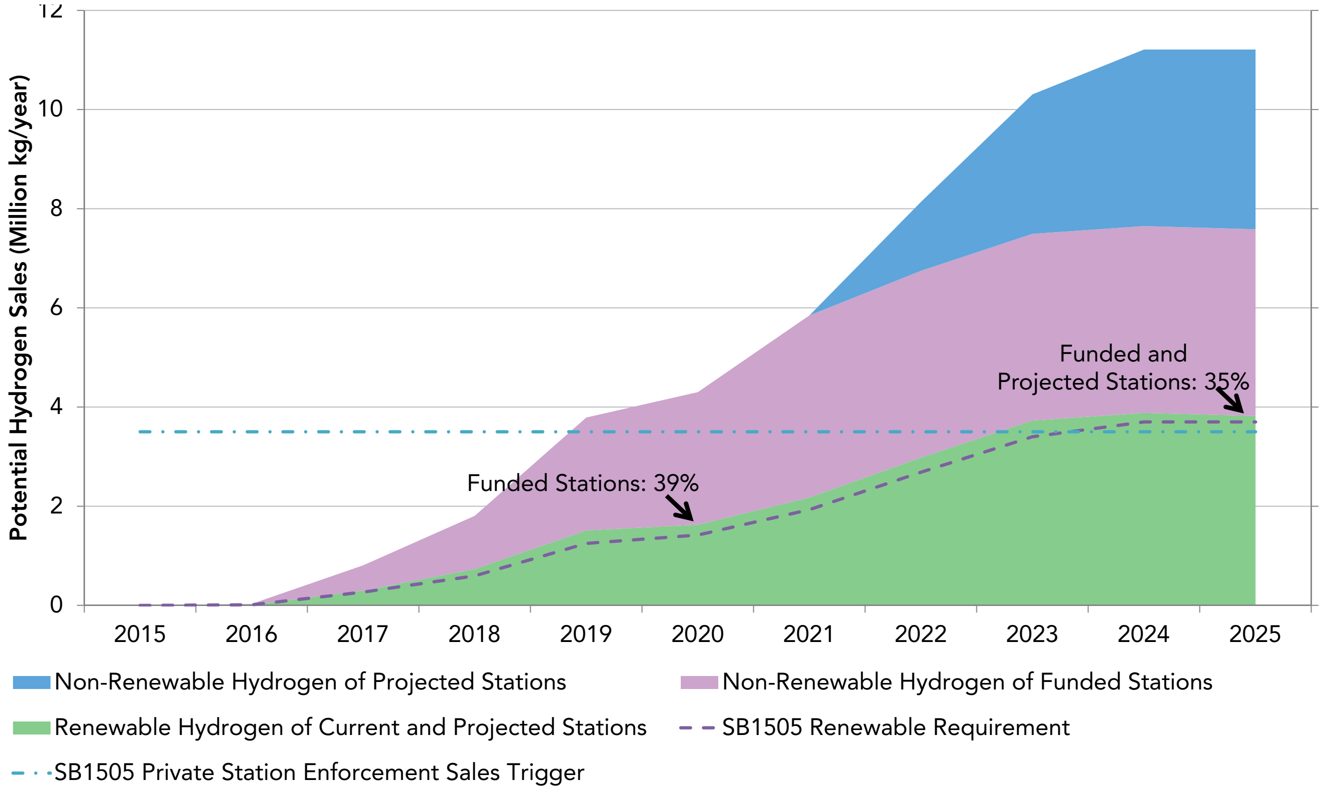
Updated estimates of the renewable content of hydrogen sold at California's 64 funded and future projected stations continue to show compliance with the requirements of Senate Bill 1505, as shown in Figure 26: Evaluation of Compliance with SB 1505 Renewables Requirement and Trigger for Enforcement of the Requirement on Stations without State Co-Funding. In this analysis, the renewable content of funded stations is in agreement with station developer statements from the corresponding application material submitted to the Energy Commission. Thus, for most stations, the renewable content is approximately 33%. Exceptions include stations that indicated higher renewable content (notably those funded as 100% renewable stations) and stations that have since been approved within the LCFS HRI program. Eligibility requirements for the HRI program state that stations must dispense hydrogen with a 40% renewable content (taken as the company-wide average for all stations receiving HRI credits by the operating company). For all projected stations in this analysis, the minimum 33% required by SB 1505 was assumed. While the participation of 31 stations in the HRI program is a significant programmatic achievement, the additional renewable content required of these stations does not change the overall network evaluation very much from the *2018 Annual Evaluation*.

When all funded stations are completed by 2020, the hydrogen fueling station network is expected to comply with SB 1505, with an overall renewable content of 39%. The addition of projected stations further in the future, each with an assumed 33% renewable content, results in renewable content trending towards 35% by 2025. Given the early stage of the program, CARB has not assumed that any current or projected stations other than those already approved in the LCFS HRI program will participate and therefore provide hydrogen at more than the 33% requirement of SB 1505. However, it should be noted that several hydrogen and FCEV stakeholders (including the California Fuel Cell Partnership, the multi-national Hydrogen Council, and individual station operators, hydrogen providers, and other companies) have indicated goals and desires for renewable hydrogen implementation that surpass the 33% requirement of SB 1505. CARB has not taken these stated goals into consideration for its analysis in order to provide an assessment of the assured minimum renewable content of the current and projected network.

Finally, as previously reported, CARB projects that hydrogen fuel throughput will exceed 3.5 million kilograms per year sometime in 2019. SB 1505 requires that once this threshold is crossed, its requirements must be applied to all hydrogen fueling stations, regardless of whether or not they receive State co-funding. In this analysis, throughput is taken as the lesser of hydrogen station capacity and hydrogen demand in each year.

16 All certificates issued to date have been for the 5% accuracy class, with the exception of certificate 5824-18, which has been certified to the 10% accuracy class

Figure 26: Evaluation of Compliance with SB 1505 Renewables Requirement and Trigger for Enforcement of the Requirement on Stations without State Co-Funding

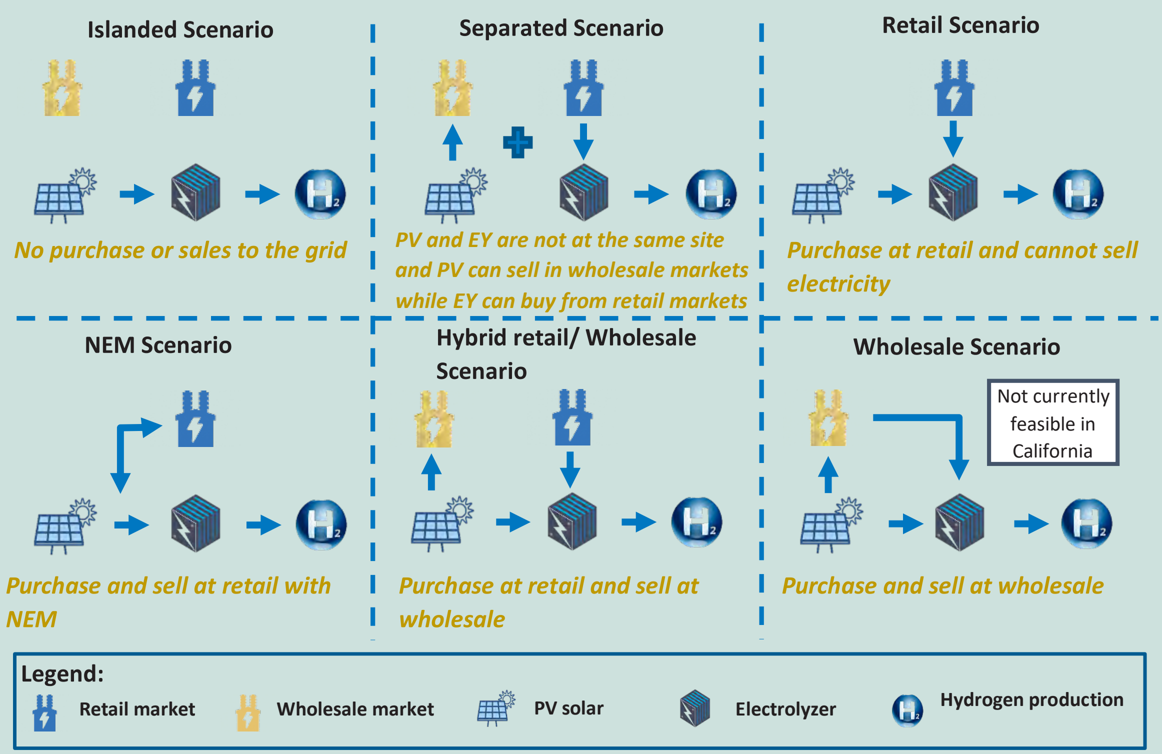


H2@Scale CRADA: Integrated Solar-Electrolysis Project

In addition to the California Hydrogen Infrastructure Research Consortium, CARB is participating in an Integrated Solar-Electrolysis Project through the H2@Scale CRADA. This project is a cooperative effort between CARB, the Governor's Office of Business and Economic Development, Pacific Gas and Electric, the National Renewable Energy Laboratory, and the United States Department of Energy. This project aims to provide insights into the financial tradeoffs involved with operating an electrolyzer tied to a renewable generation system (in this project primarily taken to be a solar generation system). The project provides estimates of real and opportunity costs of a solar-electrolyzer system and identifies optimized system design and operation modes to provide the lowest possible cost hydrogen while in the process providing benefit to the grid. The system designs that are evaluated within the project are shown below (the Wholesale Scenario as noted is not feasible in California only due to limitations of utility and system operator participation rules; there do not currently appear to be any technology limitations).

A central aspect of the project is the development of a holistic model that accurately captures the multiple value streams presented by a system that can produce renewable electricity, produce hydrogen, store renewable electricity as hydrogen, and interact with the dynamic demands of the electricity grid. In particular, the analysis is completed for a case study involving existing solar facilities within PG&E's service area and utilizes real-world electricity grid demand data. A final report is due this year, though preliminary findings suggest that integrating electrolysis with renewable electricity systems is more cost-effective than electrolysis systems that are installed in isolation and cannot interact directly with renewable energy resources. Co-location with electrolysis can provide the renewable energy resources a hedge against wholesale market price volatility and downward pressure on prices from other low-cost resources. In addition to providing benefits to the equipment owners, integrated renewable electrolysis can present a valuable asset to the operation of the overall energy system, especially for their ability to act as a highly flexible load.

Solar-Hydrogen System Designs Evaluated by Integrated Solar-Electrolysis Project[17]



17 Figure provided by NREL; PV = (solar) photovoltaic; EY= electrolyzer

Conclusions & Recommendations

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

CARB 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.

The past year of development and deployment for the hydrogen fueling and FCEV markets has continued mostly at the expected pace. However, the next year in particular presents an opportunity for significant advancement, especially with the expectation of 11 additional hydrogen fueling stations currently planned to begin retail operations before January 1, 2020. This accomplishment will demonstrate the continued success of the AB 8 program and provide renewed momentum at the same time that more forward-looking plans and programs initiate a push towards 200 hydrogen fueling stations by 2025. In addition, private investments are expected to start developing facilities to address upstream hydrogen production and distribution limitations that would present bottlenecks to industry growth.

As the industry has progressed out of a pre-market phase and begun early market growth in the past few years, the Energy Commission and CARB have strived to continue developing programs and analyses that meet the needs of the current development and anticipate the coming changes that must occur to ensure success. Goals of 100 stations by 2024 and 200 stations by 2025 guide the agencies' efforts and provide a starting point for public-private collaboration and planning. It is clear through these analyses that a step-change in deployment will need to occur within the next five years in order to meet these goals. It is plainly evident that continued expenditure of the full $20 million available per year for light-duty hydrogen fueling stations, as provided by AB 8, is still necessary. Grant solicitations through AB 8 and LCFS credit generation through the new HRI program are currently the principal financial mechanisms by which the State supports its hydrogen station targets; it appears that both programs remain necessary, and that achieving goals beyond 2025 (including a self-sufficient market) may further require additional programs to be put in place.

Additionally, EO B-48-18 targets five million ZEVs on the road by 2030; the members of the public-private California Fuel Cell Partnership aim for one million of those ZEVs to be FCEVs. Achieving this further target requires at least another step change beyond the 2025 goals and likely sustained acceleration over an extended period of time. While early market progress has been significant, a path that can realize the necessary acceleration has yet to be demonstrated.

While the programs currently in effect are clearly necessary to preserve the success of the early market launch, industry and public entities agree that a truly successful launch is one that eventually stands on its own financial performance. Ongoing work to assess the financial performance potential of the hydrogen fueling station network with various forms and amounts of State support may elucidate this path. CARB and the Energy Commission's collaboration on analyzing paths towards industry self-sufficiency is intended to provide such insight, validated by industry-provided data and review. This work may also emphasize the FCEV and station network growth rates that will be necessary to achieve these goals.

Based on the preceding analysis and discussion in this Annual Evaluation, CARB makes the following recommendations:

- The Energy Commission has proposed that the next grant solicitation incorporate many new concepts and methodologies, including: 1) Use of HySCapE as a "standard ruler" for evaluation of proposed station capacity, 2) Establishing multi-year funding tranches for successful applicants to build a network-style approach to station development, 3) Utilizing a pre-determined set of expectations for station capacity based on location to achieve a station network structure balanced between larger core markets, smaller secondary markets, long-distance travel corridors, and popular sightseeing and vacation destinations. These are all new methodologies that CARB finds will support the growth of a healthy and robust hydrogen fueling network and likely streamline the application and award process while still allowing close private-public collaboration for achieving the most effective network with the State's co-funding dollars.

- With the implementation of the new LCFS HRI credit provisions, and the proposed structure of the next station funding program, the State has potentially established financial assistance mechanisms and a supporting policy environment to achieve or nearly meet the 200 station goal of EO B-48-18 by 2020. While there are additional steps beyond these programs that may also be necessary (especially to establish a financially self-sufficient fueling market), current programs should enable FCEV deployment up to three times the current projections in the same period as reported by auto manufacturers. The State agencies will need to continue to collaborate with auto industry stakeholders to ensure that the planned vehicle deployment will keep pace with this station deployment rate. Achieving the 200 station goal would involve a step-change in station deployment rate compared to historical trends; while the State's programs have the possibility of enabling this revolution in network growth, similar acceleration has not yet become apparent for FCEV deployment. Public-private partnerships like the California Fuel Cell Partnership can help the State and industry constructively and transparently plan for success and ultimately reach a self-sustaining market.
- The Energy Commission's next station funding solicitation could establish all remaining planning to achieve the 100 station goal of AB 8 and put the network well on its way to also achieving the 200 station goal of EO B-48-18. As these paths become clearer and crystallize through the next grant solicitation program, bolstered by the LCFS HRI credit provision, CARB and the Energy Commission will still need to develop assessments of an approach to financial self-sufficiency for the hydrogen fueling industry. While continuing to shepherd the developing hydrogen fueling and FCEV markets, the State agencies will need to focus analysis efforts on answering the question of potential cost and timing for the industry to no longer require assistance from the State. An analysis framework has been developed and is currently under review, and the first steps of supporting data collection have been completed. Future work will need to focus on validating and finalizing these analyses to provide insight and certainty to public and private decision-makers alike.
- CARB anticipates that the Energy Commission's station funding solicitation requirements and the LCFS HRI credit provision will induce the State's co-funded hydrogen fueling network into compliance with SB 1505. The HRI credits in particular explicitly require station operators to actually exceed this requirement by dispensing hydrogen of 40% renewable content. CARB expects that most station developers will likely opt to apply for both LCFS HRI credits and the station funding solicitation. Therefore, CARB recommends that the Energy Commission consider raising the minimum renewable content requirement in its finalized solicitation to 40%. This will provide additional alignment with the LCFS HRI program and likely make renewable implementation tracking more straightforward for industry and government alike. In addition, as recommended in the *2018 Annual Evaluation*, CARB continues to support ARFVTP investment plan allocations for low-carbon fuel production and recommends that expansion of in-state 100% renewable hydrogen production should be maximized to the greatest extent possible through that program.
- With approximately 6,000 FCEVs currently on the road in California and a network of 52 hydrogen fueling stations expected by the end of the year, California is clearly demonstrating the feasibility of launching an FCEV market. FCEVs provide a zero-emission option that consumers can seamlessly integrate into their lives, provided ample support from a network of retail hydrogen fueling stations. State efforts continue to ensure this market launch is a success, but focus is clearly shifting towards translating the proof of market launch into

enduring and expanding growth. With the understanding that early markets require station development to lead FCEV deployment, the State has developed several programs to address the needs of rapid network expansion, including both hydrogen fueling station deployment and 100% renewable hydrogen production capacity. These programs will need to be the launch points for even larger public and private efforts in order to make the large-scale transition and enable FCEVs to play a meaningful role in achieving air quality and GHG emission reduction goals. The experiences gained to date and the remaining analyses through the AB 8 and associated programs are proving to provide a template for success.

Fuel Cell Market & Technology Developments across Transportation Sectors

- Plug Power, Inc., manufacturer of fuel cell-powered forklifts and fueling systems (as well as fuel cell systems for other applications), announced this year that they will open a new manufacturing facility in Rochester, New York [20]. The facility will increase the company's production capacity to 200,000 units per year, a 30% increase over current capabilities [21]. Fuel cell-powered forklifts are widely regarded as one of the most successful hydrogen and fuel cell markets in the United States, and are often cost-competitive with battery-powered options, given the fast fueling time that provides improved productivity over other options.
- Ballard Power Systems, a fuel cell system manufacturing company, announced the launch of its next-generation fuel cell stack for heavy-duty vehicle applications [22]. The new stack is expected to provide 40% reduced cost-of-ownership compared to prior offerings, 30,000 hours of operational lifetime, and increased power density by 33% compared to prior technology.
- Transit bus and motor coach manufacturer New Flyer became the first company to offer two models of fuel cell-powered bus that have passed federal Altoona testing and qualify for federal funding programs [23]. Its XCelsior Charge H2 35, 40, and 60-foot (itself an industry first) buses are powered by Ballard fuel cells, can travel up to 350 miles on a full hydrogen tank, and can be refilled in 6-20 minutes [24].
- Hydrogen and battery electric truck manufacturer Nikola hosted a two-day event in early April to unveil several new electric and hydrogen powered product offerings, mainly for military and commercial applications [25]. Two hydrogen-powered semi-trucks with up to 750 miles of range and a target market introduction in 2022-2023 were introduced on the first night of the event. The Nikola Two is intended for the domestic market, while the Nikola Tre is designed for the European market and has been described as capable of level 5 autonomous driving, due in part to intentional redundancy built into the powertrain design. Nikola also discussed its planned hydrogen fueling network and advancements currently in development with industry partners and collaborators to develop hydrogen fueling protocols and methods for the heavy-duty industry that provide fast (15-20 minute), safe, and reliable fills, similar to the accomplishments in the light-duty sector.
- Golden Gate Zero Emission Marine, a newly-formed company dedicated to the development and deployment of hydrogen-powered marine craft, held a keel laying ceremony earlier this year for the construction of the world's first hydrogen-powered passenger ferry [26]. The ceremony marks the start of construction of the vessel, with a target completion date later this year. The 70-foot catamaran, designed with enough onboard hydrogen storage for two full days of operation, will provide proof-of-concept in commercial operations with the San Francisco Bay Area's Red and White Fleet [27].
- The Automobile Club de l'Ouest, the organizer of the Le Mans racing tour, has announced an initiative to launch a hydrogen-powered race category by 2024 [28]. Since the announcement, the organization has also completed prototype testing and demonstration of hydrogen-powered vehicles under racing conditions [29].

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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

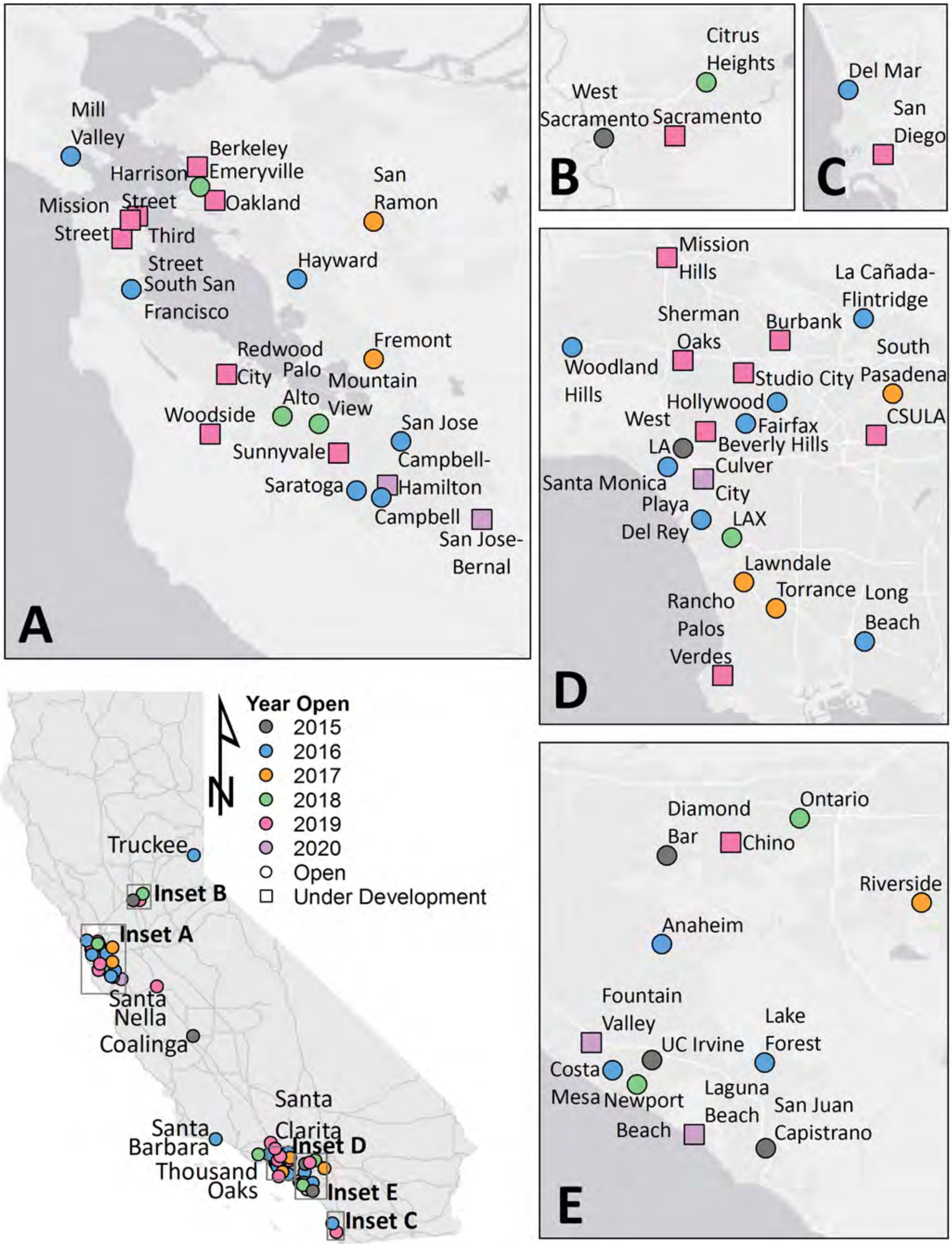
List of Hydrogen Fueling Station Retail Open Dates (2015-2021), as of June 1, 2019[18]

Name	Address	City	Capacity (kg/day)	County	Retail Open Date	Renewable %
West Sacramento	1515 South River Rd	West Sacramento	350	Yolo	2015, Q2	33
Diamond Bar	21865 E Copley Dr	Diamond Bar	180	Los Angeles	2015, Q3	33
Coalinga	24505 W Dorris Ave	Coalinga	180	Fresno	2015, Q4	0
San Juan Capistrano	26572 Junipero Serra Rd	San Juan Capistrano	350	Orange	2015, Q4	33
UC Irvine	19172 Jamboree Road	Irvine	180	Orange	2015, Q4	33
West LA	11261 Santa Monica Blvd	Los Angeles	180	Los Angeles	2015, Q4	33
Costa Mesa	2050 Harbor Blvd	Costa Mesa	180	Orange	2016, Q1	100
La Cañada-Flintridge	550 Foothill Blvd	La Canada Flintridge	180	Los Angeles	2016, Q1	100
Lake Forest	20731 Lake Forest Dr	Lake Forest	180	Orange	2016, Q1	100
Long Beach	3401 Long Beach Blvd	Long Beach	180	Los Angeles	2016, Q1	100
San Jose	2101 North First St	San Jose	180	Santa Clara	2016, Q1	0
Santa Monica	1819 Cloverfield Blvd	Los Angeles	180	Los Angeles	2016, Q1	33
Saratoga	12600 Saratoga Ave	Saratoga	180	Santa Clara	2016, Q1	0
South San Francisco	248 S Airport Blvd	South San Francisco	180	San Mateo	2016, Q1	0
Campbell	2855 Winchester Blvd	Campbell	180	Santa Clara	2016, Q2	0
Fairfax	7751 Beverly Blvd	Los Angeles	180	Los Angeles	2016, Q2	33
Hayward	391 West A St	Hayward	180	Alameda	2016, Q2	0
Mill Valley	570 Redwood Highway	Mill Valley	180	Marin	2016, Q2	0
Santa Barbara	150 S La Cumbre Rd	Santa Barbara	180	Santa Barbara	2016, Q2	100
Truckee	12105 Donner Pass Rd	Truckee	180	Nevada	2016, Q2	0
Playa Del Rey	8126 Lincoln Blvd	Los Angeles	180	Los Angeles	2016, Q3	100
Anaheim	3731 E La Palma Ave	Anaheim	100	Orange	2016, Q4	33
Del Mar	3060 Carmel Valley Rd	San Diego	180	San Diego	2016, Q4	100
Hollywood	5700 Hollywood Blvd	Los Angeles	180	Los Angeles	2016, Q4	100
Woodland Hills	5314 Topanga Canyon Blvd	Woodland Hills	180	Los Angeles	2016, Q4	33
Riverside	8095 Lincoln Avenue	Riverside	100	Riverside	2017, Q1	33
Lawndale	15606 Inglewood Avenue	Lawndale	180	Los Angeles	2017, Q2	33
South Pasadena	1200 Fair Oaks Ave	South Pasadena	180	Los Angeles	2017, Q2	100
Fremont	41700 Grimmer Blvd	Fremont	180	Alameda	2017, Q3	0
San Ramon	2451 Bishop Drive	San Ramon	350	Contra Costa	2017, Q3	33
Torrance	2051 W 190th St	Torrance	200	Los Angeles	2017, Q3	33
Thousand Oaks	3102 Thousand Oaks Blvd	Thousand Oaks	180	Ventura	2018, Q1	100
Mountain View	830 Leong Drive	Mountain View	350	Santa Clara	2018, Q2	33
Newport Beach	1600 Jamboree Road	Newport Beach	100	Orange	2018, Q2	33
Ontario	1850 Holt Blvd	Ontario	100	San Bernardino	2018, Q2	100
Burbank	145 W Verdugo Rd	Burbank	100	Los Angeles	2018, Q3	33

18 Values shown in the "Renewable %" column have changed compared to previous reports. Stations that participate in the LCFS HRI program are required to maintain a 40% renewable content on a company-wide average for participating stations; thus, all stations are shown based on the company-wide average basis. Prior reports showed the individual station renewable implementation.

Name	Address	City	Capacity (kg/day)	County	Retail Open Date	Renewable %
CSULA	5151 State University Dr	Los Angeles	60	Los Angeles	2018, Q4	100
LAX	10400 Aviation Drive	Los Angeles	180	Los Angeles	2018, Q4	33
Palo Alto	3601 El Camino Real	Palo Alto	180	Santa Clara	2018, Q4	33
Woodside	17287 Skyline Blvd	Woodside	140	San Mateo	2018, Q4	33
Berkeley	1250 University Avenue	Berkeley	360	Alameda	2019, Q1	33
Citrus Heights	6141 Greenback Lane	Citrus Heights	360	Sacramento	2019, Q1	33
Huntington Beach	16001 Beach Blvd	Huntington Beach	500	Orange	2019, Q1	33
Sacramento	3510 Fair Oaks Blvd	Sacramento	360	Sacramento	2019, Q1	33
Santa Clarita	24551 Lyons Ave	Santa Clarita	180	Los Angeles	2019, Q1	33
Santa Nella	12754 State Hwy 33	Santa Nella	180	Merced	2019, Q1	33
SF Harrison Street	1201 Harrison St	San Francisco	360	San Francisco	2019, Q1	33
SF Mission Street	3550 Mission St	San Francisco	360	San Francisco	2019, Q1	33
SF Third Street	551 Third St	San Francisco	360	San Francisco	2019, Q1	33
Sunnyvale	1296 Sunnyvale Saratoga Rd	Sunnyvale	500	Santa Clara	2019, Q1	33
Walnut Creek	2900 N Main St	Walnut Creek	360	Contra Costa	2019, Q1	33
Campbell-Hamilton	337 East Hamilton	Campbell	500	Santa Clara	2019, Q2	33
Emeryville	1152 45th Street	Emeryville	350	Alameda	2019, Q2	33
Rancho Palos Verdes	28103 Hawthorne Blvd	Rancho Palos Verdes	180	Los Angeles	2019, Q2	33
Sherman Oaks	14478 Ventura Blvd	Sherman Oaks	500	Los Angeles	2019, Q2	33
Irvine	5333 University Dr	Irvine	500	Orange	2019, Q3	33
Mission Hills	15544 San Fernando Mission Blvd	Mission Hills	500	Los Angeles	2019, Q3	33
Oakland	350 Grand Ave	Oakland	500	Alameda	2019, Q3	33
Chino	12610 East End Ave	Chino	100	San Bernardino	2019, Q4	100
Redwood City	503 Whipple Ave	Redwood City	500	San Mateo	2019, Q4	33
San Diego	5494 Mission Center Rd	San Diego	500	San Diego	2019, Q4	33
Santa Monica-Lincoln	1866 Lincoln Blvd	Los Angeles	500	Los Angeles	2019, Q4	33
Beverly Hills	9988 Wilshire Boulevard	Beverly Hills	500	Los Angeles	2020, Q1	33
Studio City	3780 Cahuenga Blvd	Studio City	500	Los Angeles	2020, Q1	33

Appendix C: Auto Manufacturer Survey Material



Appendix D: Self-Sufficiency Evaluation Update

Overview of Self-Sufficiency Effort

Following the requirements of AB 8, CARB and the Energy Commission are collaborating to develop an analysis of the funding needs and timing that would be required to bring the hydrogen fueling network to a state of financial self-sufficiency. Such a network would no longer require additional State funds in order to maintain the operations of existing stations or to continue the development of new stations to expand the coverage and capacity of California's hydrogen fueling network. The analysis is a multi-year effort that began in 2016 and was last updated in the *2018 Joint Agency Staff Report*. In that update, the agencies reported findings of minimum requirements for individually profitable hydrogen fueling stations and other business environment metrics gained through a survey of industry participants in California's hydrogen fueling network market.

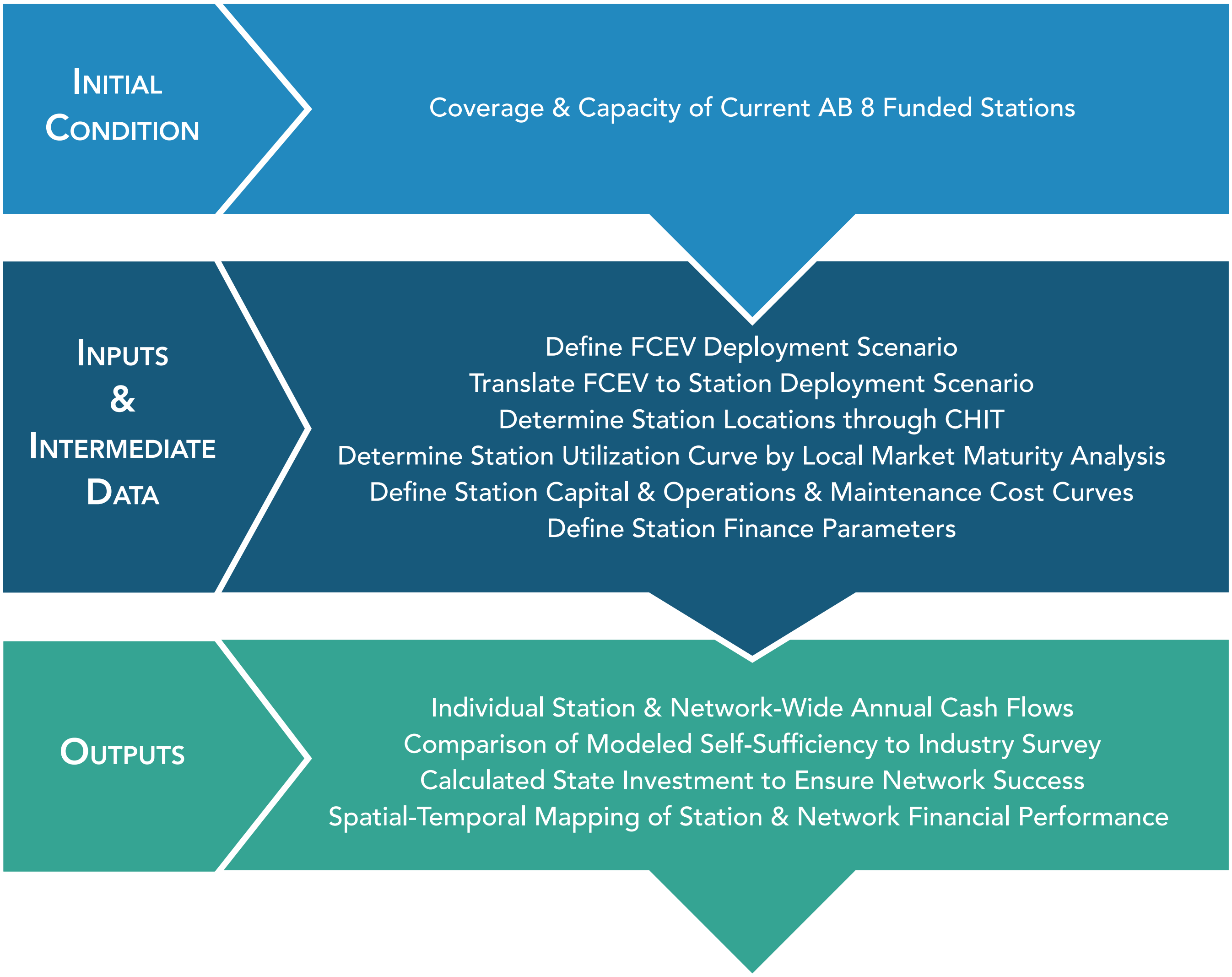
The insights gained through that survey are now being leveraged to develop a network-scale cash flow analysis. The goal is to understand the potential economic performance of individual hydrogen fueling stations and the fueling network as a whole in potential future scenarios of FCEV deployment and network development. Comparing the potential economic performance of stations over time to the minimum requirements for profitability and other metrics provides a gauge for the amount of funding that may be required to help the network achieve self-sufficiency and the timeframe over which these funds would be needed. While there are several other aspects of the hydrogen fueling industry that would have implications for this analysis (such as hydrogen production and distribution), this endeavor only examines the stations' economic performance. The upstream costs of hydrogen production, distribution, etc. are considered to be captured by the input assumptions for hydrogen procurement costs and station capital costs and the scenario definition.

The self-sufficiency cash flow analysis is currently in draft form. CARB and the Energy Commission are collaborating and working with industry and government stakeholders through the California Fuel Cell Partnership to evaluate the validity of the methodology and assumptions. Preliminary draft results and findings have been developed. However, given the immature status of these outputs, this Annual Evaluation focuses primarily on providing a description of the analysis methodology and plans for evaluations going forward. Future Annual Evaluations or Joint Agency Staff Reports will provide updated information as methods are validated and full scenario analyses are completed.

Methodology of Network Cash Flow Analysis

The overall process and methodology currently proposed for the self-sufficiency cash flow analysis is shown in Figure 27. There are three main phases to the analysis: 1) definition of the initial condition, 2) definition of scenario inputs and development of auxiliary intermediate data, and 3) production and evaluation of outputs. CARB proposes that all analyses completed within this effort begin with the assumption that the initial condition for analysis is comprised of all currently-funded hydrogen fueling stations. This allows the self-sufficiency analysis to explore scenarios with a common starting point to the scenario developed for the CaFCP *Revolution* document and further detailed in the *2018 Annual Evaluation*. Thus, the approach to self-sufficiency can be evaluated for the known and publicly-reported *Revolution* scenario as a baseline. Evaluations for additional scenarios that vary from this baseline can also be developed based on this same initial condition, so that sensitivities to various evaluation inputs can be accurately investigated.

Figure 27: Overview of Methodology for Network Cash Flow Analysis used in Self-Sufficiency Effort



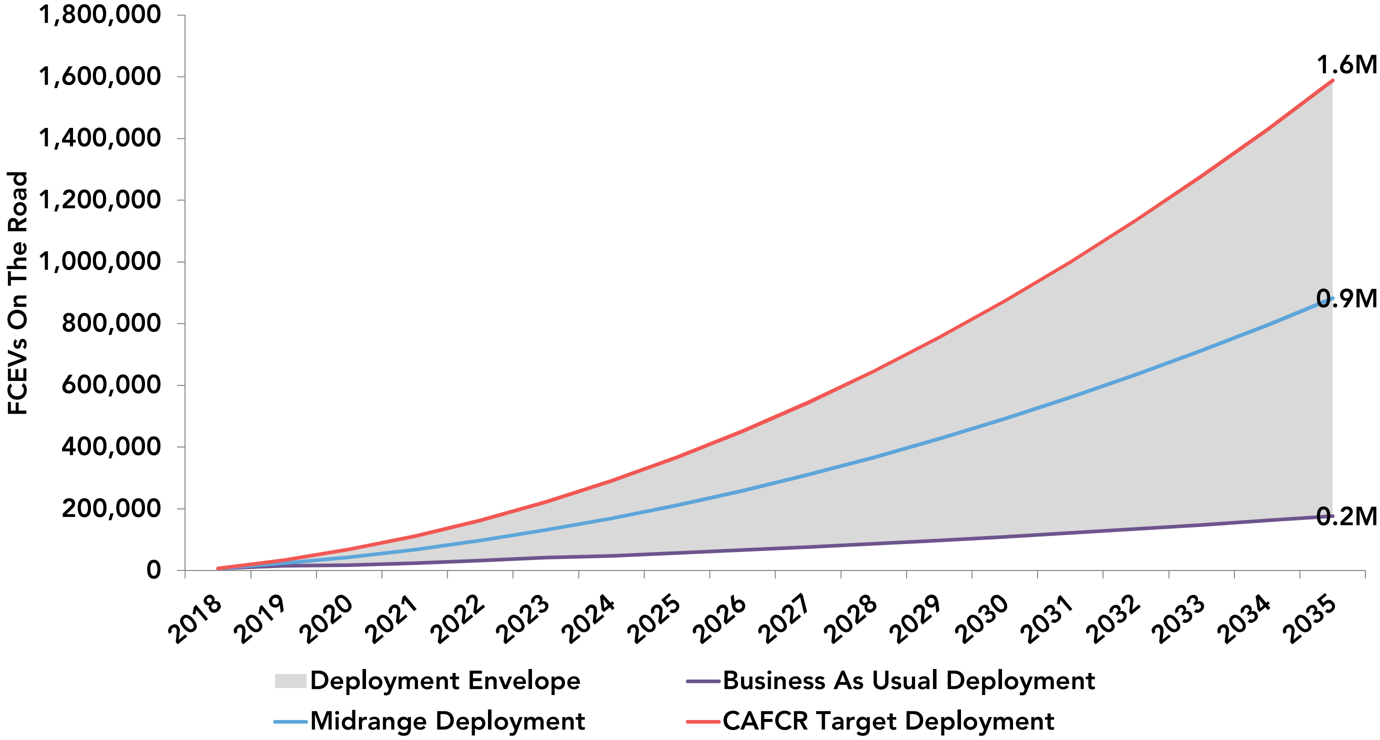
The cash-flow analysis is meant to be a scenario evaluation tool rather than a predictive or optimization tool. Thus, the methodology is based on assuming that FCEV deployment is an input parameter, defined prior to the calculations of cash-flow. In the real world, FCEV deployment will depend on hydrogen fueling station development and related economics; however, accounting for such a feedback mechanism would require more detailed modeling and additional assumptions that are beyond the scope of interest for this work. Assumed FCEV deployment implies a total network-wide capacity need, through the assumption of 0.7 kg/day demand per vehicle on average. A schedule for new station development can then be determined by making two additional assumptions:

1) Developing a schedule for the availability of hydrogen fueling stations of varying capacities. In general, larger stations are assumed to start becoming available further in the future. The share of new development for any given capacity starts small as it is first introduced, approaches a peak, and then diminishes again to a baseline of at least 5%. Small station capacities are always available for new build in the network, due to the expected ongoing need for connector, destination, and market initiation stations. The set of available station sizes throughout the evaluation is also dependent on the scale of FCEV deployment, since fewer FCEVs may imply that larger stations will not be demanded in the fueling market.

2) Assuming a strategy for satisfying hydrogen demand. In this work, two approaches have been developed and proposed for evaluation:
   - **Back-Loaded Development:** Recognizing that larger stations will enter the network in later years, the total new hydrogen capacity need may be distributed through the years of the evaluation scenario such that more of the need is built later in the future. This enables fewer hydrogen fueling stations, of larger average size, to meet the projected demand.
   - **Annually Matched Development:** Hydrogen fueling stations can also be assumed to be built on a pace such that the additional demand in each year is exactly met by the additional capacity built in the same year. This method directly ensures no lag in hydrogen station development relative to FCEV deployment but also requires more stations to meet the same ultimate demand since the average station capacity is smaller.

For the baseline scenario, CARB has proposed the FCEV and hydrogen fueling station deployment scenario of the *Revolution* (CAFCR). This scenario was built for an endpoint of one million FCEVs in 2030. To allow the self-sufficiency analysis to capture the possibility that the point of self-sufficiency may come after 2030, the FCEV deployment and station buildout have been extended an additional five years along the same trajectory. CARB also proposes extension of the Business-as-Usual (BAU) case discussed in the *2018 Annual Evaluation*. Together, these represent likely bounding scenarios for the eventual FCEV deployment in California. Figure 28 highlights these projections and also shows an illustrative midrange case that would achieve roughly the same FCEV population as the CAFCR case, but 5 years later. This midrange case could be used in future analyses to refine estimates of the sensitivity of outcomes to FCEV deployment. Figure 29 demonstrates how FCEV deployment scenarios are combined with station-related assumptions to generate schedules for hydrogen fueling station development of various capacities.

Figure 28: FCEV Deployment Scenarios for Self-Sufficiency Analysis



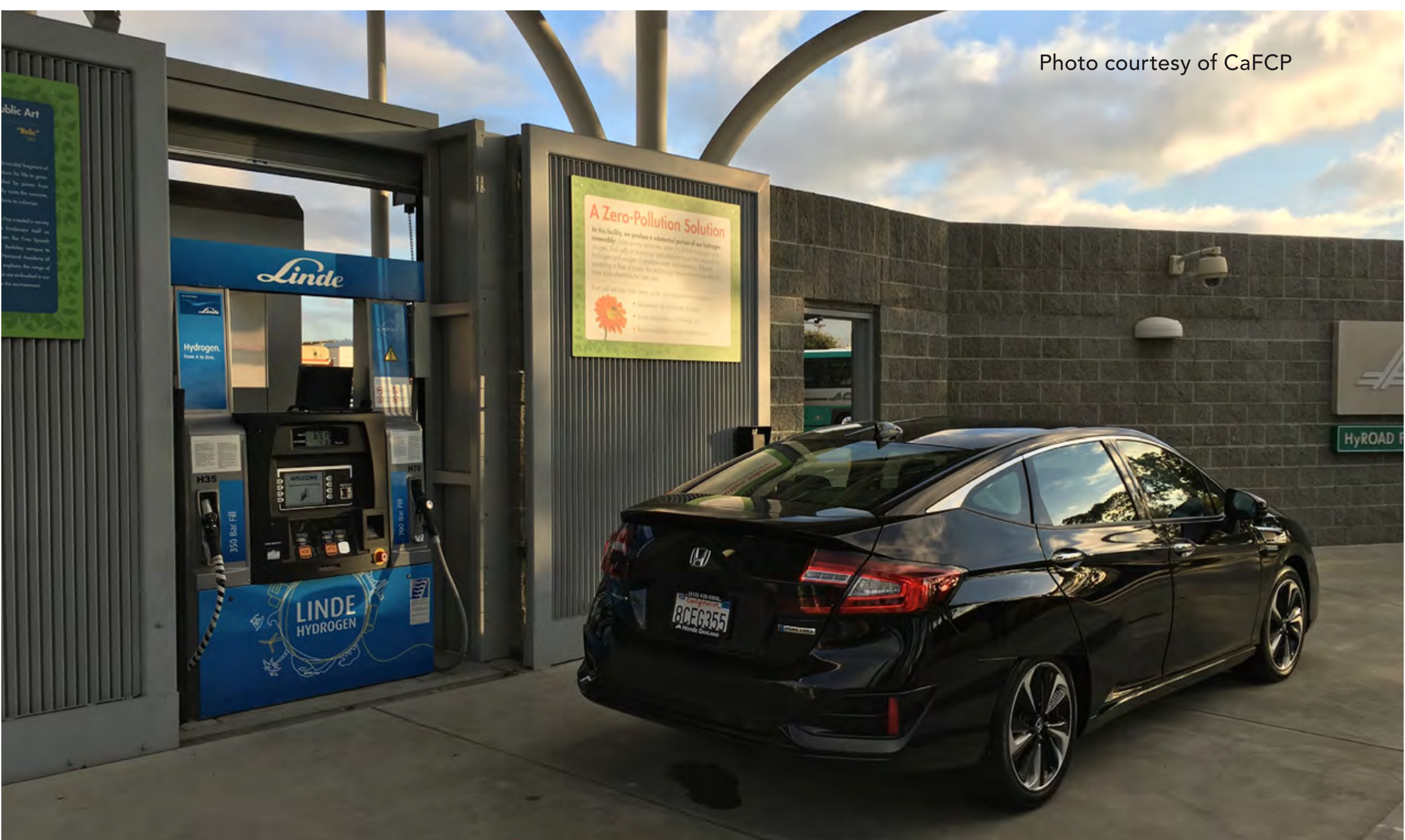
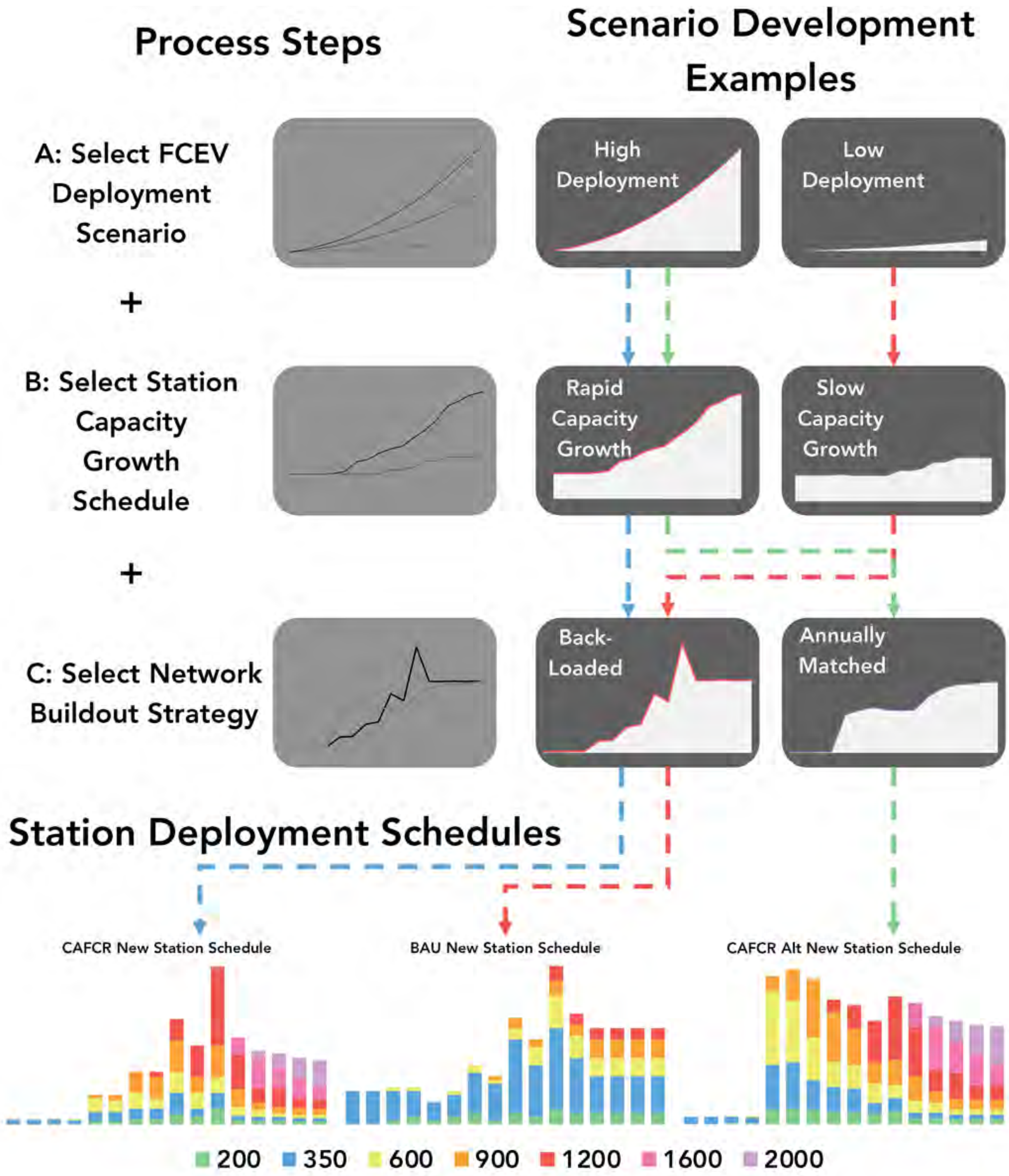


Figure 29: Schematic of Translating FCEV Deployment and Hydrogen Station Assumptions to Schedules of Station Buildout by Capacity



With a station development scenario determined, the network buildout can then be simulated through CHIT, according to the scenario evaluation methods described in Appendix D of the *2018 Annual Evaluation*. In brief, the coverage and capacity gap analysis capabilities of CHIT were leveraged to develop a method to sequentially and iteratively place hydrogen fueling stations into the existing network according to the schedule defined by the scenario. The process identifies priority areas for new development based on the coverage gap assessment and a capacity score that determines the degree to which local capacity need matches the capacity of the next station in the development sequence. In addition, the station placement algorithm is tuned to the local density of gasoline fueling stations, ensuring that hydrogen fueling station coverage could ultimately mirror gasoline station coverage, even with fewer total stations.

The iterative CHIT process results in spatial allocation of all stations defined in the buildout schedule. Afterwards, a second geospatial analysis is performed that determines the number of neighboring stations for each new hydrogen station at the time it is placed into the network. Neighboring stations are assumed to be only those stations within the 15-minute extent of coverage for any given station. This metric provides an assessment of the local station network development status at the time of new station build. CARB has proposed that this local status impacts the progression of station utilization and has assumed that a station entering a more mature local market will experience higher utilization rates earlier in its operational lifetime. This provides a method for each station to also be assigned an individualized utilization trajectory informed by the development status of the local network.

Finally, scenarios for cost and revenue streams are developed and can be applied to assessment of each station's cash flows. Cash inflows consist of four primary sources:

1) Hydrogen throughput sales revenue
2) Low Carbon Fuel Standard throughput-based credit generation
3) Low Carbon Fuel Standard Hydrogen Refueling Infrastructure credit generation
4) State-funded Financial Assistance

Cash outflows consist of two primary sources:

1) Capital Cost Financing Expenditures
2) Operational and Maintenance Costs (which includes costs to procure hydrogen fuel)

These costs and revenues vary with network development status, the capacity of the hydrogen station, the age of the station, and the year of evaluation. Each station's cash inflows and outflows are evaluated from the first year of development to 2050 through the execution of a simplified scenario cashflow calculator. All cashflows are tracked for each individual station for all years so that analysis can be performed on individual stations, the network as a whole, and subsets of the stations (such as all stations of a certain capacity, or all stations in a given region). These cashflow outputs also provide the basis for evaluation of the evolving financial health of stations and the network as a whole, which is the primary output of this analysis.

Once these metrics are developed for all stations, the results of the scenario analysis are then compared to the insights gained through the industry survey. This is a crucial step, as the scenario analysis method does not directly use the survey results as input; instead, they are used as a check on the validity of the output. The survey results cannot be used directly as input because it is assumed that many of the metrics (such as station capital costs) will evolve with time, whereas the survey results provide a picture of a static set of minimum criteria for financially profitable stations. In addition, not all stations throughout the scenarios evaluated can be assumed to be profitable; enforcing the criteria of the survey responses results in a priori determination of the final result.

Scenarios are evaluated both with and without the assumption of State-funded financial assistance. Evaluations that include this aid provide a way to estimate the total cost and duration of a State program that would be required to ensure the network as a whole could develop into financial self-sufficiency. This is the ultimate goal of the work and can help frame future discussions of the potential financial performance, opportunities, and needs of the hydrogen fueling industry. Finally, all stations are tracked through all phases of the evaluation with consistent identifiers, enabling data developed through the cashflow calculator to be associated with the geospatial station location data developed through CHIT. This enables geospatial analysis of the evolving financial performance of individual and groups of stations through time.

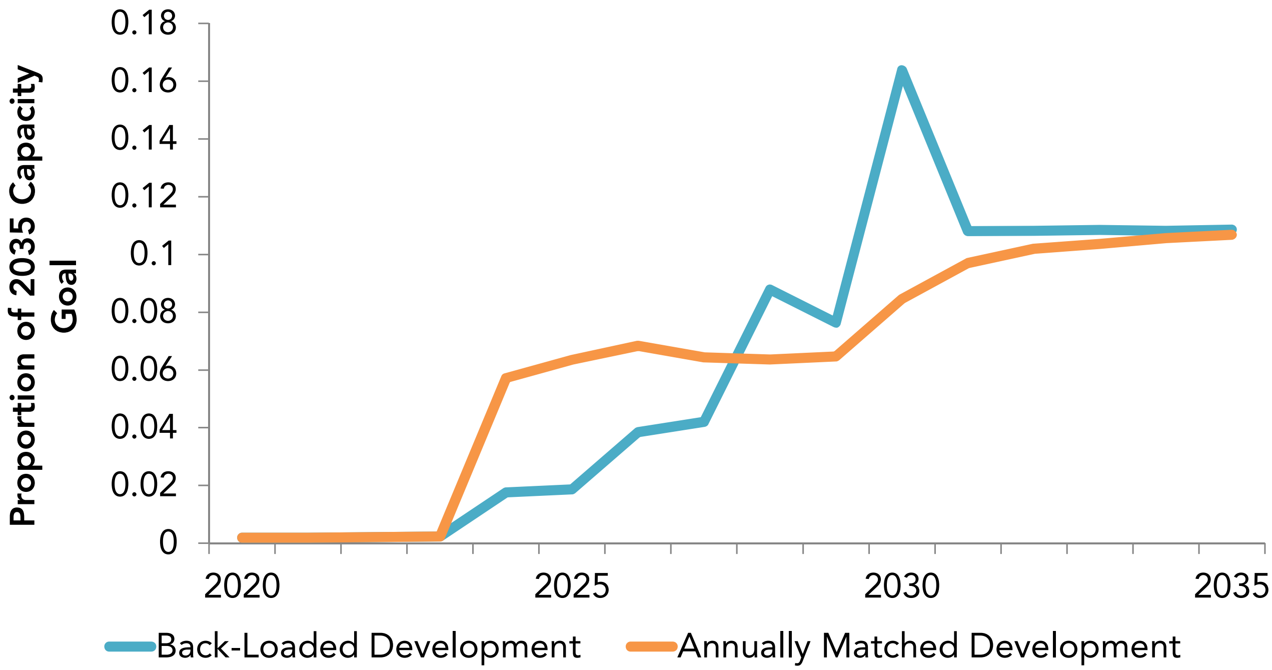
It is important to note that many of the input and output parameters are correlated to one another in the real-world industry. Network development pace could dictate vehicle deployment rates and vice-versa. Network development could attract increased private investment in the supply chain and reduce station developer/operator costs. On the other hand, if the market remains constrained, prices and costs could instead rise. Similar can be said for the effect that increased demand for hydrogen fuel will have across the industry. Nearly every aspect of the analysis could have an implication on the others. Rather than attempt to predict and model these interactions, CARB's proposed method should be viewed as a scenario analysis. Suites of trajectories and schedules for key parameters are developed independent of the potential interactions with other parameters. Scenarios are then defined by the combination of particular trajectories for each parameter. Not all combinations are valid or sensible, but proper selection of scenario definitions provides focus for the study outcomes to provide valuable insight.

Summary of Major Assumptions and Scenario Definition Parameters

Vehicle Deployment and Station Capacity Assumptions

Figure 28 shows the bounding CAFCR and BAU cases for vehicle deployment, which result in 1.6 and 0.2 million FCEVs on the road in 2035, respectively. Regardless of the FCEV deployment scenario, all vehicles are assumed to consume an average of 0.7 kg of hydrogen per day. For the CAFCR case, it has been assumed that the progression of available hydrogen fueling station capacities matches the case discussed in Appendix D of the *2018 Annual Evaluation* through 2030. For years 2030 through 2035, two additional station capacities are assumed to enter the market: 1,600 kg/day and 2,000 kg/day. All capacities in this effort should be interpreted as 12-hour nameplate capacity for the period that spans the morning peak and the afternoon peak demand. For the BAU case, the relative proportion of installed station capacities is assumed to match the CAFCR, though the numbers of stations built in each capacity are necessarily fewer. For 2030-2035, the BAU scenario assumes that the largest station size remains capped at 1,200 kg/day and that the mix of station capacities remains constant over this period. Capacity buildout in each year for the Back-Loaded and Annually Matched strategies are shown in Figure 30 as a proportion of the total 2035 capacity goal. In both strategies, the first four years of development were restricted according to previously-reported assumptions of the remaining buildout schedule for the AB 8 program.

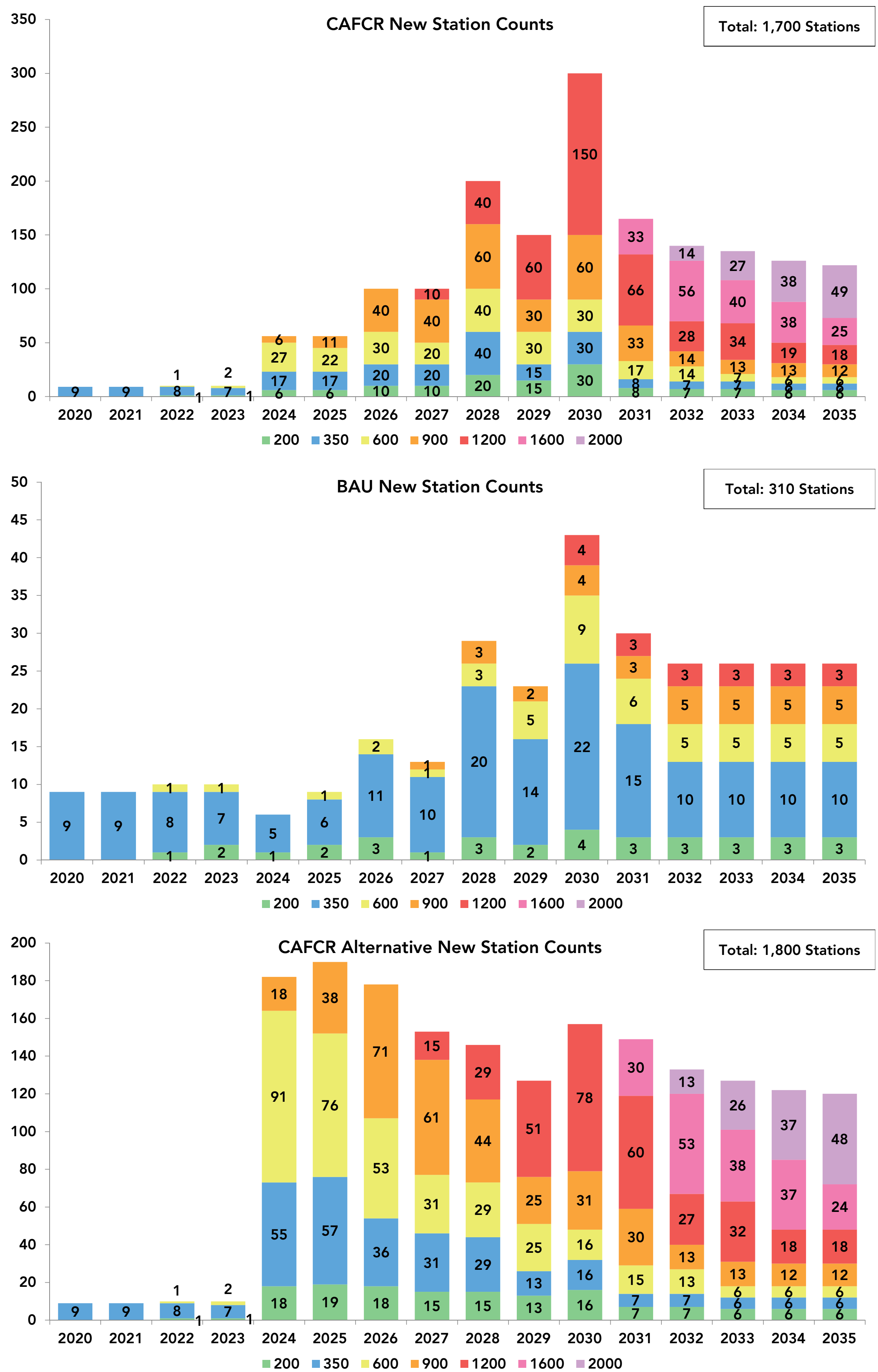
Figure 30: Annual Proportion of 2035 Capacity Goal Built in Each Year According to Various Network Buildout Strategies



For initial exploratory analysis, three overall station deployment scenarios have been developed, demonstrated in Figure 29 and shown in greater detail in Figure 31:

1. **CAFCR:** CAFCR vehicles with CAFCR station capacity mix and Back-Loaded Development
2. **BAU:** BAU vehicles with station capacity limited to 1,200 kg/day and Back-Loaded Development
3. **CAFCR Alternative:** CAFCR vehicles with CAFCR station capacity mix and Annually Matched Development

Figure 31: Station Deployment Schedules for Initial Exploratory Scenarios

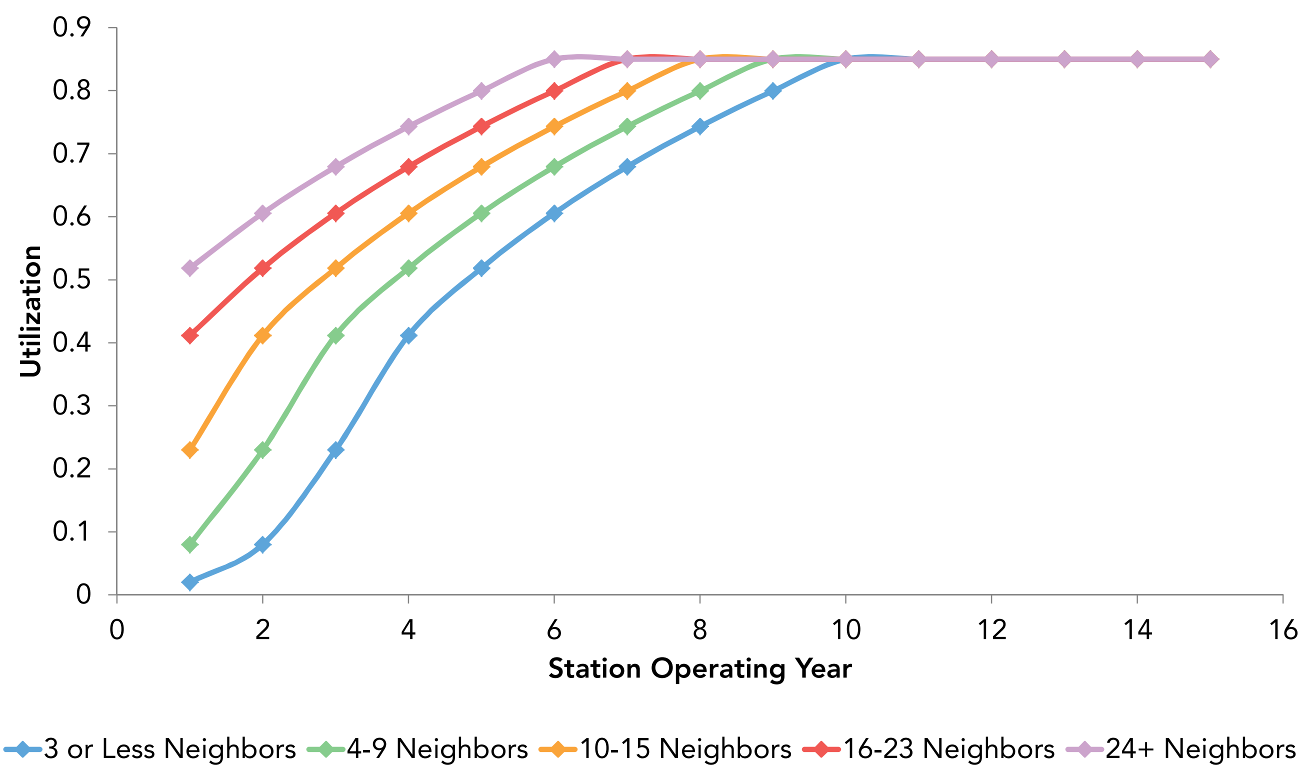


Station Utilization Schedule Determined by Local Market Maturity

All stations in the self-sufficiency effort were placed geographically using the CHIT-enabled methods leveraged for the *Revolution* document and detailed in the *2018 Annual Evaluation*. Once all stations were placed for the selected scenario, the local market conditions at the time of their opening could be evaluated. A generalized utilization curve was developed based on prior analyses reported in Joint Agency Staff Reports, which reach maximum utilization within 10 years. High and low cases of utilization were defined as 85% and 75% maximum utilization at any station. This enables independent consideration of the planned demand and station buildout compared to actual demand provided by deployed vehicles. Implementation of the lower utilization case could emulate a situation where station developers plan for a larger vehicle fleet than is actually deployed, providing insights into risks inherent to the industry.

Stations that are among the first in their local market are assumed to take 10 years to reach maximum utilization. However, stations that are built in more mature markets are assumed to start later on the utilization curve and therefore require fewer years to reach maximum utilization. Figure 32: Station Utilization Dependence On Age and Local Market Maturity portrays the utilization curve experienced by stations placed into local markets of varying maturity for the high (85%) maximum utilization case. The local market that a new station entered into was defined as the set of fueling stations within a 15-minute drive of that station. As described in the *2018 Annual Evaluation*, a network of 1,000 hydrogen fueling stations by 2025 provides similar coverage as today's gasoline station network, but not the same capacity and therefore local density. In addition, based on the 15-minute local market definition, today's gasoline station network has many locations with much higher density than even the maximum group of 24 or more stations used for the hydrogen station analysis.

Figure 32: Station Utilization Dependence On Age and Local Market Maturity



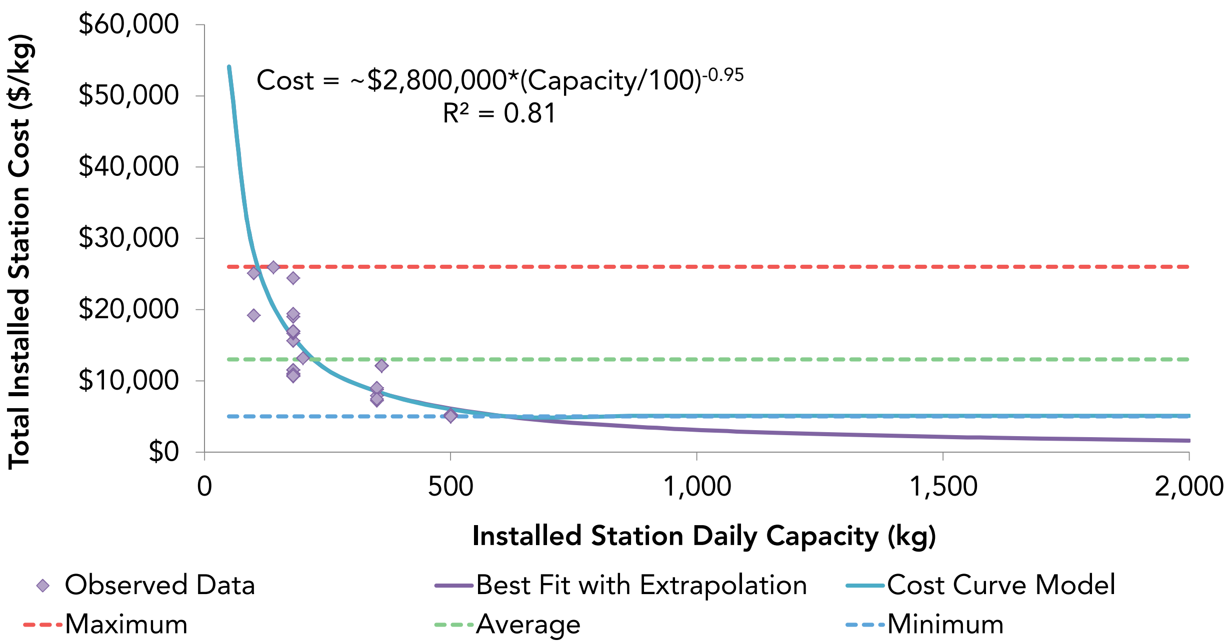
Station Capital Costs

Station capital costs are informed by analysis of the hydrogen fueling stations included in the AB 8 program, based on the total costs reported to date to the Energy Commission. These costs include the State grant award amount, the stated private match share, and the privately-funded cost overrun whenever available. An empirical curve fit was developed based on these data to describe station costs as a function of 12-hour capacity. Two identified outliers were not included in the development of the empirical curve fit. As shown in Figure 33: Cost Curve Model Based on AB 8 Funded Stations, costs per kilogram of installed capacity reported in the AB 8 program can be modeled by a nearly direct inverse relationship with total station capacity.

Station capacities in the self-sufficiency study exceed the largest station data available through AB 8. Costs for stations significantly larger than 500 kg/day based on extrapolating this model therefore incur significant uncertainty. In addition, at large values of station capacity, the increased cost incurred by the additional kilograms is nearly exactly offset by the reduction in cost per kilogram. This results in all stations larger than approximately 600 kg/day having the same total cost. Therefore, the recommended cost curve model follows the best fit to 600 kg/day, where the model and the observed minimum cost per kg are in agreement. All stations larger than 600 kg/day are then assumed to incur the same cost per kilogram of capacity, resulting in a linear relationship between total cost and total station capacity for these larger stations.

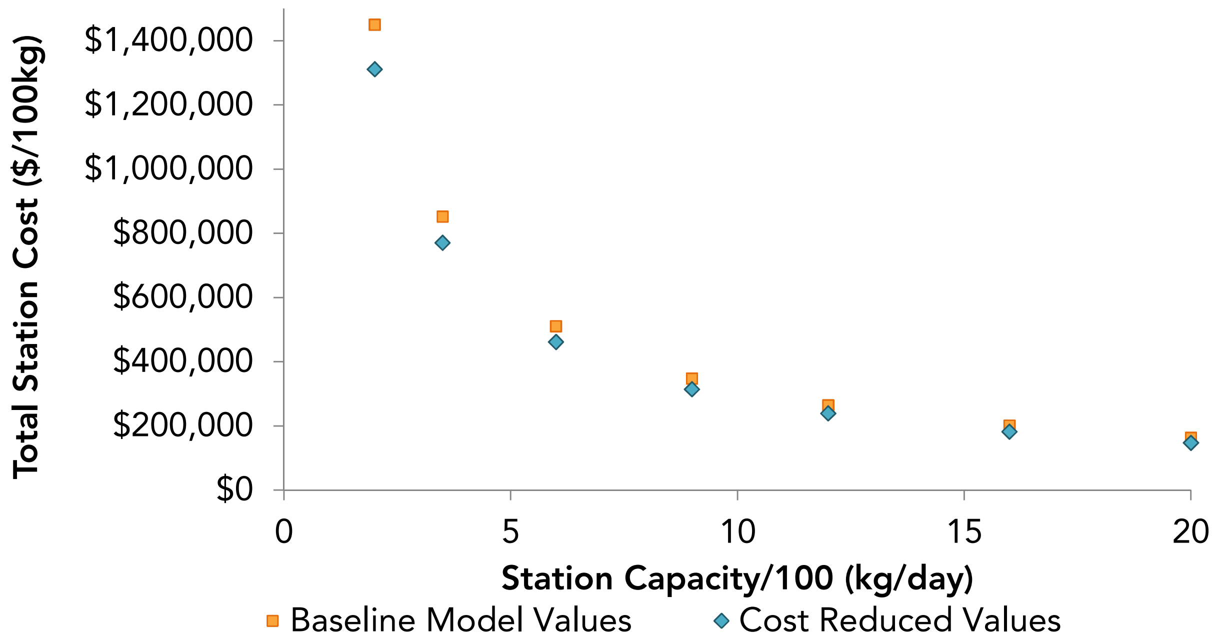
The adopted cost curve describes the change in station cost with capacity. While it does not directly vary with time (a 300 kg/day station placed in 2020 will cost the same as one placed in 2030, aside from inflation effects), the average station cost per kilogram for the network does decrease over time as the network progresses to greater numbers of larger stations in the later years of evaluation. However, it is also possible to adjust station costs with time by making simple assumptions about the potential cost reduction due to technology and/or supply chain advances. For this effort, CARB proposes that a subset of evaluations will be completed with the assumption of a simple 1% cost reduction per year for the first ten years after a given station capacity enters the network. Preliminary sensitivity analysis has shown that even this small amount of annual cost reduction can have a significant effect on many of the study's outcomes. The effective change in station costs after 10 years is shown in Figure 34: Cost Reduction after 10 Years of Network Deployment; smaller stations' costs are more sensitive than larger stations' due to the higher baseline costs.

Figure 33: Cost Curve Model Based on AB 8 Funded Stations



Note: Does not include 2 outliers (verified by Grubbs' test at 0.05 significance) , 1 Null (Incomplete) data point, nor mobile fueler

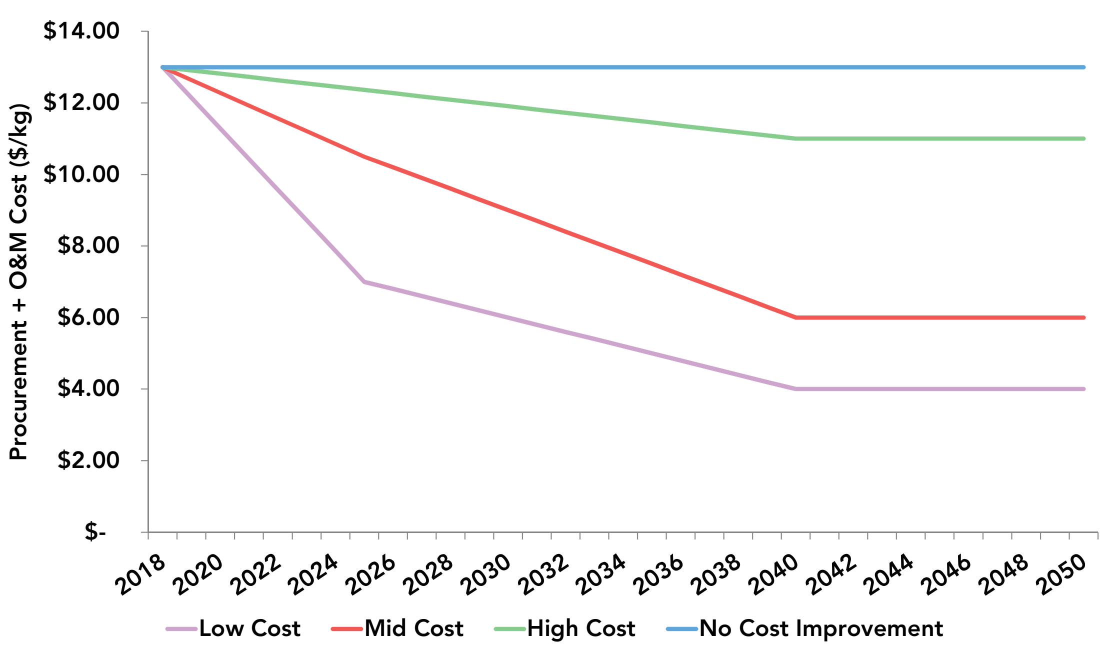
FIGURE 34: COST REDUCTION AFTER 10 YEARS OF NETWORK DEPLOYMENT



Station Operations and Maintenance Costs

Station Operations and Maintenance (O&M) cost trajectories, inclusive of the cost to procure hydrogen, were developed by consulting various sources available in the hydrogen industry literature and the data collected through the self-sufficiency survey process. United States Department of Energy cost targets and estimates [53], the Shell *Hydrogen Refueling Station Cost Reduction Roadmap* [54], and data collected by the National Renewable Energy Laboratory [55] informed the development of the cost curves shown in Figure 35: Combined Hydrogen Procurement and Station O&M Cost Trajectories. Because of the high degree of uncertainty, very few future cost points were projected and simple linear interpolation was assumed between them in all proposed trajectories.

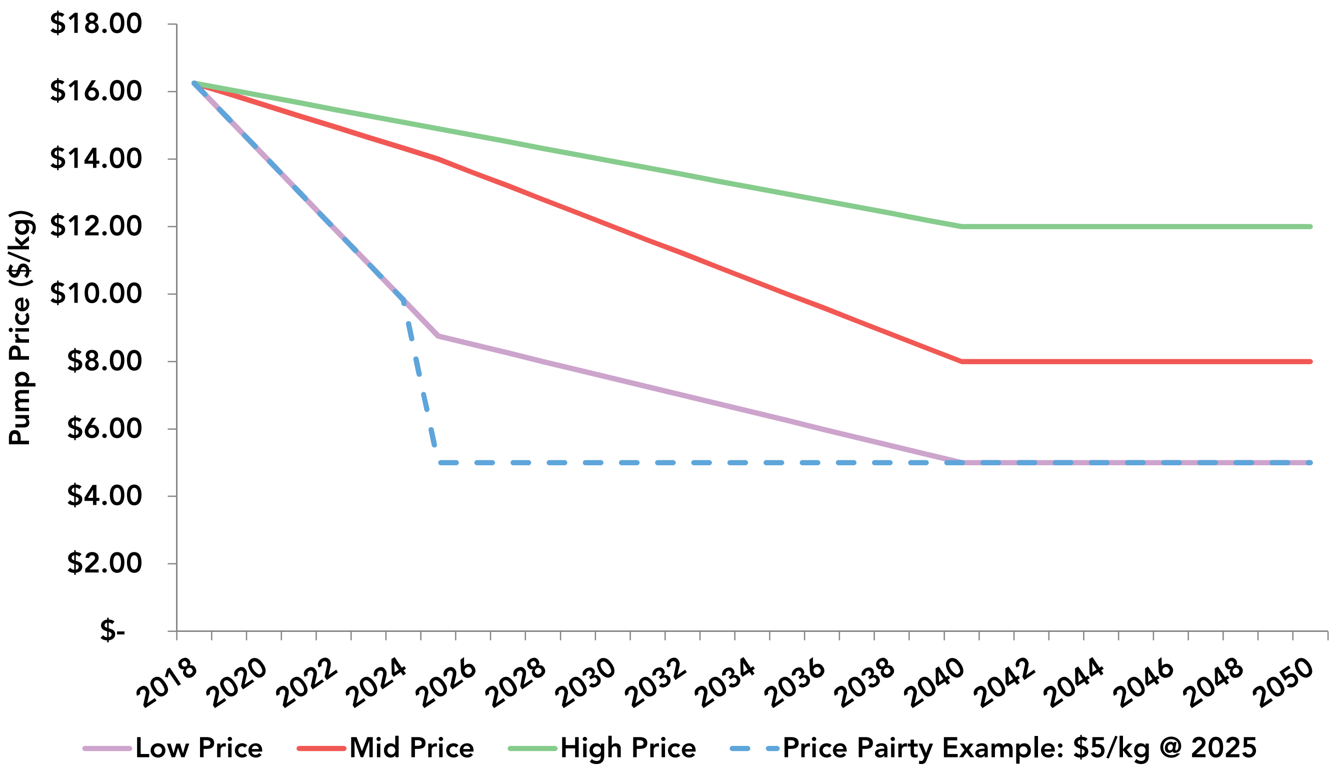
FIGURE 35: COMBINED HYDROGEN PROCUREMENT AND STATION O&M COST TRAJECTORIES



Station Fuel Sales Revenue

Many of the same resources used to define O&M cost trajectories were referenced for the proposed hydrogen sale price trajectories shown in Figure 36: Customer-Facing Hydrogen Sale Price. In addition, industry stakeholders recommended the investigation of cases that force hydrogen price parity with gasoline at a given date. This could help estimate the total cost of developing not only a self-sufficient hydrogen fueling network, but one that also simultaneously attracts more FCEV adopters by eliminating fuel price effects on adoption rate. While the concept of price parity is widely referenced, CARB has observed that there is no clear consensus on what that means in terms of sale price per kilogram of hydrogen. This is reasonable, given that the concept of price parity involves assumptions for several factors, including consumer price elasticity, the future price of gasoline, the energy conversion efficiency of FCEVs, future gasoline-powered vehicle fuel economy, and more. Rather than generating a strict definition, the analysis tool provides the option to specify any desired hydrogen sale price to be defined as the "parity price," and for this price to be forced in all sales revenue calculations beginning in any desired year. Both the parity price and first enforcement date are specified at runtime so that various scenarios exploring the potentially different definitions of price parity can be explored. Because values cited as price parity are often low, the Low Price trajectory is assumed for revenue calculations in years prior to the beginning of the forced parity.

Figure 36: Customer-Facing Hydrogen Sale Price



Low Carbon Fuel Standard Credit Revenue

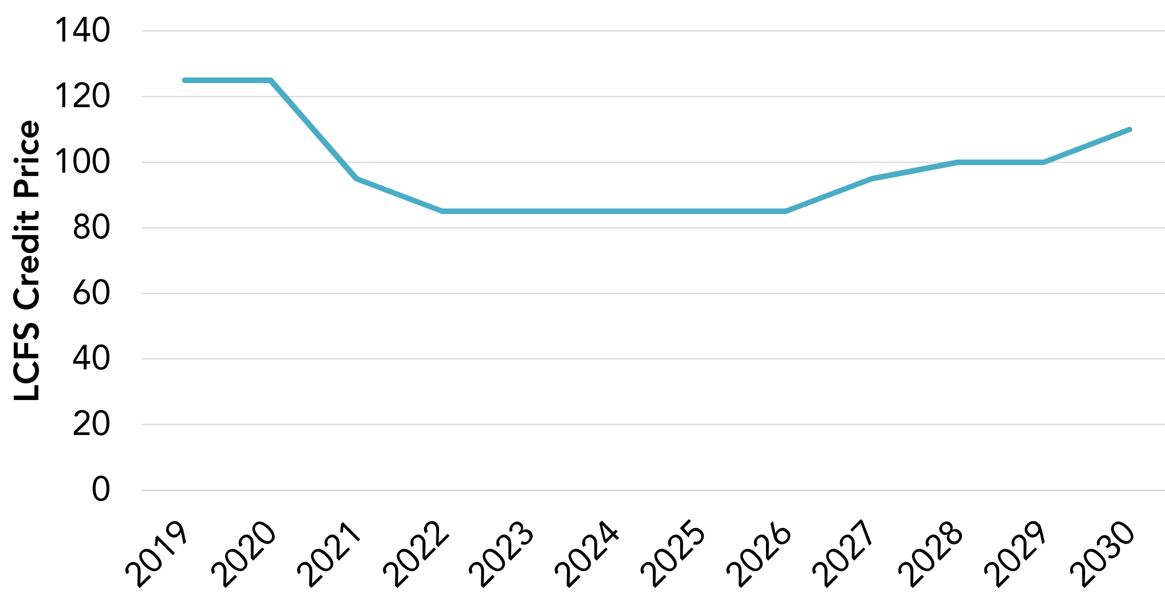
Stations in the self-sufficiency evaluation were assumed to have the potential to earn both types of Low Carbon Fuel Standard credits currently available through the regulation: credits based on the throughput of hydrogen sold at fueling stations and credits for the remaining installed capacity above this throughput (known as HRI credits). The LCFS HRI credit provision includes limits on the per-station and total credits that can be earned:

1) Only stations up to 1,200 kg/day can earn credits
2) Stations must apply for HRI credits in 2025 or earlier (in the LCFS program, developers are allowed to build the station up to 2 years after the application is approved; the self-sufficiency analysis collapses these dates and only provides HRI credits to stations built in 2025 or earlier)
3) Stations are eligible to receive credits for up to 15 years
4) The total HRI credits cannot exceed 2.5% of the total LCFS program deficits

All these requirements are enforced in the self-sufficiency evaluation. To satisfy requirement 4, some stations built in a given year may not be able to qualify for HRI credits while others can. Based on analysis of the self-sufficiency survey, CARB's best understanding of independent industry analyses, and validation through this work, it was assumed that the smallest stations would have greater need for HRI credits than larger stations. Thus, in any given year, HRI credits were assigned to stations in order of capacity and then order of placement within capacity groups; the CHIT-based station location process similarly places smaller stations before larger stations because it is assumed that areas with demand that is well-matched to smaller station capacities will be less common than larger stations.

Several assumptions affect the total revenue of both types of LCFS credits. These include the gasoline baseline carbon intensity, the hydrogen carbon intensity, the energy economy ratio (EER), the available credit deficit in future years, and the LCFS credit value. The gasoline baseline carbon intensity was assumed to be as published in Table 1 of the LCFS regulation, which went into effect on January 1, 2019. The hydrogen carbon intensity was assumed to start at 150 gCO_2e/MJ and decline linearly to 75 gCO_2e/MJ in 2030, which was maintained through the remainder of the evaluation period. The EER was assumed to be 2.5 as published in Table 5 of the current LCFS regulation. The available credit deficit was assumed to follow projections provided with the LCFS Illustrative Compliance Calculator ("Low Demand with Project/LD/Low ZEV/20%/infra" case). Deficits after 2030 were assumed to be equal to the deficits available in 2030, the latest year for which projections are available. Finally, the LCFS credit price was assumed to follow the schedule supplied in the Illustrative Compliance Calculator, shown in Figure 37: LCFS Credit Price Schedule. After 2030, the credit value was assumed to stay constant at the 2030 value of $110.

Figure 37: LCFS Credit Price Schedule



State Support Program

Combining individual trajectories from the above suites of assumptions provides an assessment of station and network financial performance with respect to self-sufficiency absent any State aid besides the LCFS program. Although the AB 8 program remains in effect, these grant funds were not calculated separately; instead, they are interpreted to be included in the total State support calculated in each scenario as necessary to achieve network self-sufficiency. In order to determine this amount and timing of State support, this work assumes a simple grant structure that provides a uniform amount of funding for the first five years of each station's operations. This structure was chosen for ease of implementation within the analysis; CARB does not intend to imply it recommends this structure for any possible future programs. The structure of any potential future programs will be best determined by further evaluation and analysis at a future date.

The amount of supporting State funds was calculated individually for each station. An iterative guess-and-check solution method was employed to calculate the appropriate amount by assuming that every station must meet a minimum metric for financial performance. The metric chosen was a minimum Modified Internal Rate of Return (MIRR), with the value and period of evaluation (e.g. 10-year vs 15-year MIRR) set at runtime. CARB has completed preliminary investigations at 10% and 15% MIRR. Calculation of MIRR requires a time series of expenditures and revenues (taken as the sums of cash outflows and inflows, respectively), an assumed financing cost rate, and an assumed rate of return of self-reinvestment. CARB assumed a 6% financing cost rate and sets the rate of return on self-reinvestment equal to the target MIRR.

General Financial Assumptions

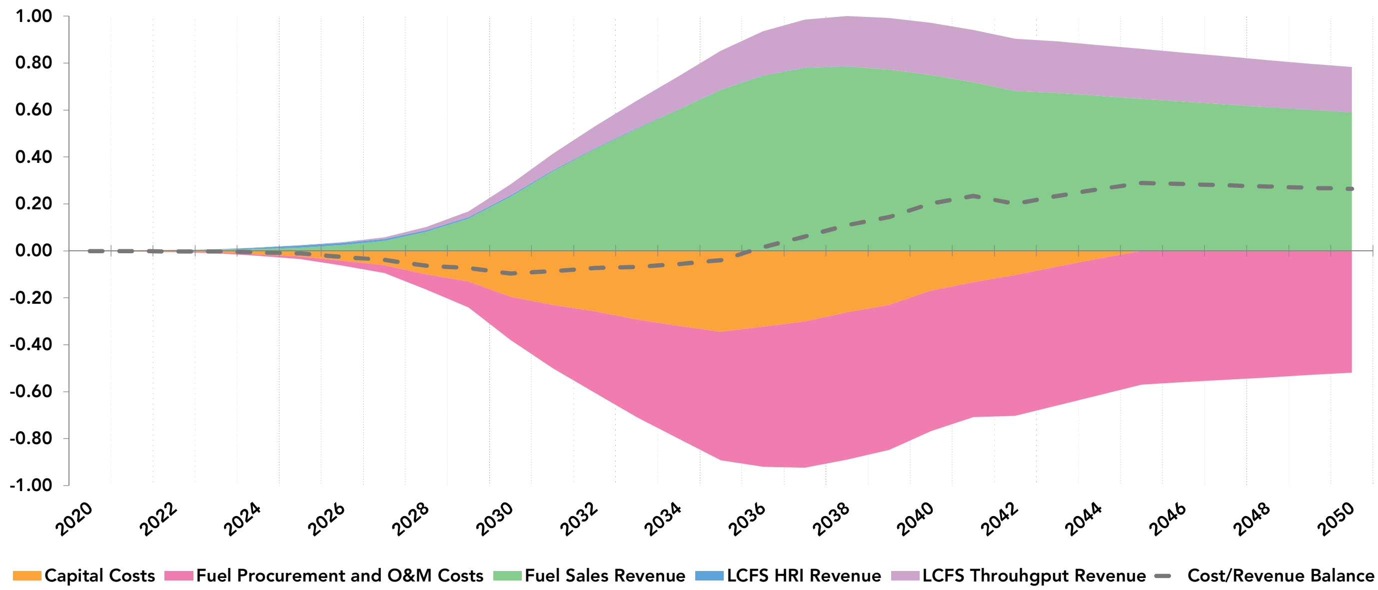
CARB made two additional financial assumptions in addition to the MIRR. First, CARB assumed that the total station capital cost was not incurred as a single lump cash outflow in the station's first year of operations. Instead, CARB assumed capital costs were paid through a 10-year loan with a 6% financing rate, in agreement with the similar assumption for MIRR. Second, CARB included an adjustment for the effect of inflation on future cash flows by assuming a 1.9% interest rate held constant over the entire period of evaluation. All cash flow values were therefore converted back to 2020 dollar values through simple Net Present Value (NPV) calculations.

Sample Outputs and Exploratory Sensitivity Analysis

CARB is currently in the process of finalizing evaluation methods and soliciting input from industry stakeholders on the validity and suitability of the assumptions described above. Thus, finalized results are not ready for reporting. However, illustrative results from initial exploration and sensitivity analysis can prove helpful in demonstrating the intended outcomes and data synthesis expected of the self-sufficiency evaluations. Because results are considered draft, limited numerical data are provided for illustrative figures.

A sample of the network-wide cash flows for a given set of scenario assumptions is shown in Figure 38: Illustrative Network Cashflow; cash flows are normalized since CARB has not yet finalized these results. While insights regarding absolute cash flow values cannot be provide at this time, there are still important observations of the relative cash flows and the timing of key network metrics. First, this particular scenario shows that stations included in the scenario would not be profitable on a network-wide basis until 2036, where the annual cost-revenue balance switches from negative to positive, shown by the dashed line. This particular case is for a network that does not receive any grant support. In addition, the greatest contributor to revenues is fuel sales, followed by LCFS throughput credit revenue.

Figure 38: Illustrative Network Cashflow

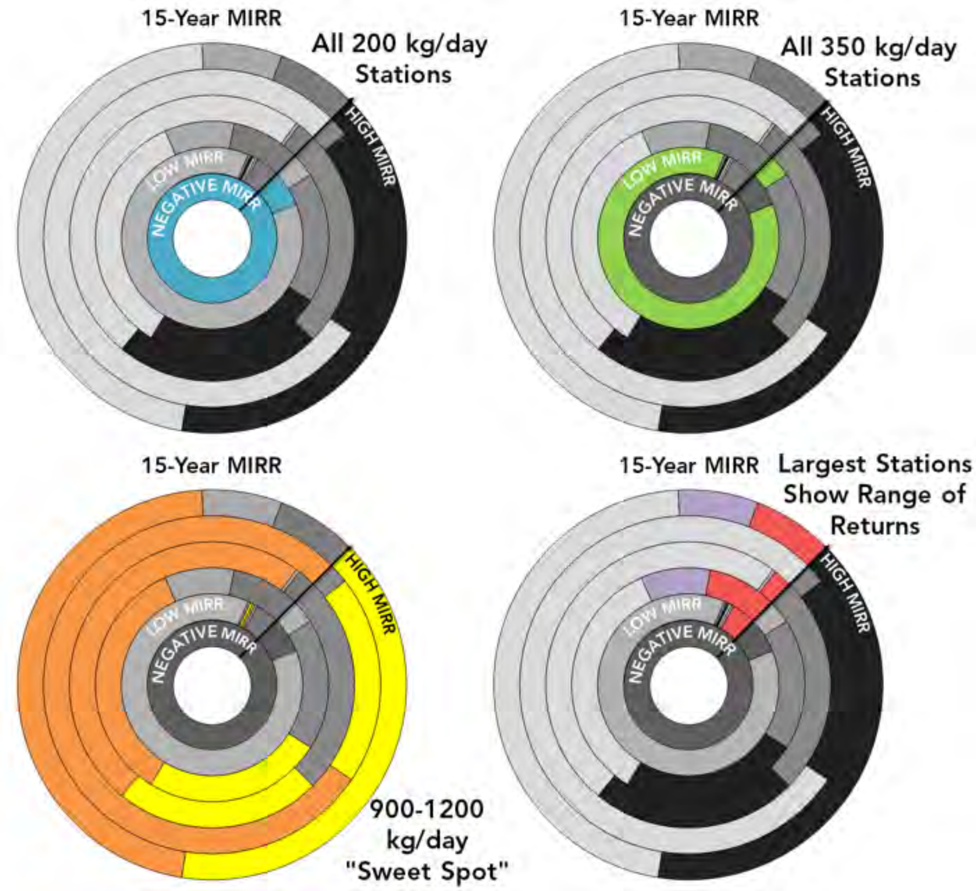


HRI revenue is a very small portion of the overall cash flow, hardly visible only in the earliest years of evaluation. While outcomes remain to be finalized, CARB has consistently found through its exploratory analyses that LCFS HRI credits are an exceedingly small part of the revenue stream over the long term. However, in the early years of future network development for most cases, the HRI credit revenue can present a significant portion of the total cash inflows. In some cases, it can even be the predominant revenue stream for a few years. Over time though, it is clearly surpassed by the throughput-based sales and LCFS credit revenue. This is especially true as station capacities grow over time, and the eligibility limits of the LCFS HRI program begin to have increasingly greater effect.

As reported in the *2018 Joint Agency Staff Report*, responses to the self-sufficiency survey indicate that industry considers a station capacity around 400-500 kg/day to be the minimum needed for stations to be profitable. Cash flow analysis of individual stations in various scenarios seems to confirm this finding, as shown in Figure 39: Illustrative Analysis of Stations' MIRR. The four panels of the figure contain the same data but colored segments in each panel highlight different groups of stations based on capacity. Each ring includes all stations within a given range of MIRR and each ring is divided proportional to the number of stations of each capacity within that MIRR range. Stations with negative MIRR are shown by the innermost ring. Stations with positive MIRR are grouped in the remaining rings, moving from low positive MIRR in the seond innermost ring to high positive MIRR in the outermost ring.

Stations with a 200 kg/day capacity are often found to have a negative MIRR; only a few show positive returns (and thus profit over a 15-year time horizon). Stations at 350 kg/day show more guarantee of profits, but they are at very low return rates. Only stations above the minimum found in the survey provide acceptable to high MIRR. Depending on the scenario evaluated, results indicate that there are typically one or two modeled station capacities that provide the greatest likelihood for high returns. For the scenario of Figure 39: Illustrative Analysis of Stations' MIRR, this is 900-1,200 kg/day. Some of the largest stations show lower returns due to the limits of HRI credits and because these stations enter the network later in the evaluation period, when margins between hydrogen cost and sale price are slimmer.

Figure 39: Illustrative Analysis of Stations' MIRR



Stations' annual and lifetime net profitability are also tracked through the analysis. As Figure 40: Illustrative Analysis of Stations' Profitability illustrates, scenario evaluations typically find that very few stations are profitable on a lifetime basis at first. While increasing numbers of stations become profitable on a net basis over the course of the evaluation period, there are typically some unprofitable stations that always remain (without the addition of State aid). Typically, these are the smallest stations in the evaluation, which mirrors the results of Figure 39: Illustrative Analysis of Stations' MIRR.

Figure 40: Illustrative Analysis of Stations' Profitability

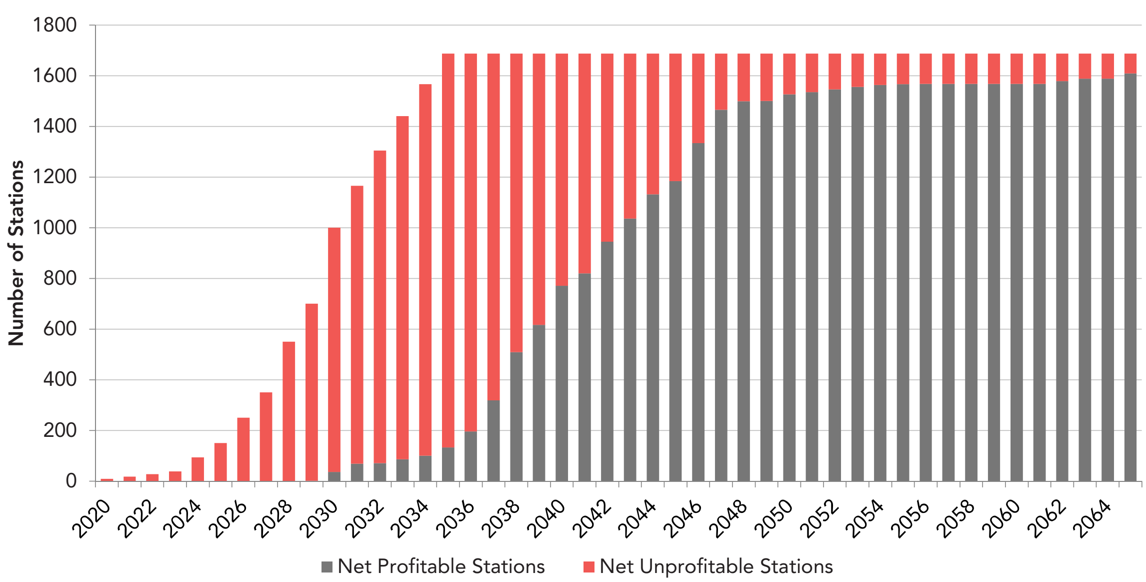
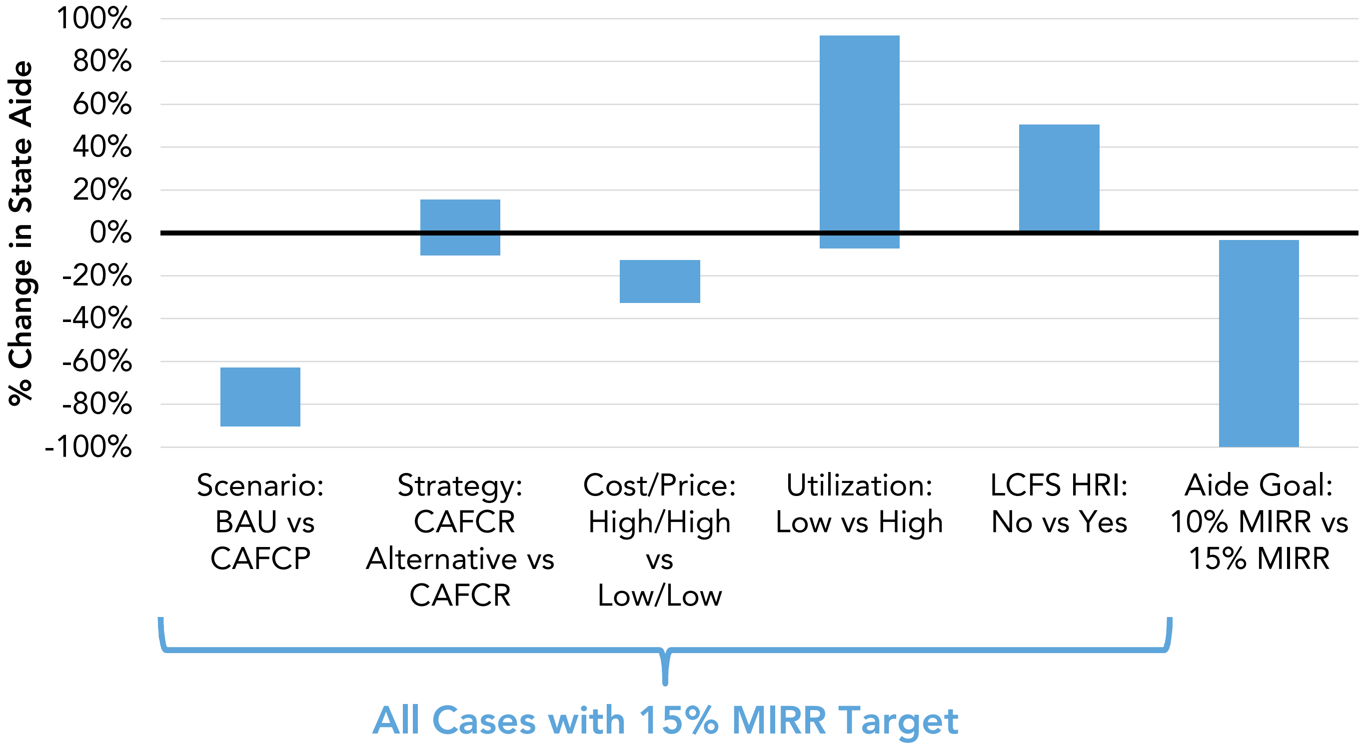


Figure 41: Illustrative Sensitivity Analysis

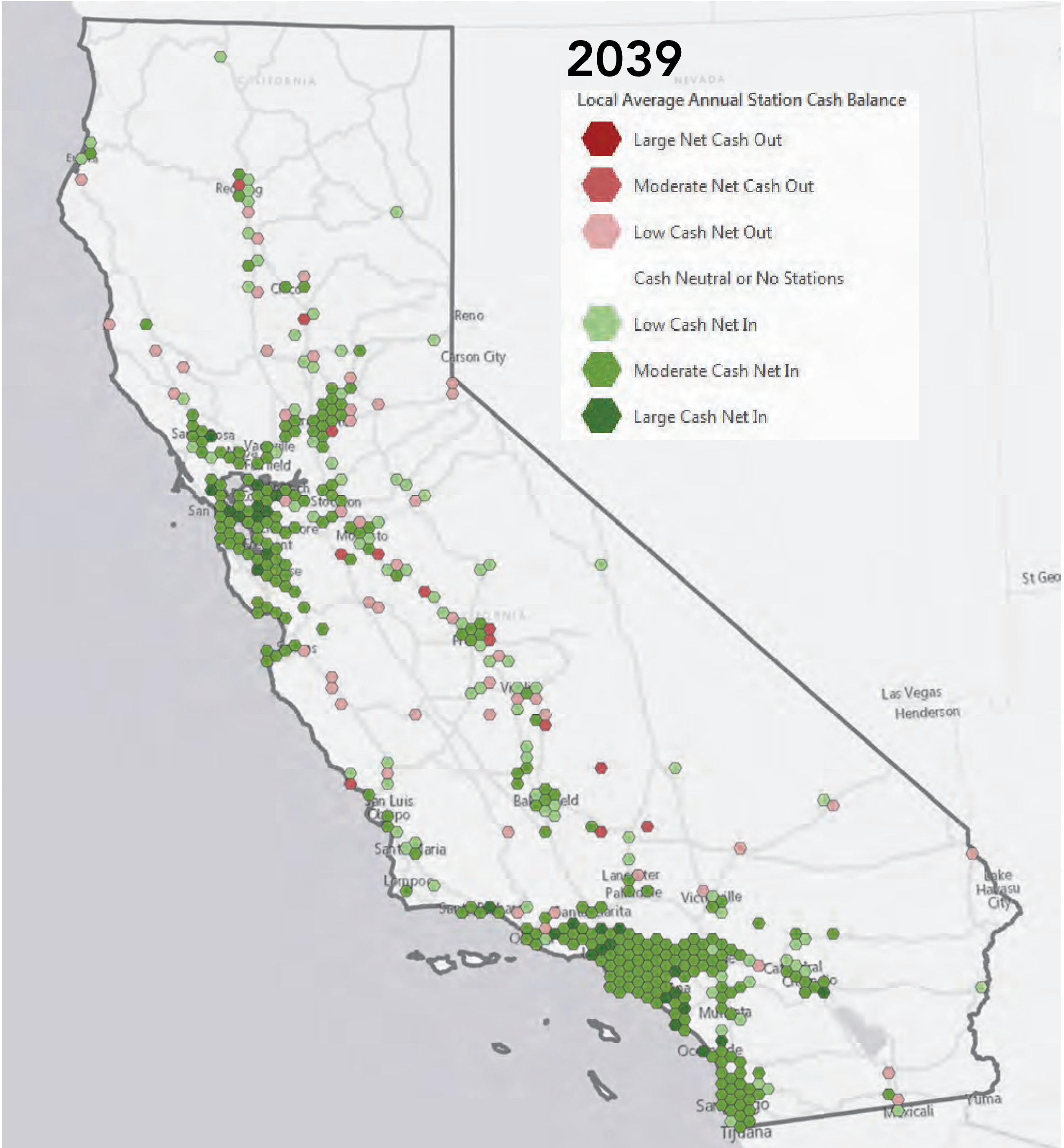


Preliminary sensitivity analysis shows that the three parameters that have the greatest effect on calculated State aid are the vehicle deployment assumption, the maximum station utilization, and the MIRR threshold. In Figure 41: Illustrative Sensitivity Analysis, the bars indicate the percent change in State aid between paired scenarios where only the indicated variables change. For example, two paired comparisons included in the bar labeled "Scenario: BAU vs CAFCP" are:

- **[BAU station and vehicle deployment**, Low hydrogen cost, Low hydrogen sale price, High max utilization, HRI credits enabled, and 15% minimum MIRR] - **[CAFCR station and vehicle deployment,** Low hydrogen cost, Low hydrogen sale price, High max utilization, HRI credits enabled, and 15% minimum MIRR]
- **[BAU station and vehicle deployment**, Low hydrogen cost, Low hydrogen sale price, Low max utilization, HRI credits enabled, and 15% minimum MIRR] - **[CAFCR station and vehicle deployment,** Low hydrogen cost, Low hydrogen sale price, Low max utilization, HRI credits enabled, and 15% minimum MIRR]

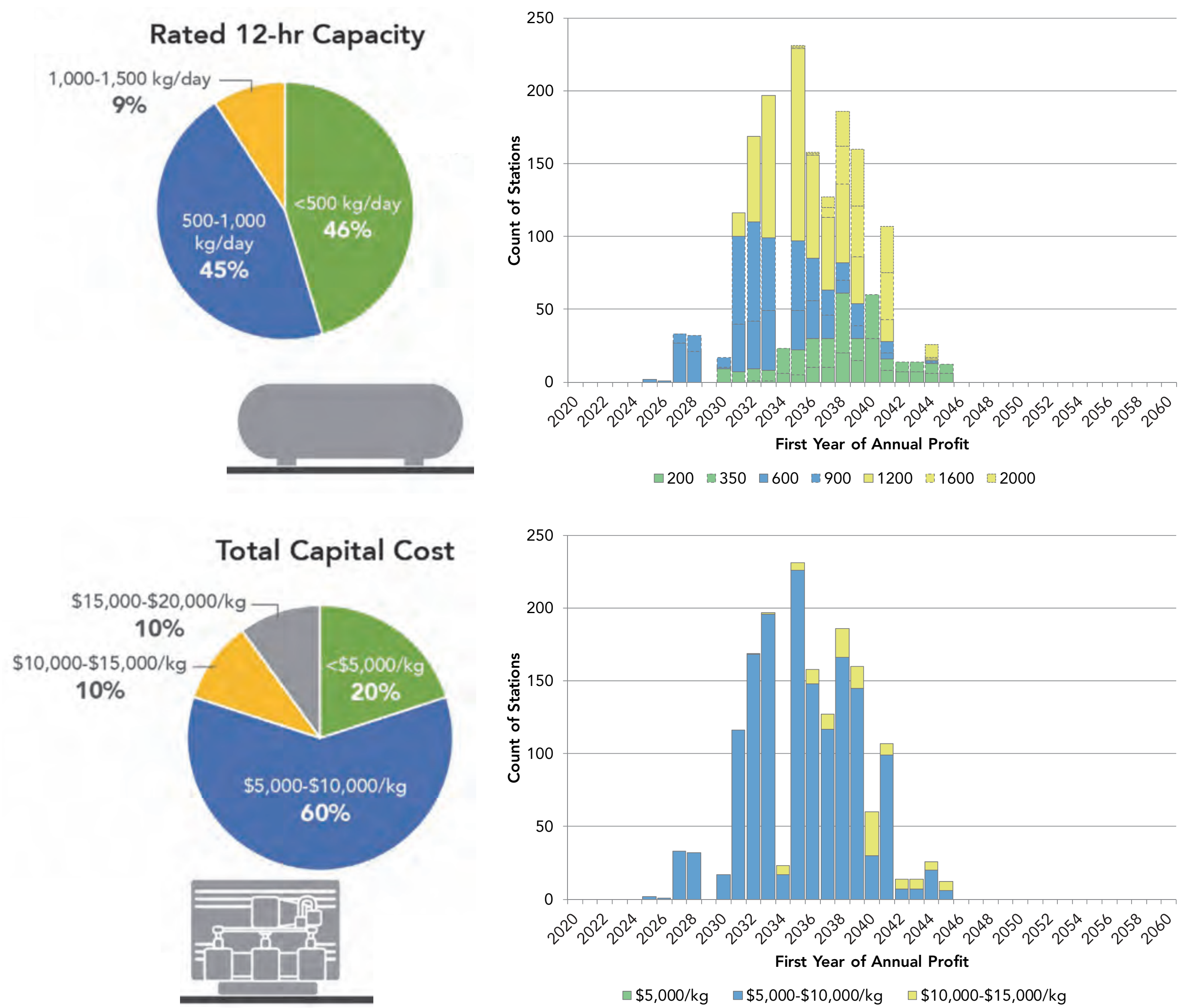
Percent changes in Figure 41: Illustrative Sensitivity Analysis are calculated as shown in the examples above: for bars labeled "A vs B", the percent change is based on the difference of A – B. The vehicle and station deployment scenario has the strongest effect on calculated State aid, as both the maximum and minimum difference between paired CAFCR and BAU cases are large. By contrast, the utilization and MIRR assumptions have the potential to have a similarly large impact on the amount of State aid needed but can also have a very small impact.

Figure 42: Illustrative Analysis of Localized Station Financial Performance



Profitability can also be explored regionally and over time as shown in Figure 42: Illustrative Analysis of Localized Station Financial Performance, which displays the financial health of the refueling network in localized markets across the state in the projected year 2039. The year 2039 is chosen for this visualization as a case that effectively demonstrates the regional variation that these evaluations have found. For the scenario shown, much of the network shows strong profitability, especially in dense urban clusters. While there are several areas of the more extended hydrogen network that also show good profitability, there are also many locations in these areas that show financial difficulty enduring to this point in the future. Analysis of these geospatial results on finalized evaluations may help provide insight for the types of station network roles (e.g. Connector and Destination) or specific locations that may need to have increased focus in the consideration of future State aid programs.

Figure 43: Illustrative Comparisons of Self-Sufficiency Survey Findings to Scenario Evaluation Outcomes



Results of the evaluations are also compared to the self-sufficiency survey responses to gauge the agreement of cash flow calculation results with industry expectations. This has the potential to provide some validation of results, though CARB is also interacting with industry directly for verification. Samples of these comparisons for a select scenario are shown in Figure 43: Illustrative Comparisons of Self-Sufficiency Survey Findings to Scenario Evaluation Outcomes. The bottom panel shows that the overwhelming majority of capital costs for stations that are first to make a profit are within the range of costs that industry respondents most frequently cited. Similar results are found for the capacity of these same stations.

Finally, Figure 44: Illustrative Analysis of State Funding Effects demonstrates the potential benefit of a State funding program as modeled through this analysis. The panel on the left shows the 15-year MIRR for all stations for a given evaluation scenario without State aid provided. While there are some stations that meet the indicated minimum expected MIRR and some that even have very high MIRR values, most do not meet the minimum and many even show negative MIRR. The evolving network-averaged MIRR is indicated by the blue curve, which never reaches the desired returns. Such a situation is unlikely to attract many private investors, as great risk of loss exists in this scenario. However, with the addition of State aid, risk of loss is eliminated, as shown by the panel on the right. This would prove to be a much more attractive situation for private investors. As CARB and the Energy Commission work to finalize analysis, sets of evaluations will be completed to help determine the State aid required to enable various minimum return rates. Preliminary results have so far found that State funding is a small part of the overall cash expenditures to build the hydrogen network, even for the 15% MIRR target. Figure 45 provides an example where 94% of the funds for network building came from private sources, illustrating the potential benefit of developing a funding program with network financial self-sufficiency as its goal.

Figure 44: Illustrative Analysis of State Funding Effects

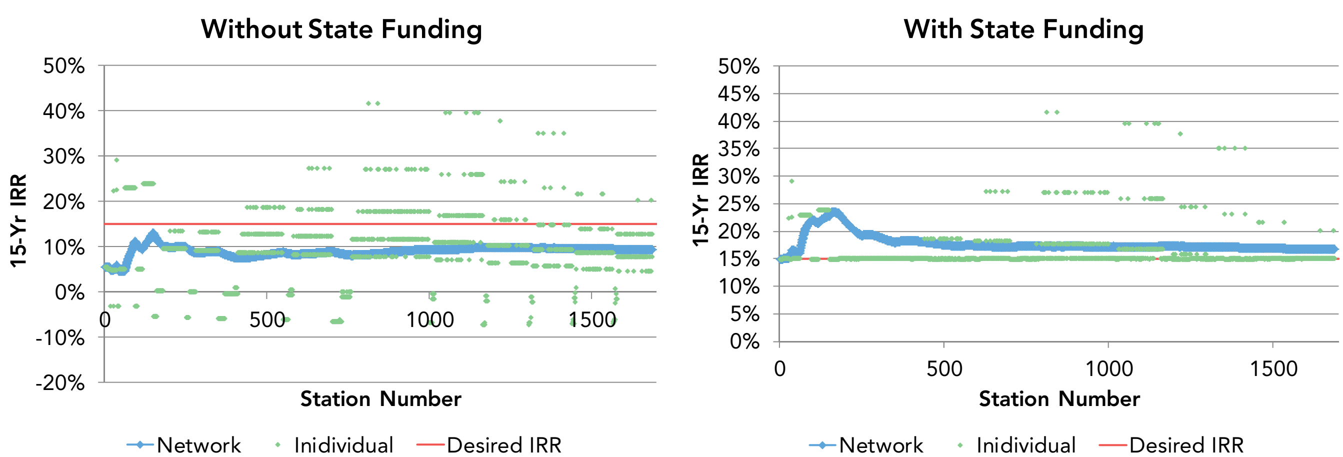
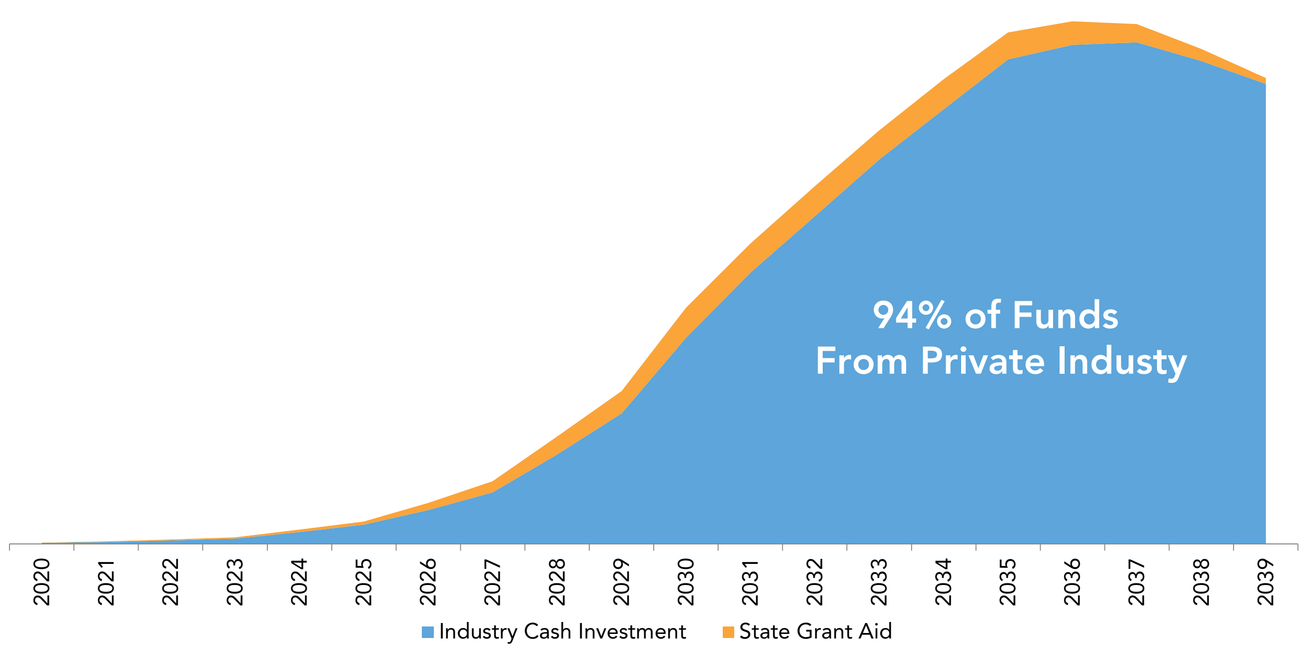


Figure 45: Illustrative Division of Network Funding Sources



Appendix E: Station Status Definition Details

The definition of an **Operational** station as adopted from Energy Commission GFO 15-605 (note that the definition included in previous and future Energy Commission grant programs like PON 13-607 may have different provisions) 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 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 has passed local inspections and has operational permit
2. The station is publicly accessible
3. The station operator has fully commissioned the station, and has declared it fit to service retail FCEV drivers. This includes the station operator's declaration that the station meets the appropriate SAE fueling protocol, and three auto manufacturers have confirmed that the station meets protocol expectations and their customers can fuel at the station, and it has passed relevant hydrogen quality tests.
4. Weights and Measures has verified dispenser performance, enabling the station to sell hydrogen by the kilogram (pursuant to CCR Title 4, Division 9, Chapter 1).
5. The station has a functioning point of sale system.
6. The station is connected to the Station Operational Status System (SOSS), maintained by CaFCP.

The remainder of the status definitions are as follows:

Fully Constructed: Construction is complete and Station Developer has notified the appropriate Authority Having Jurisdiction (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.

California Air Resources Board

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