CALIFORNIA
AIR RESOURCES BOARD

December 2023

2023 Annual Evaluation of Fuel Cell Electric Vehicle Deployment and Hydrogen Fuel Station Network Development

(Report Pursuant to Assembly Bill 8; Perea, Chapter 401, Statutes of 2013)

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Contents

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List of Acronyms

AB 126	Assembly Bill 126 (Reyes, Chapter 319, Statutes of 2023)
AB 8	Assembly Bill 8 (Perea, Chapter 401, Statutes of 2013)
ACC II	Advanced Clean Cars II
ARCHES	Alliance for Renewable Clean Hydrogen Energy Systems (California's awarded proposal for funding under the US Department of Energy's Regional Clean Hydrogen Hubs program)
BEV	Battery-electric vehicle
CARB	California Air Resources Board
CCR	California Code of Regulations
CEC	California Energy Commission
CHIT	California Hydrogen Infrastructure Tool
DAC	Disadvantaged Community
DMS	Division of Measurement Standards at the California Department of Food and Agriculture
DMV	Department of Motor Vehicles
EMFAC	CARB's EMissions FACtor model used to assess emissions from on-road vehicles
EO	Executive Order
FCEV	Fuel cell electric vehicle
GFO	Grant Funding Opportunity (California Energy Commission's formal communication of a current grant program)
GIS	Geographical Information System
HRI	Hydrogen Refueling Infrastructure
HyStEP	Hydrogen Station Equipment Performance
ISO	International Organization for Standardization
LCFS	Low Carbon Fuel Standard
MTPY	Metric tons per year
NOPA	Notice of Proposed Awards
PHEV	Plug-in hybrid-electric vehicle
RFP	Request for Proposals
SB 1291	Senate Bill 1291 (Archuleta, Chapter 373, Statutes of 2022)
SB 1505	Senate Bill 1505 (Lowenthal, Chapter 877, Statutes of 2006)
SOSS	Station Operational Status System developed and operated by the Hydrogen Fuel Cell Partnership
ZEV	Zero-emission vehicle

Courtesy of Hydrogen Fuel Cell Partnership.

Executive Summary

Zero-emission vehicle (ZEV) policies and programs have emerged as pivotal strategies in the global effort to combat climate change. This has been especially true on the national stage and in California over the past two years. In 2021, the Infrastructure Investment and Jobs Act (also often referred to as the Bipartisan Infrastructure Law) established multiple programs to catalyze the development of nationwide electric vehicle charging and hydrogen infrastructure, technology advancement, and workforce development [1]. That was followed in 2022 by the federal Inflation Reduction Act, which extended and expanded prior ZEV purchase incentives and created new programs to incentivize businesses to develop clean new fuel sources and infrastructure for industry and transportation uses [2]. More recently, in August 2022, the California Air Resources Board (CARB) voted to adopt the Advanced Clean Cars II (ACC II) regulation, which sets California on a path to 100 percent ZEV sales in all new vehicle purchases by 2035 [3]. In California, these recent developments follow prior budget commitments of up to $10 billion to advance zero-emission vehicle sales and infrastructure development [4, 5].

The scale and pace of these recent developments reflects the magnitude of the work ahead. Global climate change is an enormous challenge that will require technology transitions across all sectors of the economy in many jurisdictions across the globe. These technology transitions will require multiple parallel efforts to ensure the most rapid and effective change in how we power our daily lives. In the transportation sector, the challenge of transitioning all vehicles to 100 percent ZEVs will be centered on the consumer. Experience establishing the early ZEV market in California and elsewhere has revealed that one of the most important concerns in the transition is providing assurance that a ZEV can meet consumers' daily needs just as well as, or even better than, conventional gasoline-fueled vehicles [6, 7].Considerations from vehicle and fuel price parity to driving range, vehicle utility, and charging and fueling infrastructure (including convenience, reliability, and availability) are all at the forefront of efforts to ensure that programs like the ACC II regulation and others are successful.

To meet this challenge, California's ZEV programs and policies have long sought to support the development of all vehicle technology options that are demonstrably zero-emission. To date, the automotive industry has introduced two such technologies: battery electric vehicles (BEVs) and fuel cell electric vehicles (FCEVs)[1]. These technology options have varying strengths and requirements that tend to be complementary to one another. BEVs have a significantly larger market presence, are further in their technological development, have demonstrated significant cost reductions in recent years, and offer the convenience of at-home charging. FCEVs have the potential to provide more range and faster fueling, especially on larger vehicle platforms, and may more easily fit the daily lives of certain drivers with long commutes, limited access to home charging, significant towing needs, or other specialized use cases.

1 A third option, plug-in hybrid-electric vehicles (PHEVs), are also eligible in CARB's ACC II regulation but with limits for compliance given they are not full zero-emission vehicles. These vehicles can drive for a limited distance on all-electric power. They also include a conventional gasoline engine in a hybrid powertrain that is used for the remainder of the vehicle's range. The ACC II regulation recognizes these vehicles for their limited all-electric portion and therefore limits their use in auto manufacturers' ability to comply with the regulation.

For both technologies, widespread infrastructure development presents a primary barrier to many consumers choosing a ZEV for their next vehicle. In multiple studies and surveys, consumers have repeatedly ranked charging and fueling infrastructure as top concerns for either purchasing a new ZEV or even using the ZEV they currently drive [6, 7, 8, 9]. Large-scale development of this new infrastructure will be required to build consumer support for the transition to 100 percent ZEV sales and is the primary motivation behind many of the recent state, federal, and international announcements for investment into charging and hydrogen fueling. While the customer-facing charging and hydrogen stations are a highly visible and key touchpoint in these efforts, upstream investments in the full supply chain (such as clean hydrogen fuel production and delivery, upgrades to and expansion of the electric grid, and growth of equipment supply chains) have emerged as similarly critical pieces that must be addressed in the transportation energy transition. The *2022 Scoping Plan for Achieving Carbon Neutrality* demonstrates the scale of growth needed for the hydrogen sector across California's economy (including vehicles of all classes, industrial heat and power, chemical processing, aviation, electric grid power, and other end uses), identifying a potential need for clean hydrogen use in California to grow 1,700 times current consumption rates by 2045 [10].

The development of hydrogen fueling infrastructure in California has been largely supported by two main programs: the Clean Transportation Program reauthorized by Assembly Bill 8 (AB 8; Perea, Chapter 401, Statutes of 2013) and the Low Carbon Fuel Standard (LCFS) [11, 12]. The Clean Transportation Program has also recently been further reauthorized by the signing of Assembly Bill 126 (AB 126; Reyes, Chapter 319, Statutes of 2023). The Clean Transportation Program has provided the main avenue for co-funding the capital expenses of designing, permitting, constructing, and commissioning hydrogen fueling stations while the LCFS program more directly supports the operations of hydrogen fueling stations. Under the provisions of AB 8, the California Energy Commission (CEC) has been authorized to dedicate 20 percent (up to $20 million) of the Clean Transportation Program annual budget to co-fund the development of light-duty (and more recently in some cases multi-use light-, medium-, and heavy-duty) hydrogen fueling stations. AB 126 extended Clean Transportation Program funding for hydrogen stations to 2030. The reauthorization in AB 126 also modified the requirements, stipulating that no less than 15 percent of annual program funds (or typically around $15 million per year) are to be dedicated to co-funding hydrogen fueling stations and expanding project eligibility to "all types" of stations, which has been interpreted to include light-, medium-, and heavy-duty hydrogen fueling stations. To date, Clean Transportation Program co-funding has primarily been offered in the form of competitive grants.

In addition to providing a funding source for hydrogen fueling stations, AB 8 requires analysis and reporting on the progress and projections for future development in the hydrogen fueling network and FCEV sales. Each year, two reports are developed: 1) by June 30[2] of each year, CARB must report to the CEC with updates on the hydrogen fueling network and FCEV sales and make recommendations on locations and technical specifications for future station co-funding, and 2) by December 31 of each year, the CEC and CARB jointly provide an additional update on the network and FCEV sales and report on the cost, timing, and other operational aspects of building and operating hydrogen fueling stations in California. This *2023 Annual Evaluation* represents the tenth report from CARB to the CEC as required by AB 8 and provides perspective on the current status and future projections in the hydrogen fueling network and FCEV sales through 2029. AB 126 largely maintains these reporting requirements, though requires the annual December reports to evaluate the cost and time to achieve a "sufficient network" of hydrogen fueling stations, rather than the 100-station metric outlined in AB 8.

2 CARB also publishes this report later in the year as a publicly available document.

Since CARB published the *2022 Annual Evaluation*, there have been many changes in the funded and open hydrogen fueling network and progress has continued in network development and FCEV sales. But progress has proven to be slow and has not kept pace with even near-term projections provided one year ago. Slow network development, with commensurate delays in actual and planned FCEV sales, have consistently been a challenge for stations funded under AB 8 and the past year has proven more difficult than other recent years. Some familiar challenges have persisted, like slow permitting timelines, the loss of planned station locations, limited supply of replacement parts, and equipment reliability challenges. But the past year has also seen new challenges affect hydrogen fueling network development and impact the customer experience at operating stations, including persistent supply chain issues first introduced with the COVID-19 pandemic, high rates of inflation across the economy, high energy costs (particularly natural gas) induced by Russia's actions stemming from the war in Ukraine, and market dynamics in the LCFS program.

Recent developments also impact the outlook for future growth of California's hydrogen fueling network. The California legislature previously dedicated $60 million from the General Fund budget to hydrogen fueling station development through the Clean Transportation Program [5]. California's most recent budget reversed this decision, removing $60 million in available funds for future network development [13]. In addition, station developer Shell had previously been awarded funding for up to 51 station projects through the CEC's grant agreement funded under Grant Funding Opportunity (GFO) GFO-19-602. Shell has recently asked the CEC to cancel the grant agreement. Shell had not yet begun construction on any of the stations and does not intend to complete any of these projects. This included 13 new stations with a known address, 1 station upgrade, and 37 stations with addresses to be specified at a future time. The cancellation of these 51 station projects significantly decreases the outlook for future network growth in terms of numbers of stations, geographic coverage, and fueling capacity. Most of the awarded funds can be made available for new grants to other station developers, but the method and timing of any replacement grant award is not yet known.

Although the early hydrogen fueling market continues to face challenges, continued development is still projected through the end of the decade. The CEC has already committed to co-fund the development of more than the 100-station milestone outlined in AB 8 and will make progress toward a 200-station milestone outlined in Executive Order (EO) B-48-18 [14]. However, the timing to reach 200 stations is highly uncertain, especially given the recent budget change and Shell's decision to cancel their grant agreement with the CEC. Reaching the 200-station goal may now also be more dependent on private industry investment and development than in prior years. Uncertainty remains a major factor in projections for future growth that will likely require focused effort from public and private organizations to resolve.

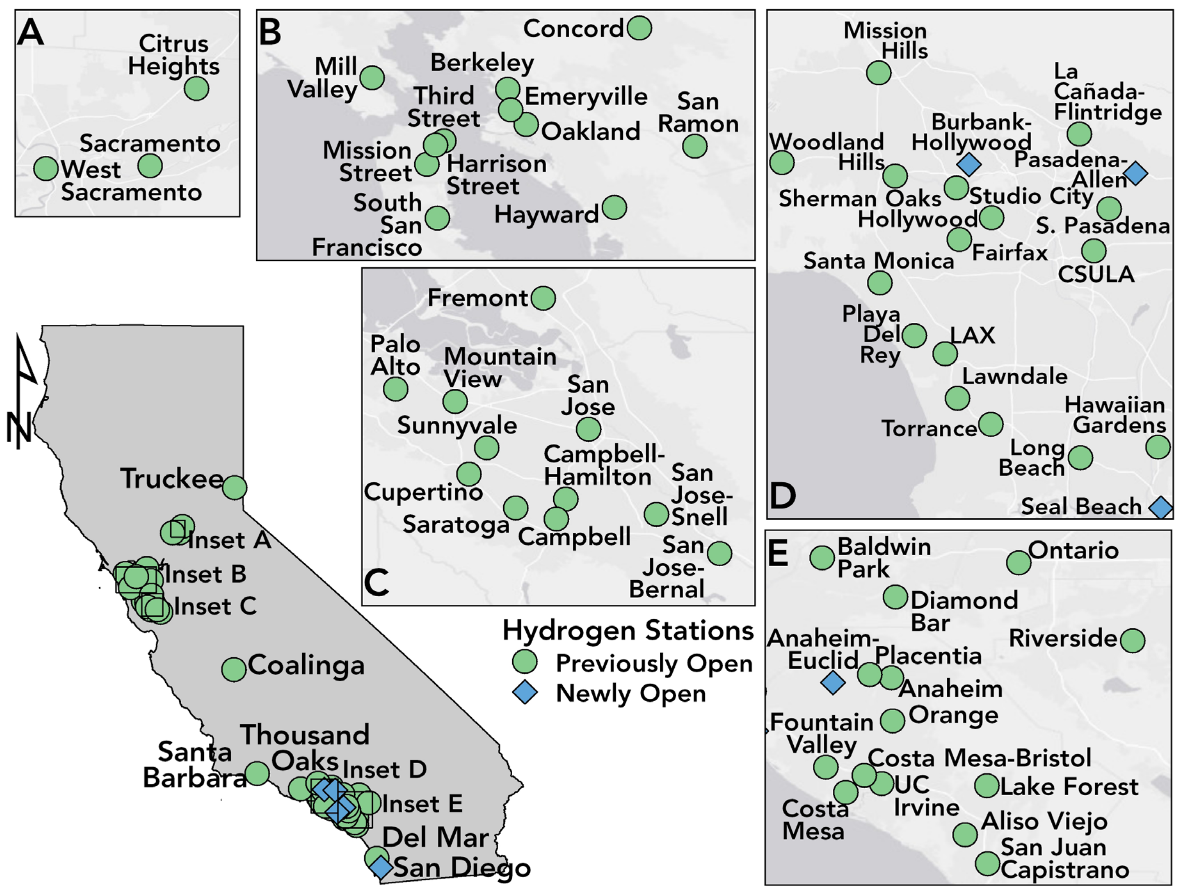
Based on analysis of progress over the past year and projections for developments through 2029, CARB staff report the following major findings for the *2023 Annual Evaluation*:

Findings

Finding 1: California's hydrogen fueling network has grown to 65 stations, with 59 Open-Retail stations available for customer fueling as of August 10, 2023

California's hydrogen fueling network now has a total of 65 hydrogen stations, with 59 of these stations currently available to hydrogen fueling customers and considered Open-Retail stations[3]. Open-Retail stations have the ability to provide a fueling experience similar to conventional fuels, where drivers can pull up next to a hydrogen fuel dispenser at a retail fueling station, pay with their preferred method of payment, and fuel their vehicle[4]. The remaining six stations are considered Temporarily Non-Operational[5] since they have been unavailable for an extended period and may eventually return to Open-Retail status.

Figure ES 1: Current Open Hydrogen Fueling Station Network as of August 10, 2023[6]



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3 On August 9, 2023, Shell provided public notice that five stations in the Sacramento and San Francisco Bay Area regions would be temporarily unavailable for an undetermined amount of time. Shell's statement indicated this was part of safety testing that is a regular part of their operations. This report does not yet count these stations as Temporarily Non-Operational.

4 See Appendix C for definitions of station status terminology used throughout this report.

5 Stations may enter the Temporarily Non-Operational status due to a variety of causes. These typically include operational difficulties with equipment maintenance, design, or failure. This category has also included stations that were unavailable for long periods of time due to hydrogen supply constraints.

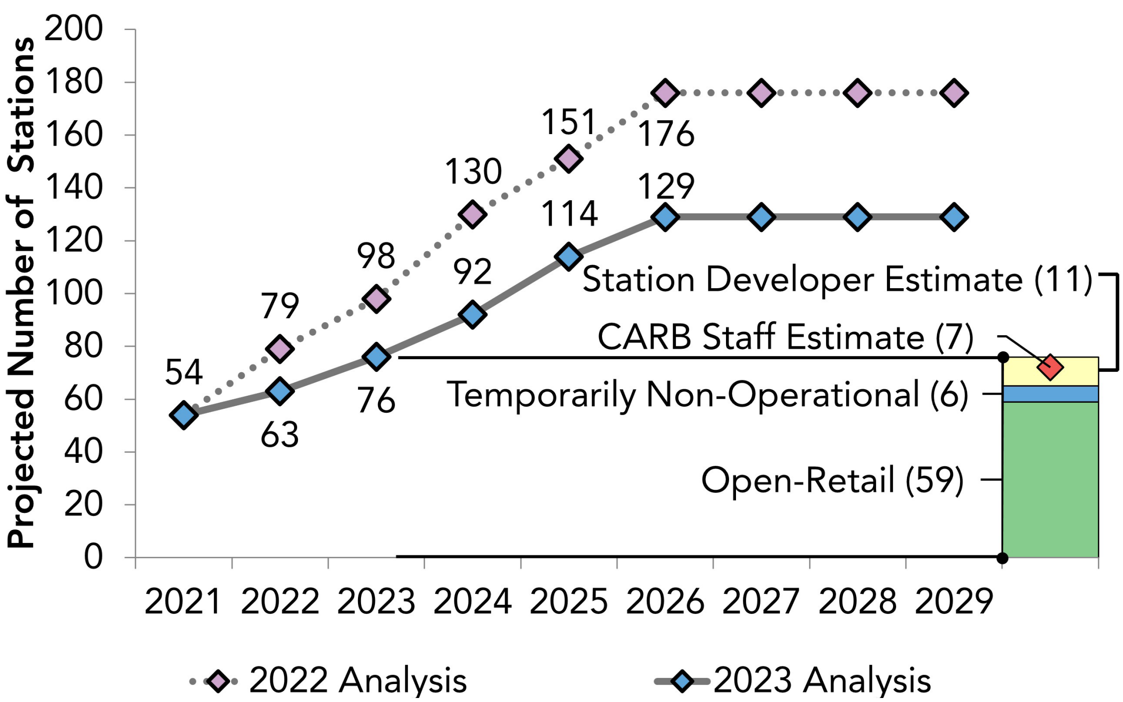
6 This map does not show real-time available status. See Figure 10 for further information regarding stations that have achieved Open-Retail status but may be temporarily unavailable. Real-time status is available to drivers via the Station Operational Status System (SOSS) maintained by the Hydrogen Fuel Cell Partnership and accessible at the website *m.h2fcp.org*.

Five new stations have opened since the publication of the 2022 *Annual Evaluation*, all of which are located in southern California: Anaheim-Euclid, Burbank-Hollywood, Pasadena-Allen, San Diego, and Seal Beach. The locations of these and all other open stations are shown in Figure ES 1. The newly opened stations add over 5,900 kg/day of fueling capacity across Southern California. Many of these stations build on existing station coverage in their local regions, increasing the number of available fueling options for local FCEV drivers. The San Diego station also plays an important role in establishing the first hydrogen fueling station within the urban core of this regional market and providing needed redundancy of fueling options for FCEV drivers in the region.

Finding 2: Hydrogen station development timelines remain a significant barrier to network growth rate and contribute to a delay in network growth projections of one to two years

Hydrogen fueling station development in the past year has continued to be slower than previously projected. During the *2022 Annual Evaluation*, station developer feedback indicated as many as 79 stations could be Open-Retail or Temporarily Non-Operational by the end of 2022. CARB staff estimates based on requests for Hydrogen Station Equipment Performance (HyStEP[7]) testing at the time indicated up to 70 such stations could be available by the end of 2022. In reality, only 63 stations were open by the end of 2022. Revised estimates from station developers and CARB staff analysis now point to a full year delay in the short term. Station developers expect 76 stations by the end of 2023, while CARB staff analysis estimates up to 72 stations by the end of this year. Station developers also appear to anticipate this delay in schedules to continue through 2024, as shown in Figure ES 2.

Figure ES 2: Comparison of Statewide Funded Station Projections Between the 2022 and 2023 Annual Evaluations



CARB staff have had several conversations with station developers over the past year regarding

7 The HyStEP program administered by CARB staff evaluates the ability of dispensers at newly constructed hydrogen stations to conform to industry-adopted fueling protocols before the station is deemed fit for retail hydrogen sales. CARB staff operate the trailer-mounted HyStEP device to complete this testing, which typically takes about two days to complete. This is followed by data evaluation and review in coordination with public and private partners.

station development timelines. As in prior reporting, securing site access, permitting timelines, utility connection timelines, and other site-specific issues appear to remain barriers to rapidly deploying hydrogen fueling stations. In addition, station developers increasingly report difficulty with securing skilled and affordable contractors, longer commissioning processes to ensure properly functioning station equipment, and other financial and logistical concerns affecting station build times. Some of these issues may be due to the currently small scale of the hydrogen refueling industry, while others appear due to broader economic concerns, such as high inflation. With respect to permitting, Senate Bill 1291 (SB 1291; Archuleta, Chapter 373, Statutes of 2022) sets limits on the time to complete permitting review for hydrogen fueling stations [15]. CARB staff are aware of individual cases where this statute has helped station permitting progress, but it does not appear to be universally implemented in all jurisdictions yet.

The recent cancellation of Shell's planned hydrogen station development also contributes to a long-term two-year delay in planned network development and a significant decrease in the total number of planned hydrogen fueling stations. One year ago, station developer projections indicated as many as 130 stations could be open by the end of 2024; current projections now point to 129 stations no sooner than 2026. The total number of station projects tracked by CARB and CEC has also decreased from 176 to 129. Some of this difference can be recovered when the CEC is able to re-direct the funds from the Shell grant to a new awardee(s), but the timing and number of stations that will result from this process is currently unknown.

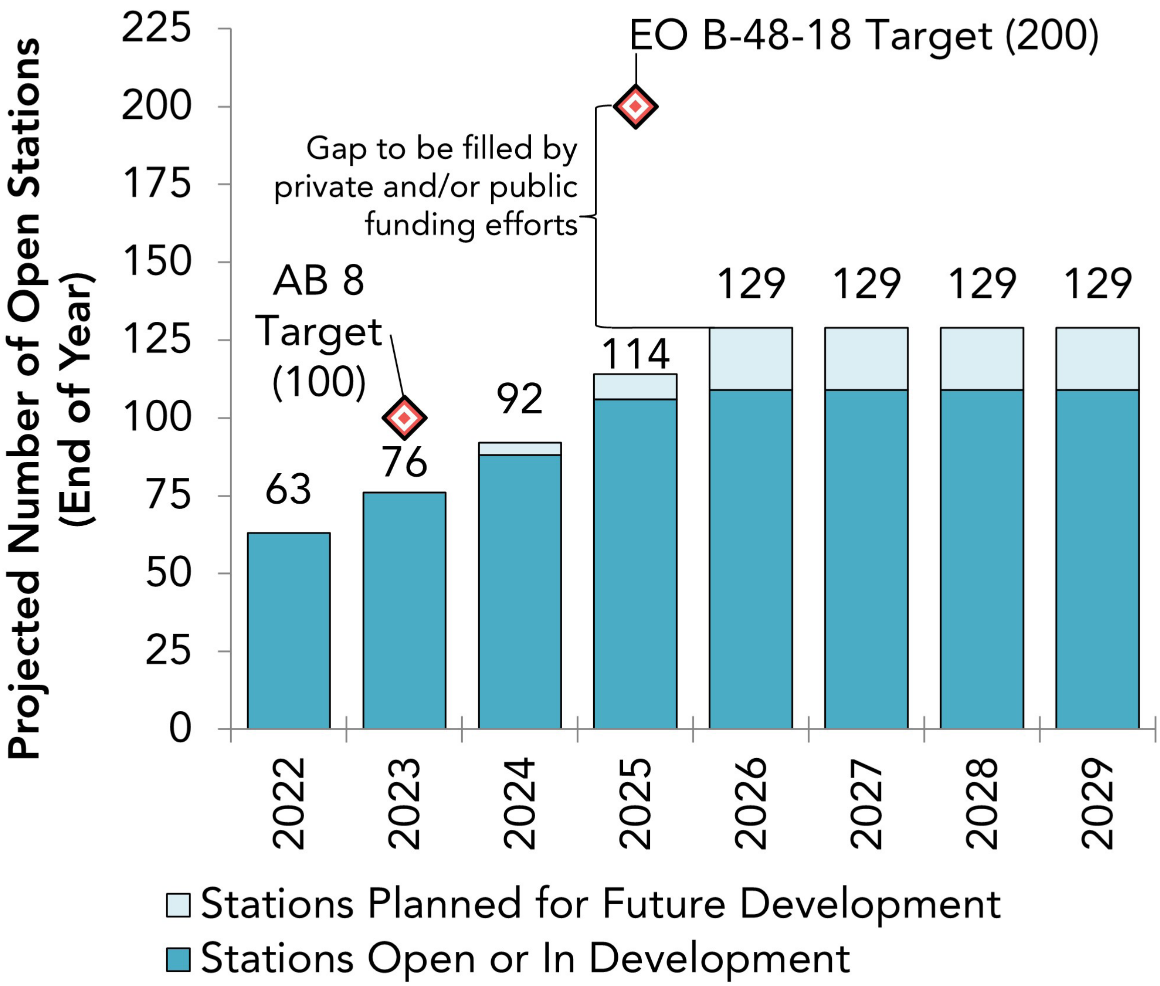
At the same time, the CEC has received notice that some prior funded stations in grants for developers other than Shell are no longer viable and will not be replaced with alternate locations. This includes the Chino and Laguna Beach station locations that were previously proposed. The LCFS program has also received notice of application withdrawal for three stations that had not yet been proposed as locations in CEC grant awards (Glendale-Broadway, Long Beach-Willow, and Northridge). In addition, the station at UC Irvine, which has been a part of California's retail hydrogen station network since 2015 (and was a technology demonstration station for many years before that), is now expected to close at the end of 2023 with no replacement currently planned.

The new count of 129 total station projects includes some new additions to the set of station projects tracked by CARB and CEC. On April 12, 2023, the CEC released its Notice of Proposed Awards for its hydrogen fueling station grant funding opportunity GFO-22-607 [16]. This includes awards for four light-duty hydrogen fueling stations (specifically targeting potential hydrogen fueling markets that were under- or unaddressed by previous station funding) and two multi-use hydrogen fueling stations intended to serve light-, medium-, and heavy-duty vehicles at the same location. Station developers still anticipate that all projects, including the newly awarded stations, will be complete by the end of 2026.

Finding 3: 2025 is the earliest that California's 100th hydrogen fueling station will open and there is currently no definitive, established path to a 200-station goal

With a full year shift in near-term projections of hydrogen station network growth, it is now clear that the 100th hydrogen fueling station in California will not open in 2023[8]. As shown in Figure ES 3, a gap of at least 24 stations is expected between the most recent network growth projections for 2023 and the AB 8 target of 100 hydrogen fueling stations. Station developer projections for network growth in 2024 through 2026 remain particularly aggressive, indicating an expectation to have as many as 92 stations open by the end of 2024. The projected rate of growth for 2024 would be on par with the fastest development seen to date in California's experience, and the projected growth in 2025 would be almost 40 percent faster. In addition, some of the challenges currently faced by station developers may require substantial or fundamental changes to the industry that may take significant time to resolve. These constraints, coupled with past experience, suggest that achieving the 92 open station estimate by the end of 2024 is not likely. Even reaching 100 open stations by the end of 2025 may not be achievable if recent challenges persist.

Figure ES 3: Projected Station Deployment Compared to AB 8 and EO B-48-18 Goals



8 100 or more stations by 2023 is often used as a metric for hydrogen fueling stations, given that the provisions of AB 8 sunset at the end of 2023 and the legislation requires co-funding of at least 100 hydrogen fueling stations. The CEC awarded funding to more than 100 hydrogen fueling stations years before the sunset date of AB 8. As has been discussed in this and prior annual reports, station development timelines have significant uncertainty outside of the timeline for awarding co-funding to station projects.

As shown in Figure ES 3, a gap also remains to achieving the target of 200 hydrogen fueling stations co-funded through private and public efforts by 2025 as directed by EO B-48-18[9]. Some of this gap may be covered by re-direction of the funds from Shell's grant award. As this report was developed, AB 126 was passed by the legislature and signed by Governor Newsom. AB 126 re-authorizes the Clean Transportation Program and extends hydrogen station funding that may also help fill the gap to 200 stations. At the same time, AB 126 expands hydrogen station funding to include "all types available", which has been interpreted to include light-, medium-, and heavy-duty hydrogen fueling stations. Further funding allocation decisions in the Clean Transportation Program will play a role in how soon the 200-station goal is reached. In addition, on October 13, 2023, the Biden-Harris administration announced awards for funding under the Regional Clean Hydrogen Hub program. California's Alliance for Renewable Clean Hydrogen Energy Systems (ARCHES) proposal for up to $1.2 billion in funding was chosen for award through this program [17]. While California's ARCHES proposal focuses on heavy-duty hydrogen fueling infrastructure for federal funding, the ARCHES project is envisioned to enable hydrogen across transportation sectors and may additionally present opportunities to finance the development of light-duty hydrogen fueling stations.

Achieving the 200-station goal also currently appears to be much more reliant on industry-driven and funded development than before. At the same time, recent feedback from industry members indicates that the economics of building and operating a hydrogen station have become more challenging. Public co-funding or other new solutions to support the industry may therefore be critical to maintain the progress to date while broader economic challenges resolve. As has been true so far of California's hydrogen fueling network development, the path forward to achieving the 200-station goal will likely require a combination of public and private efforts, potentially including co-funding and other mechanisms.

CARB and the CEC are aware that multiple private companies have made statements in the past few years stating their intent to develop hydrogen fueling stations in California. However, these public statements have typically not included important details, such as the number of intended stations to be built, the daily fueling capacities of the stations, or their locations. For example, one of the most recent of these announcements was made by Chevron and Iwatani, who have agreed to partner on the development of up to 30 hydrogen fueling stations in California with the intent to open these stations by 2026[10] [18]. From follow-up conversations with Chevron, CARB is aware that as many as nine of these stations are working through the final steps of site selection and a few are moving into the beginning of construction. Because no further details are available, this report does not include these stations in analysis though they may ultimately help close the gap to 200 stations.

Finding 4: New hydrogen station locations proposed in the past year will enhance network coverage in and near disadvantaged communities

In addition to the six new hydrogen station locations announced for award in GFO-22-607, a new set of station locations in GFO-19-602 (the CEC's prior, multi-year grant solicitation that allows developers to identify station locations in successive batches) have been announced. On May 12, 2023, the CEC released the fourth revised Notice of Proposed Award for GFO-19-602, which updated the list of proposed hydrogen station locations for awardee FirstElement Fuel [19]. All of these stations are included in the total 129 tracked station projects, but collectively represent 12 newly proposed specific addresses that were unknown at the same time last year. Especially for the stations awarded in GFO-22-607, these new station locations will bring hydrogen fueling coverage

9 EO B-48-18 established direction for California government agencies to work toward specific ZEV deployment and infrastructure development goals. Among other items, EO B-48-18 established a target of 5 million ZEVs on the road by 2030, the construction and installation of 200 hydrogen fueling stations, and the construction and installation of 250,000 chargers, including 10,000 direct current fast chargers, by 2025. The full text of EO B-48-18 by visiting the following link: *Link to EO B-48-18*

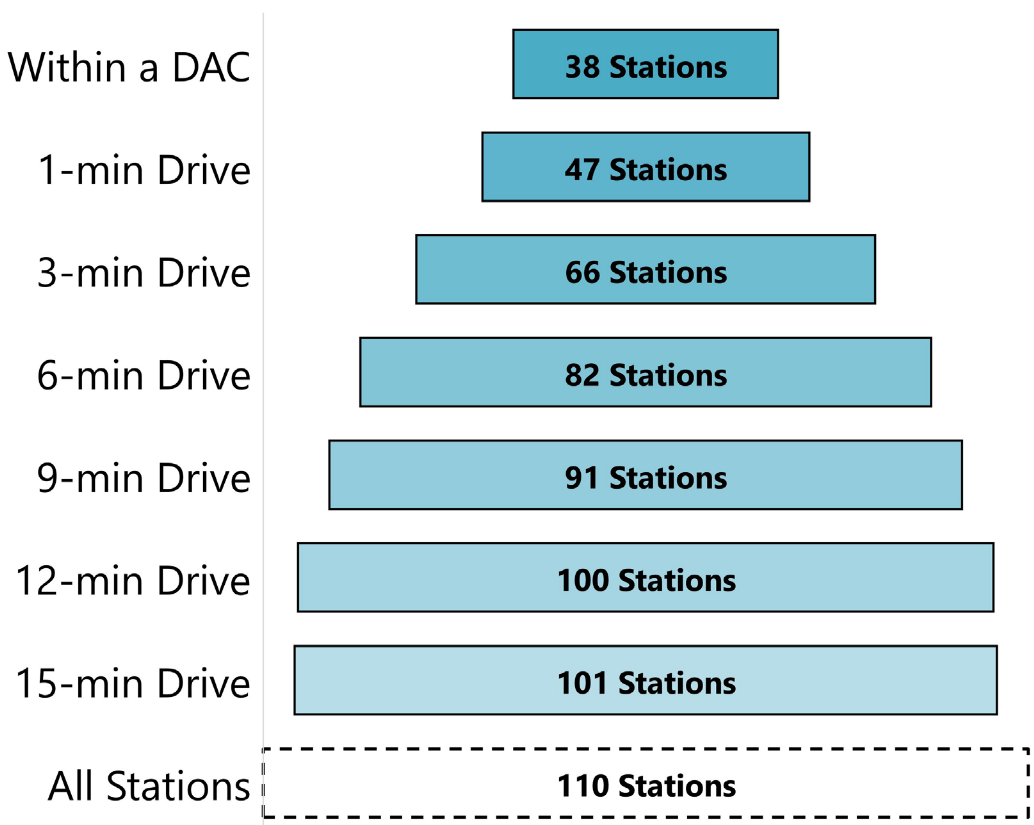
10 The announcement also mentions a combination of light-duty and heavy-duty fueling but does not specify how many of the stations are intended to serve each of these markets.

and capacity to new markets that have not been the target of previous hydrogen station grant awards.

Many of these new locations expand the network's coverage specifically in and near disadvantaged communities, including in the San Joaquin Valley and Inland Desert regions. As Figure ES 4 shows, 38 known station locations are now located directly within a disadvantaged community. In addition, the newly proposed locations maintain a high proportion of known station locations within a 15-minute drive of a disadvantaged community (94 percent of known station locations are within this limit of network coverage) and provides coverage to a large portion of California's disadvantaged community population (with 69 percent of this population within a 15-minute drive of a station).

The results of GFO-22-607 clearly helped bring coverage and capacity to new markets, and specifically to new markets including disadvantaged communities identified in the 2022 Annual Evaluation's analysis. While this progress is noteworthy, significant work to continue expanding coverage and capacity for these communities is still needed. Because some previously proposed locations will no longer move forward, some of these communities (especially in the Greater Los Angeles region) have lost planned coverage in the past year. And even though many disadvantaged and rural communities gained future coverage through these newly identified locations, the needs in many other communities remain unaddressed.

Figure ES 4: Hydrogen Station Proximity to Disadvantaged Communities for 110 of 129 Station Projects with Known Addresses



Finding 5: Needs for expanded network coverage continue to span regions and communities across the state

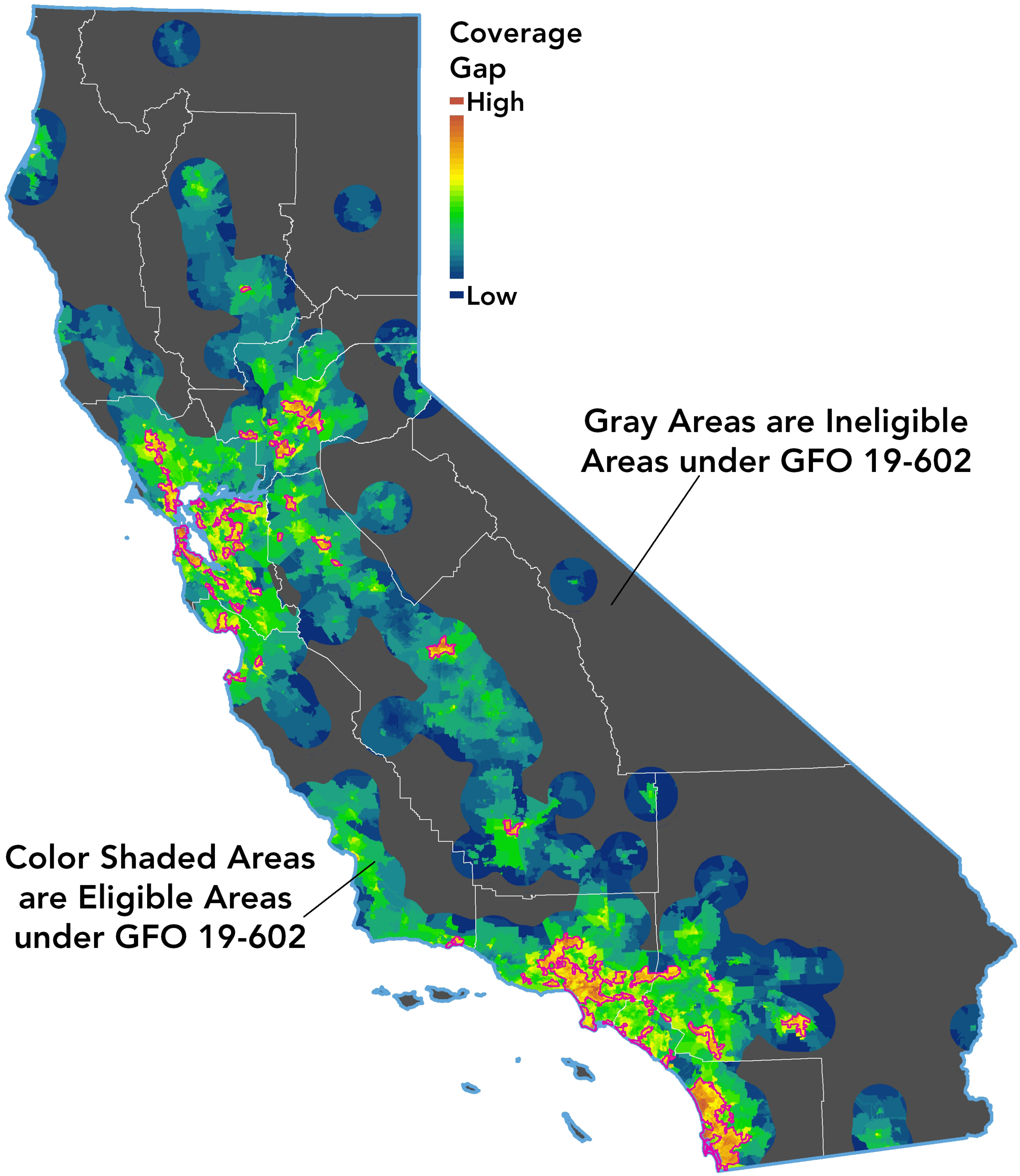
Some of the newly announced station locations will bring hydrogen station network coverage to communities that have not previously had station development planned within or near them. This is especially true for the multiple new stations now planned for development in the San Joaquin Valley. The remaining new station locations fill in some gaps or enhance existing and planned coverage in the main markets that have seen the most hydrogen station network planning and development to date. These are mostly concentrated in the Greater Los Angeles, Orange County, Sacramento, San Francisco Bay Area, and San Diego regions.

When accounting for the newly announced plans for hydrogen station locations and recent project cancellations, much of the need for new or enhanced coverage remains as previously reported and shown in Figure ES 5. Expanding coverage is still required in the markets that have been the focus of development to date, and new market development continues to be a priority across the state. Although the San Joaquin Valley now has multiple stations planned for development, many of the priority areas[11] identified in the *2022 Annual Evaluation* remain unaddressed. This is also true of the priority areas in the Inland Deserts region of southern California, especially around Palm Springs and in Riverside and San Bernardino counties. Previously identified priority areas along the Central Coast and in Chico also remain unaddressed by any of the newly announced hydrogen station plans.

The CEC's GFO-22-607 was successful in bringing hydrogen station development to new markets and particularly within and near disadvantaged communities. Station developers have shared with CARB staff that the location requirements for GFO-22-607 did not present a barrier to developing their funding applications. In the case that a new grant solicitation is required to award the returned Shell grant funds, the CEC may have an opportunity to further expand the state's hydrogen fueling network to new markets by adopting a similar strategy for location requirements.

11 A priority area is a location with a large imbalance between local hydrogen fueling coverage and the local potential market for hydrogen fueling. The evaluation is relative, comparing markets across the state to one another and emphasizing the gap between the potential FCEV fueling market and hydrogen fueling supply, rather than focusing solely on the magnitude of the potential hydrogen fueling market.

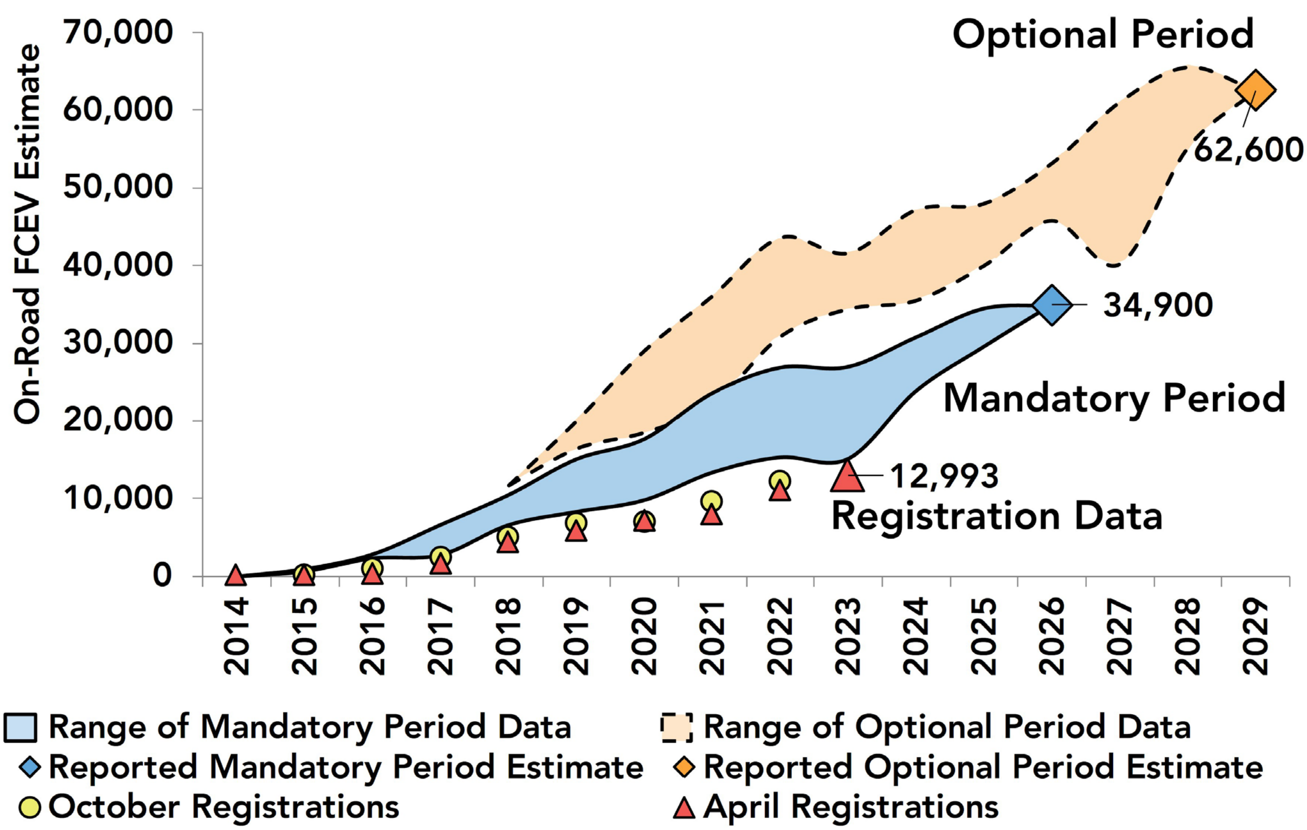
Figure ES 5: Coverage Gap Analysis to Inform Future Station Development



Finding 6: Auto manufacturer projections for future FCEV sales reflect the recent shifts in station development timelines

Reporting in prior *Annual Evaluation*s has demonstrated and discussed the close relationship between auto manufacturers' estimates for future FCEV sales and the pace of hydrogen station network development. Typically, as station development timelines extend beyond their original projections, auto manufacturers similarly indicate later growth in FCEV sales than previously reported through their responses to annual surveys of future ZEV sales projections [20, 21]. This correlation continues with the 2023 annual auto manufacturer survey responses.

Figure ES 6: Current and Projected On-Road FCEV Populations and Comparison to Previously Collected and Reported Projections



As shown in Figure ES 6, projections for on-road FCEVs informed by the CARB annual survey process show that auto manufacturers anticipate a one-year delay in near- and long-term FCEV sales compared to prior projections. The updated projection for on-road FCEVs in 2029 is 62,600 vehicles, which is nearly the same as the previously reported estimate of 65,500 on-road FCEVs in 2028. The current projection of 34,900 on-road FCEVs in 2026 is similarly nearly the same as the previously reported estimate of 34,500 on-road FCEVs in 2025. The average rate of future FCEV sales reported in the 2023 annual survey is also lower than the prior two annual surveys (but still higher than any survey prior to 2021).

The actual on-road population of FCEVs in California has continued to grow through the last year. Based on registration data from the California Department of Motor Vehicles, there were 12,993 FCEVs with an active registration status in California as of April 2023. However, these data also demonstrate a recent slowing of registrations, with only 1,859 additional FCEVs registered between April 2022 and April 2023, compared to 3,141 additional FCEV registrations in the period April 2021-April 2022.

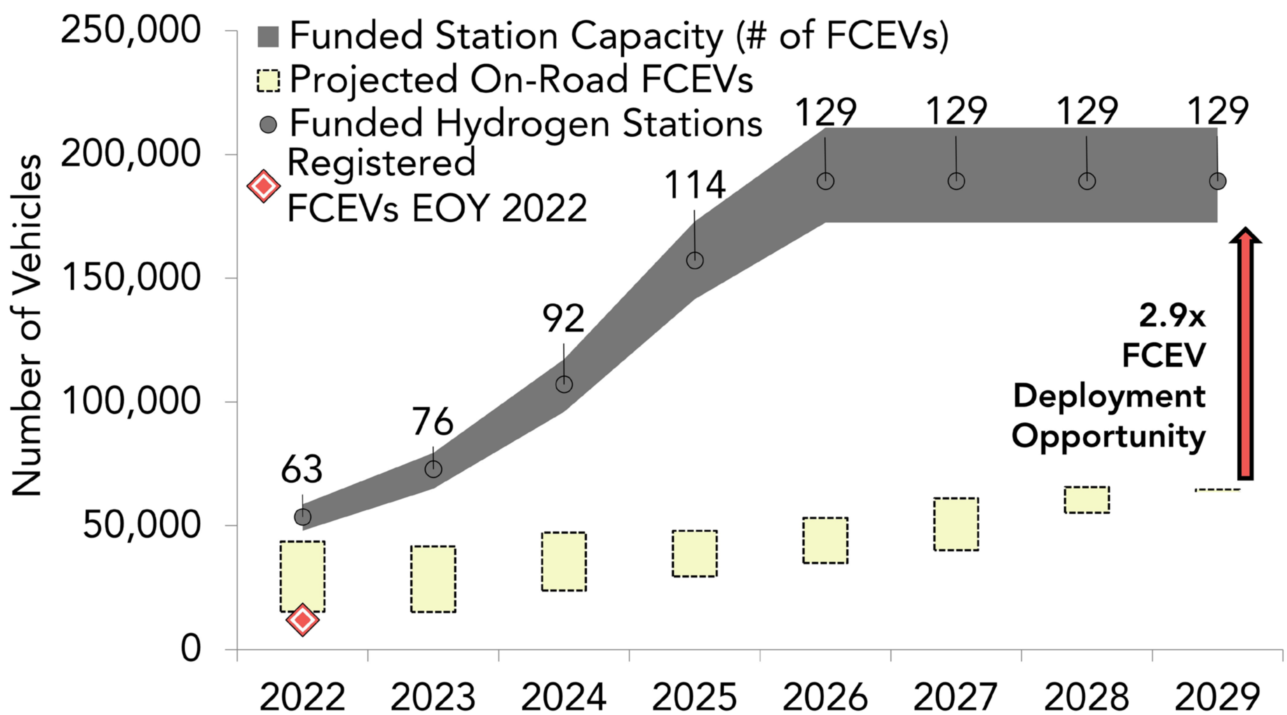
Industry-reported sales data, shared by the Hydrogen Fuel Cell Partnership, also demonstrate a recent slowing in FCEV sales [22]. In particular, sales in Q3 2022 decreased sharply from prior quarters, to only 153 FCEVs. Sales have since mostly recovered. After slow sales in Q3 2022, sales in Q4 2022 and Q1 2023 were around 720 FCEVs each, which is better than two-thirds of all other quarterly sales since 2015. Sales in Q2 2023 further improved to 1,076, making it the best-selling Q2 and among the top 5 percent of all quarterly sales to date. In total, industry reporting estimates that 16,780 FCEVs have been sold or leased in the United States through the end of June 2023[12].

12 The vast majority of these sales are in California and may differ from registrations due to differences in the nature and timing of the data. Industry sales data may also include vehicles that owners register as planned non-operation, which CARB does not include in its estimates of vehicles with active registration status. CARB has also confirmed that Hydrogen Fuel Cell Partnership data likely do not adjust fully for vehicle attrition.

Finding 7: Projected total statewide network capacity will outpace hydrogen fueling demand through the end of the decade, though station reliability plays a significant role in assessing sufficient fueling capacity relative to demand

Ever since the announcement of more than 100 new hydrogen fueling station grant awards through the multi-year solicitation GFO-19-602, California's hydrogen fueling network growth has been projected to significantly outpace auto manufacturers' planned FCEV sales in the state. This remains true when accounting for the several changes that have recently occurred in the planned hydrogen fueling network. Once all 129 stations are built and operating by the end of the decade, the statewide rated fueling capacity (which does not account for station downtime), will be sufficient for 2.9 times as many FCEVs as are expected on California's roads in 2029, based on the most recent annual auto manufacturer survey (see Figure ES 7). The rate of hydrogen station network growth is projected to ensure that sufficient fueling capacity will be available at a statewide evaluation level for all future years analyzed.

Figure ES 7: Projected Hydrogen Demand and Fueling Capacity



Factors beyond the rated statewide fueling capacity may alter assessment of the balance between future hydrogen fuel demand and available fueling capacity. First, California's hydrogen station network has experienced significant reductions in station uptime over the past few years. Station downtime has been due to a variety of causes, including lack of sufficient hydrogen supply, disruptions in hydrogen delivery, equipment failure, limited availability of replacement parts, and other issues. Although there have been highs and lows in the past few years, recent estimates of overall station availability (based on quarterly averages of daily station availability data provided by the Hydrogen Fuel Cell Partnership's Station Operational Status System) are around 60 percent. This average only includes stations that are in the Open-Retail status and does not include the downtime of stations in the Temporarily Non-Operation status.

Maintaining a high rate of station availability is a key aspect in ensuring more Californians can choose to drive a FCEV. Without reliable fueling opportunities, drivers may not have sufficient reassurance that a FCEV will meet all of their daily needs. In addition, low reliability may impact government planning for support programs. If station reliability remains low, a larger number of stations may be required in the network to maintain sufficient fueling service and capacity for the growing FCEV fleet. A need for more stations translates to greater capital investment, which may need to be funded through a mixture of public and private investments. In addition, due to the structure of the LCFS, low reliability also directly implies less financial support for station operations and maintenance. As station operators have reported, reductions in LCFS revenue directly impact the operating budget of stations, and reduced reliability directly reduces LFCS credit generation and revenue. As California's hydrogen fueling station network continues to operate and expand, state government agencies that provide support will need to closely monitor and assess station reliability to ensure that support programs are sufficient for the needs of the developing network and helping to advance the industry toward a financially self-sufficient fueling network.

Assuming an average 60 percent station availability continues into the future[13], statewide fueling capacity will be sufficient for 1.8 times the projected number of FCEVs on the road in 2029. Total statewide capacity should also be sufficient for all on-road FCEVs in the intervening years, though the margin of excess fuel availability could be slim through the remainder of 2023 and into early 2024. These small differences between projected demand and fueling capacity may result in near-term difficulties for FCEV drivers attempting to find available hydrogen fuel and may have long-term implications that limit the number of drivers who feel they can reasonably choose a FCEV over other vehicle options.

In addition, evaluation of capacity at the statewide level may mask more localized restrictions in capacity. For example, the San Diego area has previously been reported to be capacity constrained for several years even though statewide capacity has exceeded demand, because only one hydrogen fueling station had been available in the region for several years. The second station in the region has recently opened, which should alleviate near-term capacity constraints and enable further FCEV sales in the area.

Localized evaluation of planned fueling capacity reveals gaps in some regions and cities. The Greater Los Angeles and Orange County regions have some of the largest capacity currently available and planned, but there are locations near Pomona, West Hollywood, downtown Los Angeles, San Fernando, Santa Ana, and Lake Forest that will still need the largest capacity expansion (up to 1,300 kg/day) in 2029. Parts of San Diego County (especially between El Cajon and Chula Vista), San Francisco, and near Redwood City also show similar localized capacity needs. There are also smaller but notable capacity needs remaining around Santa Cruz, in the Sacramento region, in the San Joaquin Valley, and in the eastern San Francisco Bay Area. These gaps, along with the coverage gaps identified in Finding 5, will need to be addressed either through the remaining station locations to be identified in GFO-19-602 or through any potential future private or public funding efforts. In addition, if auto manufacturers are able to accelerate FCEV sales beyond current projections, then the capacity gaps identified so far (and others) will only become larger without building additional hydrogen fueling stations.

13 This scenario is for illustrative purposes only and is not an ideal or desired condition. CARB staff are actively monitoring station reliability along with public and private colleagues. In addition, station operators have shared several paths that they are currently pursuing to ensure that station reliability improves in the coming years, with strategies ranging from equipment improvements to changes in operational strategies and even workforce development.

Finding 8: Hydrogen production continues to leverage renewable assets at rates higher than required by SB 1505 but may be challenged by recent economic factors

California's light-duty hydrogen fueling stations have historically dispensed hydrogen leveraging more renewable assets than required by Senate Bill 1505[14] (SB 1505; Lowenthal, Chapter 877, Statutes of 2006) [23]. This trend appears to have continued into 2023, though the rate of implementing renewable assets has decreased over the past two years. The highest level of renewable implementation was reported in the *2021 Annual Evaluation*, when LCFS program data showed 90 percent of the hydrogen fuel sold in California in 2020 leveraged renewable assets [21]. Data for 2021 showed this high renewable implementation rate fell significantly to 59 percent. The most recent LCFS program data show a continued, though smaller, decline to 53 percent for all of 2022, with the first quarter of 2023 showing a similar 49 percent renewable implementation.

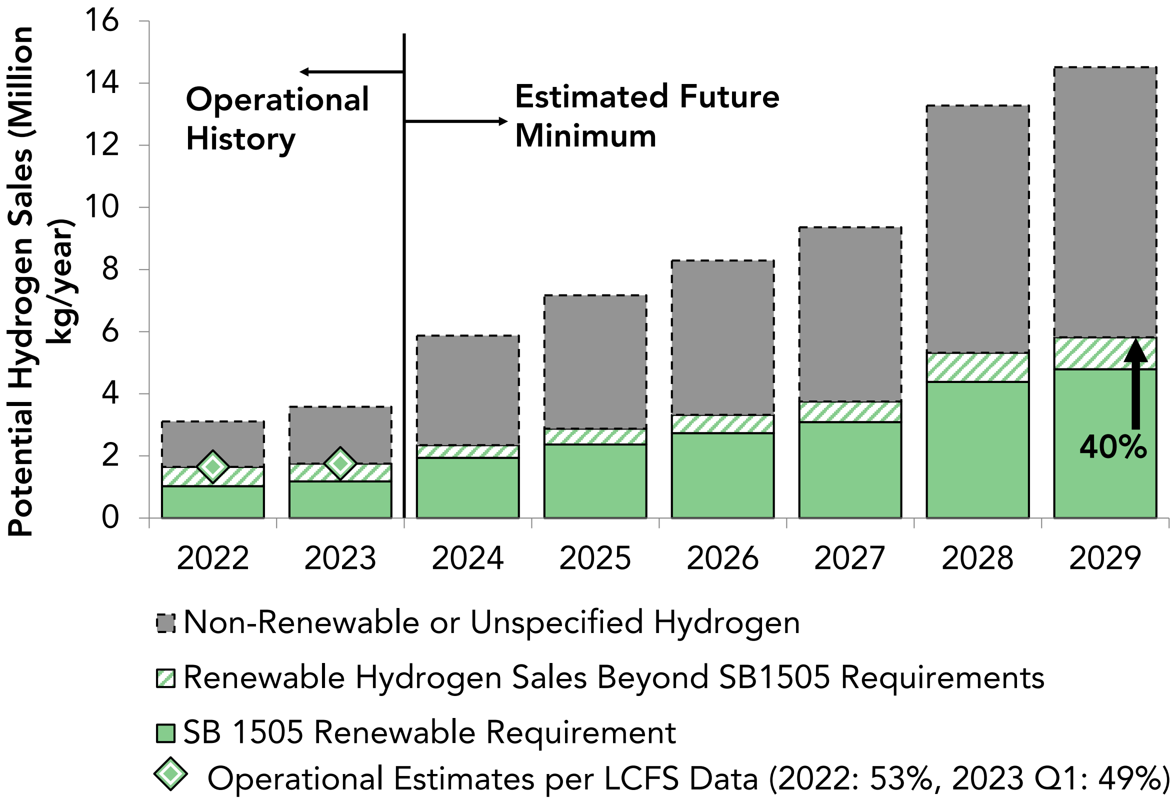
While renewable implementation has decreased over time, it has remained above the minimum requirements of SB 1505, which requires that 33 percent of the hydrogen sold at publicly co-funded stations in California leverage renewable assets. This requirement is specific to publicly co-funded stations until the total hydrogen fuel sales in any 12-month period exceed 3,500 metric tons, at which point the requirement will apply to hydrogen sold at all stations, regardless of public funding status. California's hydrogen fueling stations to date have been able to exceed this minimum largely due to the requirements of the CEC's grant funding programs and the Hydrogen Refueling Infrastructure (HRI) credit generating provisions of the LCFS program. Both programs have maintained renewable implementation requirements that meet or exceed the 33 percent minimum specified in SB 1505. The most recent requirement for both programs is 40 percent renewable implementation.

Figure ES 8 shows the projected volumes of sales of renewably sourced and non-renewable hydrogen through 2029. These estimates account for the various renewable energy requirements of the grant funding contracts that co-funded the stations and the requirements of the HRI program for participating stations. All stations not yet built are assumed to implement renewable assets at the minimum rate of 40 percent required by current support programs.

Over the past year, station operators have shared that multiple economic factors have negatively impacted the operating finances for their stations. These have included higher energy costs spurred by Russia's actions stemming from the war in Ukraine [24], recent decreases in the traded market value of LCFS credits, and continued supply chain delays that first began with the COVID-19 pandemic. These increases in costs have resulted in increased prices at the pump for hydrogen customers and may also partially explain the reduction in renewable hydrogen over the past two years. Procurement of renewable hydrogen (or procurement of the indirect renewable assets that can be applied to hydrogen fuel) costs more than procurement of conventional fossil-derived hydrogen. The increased economic pressures shared by the station developers may have therefore been a factor in the recent decreased volume of renewable hydrogen purchases by the station operators.

14 In this reporting, renewable implementation includes both renewable assets directly tied and/or dedicated to hydrogen production and indirect renewable assets, as allowed through CARB's LCFS program. These indirect renewable assets (typically associated with renewable biogas production) are not directly tied to any specific hydrogen production facility. However, the renewable assets of these operations are assigned by the hydrogen producer to the hydrogen molecules sold at California hydrogen fueling stations. This indirect accounting for renewable assets must meet strict accounting requirements in the LCFS program to ensure they are not double counted across various programs.

Figure ES 8: Evaluation of Minimum Renewable Hydrogen Content in California's Fueling Network[15]



There are additional recent trends in the LCFS program data that will need to be monitored over the coming years to understand the evolution of hydrogen fuel supply in California. While the percentage of renewable hydrogen has decreased over the past two years, the average carbon intensity of hydrogen fuel has simultaneously decreased by more than a factor of three. The decrease in average carbon intensity of California's hydrogen fuel supply is a positive development. At the same time, hydrogen production pathways that use large amounts of renewable resources also tend to have low carbon intensities. The combination of simultaneously decreasing carbon intensity and total renewable implementation in California's hydrogen supply then implies that station operators are shifting their hydrogen supply sources to tap into ever smaller volumes of renewable hydrogen that are produced through pathways with exceedingly low carbon intensities. Future support programs may need to consider ways to incentivize more expansive use of these low-carbon hydrogen production pathways to help support broader market transformation and maximize the emissions benefit of hydrogen fuel use in California.

15 Note that this analysis is a statewide estimate and does not consider the details of individual station utilization. In addition, the 53 percent renewable content reported for 2022 and 49 percent in the first quarter of 2023 are specific to light-duty vehicle fueling.

Conclusions

The Clean Transportation Program, as reauthorized through AB 8, has made significant progress over the past ten years for the development of an in-state hydrogen fueling network. California is the first state in the nation with a network of publicly available retail hydrogen fueling stations. Many technical standards, station equipment designs and advancements, business practices, and policy support mechanisms have been first tested and proven in California. California leads the nation in FCEV sales and ranks among the largest markets in the world for light-duty FCEVs and hydrogen fueling network development.

California's experience in establishing and operating a hydrogen fueling network has previously demonstrated the potential of this ZEV fuel option. At the same time, the experience has revealed many challenges and vulnerabilities in the industry, particularly in the past year. Some of the prior progress made, especially in terms of station economics, prices paid by consumers at the pump, the pace of new station development, and the rate of procuring renewable and low-carbon hydrogen for sale at retail stations, has slipped in the past year.

Developments in the past few months have significantly altered the outlook for future progress. The metric of 100 hydrogen fueling stations awarded co-funding was met well before the Clean Transportation Program's sunset date of January 1, 2024 in AB 8. Station developers had previously expected to have 100 or more stations open by the end of this year, but it is now clear that 2025 is

Courtesy of First Element, Inc.

the earliest that can be achieved. Some station developers have also more recently cited economic and political uncertainty, which may have contributed to the recent cancellation of nearly one-third (51) of the tracked station development projects. In addition, $60 million in previously allocated funding for hydrogen fueling stations has recently been removed. These developments leave California currently without a clear pathway to achieving the goal of 200 hydrogen fueling stations, though there is potential for future progress through extended funding provided by AB 126 and the newly awarded ARCHES hydrogen hub in California.

The challenges facing the hydrogen fueling network and broader FCEV sales in California are significant and must be resolved to successfully launch the industry and eventually achieve the goal of financial self-sufficiency. However, past experience within California also indicates that challenges can be met and overcome and that a well-functioning and growing network of hydrogen fueling stations does hold promise for expanding the use of this ZEV option in the state. Public and private partners have historically worked closely to launch the hydrogen fueling market in California, and that collaborative work will likely be integral to overcoming the barriers witnessed in today's operating and growing network. The following chapters in this report provide greater detail and perspective on the latest developments in the hydrogen fueling network and FCEV sales projections, leading to recommendations for potential next steps through the Clean Transportation program and parallel efforts.

Courtesy of Hydrogen Fuel Cell Partnership.

Introduction

In 2023, governments around the world continued to develop and enhance interest in, and opportunities for, hydrogen as a transportation fuel, industrial process gas, and energy resource. This has generated broad momentum for the future potential uses of hydrogen across multiple sectors of the global economy. Multiple major economies around the globe have expressed this perspective through planning documents and developing new support programs, in some cases projecting hydrogen satisfying as much as 20 percent of the future global energy need with the potential to contribute 10-20 percent of economy-wide carbon emissions reductions [25, 26, 27, 28, 29, 30, 31].

While these broad advances have been made over the past year, the light-duty hydrogen fueling industry in California has faced continued challenges that have hampered progress in network development over the past year and will continue to affect network development over the next 12 months or more. Station developers and operators are diligently working to address these challenges as best they can through multiple strategies encompassing station equipment improvements, improved business operations, improved station operational strategies, and focused development of available workforce. At the same time, CARB staff and partnering California state government agencies have been monitoring to assess whether potential public support measures can help provide solutions to these challenges. These remain active conversations among public and private stakeholders.

Recent developments may hold potential for eventual improvement, though timelines are unclear. Inflation has been reported to have recently eased [32, 33]. Energy prices (especially for natural gas that is used for the majority of hydrogen fuel production) have returned to pre-pandemic levels [34]. Federal programs that could help spur hydrogen industry development and catalyze the emergence of economies of scale are still anticipated for the following years. This includes the eventual finalization of the Clean Hydrogen Production Tax Credit rules authorized by the Inflation Reduction Act and the awarded funding of regional hydrogen Hubs authorized by the Infrastructure Investment and Jobs Act. California's application for Hydrogen Hub funding envisions substantial growth in clean, renewable hydrogen production in California to support transportation, industry, and energy markets.

This new federal support complements California's programs discussed in this report. California's Assembly Bill 8 (Perea, Chapter 401, Statutes of 2013) extended authorization for the Clean Transportation Program and Fund through the end of 2023 and established analysis and reporting requirements for CARB and the CEC with respect to light-duty hydrogen fueling and FCEV market development. Through the Clean Transportation Program, the CEC co-funds the development of several categories of clean and zero-emission transportation projects in California, focused primarily on infrastructure development. These include categories for electric charging and hydrogen fueling infrastructure for medium- and heavy-duty vehicles, charging infrastructure for light-duty vehicles, clean fuel production including hydrogen, and workforce development. In particular, AB 8 authorizes the CEC to spend up to 20 percent (up to $20 million annually) of each year's allocation in the Clean Transportation Fund to co-fund the development of light-duty hydrogen fueling stations.

Each year, CARB is required to report to the CEC on progress in the development of the hydrogen fueling network, sales of FCEVs, future projections for station development and FCEV sales, recommendations for locations where new station development is most needed, and recommended technical requirements for future station co-funding. This *Annual Evaluation* is the tenth such report to date. The CEC and CARB are also required to publish a *Joint Agency Staff Report* each year that provides an end-of-year update on hydrogen network development and FCEV sales while also providing further detail on the cost and timing of building hydrogen fueling stations funded through the Clean Transportation Program and other related topics.

The *2023 Annual Evaluation* is broken into six chapters (and an executive summary with a discussion of major findings in the report):

1. This chapter broadly discusses the current status of station projects in California's hydrogen fueling network and provides context regarding the market conditions and other factors that have played a role in the past year. This information is foundational to analyses presented throughout this report. This chapter also provides an update on participation in the LCFS HRI program.
2. The next chapter presents detailed information on recent progress and projections in FCEV registrations and sales, including spatial analysis of markets across California.
3. The third chapter provides an analysis of hydrogen station locations, along with development status and spatial analysis of recent trends and future projections of network development. The chapter also presents analysis of the coverage metric, which is used to identify locations where new stations are needed to meet potential localized growth in FCEV market demand.
4. The fourth chapter assesses the available fueling capacity of the network, especially with respect to the hydrogen demand that is implied by projected FCEV sales rates. Localized needs for new station capacity are also analyzed and presented in this chapter, along with assessment of renewable energy implementation in the production of hydrogen sold for transportation fuel in California.
5. The fifth chapter provides updates on technical standards that are recommended as requirements for the development of future co-funded hydrogen fueling stations. The chapter also discusses related programs and efforts that help ensure stations continue to operate according to industry-adopted standards.
6. The final chapter provides a set of conclusions and recommendations for California state government efforts to help support the ongoing development of the light-duty hydrogen fueling network. These recommendations are made with the goal of helping to ensure that hydrogen network development can ultimately reach economies of scale and become a financially self-sufficient industry.

Station Network Progress

Growth in California's hydrogen fueling network has slowed substantially in the past year. Although station developers had previously indicated the potential for as many as 19 new stations to achieve Open-Retail status between June and December 2022[16], far fewer stations achieved that milestone. Only 3 of the 19 projected stations opened by the end of 2022, and an additional 2 stations have opened as of the time of this report's writing. Moreover, station developers now project that this slower pace of network development will likely continue through the remainder of 2023, with current projections for the number of open stations at the end of 2023 now closely matching the prior estimate for 2022, at 76 total stations. This may still represent a high estimate, as CARB staff estimate 72 total stations by the end of 2023, given information shared through the HyStEP station testing process. In addition, due to a combination of slower than expected station development time and the cancellation of several station projects, the long-term network buildout will now be slower than previous estimates by as much as two years and the overall size of the currently funded and planned network is smaller, at 129 stations compared to 176 stations reported at this time last year.

Station developers have shared that multiple factors have posed challenges this past year to both opening new stations and maintaining consistent operations at the currently open stations. Some of these factors are financial in nature, which ultimately may affect investment timing to procure station equipment, begin construction, or finalize commissioning of a station to begin retail fuel sales. Station developers have shared that these financial considerations include rising costs for construction, general cost increases due to inflation, higher energy costs leading to higher costs to procure hydrogen fuel, and recent reductions in the traded value of LCFS credits. Other factors shared by the station developers include challenges with equipment (both achieving expected performance when newly commissioned or maintaining reliable and expected performance during operations), limited availability of skilled workforce, and continued difficulties with site acquisition and the permitting process[17].

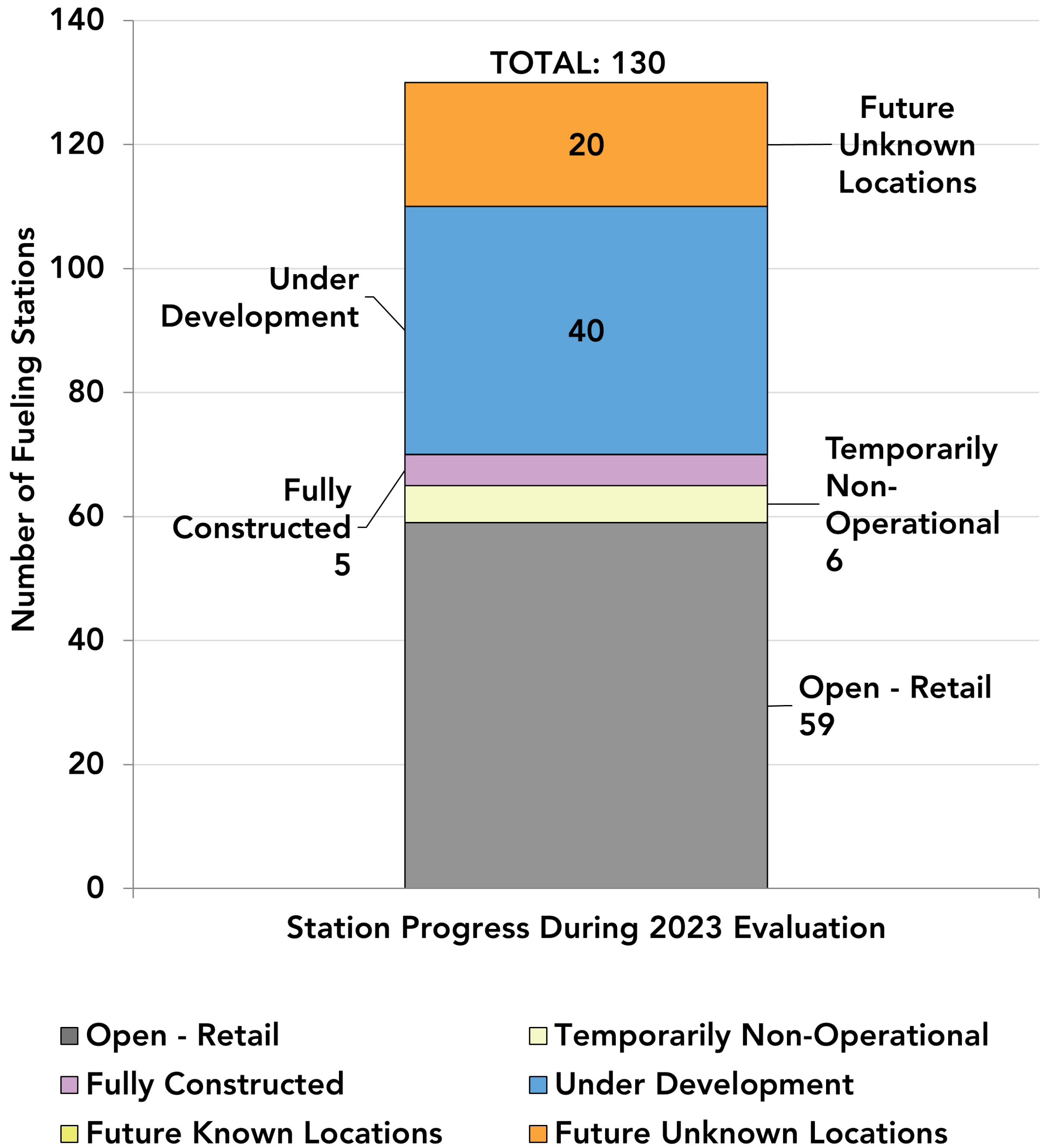
Station developers currently project that the pace of projects under development should largely return to prior expectations by 2025, even though the total number of stations in the network will be smaller due to project cancellations. These projections are likely to evolve over time as they have in the past, given that projections further into the future are more difficult to make with a high degree of accuracy. Some of the longer-term projections may therefore change as station operators continually revise their evaluations of current and future station development timelines.

The status of all known station development projects is shown in Figure 1. At the time of writing this report, California's hydrogen fueling network included 59 stations in Open-Retail status. Open-Retail stations are available to FCEV drivers to fuel their vehicles in a typical retail setting similar to the gasoline station experience. While these stations may experience downtime due to various causes, the events are limited in their duration. An additional six stations are currently considered Temporarily Non-Operational. These stations have previously achieved Open-Retail status but have experienced various operational difficulties that have led to extended periods of downtime. While these stations have been unavailable for longer periods of time, the station operators have remained active in developing solutions for the stations' challenges and they are expected to return to Open-Retail status at some point in the future.

16 CARB staff estimates made at the same time, based on HyStEP testing schedules and conversations with on-site construction development staff, indicated 10 new stations in the same timeframe.

17 Senate Bill 1291 (Archuleta, Chapter 373, Statutes of 2022) requires a streamlined administrative approval process for the permitting of new hydrogen fueling stations by limiting review to health and safety requirements. This streamlined review process appears to have been applied in at least some recent station permit reviews, but information shared by station developers may indicate that it is not yet being applied in all jurisdictions.

Figure 1: Hydrogen Fueling Station Network Status as of August 10, 2023



The remaining stations in the network are in some phase of active development or are planned for future development through existing grant contract agreements. A total of 130[18] station projects are currently being tracked by CARB and other partners. Five stations have been fully constructed and are undergoing commissioning and other processes before opening for retail hydrogen fuel sales. A total of 40 stations are currently in some phase of active development, which spans all processes from station design and engineering through permitting and into station construction. This includes six stations with locations identified (through new grant funding award made in GFO-22-607[19]) that recently began the station development process. Finally, 20 additional station projects are expected for future development but do not yet have a location identified. These represent station grants made through the multi-year grant solicitation GFO-19-602. In GFO-19-602, station developers were asked to propose sequential batches of stations for development over multiple years. Locations for stations in a batch are not required until the previous batch has reached certain milestones. One station developer (FirstElement Fuel) has recently received approval for the locations of their second batch of stations, which are accounted for in this report. The 20 unknown locations represent the remaining stations in future batches of all awardees under GFO-19-602.

Hydrogen Sale Prices

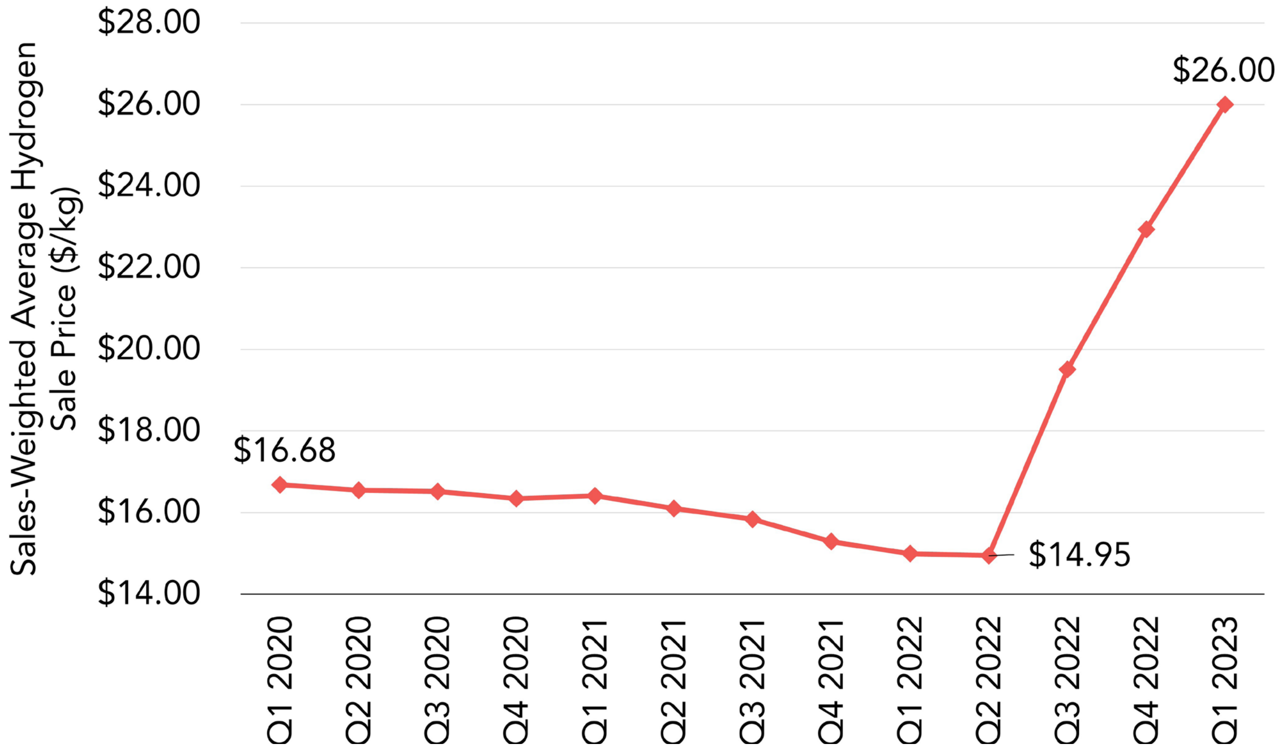
The recent challenges faced by hydrogen fueling station developers appear to be related to multiple developments beyond delays in new station construction and openings. Many of the same financial pressures (higher cost to procure hydrogen, higher construction costs, inflation, etc.) have also led station operators to decide that they need to increase the price of hydrogen sold at their stations to maintain a viable financial outlook for the continued operation of their stations.

As reported in the 2022 *Joint Agency Staff Report* and shown in Figure 2, the sales-weighted price of hydrogen sold at California stations had recently begun to decrease [35]. Between 2020 and 2022, the average sale price of hydrogen had dropped approximately 10 percent. This was largely attributed to the introduction of new hydrogen fueling stations in the network that were higher capacity and integrated newer station equipment. As more of these stations with newer designs entered the market, the average price of hydrogen sold was expected to continue to decrease. The new equipment at these stations was expected to have lower operating and maintenance costs, while the higher capacity not only enabled larger daily sales and revenue but was also expected to help reduce operational costs. Many of these stations also adopted liquid on-site storage, which has the potential to reduce on-site energy costs through more efficient pressurization and reduce delivery costs since a single delivery could provide larger amounts of hydrogen to the station than gaseous delivery options.

18 Note that the total count of 130 station projects is one more than reported elsewhere in this report because this figure provides the current snapshot in time of network status. Specifically, this count includes the station currently in Open-Retail status at UC, Irvine. This station is expected to continue operations through the end of 2023, but no path has been identified to keep the station open into 2024 and beyond. Other figures in this report show 129 total stations because they show future totals that account for this station closing at the end of 2023.

19 At the of writing this report, two of the six stations proposed for award in GFO-22-607 had been approved at a CEC Business Meeting. Phillips 66, the developer of the remaining four awarded stations, has not yet submitted for approval at a CEC Business Meeting and may be in the final stages of project planning and approval.

Figure 2: Historical Trend of Sales-Weighted Hydrogen Sale Price[20]



However, these savings have since been outweighed by the combination of increased construction, operating, and capital costs and a reduction in revenue as a result of lower credit values through the LCFS program. In late 2022 and early 2023, all three of the largest station operators — FirstElement Fuel, Iwatani, and Shell — separately significantly raised the prices of hydrogen sold at their stations, often accompanied by press releases describing their reasons for doing so [36, 37]. Stations across California are now charging more than $20 per kilogram of hydrogen, with some charging as much as $36 per kilogram of hydrogen. As Figure 2 shows, the average sale price increased to $26 per kilogram in Q1 2023. The average sale price is likely higher now, given additional price increases since Q1 2023. This increased price is a significant concern as it directly affects FCEV drivers and limits the usability of the auto manufacturer-provided fuel cards. These fuel cards have likely been a significant factor in many drivers' purchase decisions for an FCEV.

CARB staff, along with colleagues at the CEC and the Governor's Office of Business and Economic Development are actively monitoring and are maintaining open lines of communication with the station operators. Some of the factors that have recently led to higher prices are the result of systemic changes outside the control of any individual or even group of organizations (such as high natural gas prices, limited supply chains, or inflation). These factors may require broader industry- or economy-wide developments that may take some time to resolve. At the same time, recent conversations with station developers indicate that they are actively searching for and developing solutions that may help improve station finances and eventually result in lower prices paid by FCEV drivers at the pump. The CEC has previously shared that they are planning a driver experience workshop or similar event to collect FCEV drivers' perspectives, potentially to be held sometime in 2023 or 2024. Interested stakeholders are encouraged to monitor for announcements regarding this event[21].

20 Data from the 2022 Joint Agency Staff Report on AB 8 [34] and CEC

21 Interested parties may want to sign up for email alerts through the CEC's website at *https://public.govdelivery.com/accounts/CNRA/signup/31898*. Information will likely be distributed through the Clean Transportation Program email list.

Low Carbon Fuel Standard Hydrogen Refueling Infrastructure Program Update

The HRI crediting provision of the Low Carbon Fuel Standard has been viewed by station operators as an essential component of public support for maintaining hydrogen fueling station operations. The HRI provisions help ensure an additional stream of income for hydrogen fueling stations when the on-road FCEV population may still be small, thereby providing station operators increased incentive to plan for the future and build and maintain larger stations that will enable future growth of in-state FCEV sales. The provisions may also help incentivize station operators to seek lower-carbon sources of hydrogen to sell at their stations.

There are currently 67 hydrogen fueling stations approved for HRI crediting in the LCFS program (an additional 15 stations had previously been approved but have been either withdrawn or cancelled). The 67 currently approved stations have a total credited capacity of nearly 46,000 kg/day. Table 1 lists the details of all currently approved stations in the LCFS HRI program.

Table 1: Stations Approved for LCFS HRI Credit as of June 30, 2023[22]

Applicant	Address	City	Capacity (kg/day)	HRI Crediting Ends
FirstElement Fuel Inc.	14478 Ventura Boulevard	Sherman Oaks	808	12/31/2031
Shell Oil Products US	1250 University Ave.	Berkeley	513	12/31/2032
Shell Oil Products US	101 Bernal Road	San Jose	513	12/31/2032
FirstElement Fuel Inc.	2855 Winchester Boulevard	Campbell	266	3/31/2034
Shell Oil Products US	6141 Greenback Lane	Citrus Heights	513	3/31/2034
FirstElement Fuel Inc.	24505 W Dorris Avenue	Coalinga	266	3/31/2034
FirstElement Fuel Inc.	2050 wHarbor Boulevard	Costa Mesa	266	3/31/2034
FirstElement Fuel Inc.	41700 Grimmer Boulevard	Fremont	266	3/31/2034
FirstElement Fuel Inc.	391 W A Street	Hayward	266	3/31/2034
FirstElement Fuel Inc.	550 Foothill Boulevard	La Cañada Flintridge	266	3/31/2034
FirstElement Fuel Inc.	20731 Lake Forest Drive	Lake Forest	266	3/31/2034

22 Note that capacity in this table refers to the approved capacity for generating credits in the LCFS program through the HRI pathway. The HRI pathway has a cap of 1,200 kg/day credit generating potential for each station. Some stations listed in this table as 1,200 kg/day capacity may therefore have an actual dispensing capacity higher than the approved capacity shown. Refer to Appendix B for actual capacities of all stations.

Applicant	Address	City	Capacity (kg/day)	HRI Crediting Ends
FirstElement Fuel Inc.	3401 Long Beach Boulevard	Long Beach	266	3/31/2034
FirstElement Fuel Inc.	10400 Aviation Boulevard	Los Angeles	200	3/31/2034
FirstElement Fuel Inc.	5700 Hollywood Boulevard	Los Angeles	266	3/31/2034
FirstElement Fuel Inc.	8126 Lincoln Boulevard	Los Angeles	266	3/31/2034
FirstElement Fuel Inc.	570 Redwood Highway	Mill Valley	266	3/31/2034
Shell Oil Products US	3510 Fair Oaks Boulevard	Sacramento	513	3/31/2034
FirstElement Fuel Inc.	3060 Carmel Valley Road	San Diego	266	3/31/2034
Shell Oil Products US	1201 Harrison Street	San Francisco	513	3/31/2034
Shell Oil Products US	3550 Mission Street	San Francisco	513	3/31/2034
Shell Oil Products US	551 3rd Street	San Francisco	513	3/31/2034
FirstElement Fuel Inc.	2101 N 1st Street	San Jose	266	3/31/2034
FirstElement Fuel Inc.	150 South La Cumbre Road	Santa Barbara	266	3/31/2034
FirstElement Fuel Inc.	12600 Saratoga Avenue	Saratoga	198	3/31/2034
FirstElement Fuel Inc.	1200 Fair Oaks Avenue	South Pasadena	206	3/31/2034
FirstElement Fuel Inc.	248 S Airport Boulevard	South San Francisco	266	3/31/2034
FirstElement Fuel Inc.	3102 E Thousand Oaks Boulevard	Thousand Oaks	266	3/31/2034
FirstElement Fuel Inc.	12105 Donner Pass Road	Truckee	266	3/31/2034
FirstElement Fuel Inc.	350 Grand Avenue	Oakland	808	6/30/2034
FirstElement Fuel Inc.	3601 Camino De Real Street	Palo Alto	136	6/30/2034

Applicant	Address	City	Capacity (kg/day)	HRI Crediting Ends
FirstElement Fuel Inc.	3780 Cahuenga Boulevard	Studio City	808	6/30/2034
FirstElement Fuel Inc.	337 East Hamilton Avenue	Campbell	1200	9/30/2034
FirstElement Fuel Inc.	18480 Brookhurst Street	Fountain Valley	1200	9/30/2034
FirstElement Fuel Inc.	15544 San Fernando Mission Blvd	Mission Hills	1200	9/30/2034
FirstElement Fuel Inc.	1296 Sunnyvale Saratoga Road	Sunnyvale	1200	9/30/2034
FirstElement Fuel Inc.	26813 La Paz Road	Aliso Viejo	1200	12/31/2034
FirstElement Fuel Inc.	14477 Merced Ave	Baldwin Park	1200	12/31/2034
FirstElement Fuel Inc.	605 Contra Costa Blvd	Concord	1200	12/31/2034
FirstElement Fuel Inc.	2995 Bristol Street	Costa Mesa	1200	12/31/2034
FirstElement Fuel Inc.	21530 Stevens Creek Blvd	Cupertino	1200	12/31/2034
FirstElement Fuel Inc.	615 S Tustin Street	Orange	1200	12/31/2034
FirstElement Fuel Inc.	313 W. Orangethorpe Ave	Placentia	1200	12/31/2034
FirstElement Fuel Inc.	503 Whipple Ave	Redwood City	1200	12/31/2034
FirstElement Fuel Inc.	1832 W. Washington St	San Diego	1200	12/31/2034
FirstElement Fuel Inc.	3939 Snell Ave	San Jose	1200	12/31/2034
Iwatani Corporation of America	830 Leong Drive	Mountain View	349	6/30/2035
Iwatani Corporation of America	26572 Junipero Serra Road	San Juan Capistrano	394	6/30/2035
Iwatani Corporation of America	4475 Norris Canyon Road	San Ramon	393	6/30/2035
Iwatani Corporation of America	1515 South River Road	West Sacramento	394	6/30/2035

Applicant	Address	City	Capacity (kg/day)	HRI Crediting Ends
Cal State LA	5151 State University Dr.	Los Angeles	51	12/31/2035
Iwatani Corporation of America	1100 N Euclid St	Anaheim	808	3/31/2036
Iwatani Corporation of America	616 Paseo Grande	Corona	808	3/31/2036
Iwatani Corporation of America	16880 Slover Ave	Fontana	1200	3/31/2036
Iwatani Corporation of America	11807 E Carson St	Hawaiian Gardens	808	3/31/2036
Iwatani Corporation of America	13550 S Beach Blvd	La Mirada	808	3/31/2036
Iwatani Corporation of America	2714 Artesia Blvd	Redondo Beach	808	3/31/2036
Iwatani Corporation of America	2120 E McFadden Ave	Santa Ana	808	3/31/2036
Iwatani Corporation of America	8095 Lincoln Ave	Riverside	808	6/30/2036
Iwatani Corporation of America	13980 Seal Beach Blvd	Seal Beach	808	6/30/2036
Iwatani Corporation of America	3260 Chino Ave	Chino Hills	808	9/30/2036
Iwatani Corporation of America	4475 Norris Canyon Road	San Ramon	1200	3/31/2037
FirstElement Fuel Inc.	800 N Hollywood Way	Burbank	1200	9/30/2037
FirstElement Fuel Inc.	4280 Foothill Boulevard	Oakland	1200	9/30/2037
FirstElement Fuel Inc.	475 N. Allen Ave	Pasadena	1200	9/30/2037
FirstElement Fuel Inc.	5494 Mission Center Road	San Diego	1200	9/30/2037
Chevron Products CompanyY	12431 Heacock Street	Moreno Valley	808	12/31/2037
Chevron Products Company[23]	299 Orange Drive	Vacaville	808	12/31/2037

23 These stations are part of the nine stations CARB is aware Chevron is working to develop. Chevron staff have indicated that construction could soon begin at some of the stations while site selection has not yet been finalized at others. Overall project timelines are not yet available. Because no further details are available, this report does not include these stations in analysis though they may ultimately help close the gap to 200 stations.

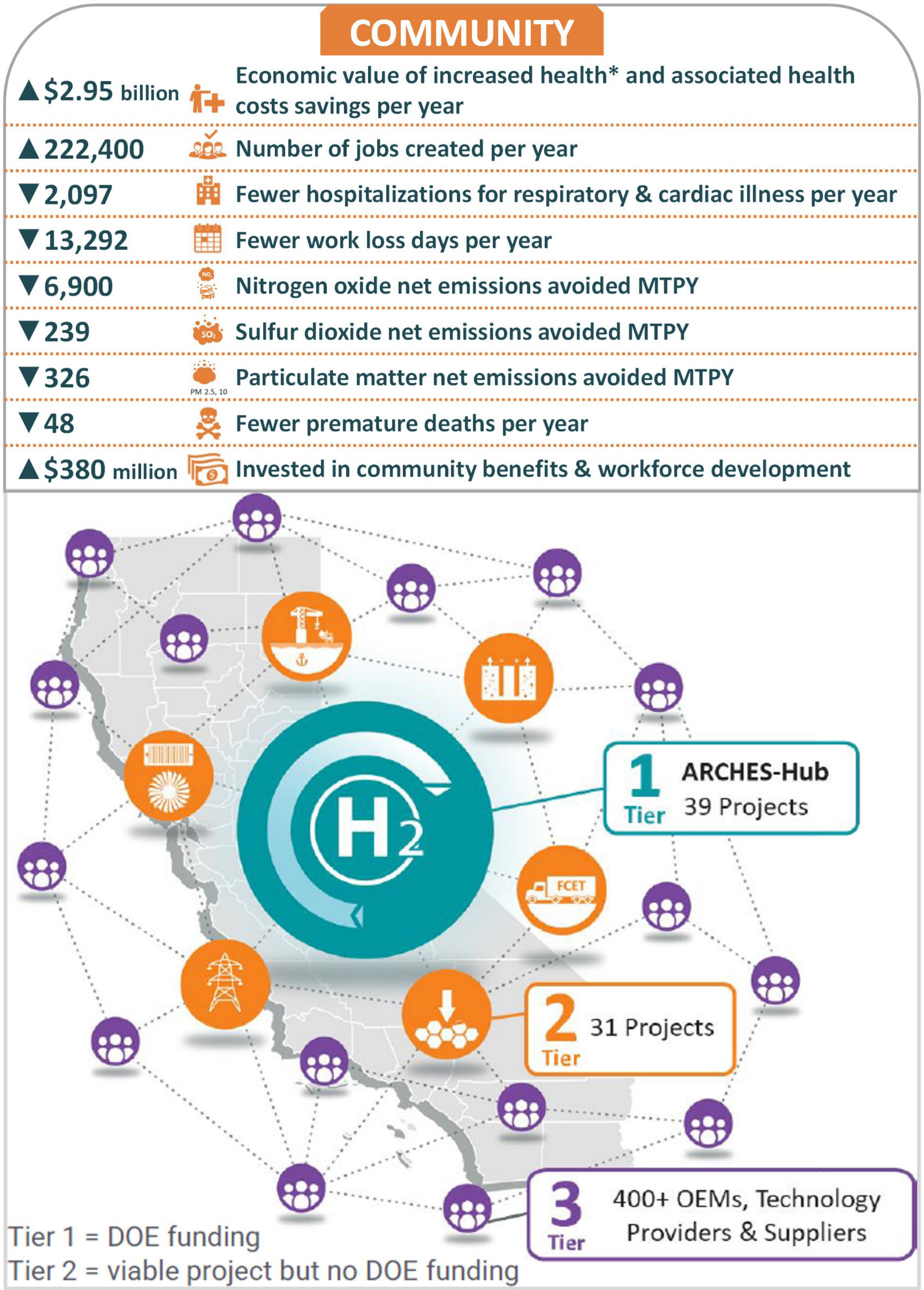
California ARCHES Hydrogen Hub Award

The Infrastructure Investment and Jobs Act (IIJA) in 2021 established the federal Regional Clean Hydrogen Hubs initiative. This initiative aims to provide federal co-funding for the development of multiple hydrogen hubs across the United States. Each hub is intended to include interconnected production facilities, distribution and transportation infrastructure, and end uses of hydrogen. In response to the US Department of Energy's related funding opportunity announcement, the Governor's Office of Business and Economic Development (GO-Biz) joined with the University of California (UC), two UC-affiliated national laboratories, state agencies, elected leaders, organized labor, and non-profit organizations to build the framework for California's renewable, clean hydrogen hub. As a result, the Alliance for Renewable Clean Hydrogen Energy Systems (ARCHES) LLC was established in 2022.

ARCHES is "a public-private partnership to create a sustainable statewide clean hydrogen (H2) hub in California and beyond, utilizing local renewable resources to produce hydrogen with the objective of fully decarbonizing the regional economy, while prioritizing environmental justice, equity, economic leadership, and workforce development [38]." ARCHES consists of a network of 400+ partners across the state of California. The partnership pairs decades of technical expertise, extensive hydrogen infrastructure development capacity, and significant fund matching capacity from industry members with additional funding opportunities and leadership from state and local government agencies, environmental justice advocates, nonprofits, and organized labor. This structure helps ensure a strong focus on community engagement, public health, environmental protection, workforce development, and other critical issues as individual projects within the ARCHES partnership are designed, developed, built, and operated.

ARCHES submitted the California proposal to become a national hydrogen hub on April 7, 2023. The ARCHES concept paper was submitted in December 2022 and requested the maximum $1.25 billion (of a total $7 billion available for all projects) in federal funds, with a private funds match share of $11.3 billion. The project proposal outlines in-state hydrogen industry development through 2031 and focuses on the production, distribution, and use of clean renewable for transportation fuel, electric power, and freight handling at California's ports. Figure 13 provides an overview of the hubs concept in the ARCHES proposal, along with several estimated benefits.

Figure 3: Overview of ARCHES Hub Concept and Estimated Benefits (Adapted from [39]; MTPY= Metric tons per year)



Reduced premature death, asthma, cancer risk, missed workdays

On October 13, 2023, ARCHES was selected by the U.S. Department of Energy (DOE) as one of seven regional clean hydrogen hubs across the country. ARCHES was selected to receive up to $1.2 billion in DOE funding to support renewable hydrogen projects in California. The proposal identifies 39 major projects along with participation from 400+ original equipment manufacturers, technology providers, and suppliers to support the development of California's hydrogen hub. The projects will cluster around the Los Angeles Basin and Bay Area and extend into the Central Valley, Inland Empire, and other regions with high renewable resources, geologic storage possibilities, key transportation corridors, and a need for clean energy and reduced pollution. ARCHES' goal is to produce and use 500+ tons per day of renewable hydrogen per year by 2030, distributing around 200 tons per day for power generation, 252 tons per day for transportation, and 63 tons per day for maritime equipment at ports.

The statewide hub will leverage the state's leadership in clean energy technology to produce hydrogen exclusively from renewable energy and biomass. Renewable electricity will power hydrogen production via electrolysis (an electrochemical process that splits water into hydrogen and oxygen), while biomass will be a feedstock for hydrogen production via reformation, pyrolysis, or similar hydrogen production methods. The proposed distribution infrastructure is mostly in liquid form by fuel cell trucks and includes seasonal storage and some distribution by pipelines. The hub will provide a blueprint for decarbonizing public transportation, heavy duty trucking, and port operations—key emissions drivers in the state and sources of air pollution that are among the hardest to decarbonize [40]. The focus will be introducing clean hydrogen to heavy duty transport through cargo handling equipment and drayage, supporting maritime equipment conversion at ports and preparing potential hydrogen export. The hub aims to reduce carbon emissions by 2 million metric tons per year—roughly equivalent to the annual emissions of 445,000 gasoline-powered cars [40]. This will not only improve air quality in and around interstate transportation corridors but also facilitate connectivity to nearby hubs.

ARCHES is also committed to ensuring an equitable transition to renewable hydrogen and all projects must advance diversity, equity, inclusion, and accessibility. Projects will be focused on communities with the largest pollution burden and at least 40 percent of the benefits from ARCHES projects will flow to California's disadvantaged communities. Along with the creation of over 220,000 new green jobs, it is also estimated that ARCHES projects will ultimately result in $2.95 billion per year (starting in 2030) in economic value including increased health and healthcare cost savings due to reductions in pollutant emissions. As project buildout details are finalized, ARCHES members will collaborate closely with local communities and key stakeholders to further educate and engage all parties involved about California's ongoing commitment to decarbonizing the state through this historic, clean energy investment.

California's overall hydrogen strategy is built on a recognition of the synergies available from developing hydrogen-powered transportation across light-, medium-, and heavy-duty sectors. Given the larger potential number of vehicles, development of hydrogen-powered transportation in the light-duty market may achieve economies of scale and reduce costs of fuel cell powertrains faster than development of the medium- and heavy-duty market. Since fuel cell technology and components are shared across these sectors, the fuel cell cost benefit developed by the light-duty market is expected to translate to the other sectors. On the other hand, because of the larger amount of hydrogen fuel used by individual vehicles in the medium- and heavy-duty market, these sectors may rapidly bring about economies of scale and cost reduction for the hydrogen fuel, which may similarly translate to the light-duty sector. The significant growth in hydrogen production outlined by the ARCHES proposal will likely result in reduced hydrogen costs for the light-duty hydrogen stations discussed in this report, in addition to any light-duty hydrogen fueling infrastructure that may be directly co-funded through the project.

Courtesy of First Element, Inc.

Location and Number of Fuel Cell Electric Vehicles

AB 8 Requirements: Estimates of FCEV fleet size and basis 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 network coverage.

Information Sources for Fuel Cell Electric Vehicle Projections

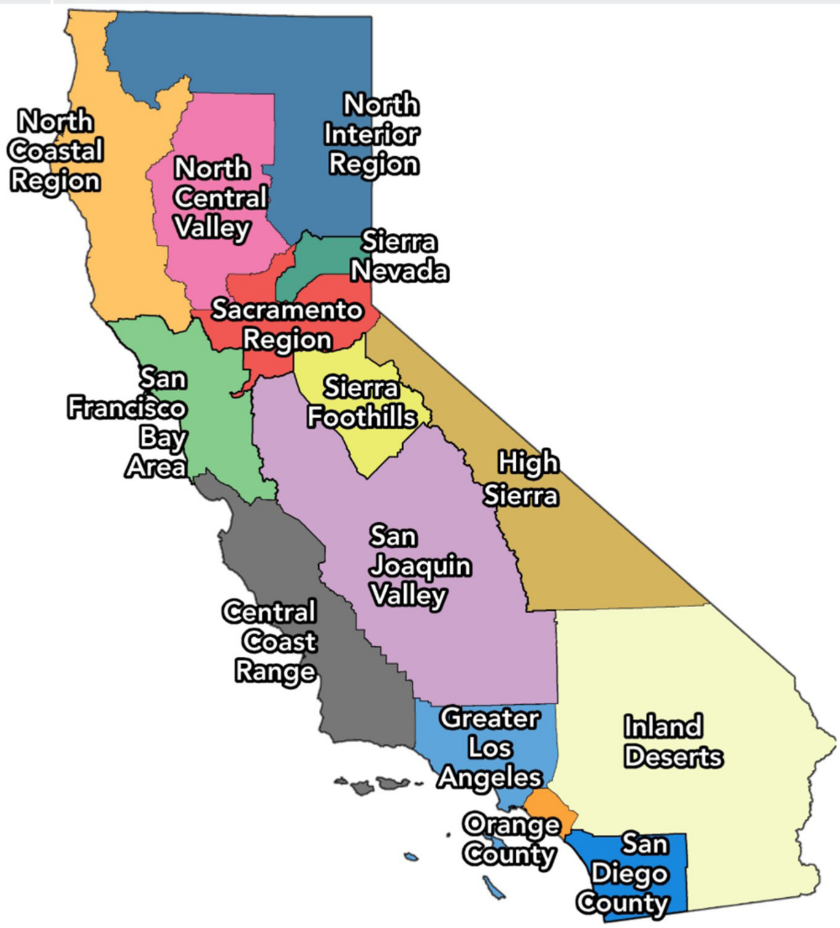
Assembly Bill 8 provides direction to CARB staff for the data resources that are to be used to inform each *Annual Evaluation*. In addition to information gained by monitoring public announcements and one-on-one conversations with industry stakeholders, AB 8 requires CARB to build its analysis of on-road FCEV populations from two defined sources. For estimates of FCEVs currently operating on California roads, CARB analyzes vehicle registration data received from the California Department of Motor Vehicles (DMV) at the beginning of April each year. CARB staff filter the DMV data to ensure no duplicate entries for the same vehicle are counted, the most current registration status is applied to each vehicle, all vehicles with a registration status that indicates it may no longer be in use are removed from analysis, and all vehicles registered to locations out of state are also removed from analysis. These registration data are provided to CARB with a ZIP code-level geographic resolution and provide CARB with the number of vehicles registered in each ZIP code for every combination of FCEV model and model year in the data set.

The other information resource that CARB uses for FCEV data is an annual survey of auto manufacturers that asks for their ZEV sales projections for the remainder of the current model year and two periods of future model years. The first period is considered the mandatory period and all auto manufacturers are required to provide their projections during this three-year period. The optional period covers the following three years after the mandatory period. Auto manufacturers are encouraged to provide their FCEV sales projections for this period, but response rates have historically been variable. All projections provided through the survey are given at the statewide level. CARB staff perform analyses (described in detail later in this report) to distribute these vehicles more locally across the state for the purposes of analysis.

All vehicle and station data are assessed at various geographic resolutions. The majority of this report focuses on aggregated reporting at the statewide, county, and regional (as defined in Figure 4) levels. Additional analyses are performed at finer geographic resolutions such as ZIP codes, census tracts, and even highly detailed local community resolutions.

Figure 4: Definitions of Analysis Regions

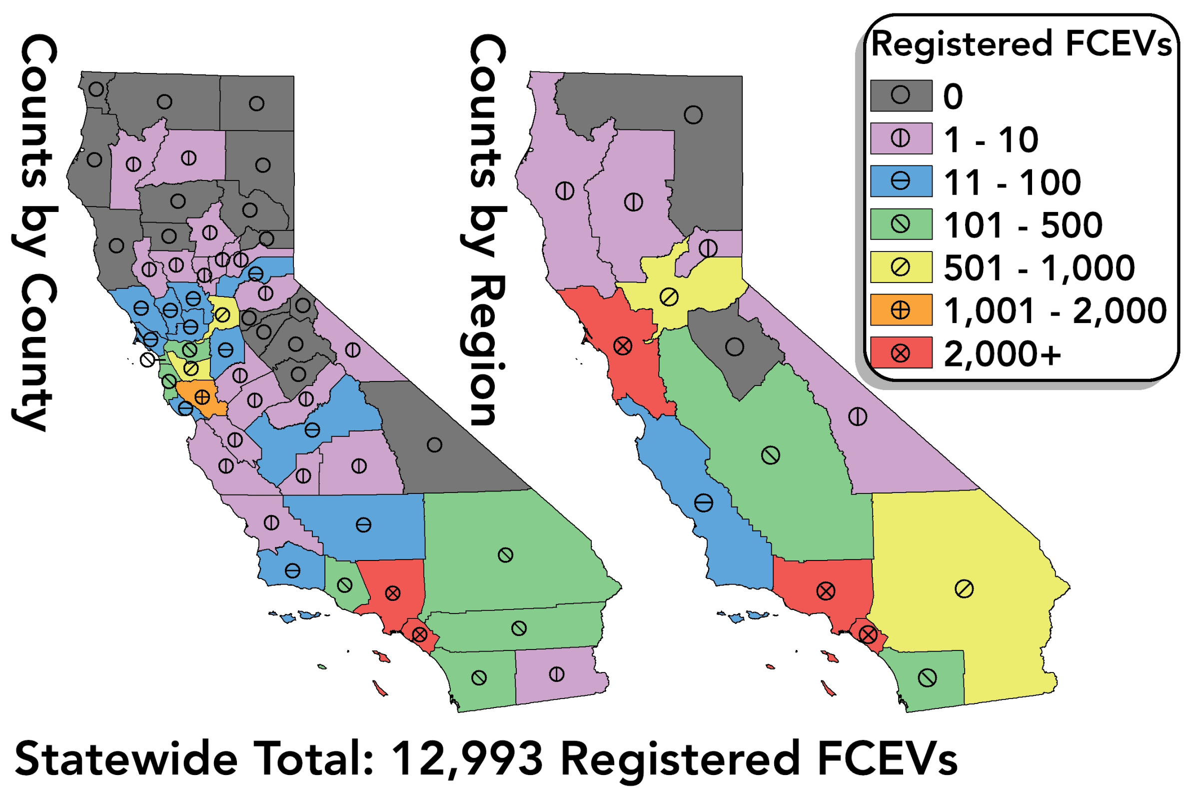
Analysis Region	Constituent Counties
Central Coast Range	Monterey, San Benito, San Luis Obispo, Santa Barbara, Santa Cruz
Greater Los Angeles	Los Angeles, Ventura
High Sierra	Alpine, Inyo, Mono
Inland Deserts	Imperial, Riverside, San Bernardino
North Central Valley	Butte, Colusa, Glenn, Shasta, Tehama
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



Analysis of Current On-The-Road Fuel Cell Electric Vehicles

The results of CARB's analysis of DMV records for currently active FCEV registrations are shown in Figure 5. Across the state, there are a total of 12,993 active FCEV registrations, an increase of 1,859 FCEVs since the same time last year. This makes the period of April 2022-April 2023 the third-highest for new FCEV registrations since reporting began in 2014 (the period April 2017- April 2018 and the period April 2021-April 2022 saw the largest and second-largest growth in FCEV registrations to date, respectively). Figure 5 also displays the distribution of these 12,993 vehicles across the state, aggregated to the county and regional level. Los Angeles and Orange counties have the largest number of registered FCEVs (at more than 2,000 registered FCEVs each), followed by Santa Clara County, Sacramento County, and Alameda County. Similarly, the Greater Los Angeles, Orange County, and San Francisco Bay Area regions have the largest number of registered FCEVs, followed by the Sacramento region and the Inland Deserts region.

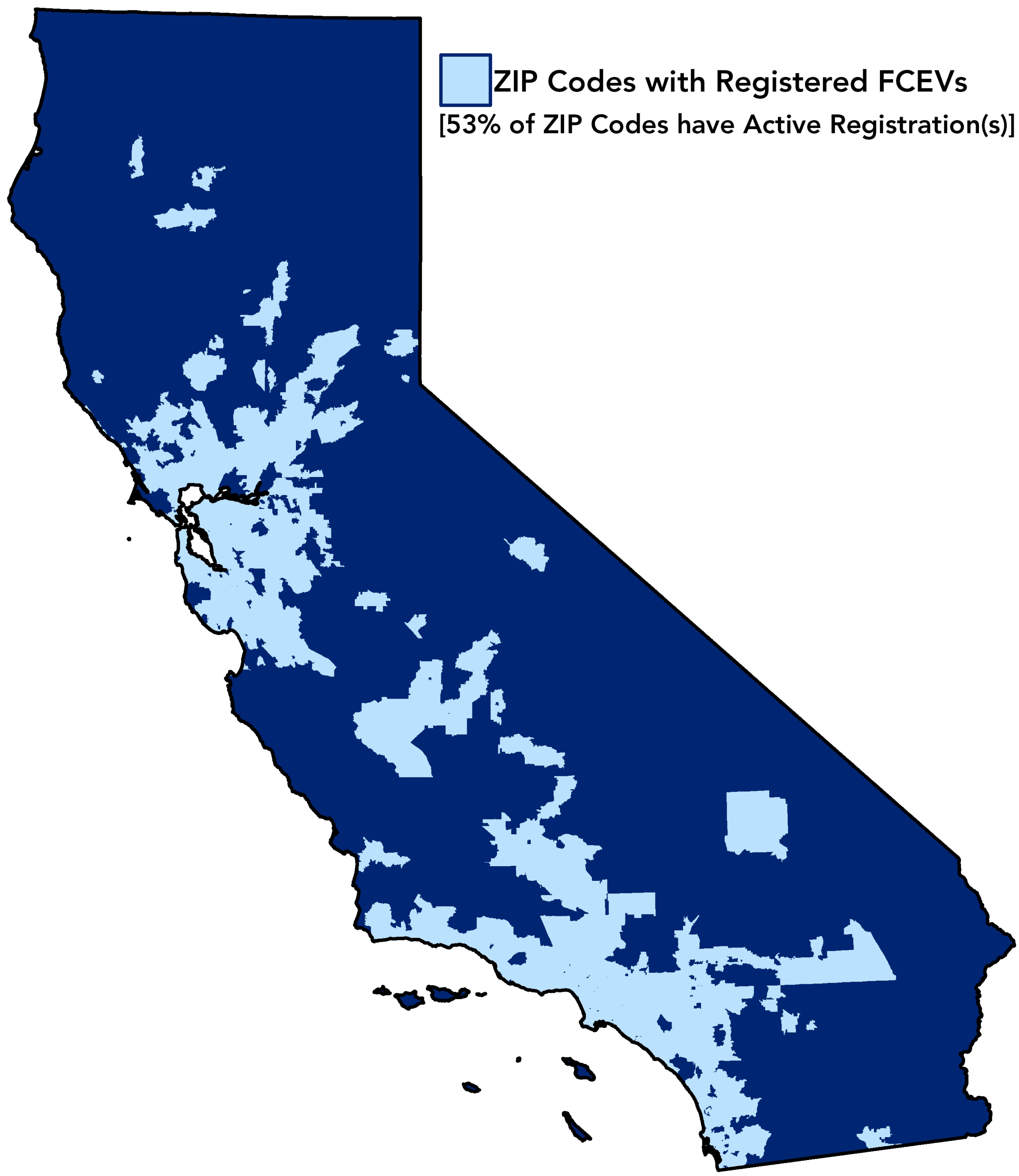
Figure 5: Distribution of Current FCEV Registrations as of April 1, 2023



These vehicle registration data appear to indicate that there may be a significant number of FCEV drivers traveling long distances to fuel, or who have commutes (or other regular trips) that bring them near hydrogen stations in counties and regions far from the vehicle's registered location. The large number of active registrations in the Inland Deserts region is notable, given the small number of stations currently open in the region. However, several currently open stations are located nearby in the Greater Los Angeles and Orange County regions. Similar conclusions could be drawn of the smaller number of registrations in Mono, Shasta, Trinity, and other counties that are quite some distance from the locations of the currently open or even planned hydrogen fueling network (further discussion on hydrogen station locations is presented in the next chapter).

More detailed registration location data are shown in Figure 6, which highlights all the ZIP codes in California that have one or more active FCEV registrations. Over the past year, active FCEV registrations have become more regionally diverse. The percentage of ZIP codes with at least one active registration has grown from 49 percent to 53 percent. The most notable growth appears to be new active registrations in ZIP codes in the San Joaquin Valley and Inland Deserts regions. Although there are currently very few Open-Retail stations in these regions, growth is expected in the next few years and could help solidify the initiation of FCEV driver markets in these regions.

Figure 6: ZIP Codes with Active FCEV Registrations



Analysis of Future On-The-Road Fuel Cell Electric Vehicles

CARB staff's estimates for future on-the-road FCEVs are built from both data sets required by AB 8: the current registered vehicles on-the-road in California and the responses from auto manufactures to the annual ZEV sales survey. When analyzing the auto manufacturers' responses on the ZEV sales survey, CARB staff make some adjustments to the data to arrive at future on-the-road FCEV estimates. First, auto manufacturers are asked to respond to the survey in terms of model years. Model years do not align exactly with calendar years, and the survey does not provide any information about when manufacturers might expect vehicles to be sold within a given model year. Based on prior evaluation of historical DMV registration data, CARB staff apply a simplifying assumption that one-third of all vehicles projected to be sold in a given model year will be sold in the prior calendar year. The remaining vehicles are assumed to be sold in the calendar year matching the model year. For example, if an auto manufacturer reports they expect to sell 3,000 FCEVs in the 2026 model year, CARB staff assume 1,000 will be sold in calendar year 2025 and the remaining 2,000 will be sold in calendar year 2026.

Second, the annual survey of auto manufacturers does not ask for any geographic distribution of the expected sales. CARB staff have attempted to collect this additional detail in prior surveys with varying degrees of success, since it has been considered voluntary information. Since the announcement of station funding grant awards in GFO-19-602 (and now bolstered by awards made in GFO-22-607), there is now a significant amount of information projected regarding the future development of California's hydrogen fueling network. With so many station locations known and estimates for their opening dates spanning significantly into the future, CARB staff make the simplifying assumption that future FCEV sales will occur in each county proportional to the counties' share of total hydrogen fueling capacity in each year. Table 2 shows these percentages for each county used in this year's analysis. Similar to observations of current FCEV registrations, Los Angeles, Orange, and Santa Clara counties are projected to have the highest rates of FCEV sales in the future.

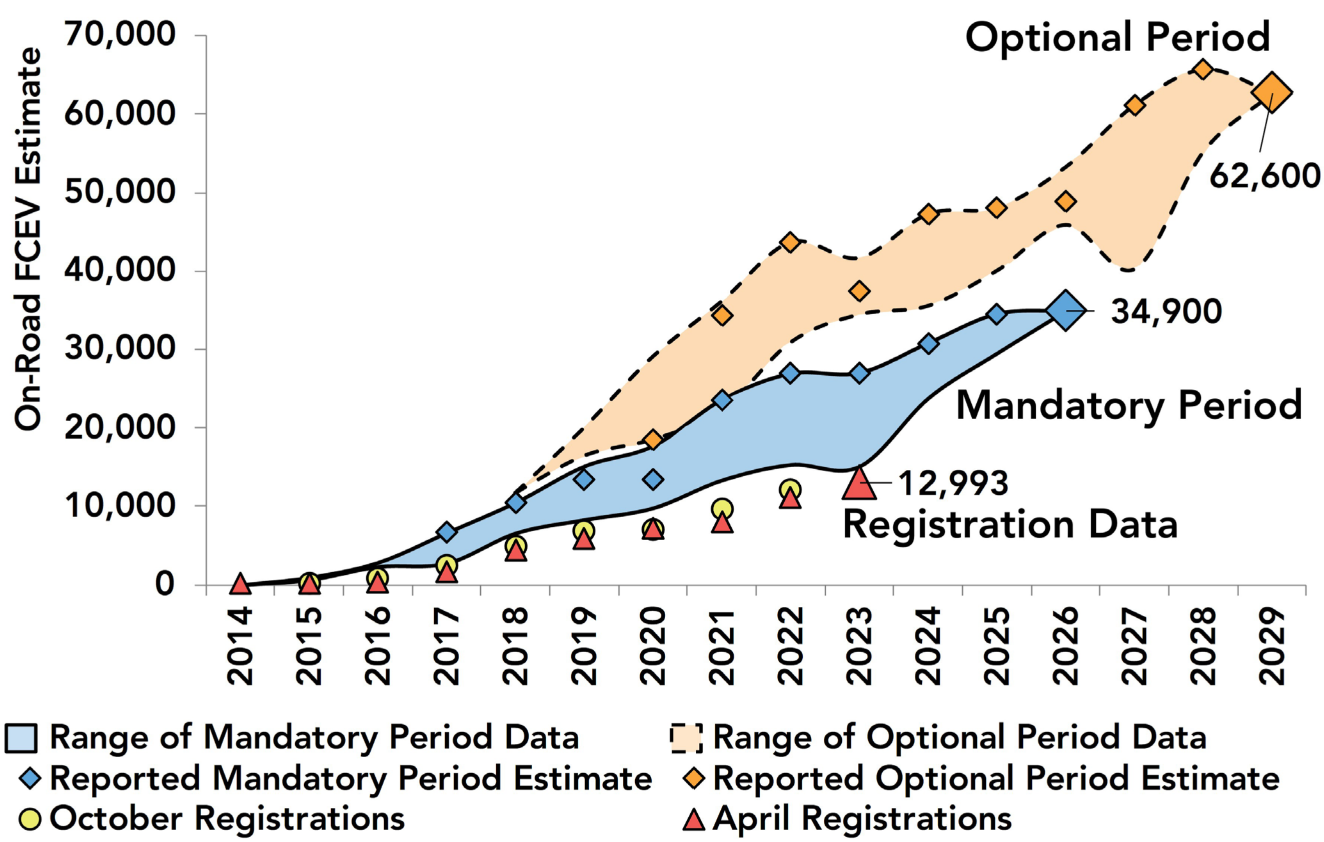
Table 2: County-Based Allocation of Future New FCEV Deployment

County	2022	2023	2024	2025	2026+
Alameda	5.96%	7.63%	8.00%	7.27%	6.92%
Contra Costa	4.34%	3.21%	8.31%	5.82%	5.54%
Fresno	0.72%	0.53%	0.39%	1.94%	1.85%
Kings	0.00%	0.00%	0.00%	1.67%	1.59%
Los Angeles	29.66%	23.71%	17.48%	18.90%	19.59%
Madera	0.00%	0.00%	0.76%	0.54%	0.51%
Marin	0.72%	0.53%	0.39%	0.27%	0.26%
Nevada	0.72%	0.53%	0.39%	0.27%	0.26%
Orange	26.45%	22.76%	18.88%	14.89%	14.18%
Riverside	0.27%	5.04%	4.76%	6.67%	6.35%
Sacramento	2.78%	2.05%	2.28%	4.93%	4.69%
San Bernardino	0.27%	8.27%	6.10%	4.27%	5.65%
San Diego	0.72%	2.95%	6.94%	4.86%	4.63%
San Francisco	4.17%	3.08%	2.27%	1.59%	1.51%
San Mateo	0.72%	3.09%	2.28%	1.59%	1.52%
Santa Barbara	0.72%	0.53%	0.39%	0.27%	0.26%
Santa Clara	19.99%	14.76%	13.26%	15.94%	16.77%
Solano	0.00%	0.00%	0.00%	3.33%	3.17%
Tulare	0.00%	0.00%	0.76%	0.54%	0.51%
Ventura	0.72%	0.53%	5.78%	4.04%	3.85%
Yolo	1.07%	0.79%	0.58%	0.41%	0.39%
ALL OTHERS	0.00%	0.00%	0.00%	0.00%	0.00%

Finally, for both the current registration data and the future sales data, CARB staff apply an attrition rate correction based on the model year of the vehicle. This attrition rate accounts for several real-world factors that may remove vehicles from active use on California's roads. This includes crashes that damage vehicles beyond repair, vehicle owners selling or otherwise transferring their vehicles out of state, owners deciding to keep their vehicle but register it in a non-active status, and other potential situations. CARB staff have adopted the same attrition rate in this analysis as used in the EMissions FACtor (EMFAC) emissions inventory modeling tool. This attrition rate model assumes a 15-year half-life for fleets of vehicles. For example, if there are 60,000 FCEVs on the road in 2030, this attrition model would project that half of those vehicles (30,000) would still be on the road in 2045, and one-quarter (15,000) would remain on the road in 2060.

By combining the DMV registration data and the auto manufacturers' survey responses, then applying the adjustments described above, CARB staff generate estimates of future on-the-road FCEV populations. Each year, CARB staff report the end-of-period estimates for the mandatory and optional periods, given the small number of auto manufacturers reporting future FCEV sales and the need to maintain as much confidentiality as possible with this business-sensitive information. Figure 7 provides the updated estimates of all vehicle-related data, including the historical and current registration data and the historical and current estimates of on-the-road FCEVs. The ranges for the on-the-road FCEV counts in the mandatory and optional periods represent the minimum and maximum estimate for all auto manufacturer surveys that include that calendar year within the associated reporting period (for example, in the 2023 survey, the mandatory period includes years 2023-2026, while the optional period includes years 2027-2029).

Figure 7: Comparison of On-the-Road Vehicle Counts in 2014-2023 Annual Evaluations



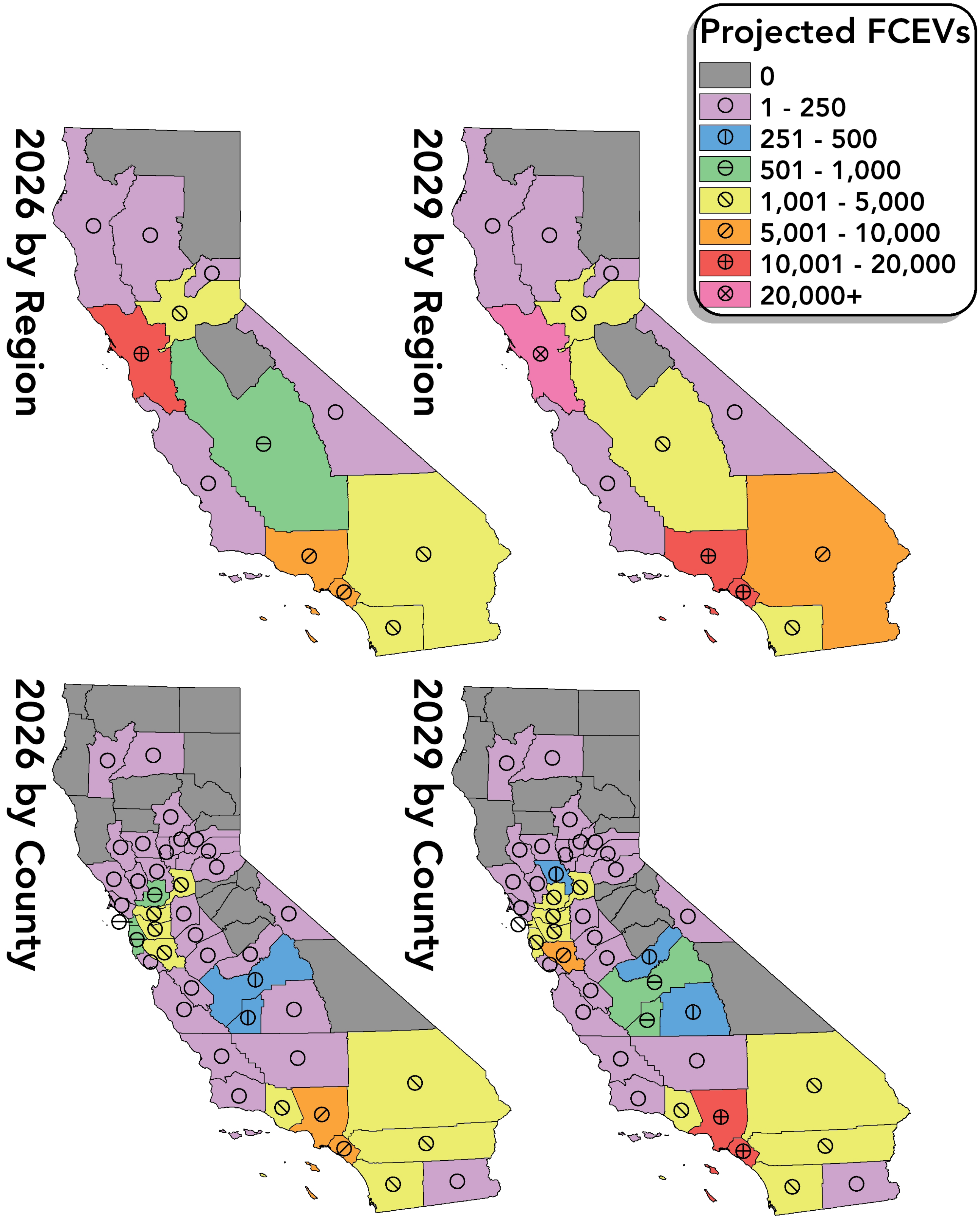
Based on the most recent data analyzed by CARB staff, the projections for on-the-road FCEVs at the end of the Mandatory and optional periods are 34,900 and 62,600 vehicles, respectively. Responses for both the Mandatory and optional period demonstrate a one-year delay in projected FCEV sales compared to last year's survey. The current estimate of 34,900 on-road FCEVS in 2026 is nearly the same as the previous estimate of 34,500 FCEVs in 2025. Similarly, the current estimate of 62,600 on-road FCEVs in 2029 is slightly less than the previous estimate of 65,500 FCEVs in 2028. Prior Annual Evaluations have presented and analyzed station development and FCEV sales projection data and demonstrated a close correlation between the two. For example, in 2020, CARB reporting showed that there have been multiple times in the past when important milestones for FCEV sales projections shifted forward or backward by a year in synch with shifts in projections for station development milestones [20]. It appears that the same type of relationship may be in effect in this year's survey data, as station opening projections (to be discussed further in the following chapter) have also largely shifted later by a year and many of the stations planned for future development (especially in years further in the future) have now been cancelled.

Although this one-year shift is present in the FCEV sales projections, the average rate of FCEV sales on the 2023 survey remains higher than all prior surveys with the exception of the 2021 and 2022 surveys. This may indicate that survey data represent adjustments for ongoing challenges in the development of the hydrogen fueling infrastructure while also indicating a general trend for continued market growth. Although the network has not grown as fast as previously projected, it is still growing, and the active station developers continue to plan developing many high-capacity stations. This would generally indicate an increasing ability to sell FCEVs over time as exemplified by the trends in average projected sales rates across survey years.

The geographic distribution of the projected on-the-road FCEV fleet in 2026 and 2029 is shown in Figure 8, aggregated at both the county and regional levels. Given that the geographic distributions of future vehicle sales are based on the data in Table 2, and the larger number of future sales compared to current registrations, the geographic distribution of future on-the-road FCEVs at the county and regional level strongly resemble the trends in Table 2. While the regions (Greater Los Angeles, Orange County, and San Francisco Bay Area) and counties (Los Angeles, Orange, and Santa Clara) with the most current registrations are expected to remain the leading areas in FCEVs on-the-road, other counties and regions are expected to see significant growth from current registrations. This growth will be brought on by future station development currently planned for these areas. Outside of the current leading areas for FCEV registrations, significant growth is expected in the Inland Deserts, Sacramento, San Diego, and San Joaquin Valley regions. At the county level, significant growth is expected in Fresno, Kings, Madera, Riverside, San Bernardino, Solano, Tulare, and Ventura counties.

Some of these projections for future growth, especially for the San Joaquin Valley region and its counties, are recent developments due to the announcement of new planned station locations through GFO-19-602 and GFO-22-607. With 20 station locations yet to be named under GFO-19-602 (and the possibility of future needs to relocate planned stations due to unforeseen challenges at currently proposed locations), future analyses may see further shifts in the geographic location where future FCEV sales may be expected to occur. If future station location announcements continue to focus on the newer markets like the San Joaquin Valley and Inland Deserts, there will be increased expectation of sales in these regions in addition to the concentration of sales expected in the San Francisco Bay Area, Greater Los Angeles, and Orange County regions that are currently leading on-the-road FCEV registrations.

Figure 8: Estimated Geographic Distribution of Future On-the-Road FCEVs



Courtesy of Iwatani Corporation

Location and 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

California's planned and open hydrogen fueling network has seen both the addition of new station locations and the removal of some previously planned locations. All told, there has been a net decrease of nearly 50 hydrogen fueling station projects being tracked by CARB, the CEC, and other collaborators in the past year. The individual station changes that have occurred since the last reporting include:

Changes in Open-Retail and Temporarily Non-Operational Stations:

- Five new stations have achieved Open-Retail status since the 2022 *Annual Evaluation*: Anaheim-Euclid, Burbank-Hollywood, Pasadena-Allen, San Diego, and Seal Beach.
- Three stations previously in the Temporarily Non-Operational status have returned to Open-Retail status. These are the Citrus Heights, Mountain View, and San Francisco- Harrison Street locations.
- Four stations that were previously in Open-Retail status are now Temporarily Non-Operational. These are the Anaheim, CSULA, LAX, and Palo Alto stations. The Ontario and Riverside stations remain in the previously reported Temporarily Non-Operational status.
- The currently Open-Retail station at UC, Irvine is expected to continue retail operations through the end of 2023 but does not currently have any plan to continue operations into 2024.

Changes in Planned Stations:

- Station developer Shell has given notice to the CEC that they are cancelling their grant agreement under GFO-19-602. This results in the removal of the following from all analyses in this report:
    - 13 stations with previously proposed addresses, including: Artesia, Carlsbad, City of Industry, Folsom, Long Beach- Lakewood, Los Angeles- Washington, Monrovia, Newport Beach, Novato, Pasadena- Arroyo, Sacramento- Martin Luther King, Jr., Santa Rosa, and Sun Valley
    - One station upgrade at the currently Open-Retail Torrance station
    - 37 stations planned for future development with an unknown station address
- A Notice of Proposed Awards (NOPA) was released for GFO-22-607. This NOPA proposes grant funding for the development of six new hydrogen fueling stations by three selected awardees:
    - Phillips 66 has been selected for award to develop four light duty-focused hydrogen fueling stations. These stations are proposed for Madera, Oxnard, Rancho Cordova, and Visalia.
    - FirstElement Fuel has been selected for award to develop one multi-use hydrogen fueling station to serve both light- and medium-duty customers. The proposed location is in Kettleman City. This location had originally been proposed as part of FirstElement's awards under GFO-19-602. Since the location has been shifted to award under GFO-22-607, a new station location will be proposed to take its place in the GFO-19-602 award.
    - Air Products and Chemicals, Inc. has also been selected for award to develop a multi-use station. This station is planned for development in Galt.

- Station developer FirstElement Fuel has submitted their second batch of 14 newly identified station locations under GFO-19-602, which were published in a revised NOPA on May 12, 2023. The new locations are: Bellflower, Fairfield, Fresno, Lakewood, Livermore, Los Angeles-Santa Monica, McClellan Park, Moreno Valley, Palm Springs, Rosemead, San Jose-Capitol, San Jose-Redmond, San Jose-Union, and Vallejo.
- A few stations that had developers previously applied for crediting under the HRI provision have withdrawn their applications. This includes the Glendale-Broadway, Long Beach-Willow, and Northridge stations. These stations are no longer included in analysis since they are not yet proposed locations in GFO-19-602 either.
- The stations previously planned for Chino and Laguna Beach are no longer moving forward and no replacements will be identified for these stations.
- The Arcadia and Glendale station locations will no longer be developed. Replacement station locations will be identified later.
- Several stations have had their projected Open-Retail station dates adjusted.

In addition, CARB staff maintain communications with station developers that are currently active in the network and new station developers that have announced their intent to enter the California market. Data from new market entrants is often limited, either until a station opens or the developer participates in any of California's station support program (like the LCFS program and the CEC's grant solicitations). For example, Chevron has recently shared their intent to develop nine hydrogen stations throughout California. However, some locations are not finalized, the design capacity of some stations are not finalized, and the expected timing for development is largely unknown. Given the limited information available at this time, these stations are not included in this years analysis. As development progresses and data about these stations become more readily available, the stations from Chevron and other developers newly entering the hydrogen fueling market will be included in future analyses.

Table 3 provides the historical record and projections for 2022 through 2029 for the number of hydrogen fueling stations by county, accounting for all of the developments listed above. All told, the 109 known station locations are currently expected to reach Open-Retail status by the end of 2026. The remaining 20 stations that do not yet have a location specified have projected opening dates between 2024 and 2026. Los Angeles, Santa Clara, and Orange counties have the largest numbers of currently open and planned hydrogen fueling stations, followed by Alameda, Riverside, Sacramento, San Bernardino, and San Diego counties. The remaining counties currently have fewer than five open or planned hydrogen fueling stations each.

Table 3: Historical and Projected Counts of Open-Retail Stations by County as of August 10, 2023

County	2022	2023	2024	2025	2026 - 2029
Alameda	5	6	7	8	8
Contra Costa	2	2	4	4	4
Fresno	1	1	1	2	2
Kings	0	0	0	1	1
Los Angeles	20	22	22	26	27
Madera	0	0	1	1	1
Marin	1	1	1	1	1
Nevada	1	1	1	1	1
Orange	11	13	13	14	14
Riverside	1	3	3	5	5
Sacramento	2	2	3	5	5
San Bernardino	1	4	4	4	5
San Diego	1	2	4	4	4
San Francisco	3	3	3	3	3
San Mateo	1	3	3	3	3
Santa Barbara	1	1	1	1	1
Santa Clara	10	10	11	15	16
Solano	0	0	0	2	2
Tulare	0	0	1	1	1
Ventura	1	1	4	4	4
Yolo	1	1	1	1	1
TOTAL with Known Location[24]	63	76	88	106	109
Future Stations (Location TBD)	0	0	4	8	20
TOTAL for All Stations	63	76	92	114	129

24 The UC Irvine station is included in counts for 2021-2023, but is not included in 2024 and later years

The number of open stations expected by the end of each year in 2022-2029 are shown aggregated by region in Figure 9. The San Francisco Bay Area, Greater Los Angeles, and Orange counties currently have the most open hydrogen fueling stations and this trend will continue into the future. These regions will be followed by the Inland Deserts and Sacramento regions, and then San Joaquin Valley and San Diego County regions. Individual station locations, projected (or historical) dates for achieving Open-Retail status, and the projects' current development status are shown in Figure 10.

Figure 9: End of Year Station Counts by Region as of August 10, 2023

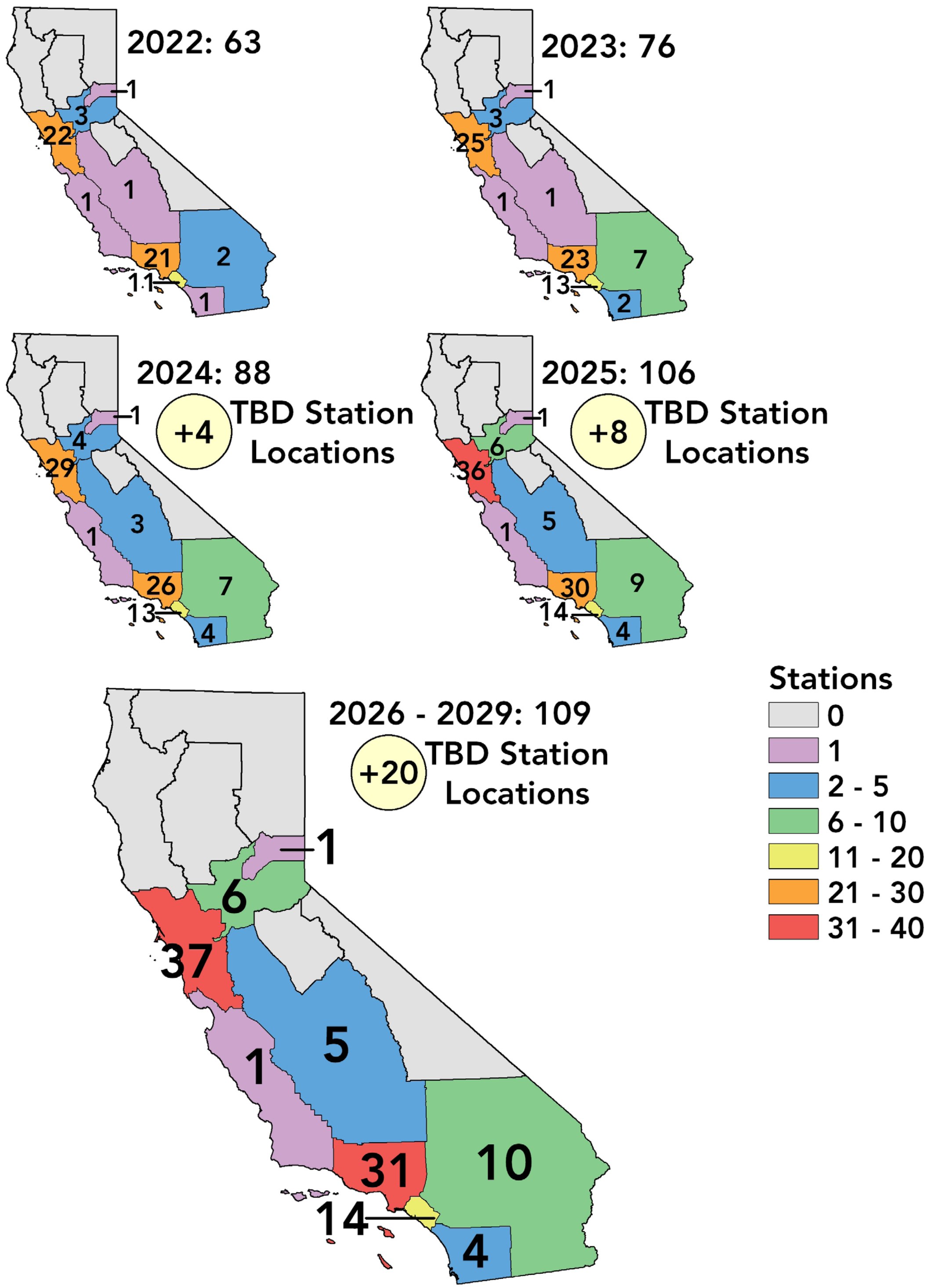
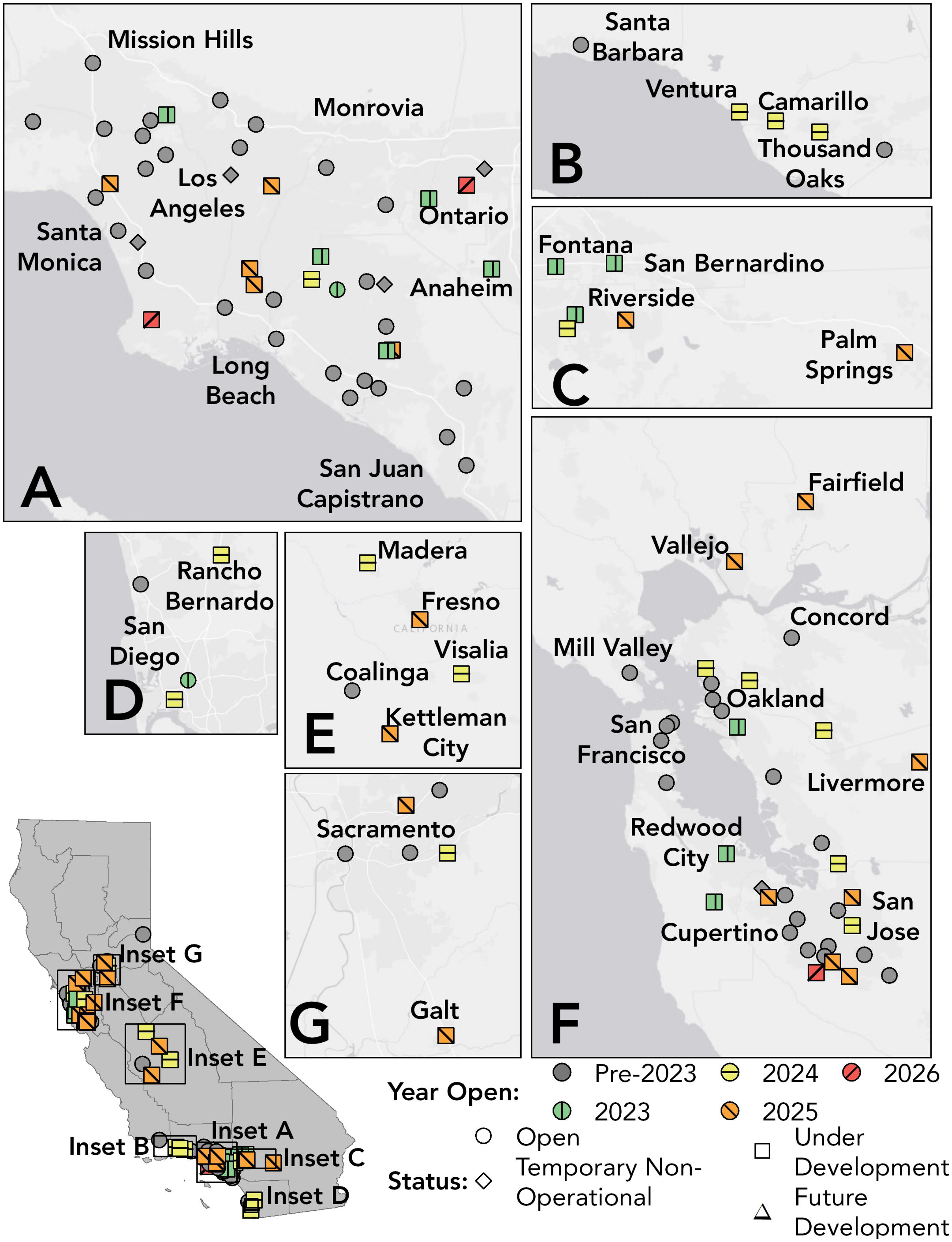


Figure 10: Map of Known Hydrogen Station Locations with Site-specific Open Date and Development Status as of August 10, 2023



In addition to tracking the locations and projected opening dates of hydrogen fueling stations, CARB staff perform analyses of the station network to understand more localized needs for two key network metrics. These include hydrogen fueling network coverage and hydrogen fueling network capacity (discussed in detail in the following chapter). Coverage is a metric that helps characterize and quantify the degree of access to the hydrogen fueling network across the state of California. In 2015, CARB first developed a methodology and tool to inform annual analysis and reporting of the coverage metric. The California Hydrogen Infrastructure Tool (CHIT), first developed in the ArcGIS Desktop environment, was then revised in 2017 to include new features and account for additional data suggested by hydrogen fueling stakeholders [41]. The 2017 version has been made available to the public on CARB's website[25]. The tool has since remained largely the same, though it has been recreated in the ArcGIS Pro environment for ongoing use internal to CARB and potential future updates.

The evaluation of network coverage through CHIT has been designed to provide a localized metric of ease of access to the hydrogen fueling network. The formulation of the coverage metric is designed such that coverage is higher for locations that are nearer to hydrogen fueling stations (in terms of time to drive to a stations(s)) and coverage is higher for locations that are closer to a larger number of hydrogen fueling stations. For example, under the formulation in CHIT:

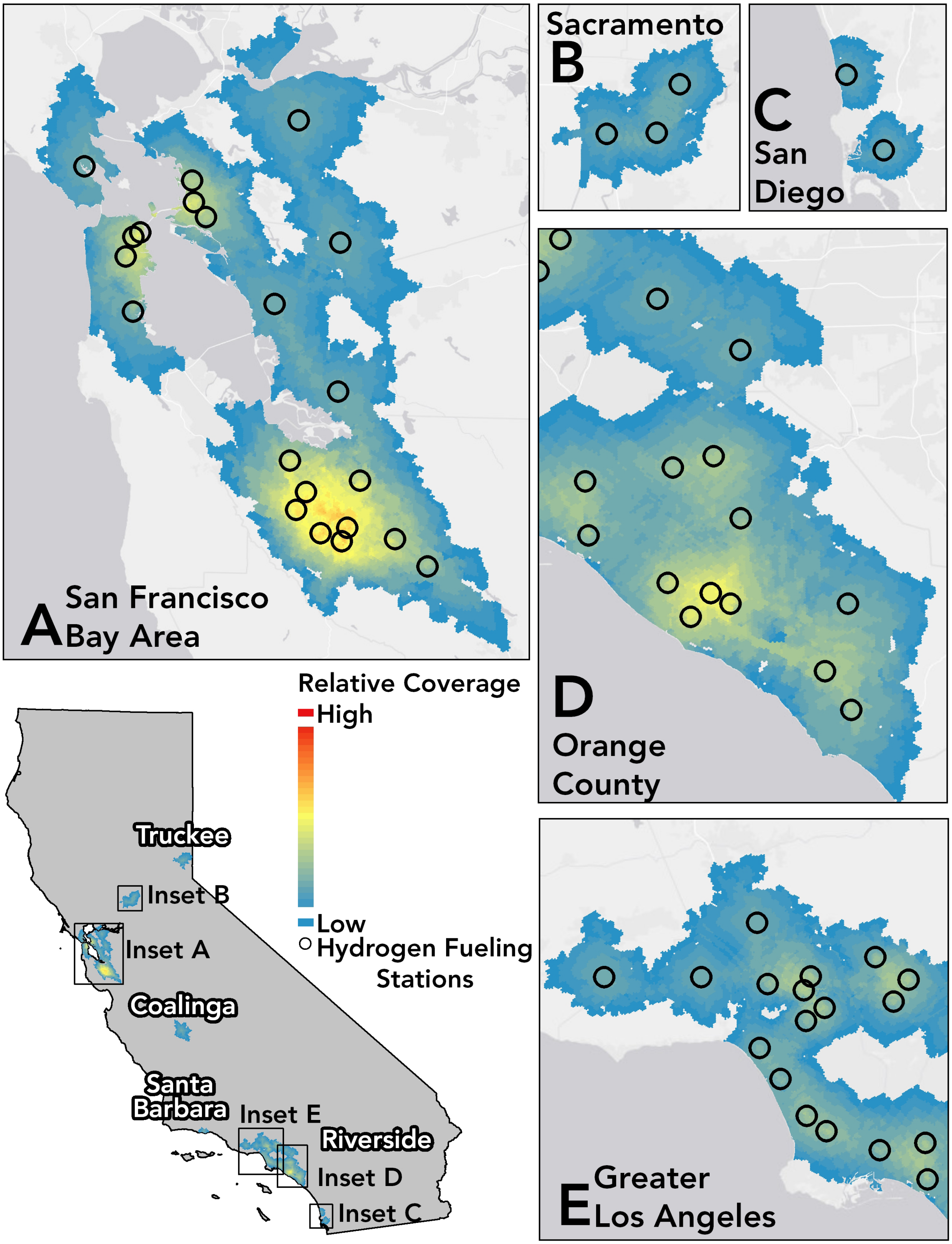
- A neighborhood that is a six-minute drive away from a hydrogen fueling station will have a higher degree of coverage than a neighborhood that is a fifteen-minute drive away from a hydrogen fueling station.
- A neighborhood that is within a six-minute drive of two stations will have a higher degree of coverage than a neighborhood within a six-minute drive of one station.
- A neighborhood with two nearby stations that are six and nine minutes away will have a higher degree of coverage than a neighborhood with two nearby stations that are six and fifteen minutes away.

Under the formulation in CHIT, coverage is assumed to extend from a station to a maximum of a 15-minute drive away from the station. Locations any further than a 15-minute drive are assumed to be beyond the limit that consumers would consider to be convenient access to a hydrogen fueling station. Drivers who live or work beyond the 15-minute limit are likely to still fuel at these stations in actual practice, but the 15-minute limit provides a bounds for assessing network development within the framework of providing a station network that is ultimately convenient for use in drivers' everyday lives.

Figure 11 shows the evaluation of coverage provided by the 59 stations that are in Open-Retail status as of August 10, 2023. This evaluation does not include the six stations in Temporarily Non-Operational status since they are not available to customers for fueling at the moment and the date for returning to Open-Retail status is not yet known. Stations that have become Temporarily Non-Operational have reduced the degree of coverage provided to nearby neighborhoods, but have not caused a notable contraction in the geographic extent of local coverage.

25 *https://ww2.arb.ca.gov/resources/documents/california-hydrogen-infrastructure-tool-chit*

Figure 11: Assessment of Coverage Provided by Network of 59 Currently Open-Retail Stations as of August 10, 2023

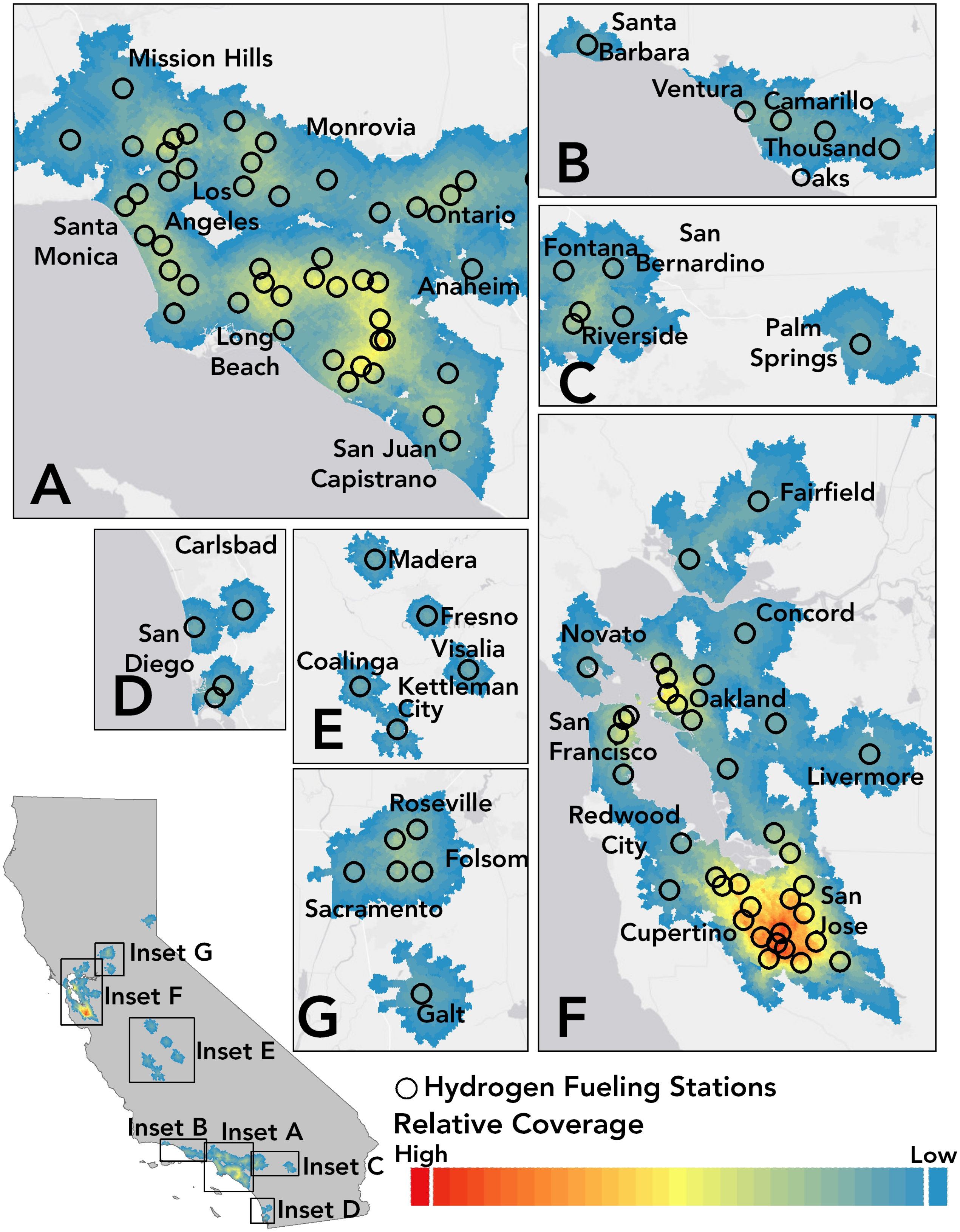


Degrees of coverage are shown in Figure 11 according to a graduated color shading scale. Areas with no color shading are outside the 15-minute limit of coverage. Areas in blue shading have limited coverage, while areas with yellow shading have midrange coverage (usually associated with 2-3 stations providing overlapping coverage), and areas with red shading have the highest degree of coverage due to many stations providing overlapping coverage[26]. As in prior reporting, the highest degree of coverage in the currently Open-Retail network is in the southwest side of the San Francisco Bay Area, around San Jose, Cupertino, and other nearby cities. Additional hot spots of overlapping coverage are in the city of San Francisco, Oakland and Emeryville, Orange County between Irvine and Costa Mesa, and in a few localized spots around Los Angeles County.

Figure 12 displays the assessment of coverage across the network for all 109 currently known hydrogen station locations, regardless of development or operational status. This represents an evaluation of coverage when all known stations in development or planned for future development will be complete and for the condition that no stations remain in Temporarily Non-Operational status. Many of the observations of relative degrees of coverage noted in Figure 11 remain the same for the full network of 109 known hydrogen fueling station locations. Specifically, the highest degrees of coverage will continue to be in the southwest San Francisco Bay Area and in Orange County between Anaheim, Irvine, and Costa Mesa. The largest difference from the currently Open-Retail network is the increase in the number of stations that will significantly expand the overall reach of coverage across the state (especially with new additions in the San Joaquin Valley, Sacramento region, eastern San Francisco Bay Area, and Palm Springs). There will also be a marked increase in the number of neighborhoods across the state that will have overlapping coverage from at least two or three stations by the time all known station locations are completely built.

26 The color shading in Figure 11 is scaled to match the color shading in Figure 12, which analyzes the full set of known hydrogen stations. The maximum coverage evaluation in Figure 12 is higher than in Figure 11. The result is that Figure 11 does not show relative coverage at the highest values in the range.

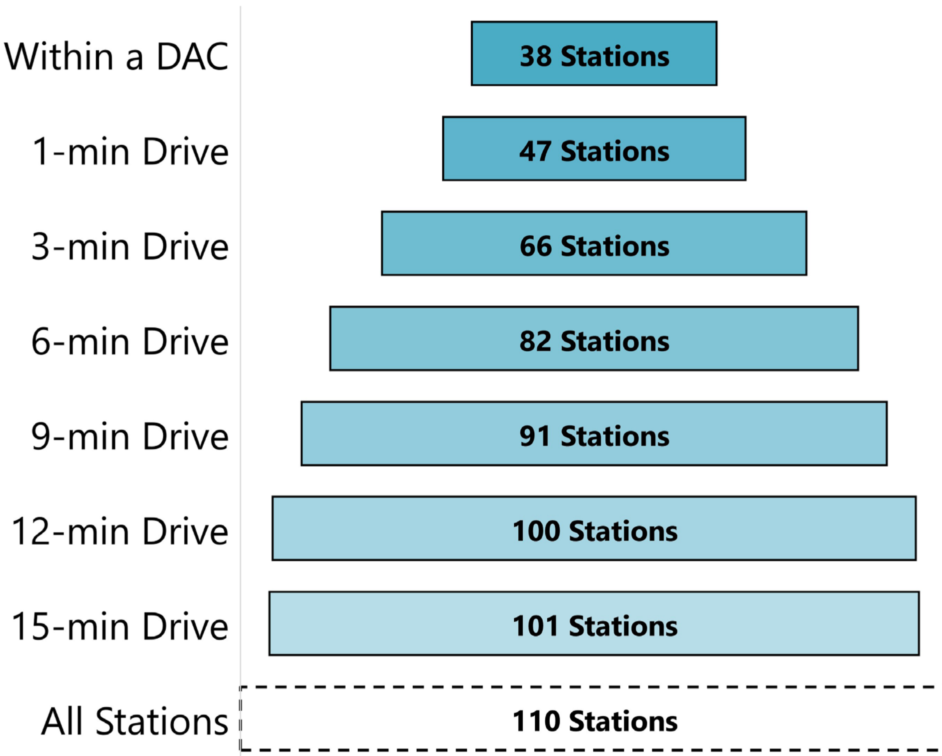
Figure 12: Assessment of Coverage Provided by Open and Funded Hydrogen Station Network as of August 10, 2023



Evaluation of Coverage Provided to Disadvantaged Communities

Figure 11 and Figure 12 provide an assessment of the degree of hydrogen network coverage for communities and neighborhoods across all of California. In addition to this general assessment, CARB and CEC staff perform additional analyses to track the network's growth with respect to California's disadvantaged communities (DACs). DACs are those communities that have historically and currently face a combination of disproportionate socio-economic and environmental hazard burden. DACs are identified according to the CalEnviroScreen 4.0 tool, developed by the Office of Environmental Health Hazard Assessment and CalEPA [42].

Figure 13: Hydrogen Station Locations at Various Proximities to a Disadvantaged Community



CARB staff analyzed the coverage metrics in more detail for disadvantaged communities by assessing the distance to a hydrogen fueling station from these communities at several different drive times. The drive time evaluations are completed at the census tract level, since this is the resolution adopted in CalEnviroScreen. CARB staff also evaluate the percentage of the DAC population within each of these drive time distances using a finer spatial detail of the census block population level and compares the DAC population coverage to the coverage provided to the general population of California.

Figure 13 displays the detailed evaluation of coverage provided by the open and planned hydrogen fueling network to DACs. The currently open and planned hydrogen fueling station network is well situated for providing coverage, and in many cases provides convenience similar to today's gas station network. After accounting for all the network changes in the past year, the coverage provided to DACs remains essentially the same as in past reporting. The vast majority of stations (101 of 110, or 92 percent) are within the 15-minute maximum extent of coverage for DACs. Prior research has identified a 6-minute drive as a standard metric for convenience matching today's gasoline station network. Again, the majority of hydrogen fueling stations (91 of 110, or 75 percent) provide this convenient level of coverage to DACs.

Table 4: Analysis of Population Proximity to Hydrogen Stations

Station Proximity to a DAC	Count of Stations	Percent of Known Locations	Percent of DAC Population	Percent of Statewide General Population in Same Drive Distance
Within a DAC	38	35%	N/A	N/A
1-min Drive	47	43%	1%	1%
3-min Drive	66	60%	7%	8%
6-min Drive	82	75%	22%	25%
9-min Drive	91	83%	42%	42%
12-min Drive	100	91%	57%	54%
15-min Drive	101	92%	67%	61%

The more detailed population-level evaluation of coverage to DAC residents and the statewide general population is provided in Table 4 . The population-based assessment shows slight improvement over previously reported values for both the DAC population and the general statewide population. This indicates that the newly announced station locations continue to be located within convenient distances of DAC residents at a similar rate, if not slightly higher rate, than previously known station locations. In addition, the coverage provided to DAC residents continues to be similar to the coverage provided to the general population. Overall, at the summary statewide level, the hydrogen fueling station network does not appear to favor non-DAC communities.

Reporting in the 2022 *Annual Evaluation* provided additional depth on evaluating these metrics and the access of various communities to the hydrogen fueling station network. While the data of Figure 13 and Table 4 indicate that as a whole the network appears to provide equivalent coverage to residents of DACs and the general population alike, it does not provide insight into which DACs enjoy this benefit. Prior analysis demonstrated that the extent of coverage of the open and planned network was particularly limited to a set of communities in the areas where hydrogen network development has been concentrated. In particular, most of the open and planned network is located in highly urbanized areas around the San Francisco Bay Area, Sacramento, Greater Los Angeles, and Orange County regions with higher population density. This meant that although the coverage provided to DAC and non-DAC communities includes a majority of each population, the number of communities (in terms of census tracts) within that coverage is still relatively small. In particular, rural and low-population communities do not have any coverage provided by the open and planned hydrogen fueling network.

The planned coverage for several of these communities has changed over the past year, due to the announcement of new station awards, new locations submitted for prior funding, and several cancelled station locations. Figure 14 and Figure 15 display the changes in the past year to coverage provided to DAC communities at the 6-minute and 15-minute driving distance metric, respectively[27]. Each figure displays the change in future coverage planned for DACs across the state compared to information known at the same time last year. For example, for a community located 12 minutes away from a station that has recently been cancelled (and no other changes in station plans affect that community), Figure 15 would identify the community as having lost coverage while Figure 14 would show no change because the community is more than six minutes from the station. In both figures, a community with no fill indicates no change in planned coverage over the past year, solid red fill indicates loss of coverage, horizontal green and black stripes indicate additional new coverage, and vertical blue and black stripes indicate simultaneous addition of coverage from one or more stations and loss of coverage from a different station(s).

Communities in the Greater Los Angeles and Orange County Regions (panel A of Figure 14 and Figure 15) experienced the most varied changes in coverage over the past year. Many communities across the area have lost coverage under a six-minute metric, including a stretch from Long Beach through Torrance and into Gardena, between Burbank and San Fernando, in the City of Industry, and near Baldwin Park. New gains in coverage are seen at the six-minute mark near Paramount, Montebello, and Rosemead. Some communities in Bellflower, a stretch south of Rosemead, and the northwest portion of Los Angeles show a mix of coverage gain and loss.

Under a 15-minute evaluation, coverage loss occurs in the same communities as at the 6-minute mark, and extends further into Santa Ana, Westminster, Hawthorne, Whittier, downtown Los Angeles, and Azusa. The areas that only gain coverage shift under a 15-minute evaluation to only a stretch between Downey and Commerce. This is because much of the surrounding areas have a mix of coverage gains and losses under a 15-minute evaluation. This includes communities between Azusa and Commerce, between Commerce and La Mirada, between La Mirada and Carson, in a large area between Inglewood and downtown Los Angeles, and in La Puente.

27 Note that in the analysis of Figure 14 and Figure 15, a change in coverage is indicated for a census tract if there has been a change in the number of stations providing coverage to any part of that census tract. For example, if new coverage has been added to only the northern half of a census tract, the figures will show the whole census tract as having gained coverage.

There are markedly fewer changes in more inland areas of southern California as shown in panel B of Figure 14 and Figure 15. Under a six-minute drive time evaluation, coverage has increased for communities in and near Moreno Valley and decreased for communities near Montclair. With a 15-minute evaluation, the gain in coverage expands further south to Perris and north into Riverside. Loss of coverage in the region also expands with a 15-minute evaluation, including communities in a stretch from Pomona to Ontario. Along the southern California coast, the only changes are increases in coverage at both drive times for communities near Oxnard and Port Hueneme, with more communities included under the 15-minute evaluation than the 6-minute evaluation.

Communities in the San Joaquin Valley similarly only gained planned coverage in the past year, with more communities included for a longer drive time metric. Under both 6- and 15-minute evaluations, communities in Fresno, Madera, and along a stretch from Coalinga through Lemoore and into Visalia gained coverage due to additions to California's planned network of hydrogen fueling stations. At a 15-minute coverage, this area of additional coverage expands and includes Merced and parts of San Joaquin.

Changes to coverage in northern California are seen only in Sacramento and the San Francisco Bay Area. In Sacramento, a six-minute evaluation shows coverage gained in communities between downtown Sacramento and Citrus Heights and near Rancho Cordova, with a loss of coverage in communities north of Elk Grove. With a 15-minute evaluation, coverage loss expands to more communities around Elk Grove and into downtown Sacramento. In addition, some communities closer to downtown Sacramento show a mix of coverage gain and loss, as do communities between Elk Grove and Rancho Cordova. In the San Francisco Bay Area, newly planned stations have added coverage for communities in and around Fairfield, San Jose, and Vallejo, using both a 6- and 15-minute drive time evaluation. Within a 15-minute drive time, communities in Lodi, Tracy, and Vacaville also see additions of planned future coverage. Western portions of Vallejo see a mix of added and removed coverage under the 15-minute evaluation.

Figure 14: Recent Changes in DAC Population Access to Planned Hydrogen Stations at Six-Minute Driving Distance

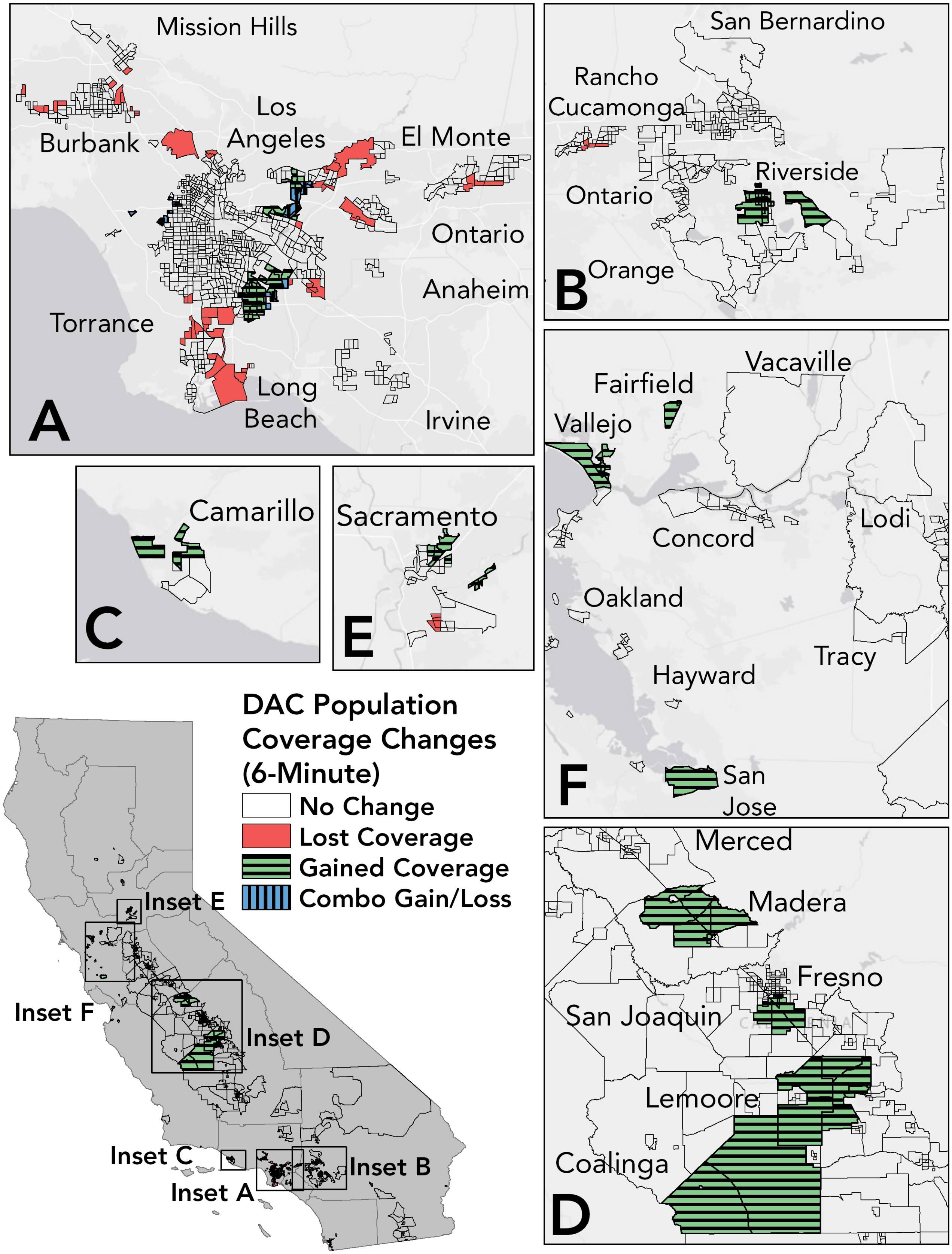


Figure 15: Recent Changes in DAC Population Access to Planned Hydrogen Stations at Fifteen-Minute Driving Distance

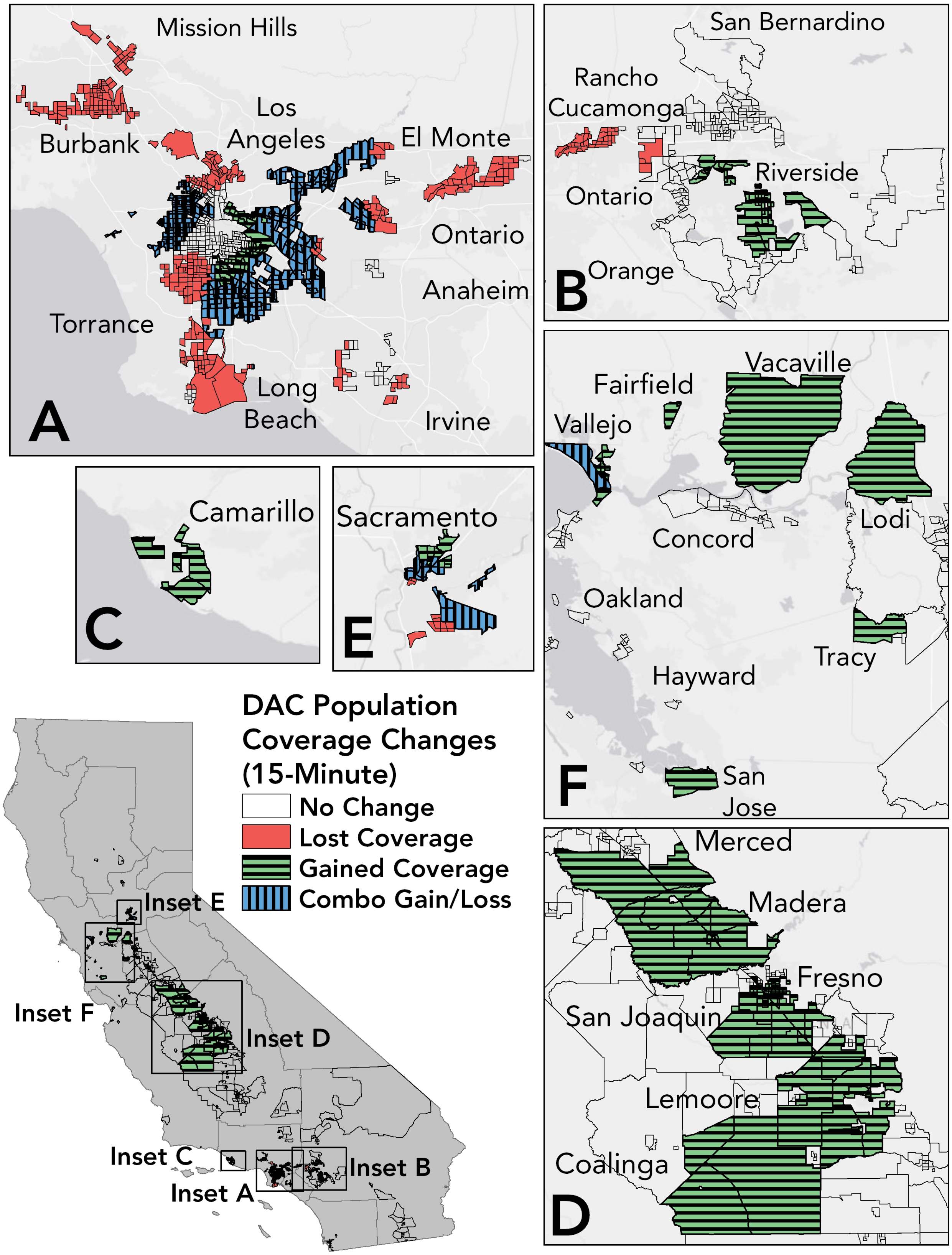


Table 5 and Table 6 summarize these changes by analysis region at a six-minute and fifteen-minute driving distance, respectively. Regions with no changes at either driving distance are not included in the tables. Data in the table report the number of DAC census tracts that have only gained coverage, have only lost coverage, or have gained and lost coverage due to changes in planning for individual stations. The tables also provide the percent of all DACs within each region that the affected communities represent.

Table 5: Summary of Changes to DAC Population Access to Planned Hydrogen Stations at Six-Minute Driving Distance

Region	Tracts that Only Gained 6-Minute Coverage (count / % of DACs)	Tracts that Only Lost 6-Minute Coverage (count / % of DACs)	Tracts that Gained and Lost 6-Minute Coverage (count / % of DACs)
Greater Los Angeles	47 / 6%	43 / 5%	18 / 2%
Inland Deserts	21 / 10%	1 / 0%	- / -
Sacramento Region	9 / 18%	4 / 8%	- / -
San Francisco Bay Area	13 / 19%	- / -	- / -
San Joaquin Valley	28 / 6%	- / -	- / -

Table 6: Summary of Changes to DAC Population Access to Planned Hydrogen Stations at Fifteen-Minute Driving Distance

Region	Tracts that Only Gained 15-Minute Coverage (count / % of DACs)	Tracts that Only Lost 15-Minute Coverage (count / % of DACs)	Tracts that Gained and Lost 15-Minute Coverage (count / % of DACs)
Greater Los Angeles	62 / 8%	265 / 34%	287 / 37%
Inland Deserts	34 / 16%	16 / 8%	- / -
Orange County	- / -	13 / 37%	- / -
Sacramento Region	9 / 18%	12 / 24%	16 / 33%
San Francisco Bay Area	13 / 19%	- / -	1 / 1%
San Joaquin Valley	120 / 26%	- / -	- / -

Evaluation of Network Coverage Gaps

Since 2015, CARB staff have used the CHIT tool (developed at CARB) to perform detailed assessments of the coverage provided by the hydrogen fueling network (as shown in Figure 11 and Figure 12) and to identify gaps between network coverage and the potential hydrogen fueling market. The potential hydrogen fueling market is evaluated in CHIT based on several factors and divided into two main components.

The first piece of the market assessment is based on an assumption that most FCEV drivers will require convenient access to at least one (if not multiple) hydrogen fueling stations near their homes. Having hydrogen stations near the home may be a critical aspect to providing assurance that an FCEV can meet daily driving needs and enable drivers to choose an FCEV over a conventionally fueled vehicle[28]. This near home fueling potential is based on an analysis of several socioeconomic factors that were based on prior research and validation during the development of CHIT. These factors include income, education, prior plug-in hybrid and hybrid vehicle ownership, prior registered vehicle values, and other indicators. These data are collected from U.S. Census Bureau data and California DMV registration data and are collected at various scales based on their data source (with aggregation levels ranging from block-level census data to as large as census tract or ZIP code level). These factors are each weighted and combined into a single market assessment factor as shown in the top left of Figure 16.

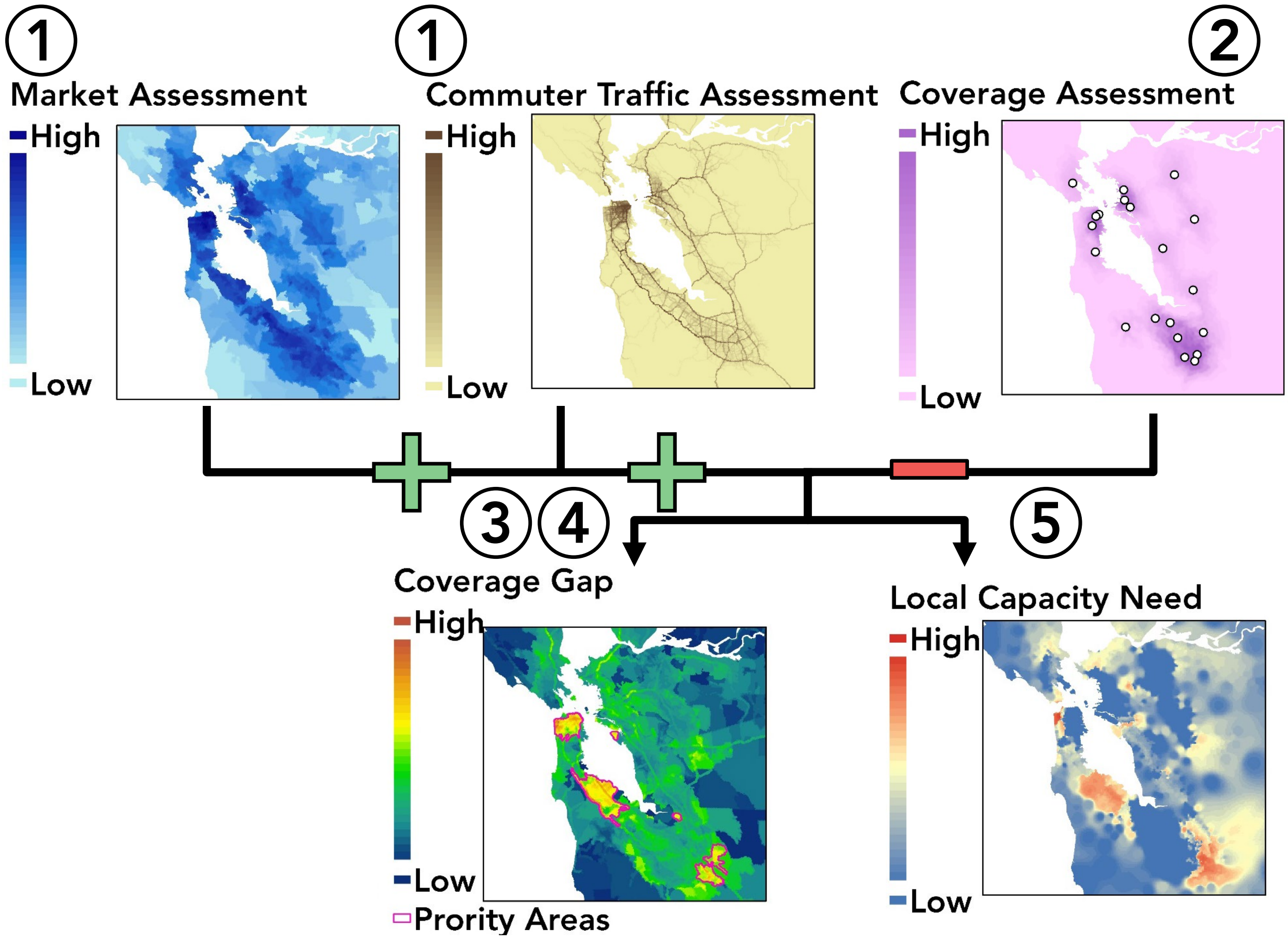
The second half of the potential fueling market evaluation is based on the assumption that some fueling demand can also occur along typical daily driving routes. CARB staff previously developed a data set of estimated traffic volume for FCEV drivers based on the near-home market evaluation and data from the U.S. Census Bureau that provides the location of commuters' home and work addresses[29]. CARB staff used this home-to-work data and modeled the fastest route for each location pairing. Total traffic volume along California's roadways was then estimated by adding all the traffic from all routes that overlap a given stretch of road and weighting each route by the relative strength of the potential FCEV fueling market at the home location. This provides an estimate of the potential demand for hydrogen fuel along all of California's roadways, as embodied by the commuter traffic assessment panel of Figure 16.

The market assessment and commuter traffic assessment (together Step 1 in Figure 16) are then combined into a single overall estimate for hydrogen fuel demand across the state. In CARB's evaluations using the CHIT tool, the home-based market assessment is assigned a much higher weighting in this summation than the commuter traffic-based assessment. The combined fuel demand assessment is then compared to the evaluation of coverage (Step 2 in Figure 16) to arrive at an evaluation of coverage gap. In particular, the analysis in CHIT is designed to evaluate the relative localized strength of the potential fueling market compared to the localized relative degree of coverage and assign a higher value the more that the relative market strength exceeds the relative local coverage. For example, an area with a high degree of coverage may still be identified to have a strong gap in coverage if the local fuel demand is still sufficiently stronger than the coverage assessment. At the same time, an area with a lower fuel demand could also still have a high assessment for coverage gap if there is relatively little to no coverage provided by the planned hydrogen fueling network. Step 3 in Figure 16 illustrates the result of this analysis step.

28 Reporting in prior Annual Evaluations demonstrates that data collected through surveys of Clean Vehicle Rebate Project participants with FCEVs justify this assumption [8, 42].

29 These data are provided by the Longitudinal Employer-Household Dynamics Origin-Destination Employment Statistics dataset. These data are based on additional surveys completed by the US. Census Bureau supplementary to the decennial census.

Figure 16: CHIT Evaluation Processes (Illustrative Example Only)



Next, the coverage gap assessment is itself further analyzed to identify priority areas for future station funding. Analysis through CHIT defines priority areas as contiguous regions of at least five square miles[30] in area that have a similar high value for coverage gap that is also verified by statistical analysis to be significantly higher than the coverage gap in surrounding areas. Step 4 in Figure 16 illustrates this step, with the priority areas shown in the panel as outlining areas of high coverage gap.

Finally, additional tools in CHIT build off the coverage and market assessment steps to generate localized estimates of the need for new hydrogen fueling capacity beyond the known network capacity. This calculation is based on the estimated FCEV population at the end of the optional period in the annual auto manufacturer survey. Step 5 in Figure 16 illustrates the results of this calculation.

30 CHIT is designed so that this minimum area can be set by the user. CARB staff have used a five square mile area as a minimum in all uses of CHIT for reporting in all Annual Evaluations to date.

Suggestions for Future Co-Funding

The most recent evaluation of coverage gap, accounting for all announced changes in station locations made in the past year, is shown in Figure 17 with more detailed views provided in Figure 18. Like the evaluation in the previous year, high coverage gaps and priority areas are identified across a wide range of communities through the state. Coverage gap is shown by the color shading, with dark blues indicating the lowest coverage gap, greens and yellows indicating midrange coverage gap, and oranges and reds indicating the highest degrees of coverage gap. Bright pink outlines indicate the priority areas across the state. There are 59 of these priority areas currently identified through the CHIT evaluation process.

Even though there have been additions and removals of station locations in the past year, many of the priority areas identified in this year's analysis are very similar to those identified in last year's analysis. In fact, there are almost no new priority areas compared to last year; most priority areas in Figure 17 and Figure 18 are either the same as previously identified or modified in shape due to changes in coverage. However, there are some priority areas that have been removed in the last year because of coverage provided by nearby newly announced stations. The changes to priority areas in the past year include the following:

- The shapes of multiple priority areas in Sacramento, around the San Francisco Bay Area, and around the Greater Los Angeles region (including an extension into Glendale) have changed based on changes in coverage.
- Due to stations added in Fairfield and Vallejo, priority areas are no longer identified in Vallejo, Fairfield, and nearby Napa.
- Due to stations added in Livermore, Moreno Valley, Oxnard, and Rosemead, priority areas are no longer identified in these places.
- Due to stations added in and near Fresno and Palm Springs, portions of the priority areas previously identified in and around these cities have been removed.
- A new priority area covers the city core of Sacramento, due to the loss of a planned station in south Sacramento.
- A series of new and reshaped priority areas cover an area north of Mill Valley Santa Rosa. These priority areas likely arose in this year's analysis because of the removal of a planned stations in Novato and Santa Rosa.
- More neighborhoods in the Greater Los Angeles Region, especially between Burbank and San Fernando, are included in a large priority area that spans from Santa Clarita and Simi Valley south to Inglewood and east through two separate branches to Arcadia and La Habra Heights.
- More coastal cities in Orange County are included in priority areas in this year's evaluation than in previously reported.
- Although no new stations have been added nearby, no priority area is currently identified for Eureka or San Luis Obispo as in the last evaluation. The areas demonstrate high coverage gap values in this year's analysis, but the gap was still not high enough compared to other areas to be identified as priority areas.

Figure 17: Coverage Gap Analysis, as of August 10, 2023

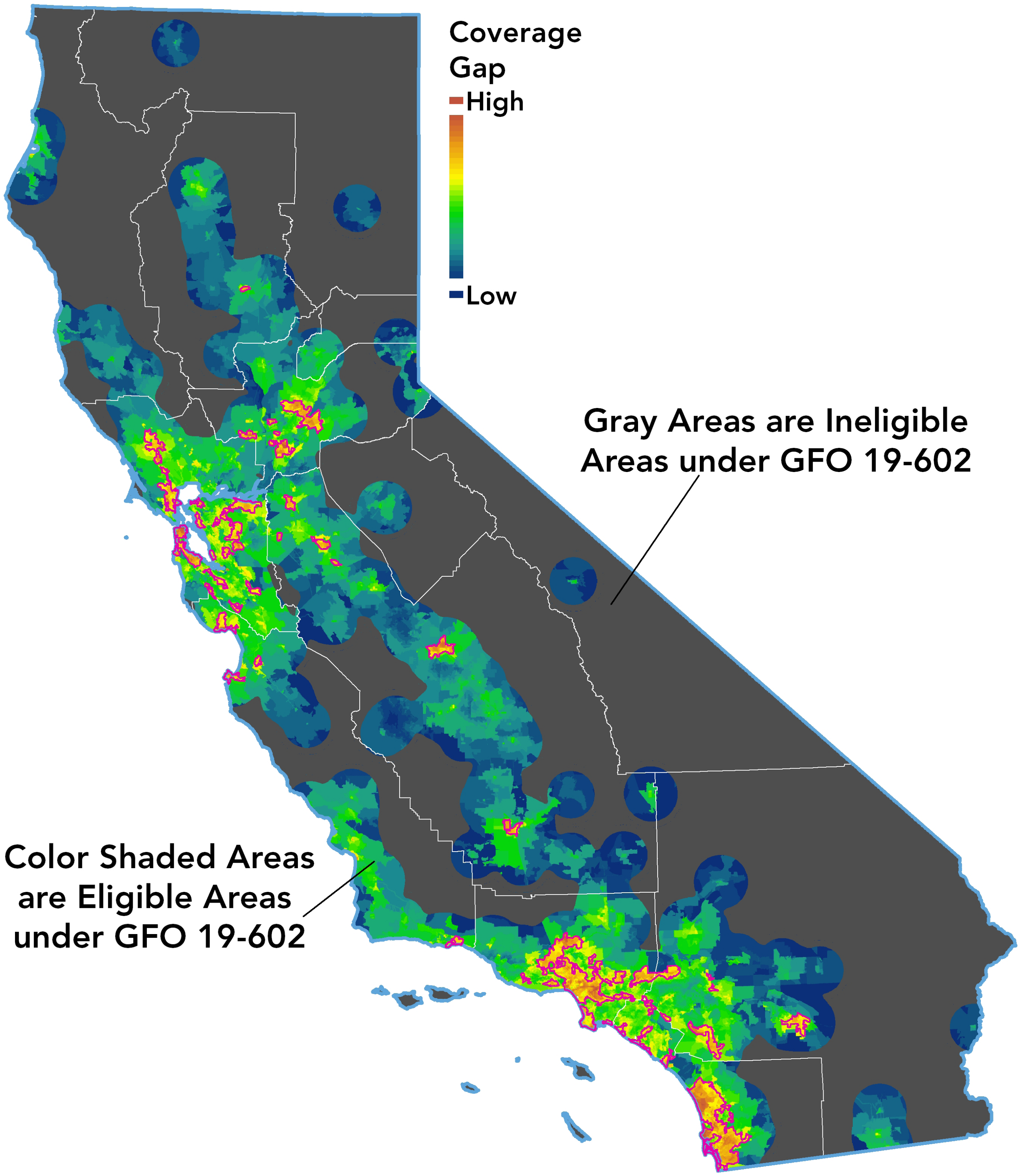
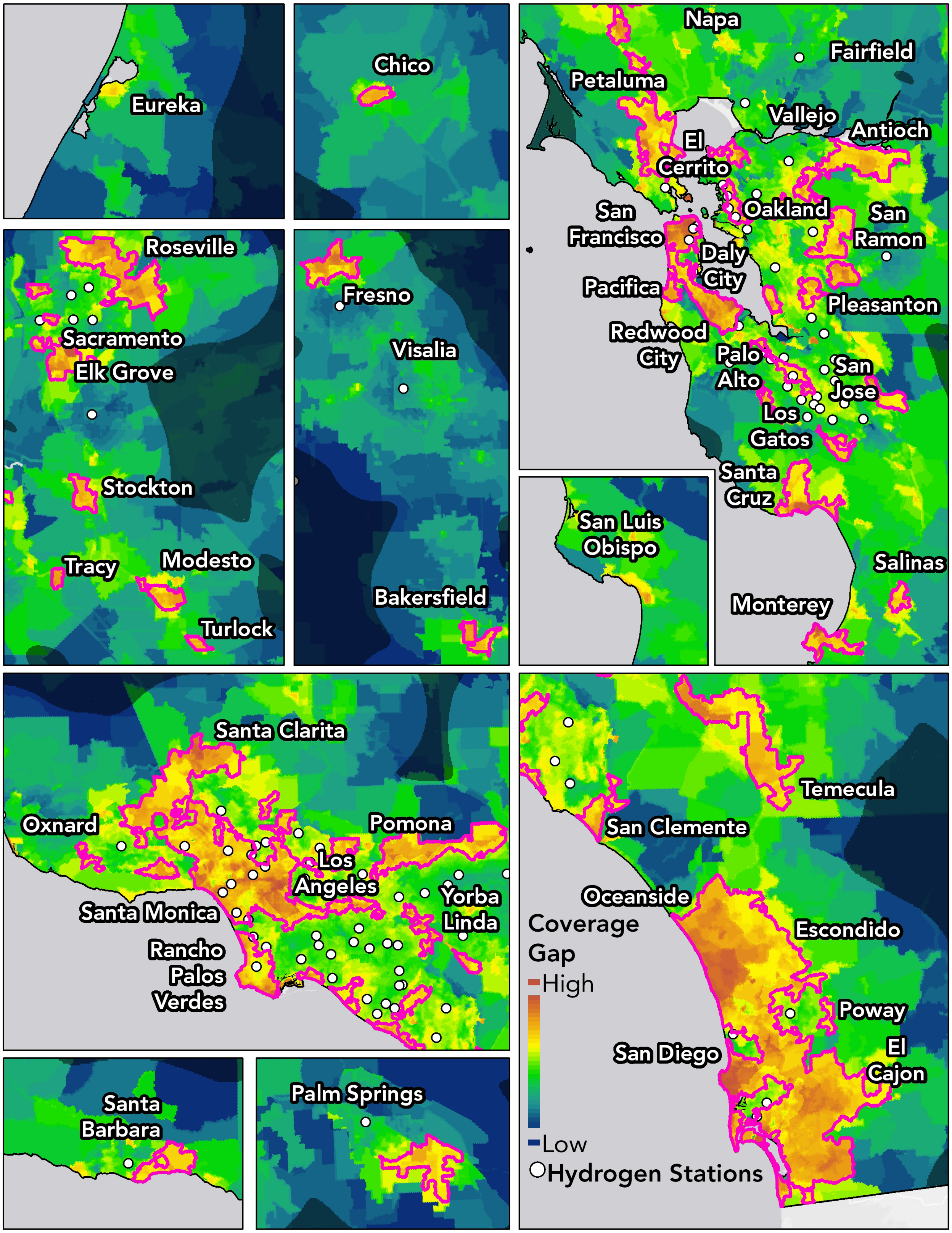


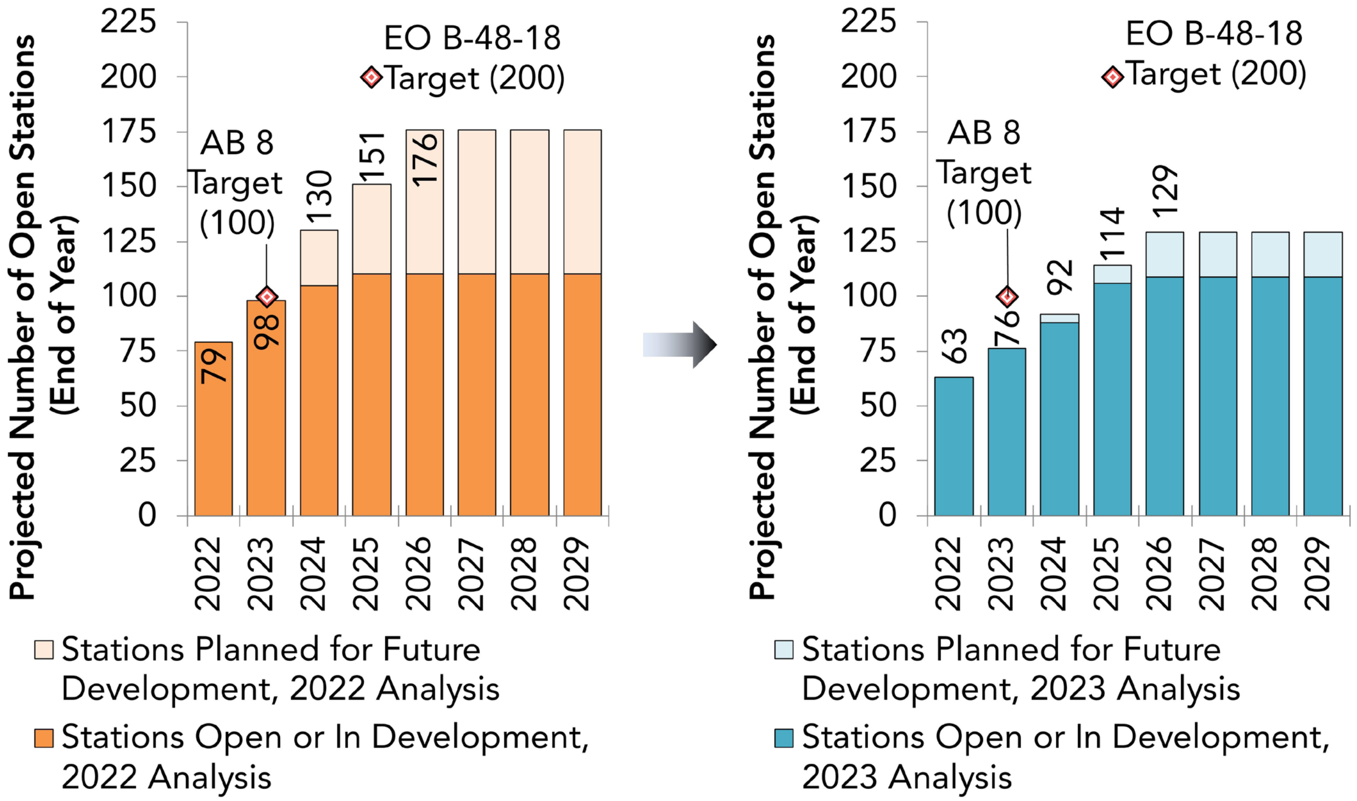
FIGURE 18: PRIORITY AREAS DETAIL FOR FUTURE STATION DEVELOPMENT



Trends of Station Deployment Rates

Over the past year, locations for previously funded hydrogen fueling stations have been proposed or changed, some station locations have been lost (to be replaced with new locations determined at a later date), some locations have been cancelled with no replacement planned, and new station awards have been announced. At the same time, station completion schedules for stations currently under development or planned for the future have been modified to account for ongoing challenges faced by the hydrogen station industry. The net result of these changes in the past year is shown in Figure 19, which compares the trajectories of total open station counts as reported in the previous *Annual Evaluation* and this report.

Figure 19: Comparison of Statewide Station Projections between 2022 and 2023 Annual Evaluations



As previously described, station development has overall progressed at a much slower pace in the past year than anticipated. In addition, the most recent data from station developers indicates that this slower development pace will continue into 2024 and 2025. At the same time, there has been a large net decrease in the total number of hydrogen station projects currently being tracked, at 129 compared to 176 at the same time last year. At least some of this difference can be recovered with future awards for replacement stations utilizing the funds previously set aside for the cancelled Shell stations. These stations are not reflected in Figure 19 since there is still significant uncertainty about the timing and number of stations that would be built as a result of re-awarding these grant funds.

While the Clean Transportation Program administered by the CEC has already dedicated grant funding to more than the 100 hydrogen fueling stations discussed in AB 8, the 100th hydrogen station is not expected to open until 2025 at the earliest. Prior estimates pointed to 98 open hydrogen stations by the end of 2023, which would imply reaching the 100th station in 2024 would not present much of a challenge. However, updated estimates from station developers show only as many as 76 hydrogen fueling stations open by the end of this year, and estimates from CARB staff indicate slightly fewer open stations by the end of the year. The projected annual growth rate for 2024, from 76 to 92 open stations, has only occurred once before in California's history (from 13 stations in 2015 to 29 in 2016). Projected development in 2025, from 92 to 114 stations, is even more ambitious. Staying on track with the current projected pace of development in the near term will therefore require progress on par with or even faster than what has been demonstrated in California to date. Although there are more supporting policies today, such as permit streamlining through SB 1291, today's stations are larger and more complex than those that were built in 2016, which may add more uncertainty to their construction timelines.

A substantial gap remains to achieving the goal of 200 total stations funded through a combination of public and private efforts, as outlined in EO B-48-18. There is now more uncertainty about the path to achieve this goal, especially since the fiscal year 2023-24 California budget removed $60 million from the state's general fund budget that had previously been appropriated for hydrogen fueling stations [43, 13]. More than 70 new stations, in addition to all the projects known today, need to be developed to reach the 200-station milestone. CARB and the CEC are aware of some private efforts that have recently begun to build new hydrogen fueling stations. However, these efforts appear to be in early planning and development stages, so the potential number, fueling capacity, and timing for construction of these remains uncertain. Given the typical timing to plan, design, construct, and commission hydrogen fueling stations, it is clear that California's hydrogen fueling network will not grow to 200 stations by 2025.

Courtesy of First Element, Inc.

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 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

In addition to the station location and coverage analysis presented in the previous chapter, CARB staff annually assess the fueling capacity provided by the open and funded network at statewide, regional, county, and local levels. Evaluation at multiple spatial resolutions ensures that localized gaps are not overlooked while also providing perspective of broader trends in future network capacity growth. Evaluations of capacity focus on the expected growth over the coming years given known hydrogen station development plans and identification of areas across the state where additional hydrogen fueling capacity may be needed. The evaluation of needs for additional capacity is complex and varies based on the assumed market demand and future targets for network growth. CARB staff assess network capacity under multiple market perspectives to provide a more holistic view in this analysis.

The progression of daily fueling capacity by region and statewide for 2022-2029 is shown in Figure 20 and Figure 21. As shown in the figures, additional capacity with location yet to be determined is currently planned for all years 2024 and later. This is due to the 20 hydrogen fueling stations that have been selected for award under future batches of GFO-19-602 but do not yet have an exact location specified. Across the entire state, hydrogen network fueling capacity is projected to grow by 260 percent compared to the open station capacity at the end of 2022, from nearly 37,000 kg/day to nearly 133,000 kg/day fueling capacity statewide.

Figure 20: Fueling Capacity By Region, 2022 (Historical) and 2023-2024 (Projected)

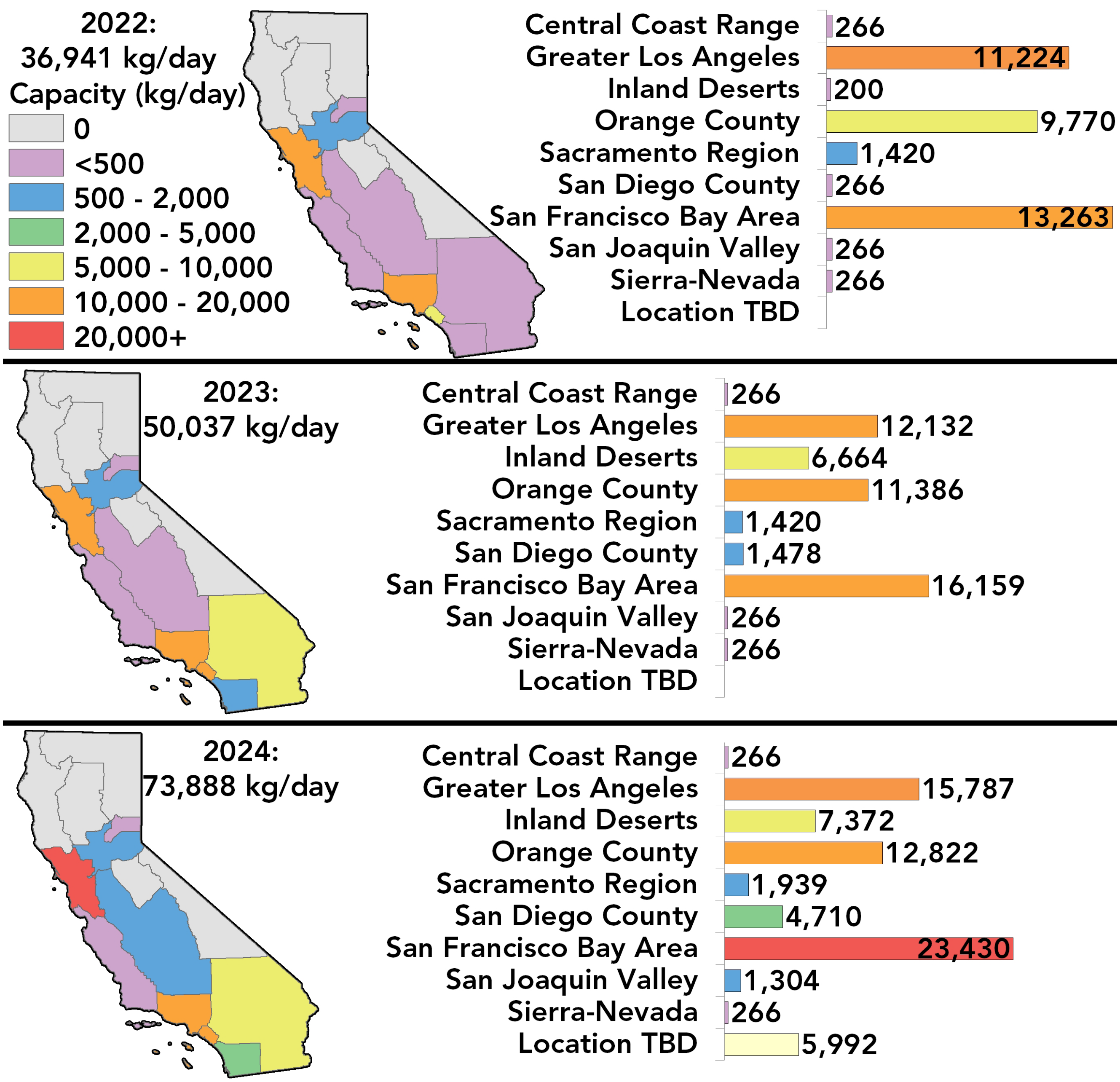
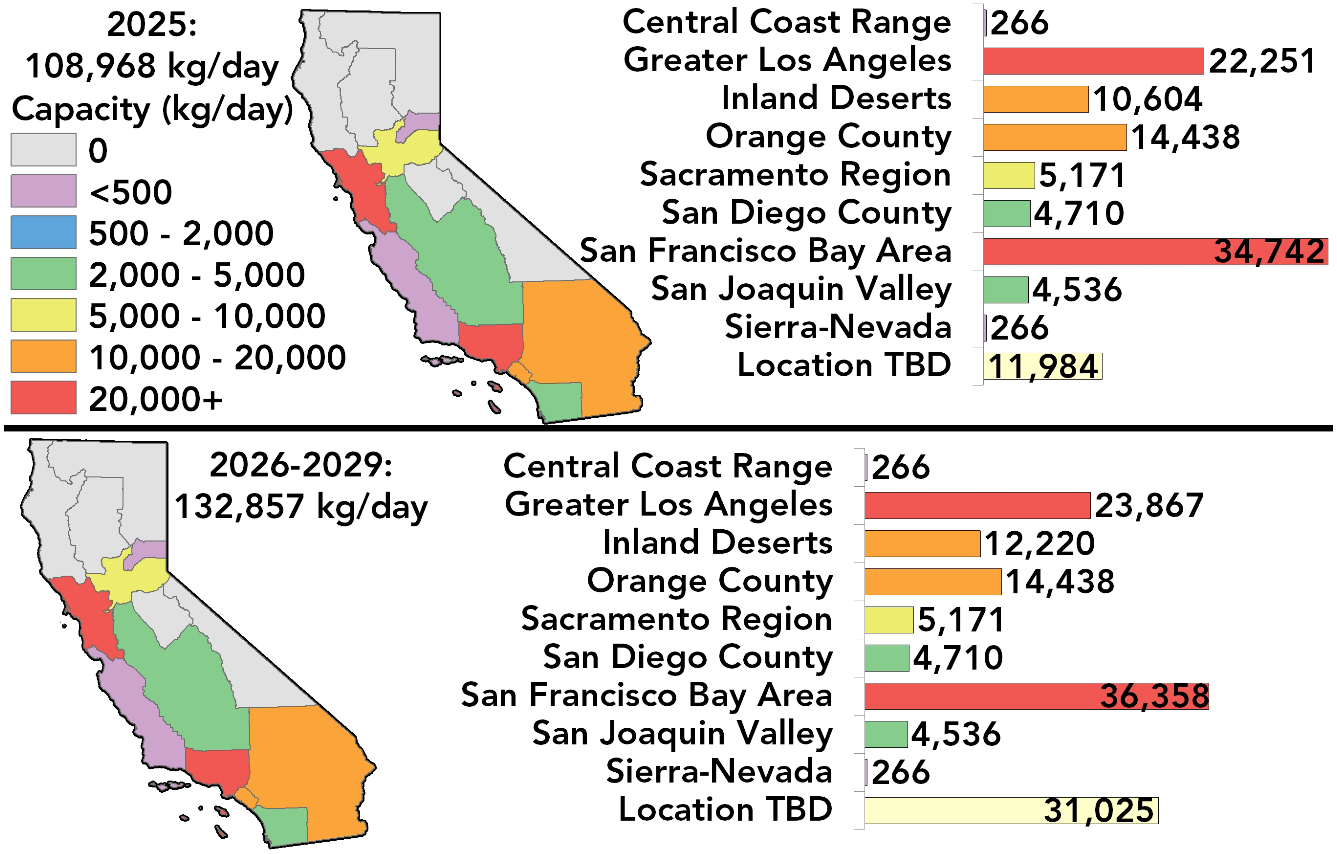


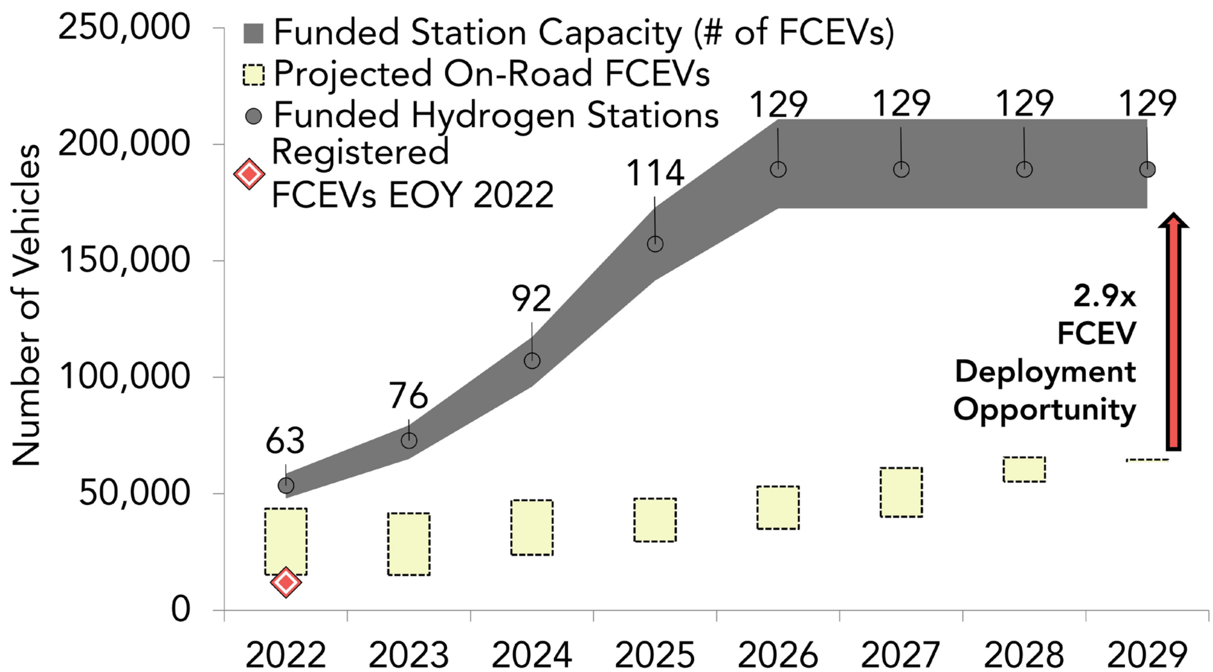
Figure 21: Projected Fueling Capacity By Region, 2025-2029



Similar to the observed trends for the expected growth in numbers of stations over the coming years, capacity growth (in terms of new kg/day capacity) will be led by the San Francisco Bay Area, Greater Los Angeles, Orange Country, and Inland Deserts regions. The regions with next-largest growth through 2029 will be the Sacramento, San Diego County, and San Joaquin Valley regions. While the Sierra-Nevada and Central Coast Range regions currently have installed capacity, no new capacity is yet planned for these regions through 2029. As a percentage of the regional installed capacity at the end of 2022, the Inland Deserts, San Diego County, and San Joaquin Valley regions will have the largest capacity growth rates by far, at 6,000 percent, 1,670 percent, and 1,605 percent, respectively. As previously discussed, the growth in the San Joaquin Valley region is a new development this past year, due to announced awards in GFO-22-607 and new station locations specified in GFO-19-602.

CARB staff evaluate the statewide fueling capacity growth in the context of the number of vehicles that could potentially be served by the network and compared to future on-the-road FCEV estimates. This comparison is achieved by converting the statewide fueling capacity into the theoretical number of vehicles served by assuming each vehicle will consume on average 0.7 kg/day (+/- 10 percent) of hydrogen fuel[31]. Figure 22 displays this comparison for an evaluation of the hydrogen station network's rated capacity compared to the latest projections for on-the-road FCEVs. This rated evaluation represents a theoretical maximum and does not account for any station downtime, theoretical optimum station use[32], or any localized mismatches between available fueling capacity and potential market demand.

Figure 22: Comparison of Projected Vehicle Deployment and Network Rated Capacity



The gray shaded area in Figure 22 depicts the range of vehicles that could be served by the planned fueling network, with the corresponding number of stations in each year indicated by the labeled gray circles. The yellow boxes represent the range of all projections for on-road FCEVs in that year, based on all past analyses of auto manufacturer surveys. Registered vehicle counts at the end of 2022 are shown by the diamond symbol. Under these idealized conditions, the projected hydrogen fueling network capacity growth is expected to stay well ahead of demand through the end of the decade. By 2029, the statewide hydrogen fueling network will have rated capacity at full availability sufficient for nearly three times the number of expected FCEVs on the road.

31 This conversion employs an industry-adopted standard assumption (established by researchers at the National Renewable Energy Laboratory) that each FCEV will consume approximately 0.7 kg/day. This assumes FCEV drivers use their vehicles in similar ways to gasoline drivers and captures the differences in energy content of gasoline and hydrogen and the efficiency of FCEVs versus conventional gasoline vehicles.

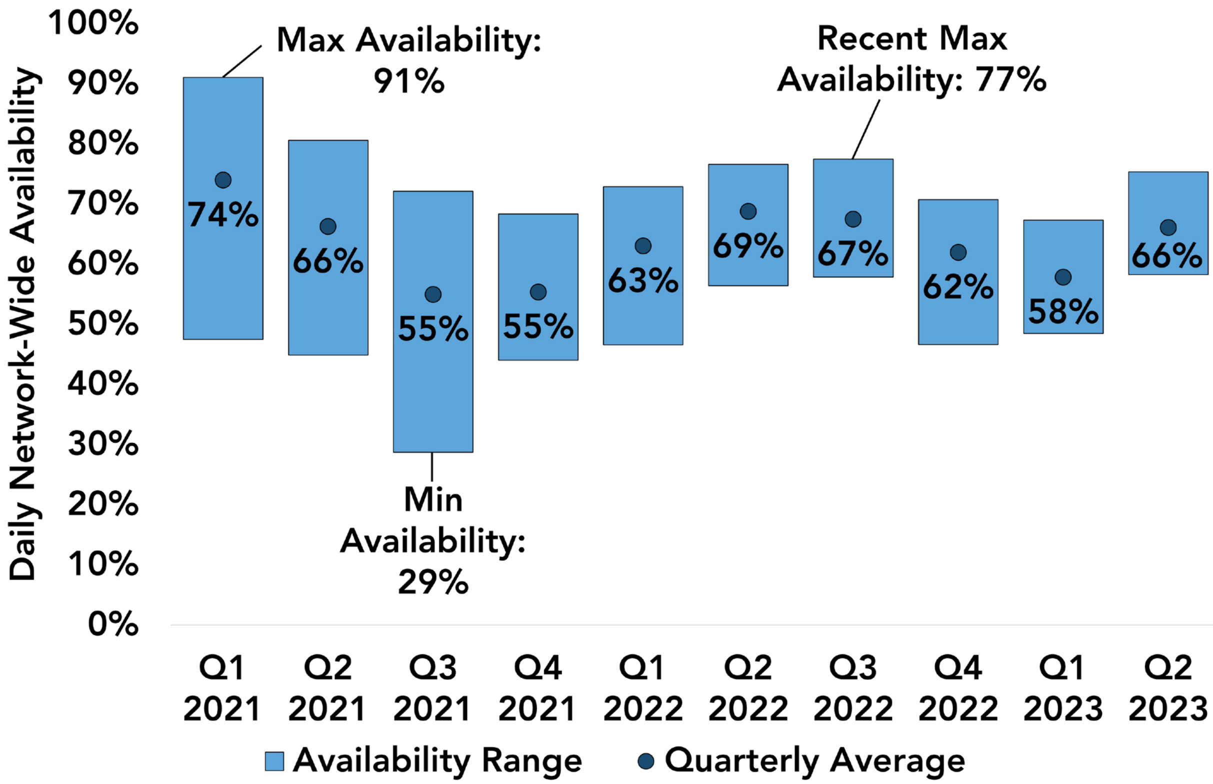
32 An optimal station use of 85 percent of rated capacity is often cited with respect to hydrogen fueling stations, based on gasoline station experience. This optimum ensures that the station maintains high fuel sales while also avoiding long lines and wait times for customers. It is separate from any considerations regarding equipment reliability and the availability of hydrogen fuel delivered to the station.

Operations of the hydrogen fueling network over the past few years have indicated that the network is not yet capable of consistently providing rated fueling capacity, as assumed in Figure 22. There have been many causes for this that have been in effect at various times over the past few years. At times, there have been limitations in the amount of available hydrogen fuel that could be delivered to stations. More recently, station operators have been challenged by difficulties with installed station equipment that may not be able to consistently provide rated fueling capacity, equipment that may wear out and need repair or replacement more quickly than previously expected, and difficulties maintaining reliable and responsive supply chains for replacement parts and technical support in making repairs.

The 2022 *Annual Evaluation* reported then-recent signs that some of the station reliability issues that affected the network were successfully being addressed and station availability was starting to approach historical highs in the 80 to 90 percent range. These trends were based on data shared by the Hydrogen Fuel Cell Partnership as collected through their Station Operational Status System (SOSS)[33]. More recent data provided by Hydrogen Fuel Cell Partnership staff indicate that network availability has remained low in the past year, largely due to challenges with station equipment. The data shared by the Partnership staff align with anecdotal information that CARB staff have heard from station operators and members of the public that have been fueling at the stations. Updated station availability data, shown in Figure 23, shows that average availability (for the most recent four quarters) has again fallen to around 60 percent, with recent lows around 45 percent, and recent highs only reaching 77 percent. Availability data indicate the percentage of time that a station is available for fueling relative to its normal operating hours. Stations are counted as available when the SOSS system indicates an online or limited status.

33 SOSS is a program developed by the Hydrogen Fuel Cell Partnership (originally the California Fuel Cell Partnership) to monitor real-time status of hydrogen fueling stations and share that information with fuel cell drivers. This allows drivers an opportunity to verify station availability before they drive to a station to refuel. The system is largely automated and provides a status (online, offline, limited, or unknown) and an estimate of available hydrogen fuel at the station. The limited status indicates that the station may be experiencing difficulty providing back-to-back fueling without interruption, which is more common during periods of high demand. Unknown typically denotes a temporary communication failure with the station.

Figure 23: Station Operational Status System Station Availability Data[34]

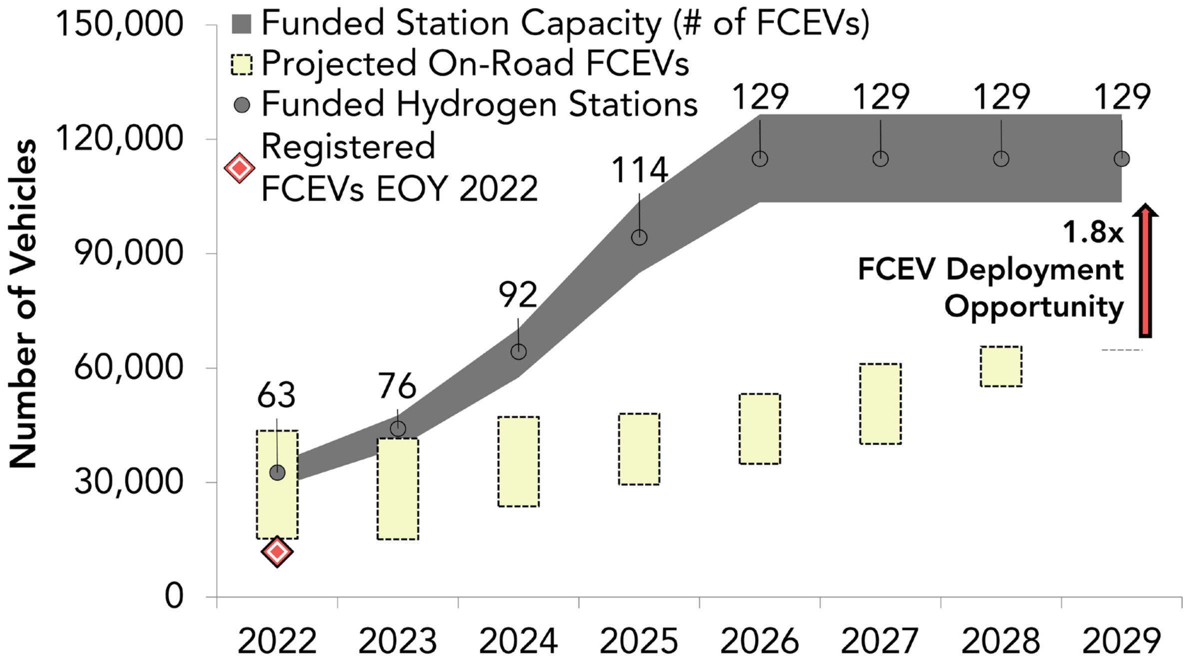


CARB, CEC, and other California government agencies continue to have active dialogue with station operators and other industry participants regarding recent trends in station availability and the outlook for future improvements. California government agencies also welcome input from today's FCEV drivers and those who might be interested in driving FCEVs but have questions and concerns about the experience they may have driving an FCEV. The CEC has previously shared that they are planning a driver experience workshop or similar event to collect FCEV drivers' perspectives, potentially to be held sometime in 2023 or 2024. Interested stakeholders are encouraged to monitor for announcements regarding this event[35].

34 This figure is developed by CARB staff using SOSS data provided by the Hydrogen Fuel Cell Partnership and other resources. The values shown should be interpreted as a representative estimate of recent availability trends. Values for Q1 2021 through Q2 2022 are slightly different than previously reported in the 2022 Annual Evaluation. After consultation with Hydrogen Fuel Cell Partnership staff, CARB staff have made a correction to all data to account for stations not reporting in SOSS because they are in Temporarily Non-Operational status. The values shown in the 2022 Annual Evaluation do not have this correction.

35 Interested parties may want to sign up for email alerts through the CEC's website at *https://public.govdelivery.com/accounts/CNRA/signup/31898*. Information will likely be distributed through the Clean Transportation Program email list.

Figure 24: Comparison of Projected Vehicle Deployment and Network Capacity at Recent Levels of Availabilty

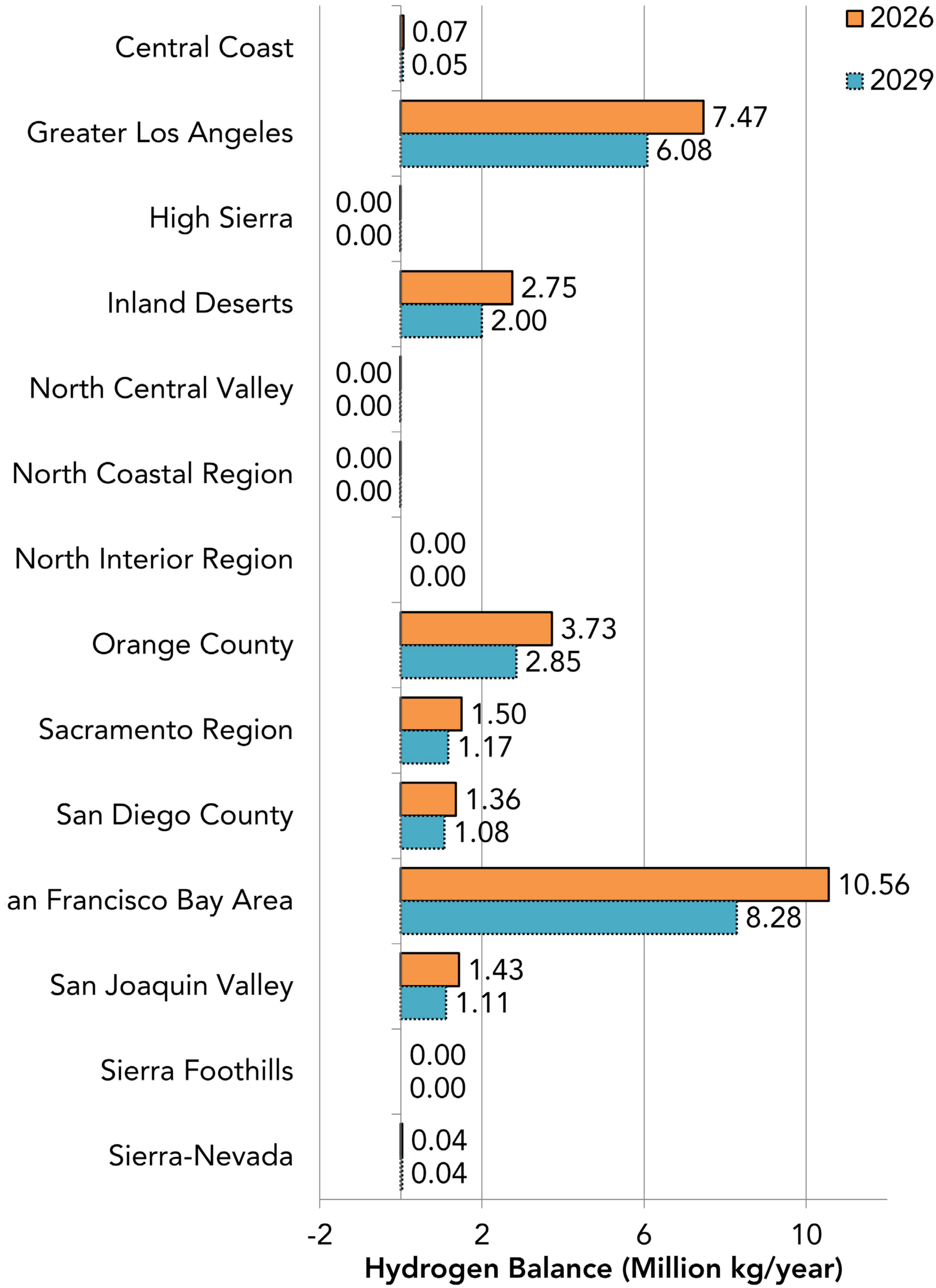


Station operators have shared that they are pursuing multiple strategies in parallel to help address the causes of low station availability recently observed in the network. These include ongoing technology development work, collaboration with equipment suppliers, and novel re-engineering on-site at many of the new stations entering the network (which may then be applicable to other new stations of similar design as they are built and commissioned). These efforts will hopefully result in improvements to individual station and overall network availability, though they may take some time to fully implement. As an illustrative example, Figure 24 compares the planned network capacity to projected vehicle deployment, assuming that station availability does not improve from recent values. This is not the desired or planned outcome but is presented as a demonstration of a potential worst-case scenario. As shown, planned capacity should still be sufficient for the number of on-road FCEVs through 2029 even with low availability. Though the margin is smaller than as shown in Figure 22, the estimated network capacity adjusted for low availability is slightly less than double potential demand in 2029.

While Figure 22 and Figure 24 demonstrate that the statewide total fueling capacity should be sufficient for the number of FCEVs on the road, more localized analyses of the balance between hydrogen fueling capacity and demand are necessary to ensure sufficient hydrogen capacity will be available at all geographic levels. Figure 25 presents one method of assessing the regional balance between fueling capacity and demand.

In this analysis, regional FCEV sales (and thus hydrogen demand) are assumed to be driven by the locations of the known hydrogen fueling stations, as previously shown in Table 2. Hydrogen station capacity and fueling demand are therefore assigned at the county level and then aggregated to the regional level in analysis. One adjustment is made from this primary driver of fuel demand in the analysis for Figure 25. In this analysis, CARB staff assume that hydrogen fueling stations that provide coverage to one or more counties may have their capacity meet the demands in each of these corresponding counties. The fueling capacity of these stations is assigned to each applicable county according to the relative demand projected within each county. Under this analysis framework, Figure 25 demonstrates that in 2026 and 2029, each region should have sufficient fueling capacity to meet the needs of on-the-road FCEVs, as all regions show a positive hydrogen balance. Hydrogen balance is defined as the difference between fueling capacity and fueling demand, with positive values indicating more capacity than demand.

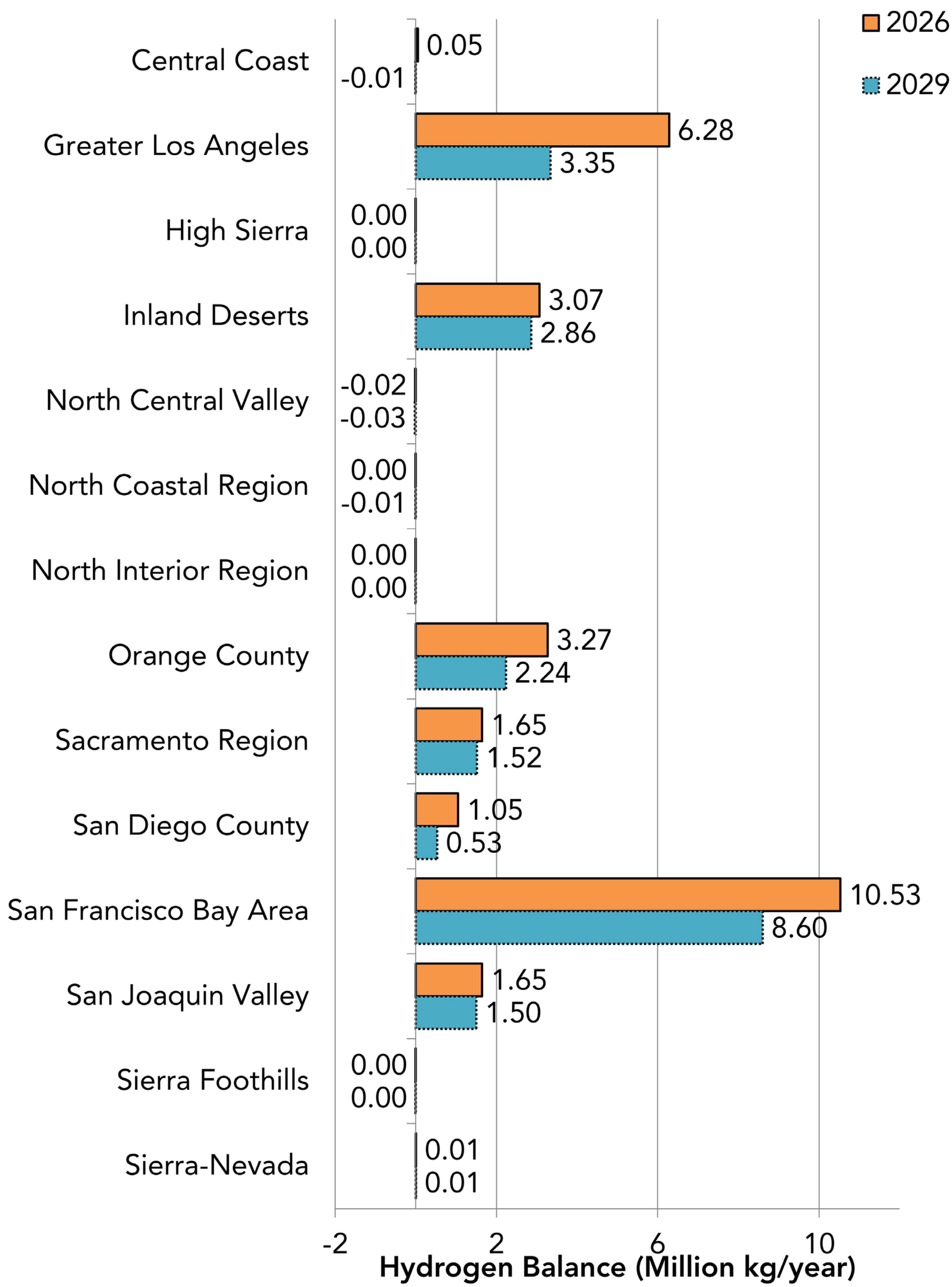
Figure 25: Hydrogen Fueling Capacity Balance by Region According to Current Known Stations



The CHIT tool offers an alternative method to investigate more localized hydrogen demand and capacity, as shown in Figure 26. Under this method, future FCEV sales are not assumed to be directly tied to the placement of hydrogen fueling stations, but rather according to the CHIT-derived evaluation of hydrogen fueling market demand previously described. This method therefore allows for the possibility (as observed with some registration data available today) that some FCEV sales will occur outside the limits of the funded and open hydrogen fueling network. The analysis of Figure 26 also assigns each station's hydrogen capacity to each county within its limit of coverage relative to each county's projected FCEV market strength, similar to the correction applied for the analysis of Figure 25.

With this fueling demand analysis driven more by potential FCEV market demand, almost all regions are similarly projected to maintain sufficient hydrogen fueling capacity in 2026 and 2029. The Central Coast, North Central Valley, and North Coastal regions show some very slightly negative hydrogen balances, indicating potential need for additional capacity in the future. However, given the small magnitude of these balances and the fact that there is currently limited to no hydrogen fueling station development planned for these regions, the need for new coverage in these regions (effectively to simply establish a local fueling network) will probably be a more significant driver than capacity growth.

Figure 26: Projected Hydrogen Fueling Capacity Balance According to CHIT Market Estimates



CARB staff investigated future capacity development from a third perspective, based on the core scenario analyzed in the 2021 *Hydrogen Station Network Self-Sufficiency Analysis* [44]. This scenario envisions the development of the hydrogen network to 1,000 hydrogen fueling stations by 2030, with sufficient capacity to support a fleet of one million FCEVs on the road in California. Although earlier growth in the hydrogen fueling network and on-the-road FCEV fleet had closely matched this scenario through the early 2020s, current projections for both hydrogen network development and FCEV sales now significantly lag this scenario, especially in the later years of the decade. This scenario does not represent a currently adopted state goal but serves to demonstrate the needed infrastructure development for one potential path to network financial self-sufficiency (subject to multiple other assumptions including reduced station and hydrogen costs, sufficient station utilization, and station development timelines).

Figure 27 and Figure 28 show the additional hydrogen fueling capacity that would be needed in each region and county, respectively, to match the self-sufficiency scenario. Across the entire state, approximately 370,000 kg/day of additional capacity beyond currently planned stations would be needed by 2029, which is equivalent to approximately 230 of the largest stations (1,600 kg/day) being built today. Some of this capacity would be met by the 20 stations with locations that are not yet specified but are funded under GFO-19-602. Some regions (High Sierra, North Interior, Sierra Foothills, and Sierra-Nevada) would need very little additional hydrogen station network development through the end of the decade under this scenario. The Greater Los Angeles and San Francisco Bay Area regions, being the largest potential markets for FCEV sales, would need the most additional capacity. These regions are followed by the San Diego County, San Joaquin Valley, and Inland Desert regions, each requiring more than 10 million kg/yr (approximately 27,000 kg/day) of additional fueling capacity. The Sacramento, Orange County, and Central Coast regions would also need significant yet smaller amounts of additional capacity during this time.

At the county resolution, Los Angeles County will require the most new capacity of any county by far in order to match the self-sufficiency driven scenario. Los Angeles County alone will require more than 100,000 kg/day in additional fueling capacity, equivalent to approximately 65 new 1,600 kg/day stations. San Diego County would require the second largest capacity growth through the end of the decade. Even though San Diego County would require the second-largest capacity growth, the number of stations needed (approximately 23) is less than half the estimated need in Los Angeles County. In addition, although the San Francisco Bay Area region would require the second-largest capacity growth at the regional level, Figure 28 demonstrates that each of the individual counties require much less new capacity than Los Angeles and San Diego Counties. Similar observations hold true for the counties that make up the San Joaquin Valley region.

FIGURE 27: PROJECTED HYDROGEN FUELING CAPACITY NEED BY REGION TO MATCH REFERENECE SELF-SUFFICIENCY SCENARIO IN 2029

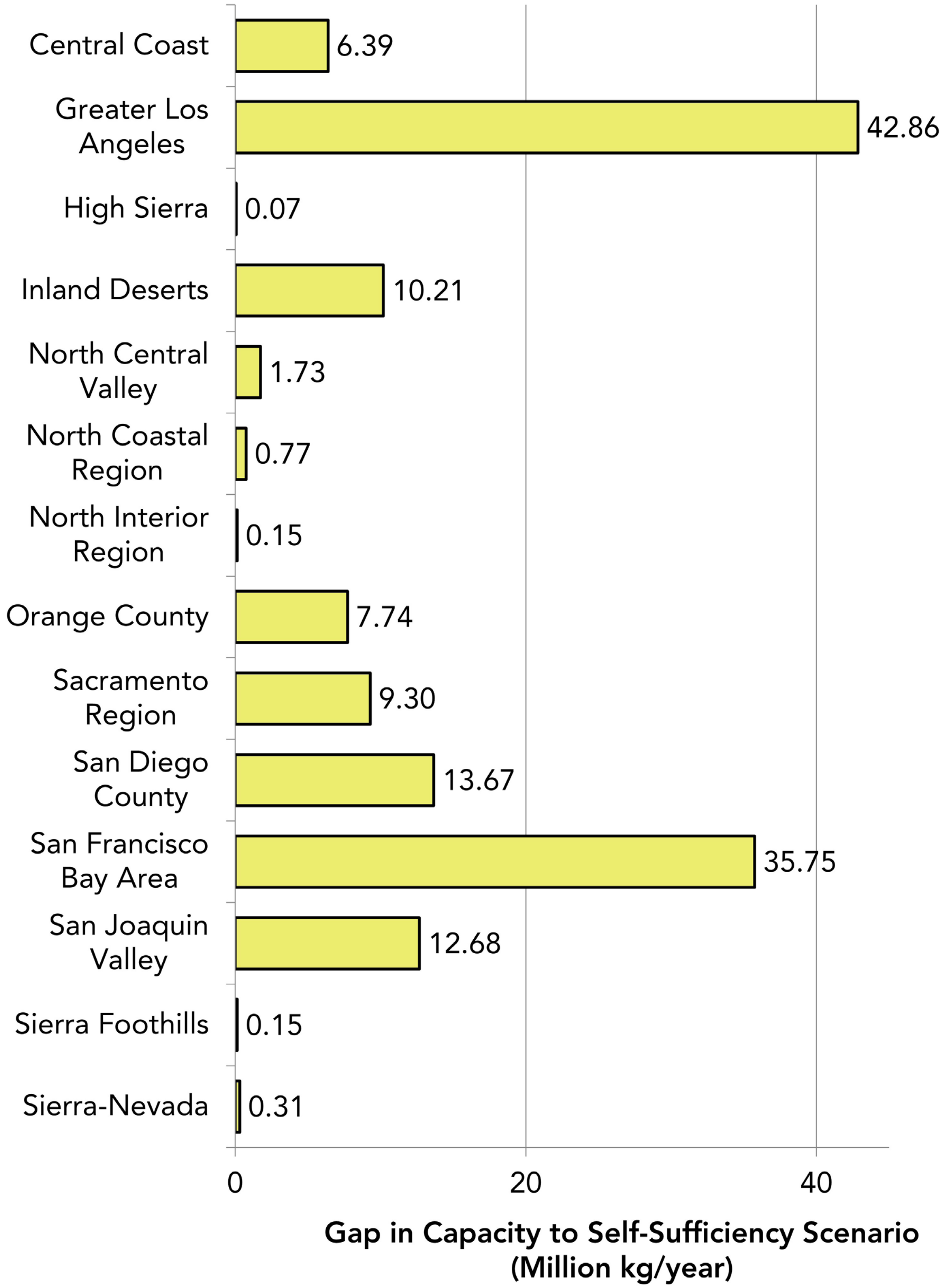
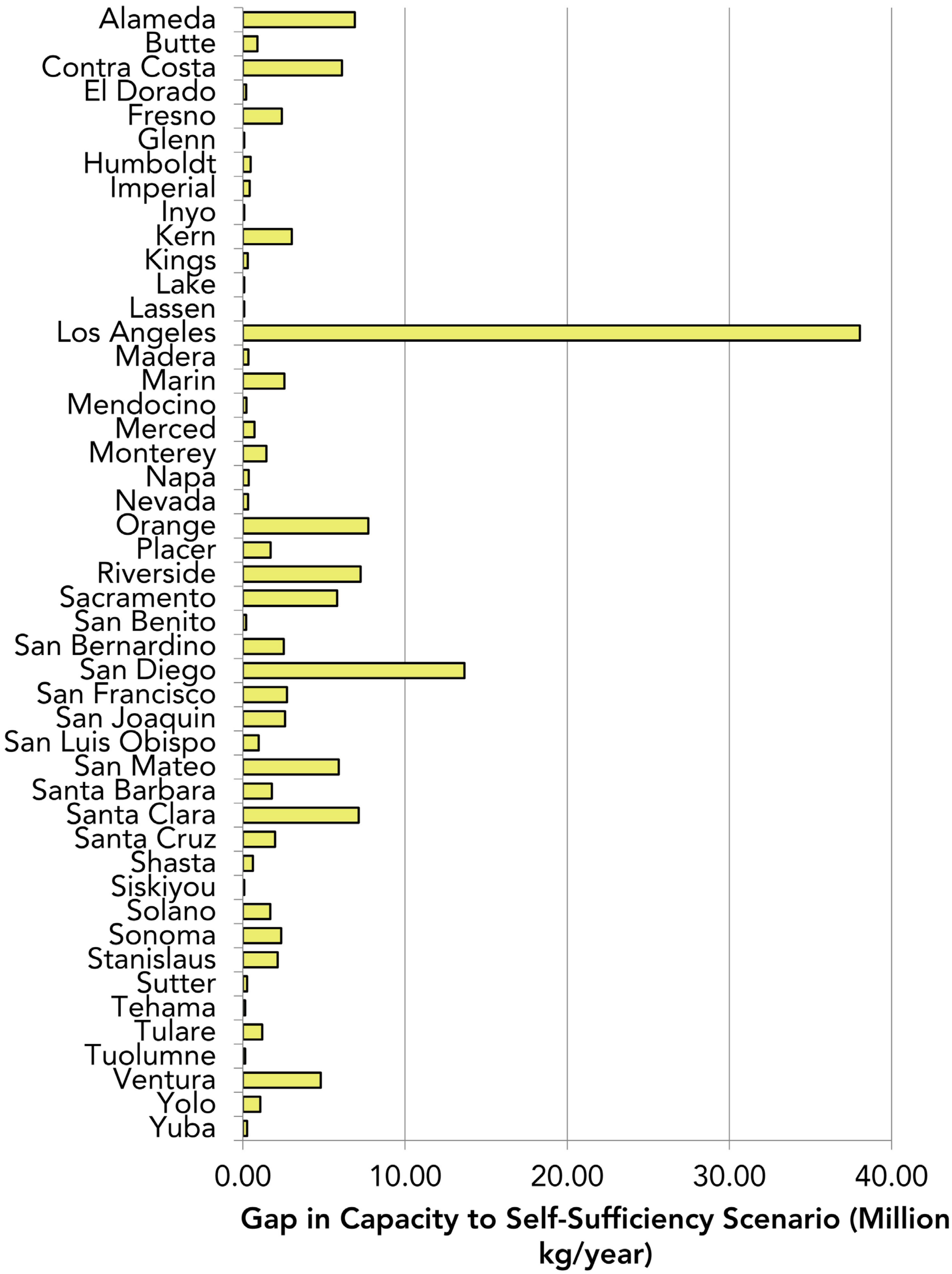


Figure 28: Projected Hydrogen Fueling Capacity Need Detail by County to Match Referenece Self-Sufficiency Scenario in 2029



The final capacity analysis method completed by CARB staff uses the CHIT tool to provide the most localized, high-resolution assessment for the potential future capacity needs of the projected 62,600 on-road FCEVs in 2029. Like the analysis in Figure 26, this localized analysis distributes future FCEV populations across the state according to the localized FCEV market potential calculations performed in CHIT. This analysis defines future hydrogen demand at the census block group level[36]. Localized needs for new hydrogen fueling capacity are then evaluated by first summing the hydrogen demand of all census block groups and rated fueling capacity of all stations within a 15-minute drive of every block group. The difference between assigned hydrogen demand and rated fueling capacity is then calculated at each block group as a representation of the localized need for additional capacity. This localized need for new capacity is zero unless hydrogen demand exceeds rated capacity. In the calculation process, this need is also assigned to the geographic center of the block group before completing the final step. Finally, interpolation is then used to estimate the capacity need in the spaces between block group centers. This process ensures a smoothly varying estimate of need for hydrogen station capacity that is larger closer to areas with higher need and gradually reduces at further distances[37].

Figure 29 shows the current evaluation of capacity need across the state, with detail views of key areas provided in Figure 30. As with the coverage gap maps of Figure 17 and Figure 18, capacity gap is displayed as a blue-to-red shading. Dark blue indicates zero need for new capacity by 2029 (assuming an on-the-road FCEV fleet of 62,600 vehicles), green and yellow indicate lower to midrange capacity needs, and orange and red indicate high capacity needs. The largest localized capacity needs in the state are 1,300 kg/day, which appear to be concentrated in San Francisco and Redwood City, across several cities in the Greater Los Angeles region, the Orange County region, a small area in the Sacramento region, and in the San Diego County region. Low to midrange local capacity needs are found in these same regions, across the San Joaquin Valley region, in the northern parts of the Central Coast Range region, and in some parts of the Inland Deserts region.

36 A block group is a geographic unit (i.e., a boundary shape drawn on a map) defined by the U.S Census Bureau. It is larger than a census block and smaller than a census tract. Block groups are made up of multiple census blocks and are the smallest geographic unit for which several data are published by the U.S Census Bureau that represent all households within the unit. For this analysis, the census block group resolution represents a balance as it provides a fine spatial resolution that provides data with a manageable size.

37 By this method, a new hydrogen fueling station that is planned for an area with an identified gap will then address all or part of the capacity needs for the entire area within its 15-minute extent of coverage. As a result, the capacity need of all points in the state in this evaluation should not be summed to arrive at total statewide capacity need. This would result in a large over estimation of the total need due to double-counting. The results of this analysis should only be interpreted at an exact location.

Figure 29: Current Capacity Gap Evaluation for Estimated 2029 FCEV Population

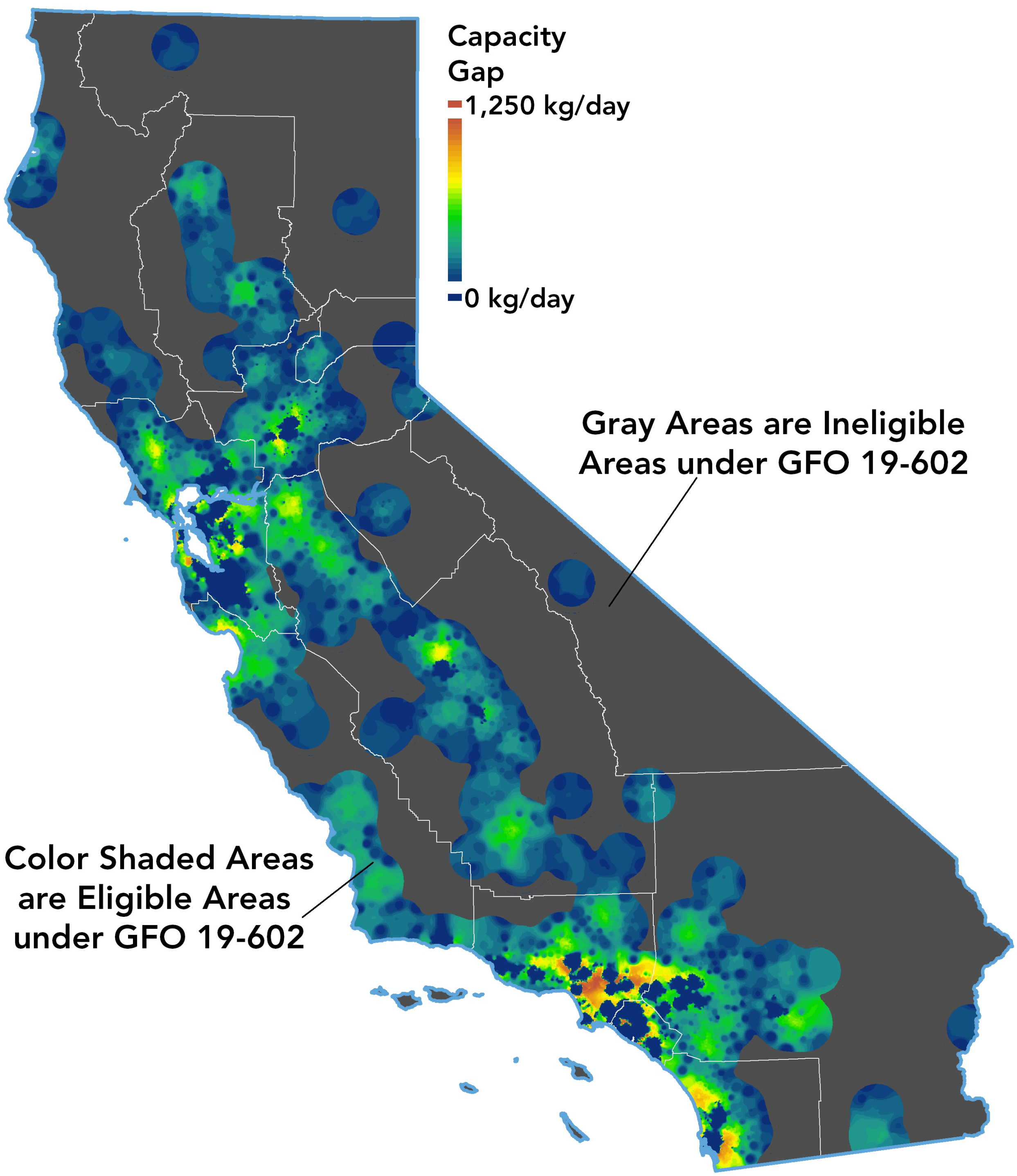
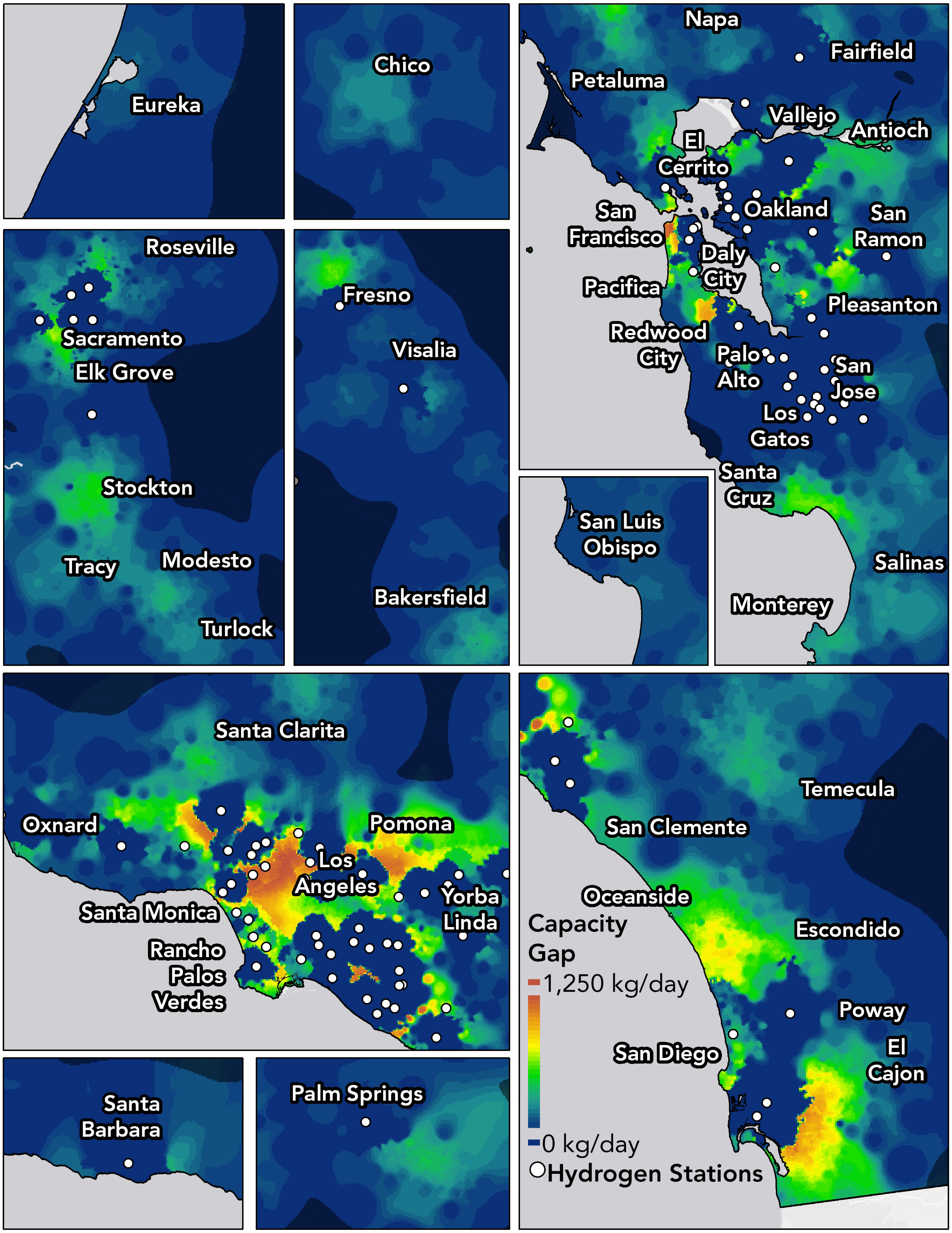


Figure 30: Capacity Gap Evaluation Detail



Capacity Requirements for Grant Funding Opportunity 19-602

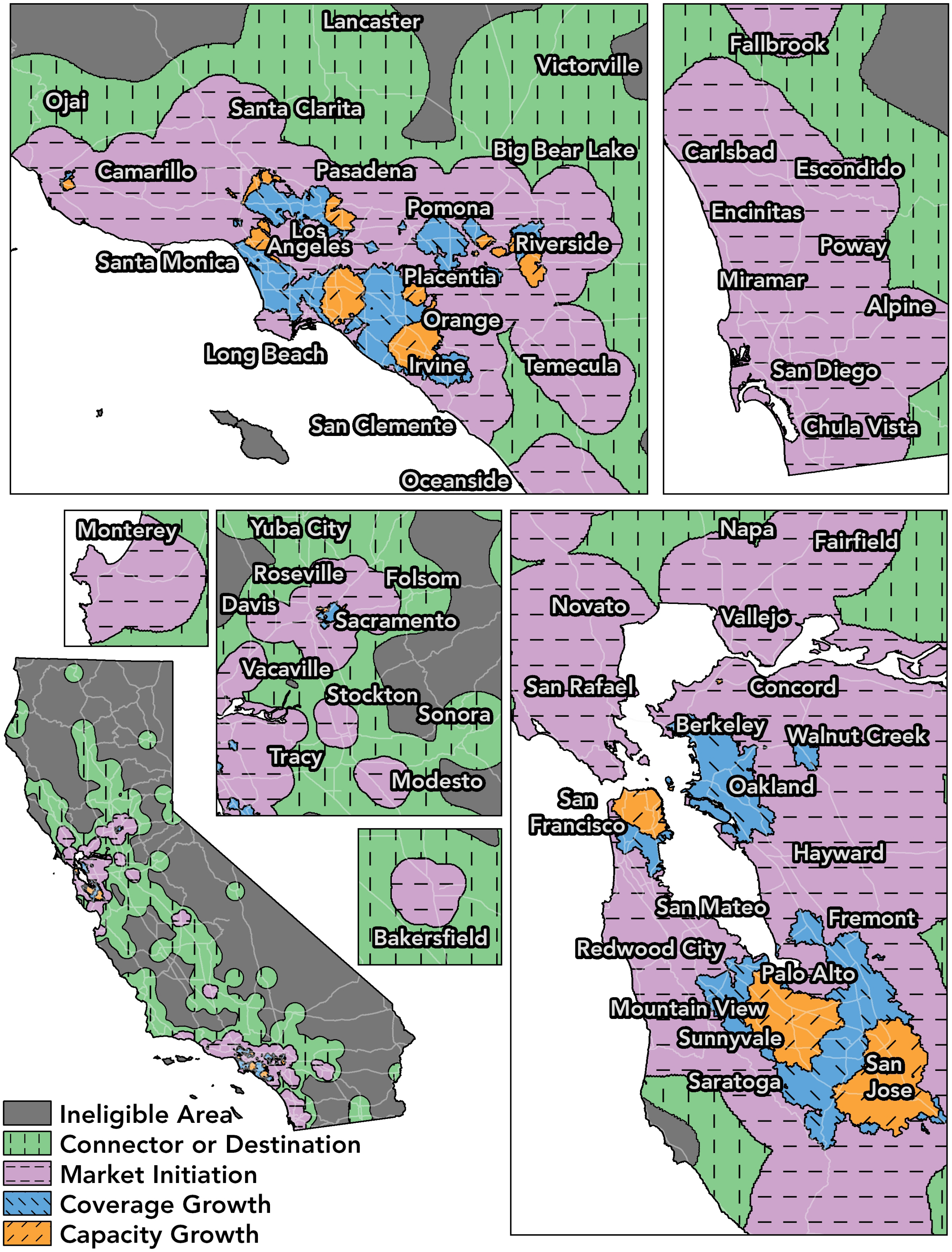
The CEC's multi-year grant solicitation GFO-19-602 includes requirements for minimum station capacity based on the location of proposed hydrogen fueling stations. This minimum capacity is based on prior evaluations of the potential market strength of FCEV demand across the state and evaluation of the locations where the largest amounts of future capacity would likely be needed to support hydrogen fueling demand. At the same time, the minimum capacity requirements acknowledge that there are many areas of the state where the hydrogen fueling market has not yet been fully initiated since there are little to no hydrogen fueling stations in the local area. In these areas where the hydrogen fueling market is still undergoing, or has yet to begin, this initiation process, smaller hydrogen fueling stations may be easier to economically justify until demand significantly increases. Finally, the capacity requirements were designed to be an evolving standard and intended to be re-evaluated as changes in the planned network occurred due to new station awards, locations of stations in new batches being submitted and approved, and other network changes.

Figure 31 displays an updated evaluation of the area classifications defined in GFO-19-602, which determine minimum capacity requirements[38]. This evaluation accounts for all changes to the open and planned hydrogen fueling network detailed in this report. Descriptions of each area classification are as follows:

- **Ineligible Area**: These locations are outside the extent of the long-term hydrogen fueling network identified in CARB's Self-Sufficiency report. This network is itself similar to, and informed by, the locations of stations in today's conventional gasoline fueling network.
- **Connector or Destination**: These locations are likely to primarily serve fueling demands of long-distance travelers or travelers to sightseeing and recreational destinations. They serve critical roles in the network but may not need as much individual station capacity as other locations.
- **Market Initiation**: These locations are part of the largest projected markets for hydrogen fuel demand, but currently have less than three hydrogen fueling stations providing coverage. Increasing coverage is a greater priority than increasing capacity until the market is more mature.
- Coverage Growth: These locations have high market potential for hydrogen fuel demand and have developed past the market initiation phase. Although these locations are part of the largest potential FCEV markets, they do not have the largest projected hydrogen demand, so focus should remain on expanding coverage.
- Capacity Growth: These locations have developed past the market initiation phase, are part of the largest potential FCEV markets, and are projected to have the highest amounts of future hydrogen demand. New stations in these locations should emphasize high capacity more than other locations.

38 The data shown should be considered temporary and should not be used to finalize any decisions that awardees in GFO-19-602 make for location and capacity of any station that will be submitted to the CEC for approval. The solicitation manual for GFO-19-602 outlines the timing for re-evaluation of the area classifications with respect to applicants' completion of stations in each batch. CARB will work with the CEC to provide an updated evaluation at the appropriate time per the GFO-19-602 guidelines. The information in Figure 31 is provided only as a reference point for the evaluation at the time this report was drafted.

Figure 31: Temporary Updated GFO-19-602 Area Classifications



Renewable Content of California's Hydrogen Fueling Network

Hydrogen dispensed at California's hydrogen fueling stations has continued to meet minimum requirements for renewable resource implementation as established by current incentive programs and SB 1505 (Lowenthal, Chapter 877, Statutes of 2006). SB 1505 first established a minimum requirement that 33 percent of all hydrogen sold at stations that receive California state government support must be derived from renewable resources. This requirement extends to all stations selling hydrogen fuel in the state regardless of funding source once the total hydrogen fuel throughput in a 12-month period exceeds 3.5 million kg.

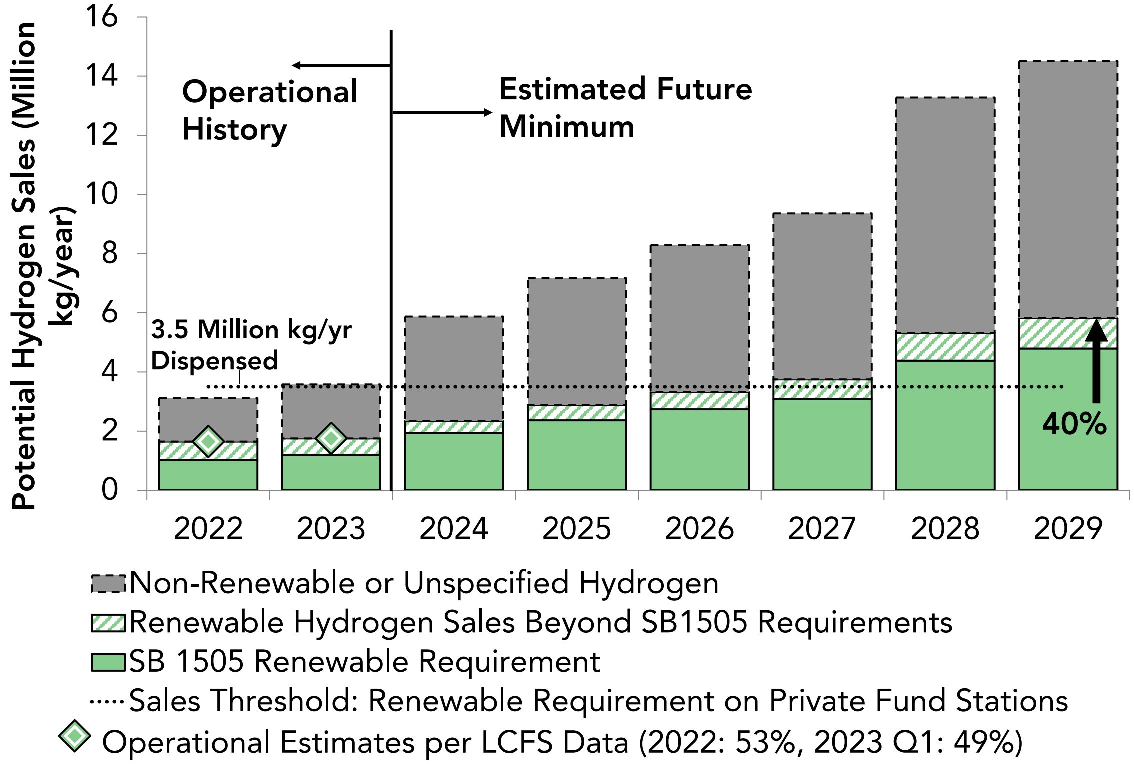
Renewable hydrogen requirements in the CEC's grant funding solicitations and the LCFS program currently set the minimum for renewable hydrogen sales across the hydrogen fueling network. Throughout all grant funding solicitations, the minimum renewable hydrogen requirement has at least matched the 33 percent requirement outlined in SB 1505 and for some stations has been as high as 100 percent. Since the adoption of amendments to the LCFS in 2019, which established the HRI crediting provision, the minimum requirement for grant funding and HRI crediting has exceeded the SB 1505 minimum, requiring at minimum a 40 percent renewable implementation.

Evaluation of the proportion of hydrogen sold that was generated through the use of renewable resources is completed in accordance with definitions of qualifying renewable energy resources outlined by the California Public Utilities Code, Sections 399.11-399.36[39]. Multiple types of renewable resources, including bio-derived gases, electricity from wind and solar resources, geothermal power, and others qualify as renewable resources under these definitions. In addition, as with all fuels tracked by the LCFS program, renewable resources are considered fungible, subject to strict accounting requirements to ensure the same renewable attributes are not used for credit across multiple regulatory and incentive programs. This allows hydrogen (and other) fuel providers to generate renewable energy through projects and installations not directly tied to the facilities that generate the hydrogen (so-called "indirect" renewable attributes). In the case of hydrogen fuel sold in California, this is most often achieved by hydrogen suppliers through the purchase of biomethane renewable attributes generated through biogas production pathways that are then attributed to the hydrogen fuel.

Using data available through the LCFS program for all reporting hydrogen fueling stations, CARB staff estimate that 53 percent of the hydrogen sold in 2022 was generated with renewable attributes. In the first quarter of 2023, 49 percent of all hydrogen fuel sold has been sourced via renewable attributes. While these rates of renewable energy use in hydrogen fuel production exceed SB 1505 requirements, CEC grant solicitation requirements, and LCFS HRI crediting requirements, they represent a continued decrease in renewable implementation over the past two years. CARB staff previously reported that renewable implementation reached as high as 90 percent in 2020 and decreased sharply to 59 percent for 2021. This reduction has continued, though at a slower pace, into 2022 and 2023.

39 California Code of Regulations Title 17, Division 3, Chapter 1, Subchapter 10, Article 4, Subarticle 7, §95481 (a)(131)

Figure 32: Evaluation of Minimum Renewable Hydrogen Content in California's Fueling Network



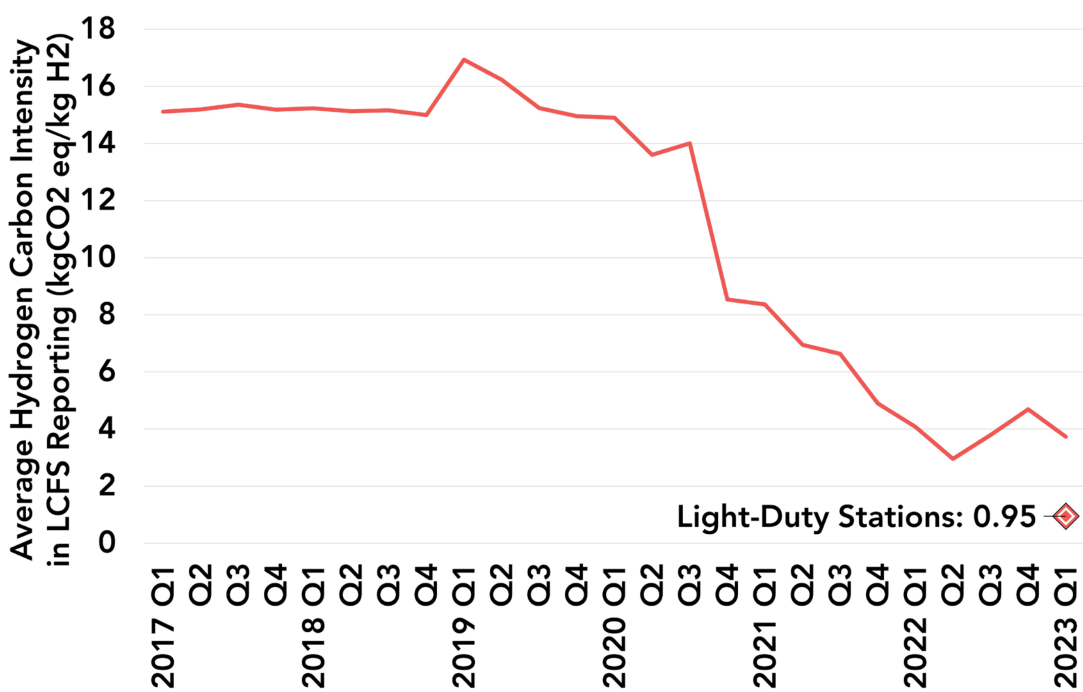
Despite this recent reduction in renewable energy attributes in hydrogen fuel production, CARB staff anticipate that the network will continue to at least meet a rate of 40 percent renewable implementation in future hydrogen fuel sales, due to the requirements of current incentive programs. Current and future anticipated renewable and non-renewable sourcing for hydrogen fuel are shown in Figure 32. CARB staff also estimate that the projected light-duty vehicle fuel demand this year (based on standard assumptions detailed in the previous chapter) could exceed the 3.5 million kilogram threshold to trigger enforcement of the SB 1505 requirements on privately funded stations (though to date, CARB staff are unaware of any fully privately funded stations that are not also participating in the LCFS HRI crediting provision, which would make them subject to a 40 percent renewable requirement).

The continued use of more renewable attributes in hydrogen produced for sale as transportation fuel is a positive outcome, though the recent trend of diminishing rates of implementation is a concern for the long-term goal of transitioning to increasingly cleaner and sustainable forms of hydrogen fuel production. This is especially true for the goal of enabling large-scale market expansion and economies of scale in clean hydrogen production that will be necessary for the fuel to remain a viable choice for consumers should FCEV demand increase and grow beyond the current very early adopter market.

Recent data regarding the carbon intensity of hydrogen production (a measure of the rate of greenhouse gas emissions associated with the production, distribution, and delivery of hydrogen fuel) underscores this concern. As shown in Figure 33, the average full fuel life-cycle carbon intensity for hydrogen fuel tracked through the LCFS program has significantly decreased since 2017, when the average was around 15 $kgCO_{2eq}/kgH_2$. More recently, the carbon intensity reached a minimum equivalent to approximately 3 $kgCO_{2eq}/kgH_2$, with the latest estimate at 3.7 $kgCO_{2eq}/kgH_2$[40]. For light-duty hydrogen stations alone, the reported average carbon intensity in Q1 2023 was even lower, at 0.95 $kgCO_{2eq}/kgH_2$. These are positive trends showing reduced emissions per unit of hydrogen. These recent values also compare well with the federally mandated definition of clean hydrogen (defined as 4 $kgCO_{2eq}/kgH_2$ for production alone and not including distribution and delivery as in LCFS data). This definition will be applied to the several targets and programs in the Inflation Reduction Act and Infrastructure Investment and Jobs Act, including clean hydrogen production tax credits, and other programs.

This marked reduction in delivered hydrogen carbon intensity over the past several years is an overall positive development. However, considering this reduction in carbon intensity in parallel with the reduction in overall renewable implementation may indicate a developing concern for the evolution of the hydrogen fuel market toward large-scale renewable implementation and the activation of economies of scale. In general, renewable hydrogen production pathways tend to have lower (sometimes significantly lower) carbon intensities than non-renewable pathways. Because of this relationship, it is not common to observe reductions in carbon intensities at the same time as reduced implementation of renewable pathways, as has recently occurred with hydrogen fuel used in California. However, these trends could simultaneously develop if station operators are procuring hydrogen from sources with progressively smaller carbon intensities in progressively smaller amounts over time. This smaller throughput of renewable-derived hydrogen, even if very low carbon, likely does not significantly contribute to market development toward the goal of achieving economies of scale.

Figure 33: Trends in Hydrogen Fuel Carbon Intensity in LCFS Program [45]



40 Similar to reporting of renewable percentage, the calculation of carbon intensity accounts for the application of fungible renewable attributes from facilities within the hydrogen producer's operations that may not be directly involved in the production of hydrogen gas dispensed in California's fueling network.

This recent trend toward smaller amounts of renewable hydrogen procurement may be driven at least in part by the operating station economic challenges mentioned earlier in this report. Station developers and operators have reported increased costs in equipment, station design and construction, and operation due to a combination of forces including inflation, limited workforce, increased energy costs, and reduced LCFS credit values over the past couple of years. Traditionally, renewable hydrogen (whether direct or indirect) has cost more to procure than non-renewable hydrogen produced from conventional fossil sources. The additional economic pressures may have pushed station operators to reduce the rate of procuring renewable hydrogen to offset the other increased costs. As previously mentioned, station operators have historically sold renewable hydrogen at rates exceeding program requirements, exceeding 90 percent renewable hydrogen sales at times.

Even though renewable hydrogen is more expensive than fossil-derived hydrogen, the other costs of building and operating stations (along with the revenue of incentive programs) may have allowed for the additional expense of renewable hydrogen in previous years. Recent increases in operating costs and decreases in incentive revenue have likely constrained station operators' budgets. As a result, station operators may now have less budget available to dedicate to paying the additional cost for renewable hydrogen procurement. Station operators would then either need to pass the additional cost to consumers or decrease the amount of renewable hydrogen they procure and sell in order to maintain economically viable stations. LCFS program data demonstrate that operators have chosen to gradually reduce the rate at which they procure and sell renewable hydrogen at their stations. Although the rate of renewable hydrogen sales has decreased from 90 percent to 50 percent over the past two years, station operators have maintained renewable hydrogen sales above program requirements.

CARB and other state government collaborators will need to continue to monitor this developing situation and may need to consider what measures might be required to ensure that the hydrogen fuel industry continues to make progress towards large-scale implementation of renewable and low-carbon pathways for hydrogen fuel production, distribution, and delivery.

Courtesy of First Element, Inc.

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.

For FCEVs to be a viable zero-emission vehicle option in California, hydrogen fueling stations must be able to provide a consistent, reliable, and safe fueling experience. Technical methods to achieve these goals and procedures to verify stations have this capability are typically addressed by industry-adopted standards published by organizations like SAE International, CSA Group, and the International Organization for Standardization (ISO). These standards address multiple aspects, including design of station equipment, communications standards and protocols between vehicles and hydrogen dispensers, hydrogen purity requirements, hydrogen dispensing protocols with limits on temperature and pressure during fill events, and several other aspects affecting the customer's hydrogen fueling experience.

Multiple programs administered by California state agencies ensure that California's hydrogen fueling stations operate according to these industry-adopted standards. Hydrogen fueling station co-funding grants administered by the CEC have continually required awarded stations to adhere to the latest published versions of the related SAE, CSA, and ISO hydrogen fueling standards. Since 2015, CARB has operated the Hydrogen Station Equipment Performance (HyStEP) device to test hydrogen stations' ability to follow the hydrogen fueling protocol established by the SAE J2601 standard. Review of station performance through the HyStEP program has been a collaborative process, involving multiple California state agencies, the station developer, and auto manufacturers. The California Department of Food and Agriculture's Division of Measurement Standards (DMS) has administered programs to ensure proper hydrogen quality according to the SAE J2719 standard and to ensure accurate measuring of the amount of hydrogen dispensed for retail sale according to standards set in the National Institute of Standards and Technology's Handbook 44.

Many standards are under near-constant review and revision to make technical improvements, address industry developments and newly recognized needs, and resolve inconsistencies or gaps in prior versions. Work has continued over the past year on some of the standards relevant to hydrogen stations, especially the fueling protocol SAE J2601, but there have been no published updates since last year's reporting. CARB staff continue to follow the developments of the standards and provide perspective based on the experience gained through the multiple programs administered by CARB and other California state agencies.

In addition to the standards themselves, CARB and collaborators have been working to update the related station testing and compliance programs. In particular, staff have been working to enhance the California state government's efforts in testing and ensuring that hydrogen fueling stations properly dispense fuel according to the SAE J2601 fueling protocol. Two main efforts have been underway in the past year: 1) the development of a hydrogen station testing regulation administered by DMS, and 2) the development and procurement of an updated HyStEP station testing device.

Updates to the Development of a Hydrogen Station Testing Regulation

As first reported in the 2022 *Annual Evaluation*, CARB and DMS have partnered to develop a regulation that would codify the type of station testing requirements currently carried out by the HyStEP program into the California Code of Regulations. Today, stations are only required to verify their conformance with the SAE J2601 fueling protocol standard via HyStEP through the various support mechanisms available today (including the LCFS HRI program and the CEC's station co-funding grant solicitations). In addition, the HyStEP device is currently the only known and named device permitted in these programs, though station developers and operators may implement devices that are demonstrated to be functionally equivalent or rely on coordination with auto manufacturers to aid in station testing (which has historically been a long and difficult process).

The new regulation would help bring more consistency in application of the requirements and provide greater opportunity for options in meeting compliance. By codifying adherence to the SAE J2601 hydrogen fueling protocol in the California Code of Regulations, the standard would be required of all stations that operate in the state, regardless of their funding source. This will help ensure that fully privately funded stations and stations that receive some form of state government aid have a consistent and equivalent set of expectations for providing safe, fast, and reliable fueling experiences to customers. The regulation development also aims to enable testing by additional entities beyond CARB to ensure that hydrogen station testing will not become a bottleneck during the station development process should network expansion accelerate in the coming years. Finally, the regulation is also intended to establish the first periodic testing requirement to ensure that stations stay within compliance of the SAE J2601 fueling protocol over time.

Over the past year, CARB and DMS partners have continued efforts to develop the regulation. The first public workshop was held in-person and virtually on August 11, 2022 to discuss the proposed regulation language and details of its implementation. The proposed language as presented at the workshop was as follows:

"DMS Recommended addition to title 4 California Code of Regulations (CCR), Division 9, Section 4002.9:

Section 4002.9. Hydrogen Gas-Measuring Devices (3.39).

UR. 2.4. Safety Requirement – All hydrogen gas-measuring devices subject to this code shall maintain verification of testing demonstrating conformance with the latest version of SAE J2601 Fueling Protocols for Light Duty Gaseous Hydrogen Surface Vehicles as determined by the latest version of ANSI/CSA HGV 4.3, Test Methods for Hydrogen Fueling Parameter Evaluation."

Feedback provided at the workshop and afterward indicated a need to further study several details of the implementation, including what organizations may perform testing, how often stations may be tested, and various technical details of the testing and implementation. CARB and DMS staff have been collecting information to address these questions. In particular, agency staff have been working in collaboration with station developers and operators to collect information and devise a test plan to make an informed decision on how often it may be necessary to re-test hydrogen fueling stations after they have first demonstrated conformance with the SAE J2601 fueling protocol standard. Further updates to the regulation development may be available later in 2023 or early 2024.

Development of a new Hydrogen Station Equipment Performance Testing Device

CARB's station testing program has been enabled by the first-generation HyStEP device that was first delivered to California in 2015. This first-of-its-kind device continues to prove useful today in testing station conformance to the SAE J2601 fueling protocol. However, through the last 8 years' worth of experience, CARB staff and their public and private partners have identified a need for an updated device with greater capabilities. In particular, a new device would be able to complete station tests more quickly, be able to provide some capability to test back-to-back fills, be able to test station protocol performance for a wider range of simulated vehicle tank capacities, provide insight on real-world total station capacity, and ideally be able to provide improved capability to test medium- and heavy-duty stations[41].

CARB and the CEC previously entered into an interagency agreement for the CEC to provide funds to CARB to procure an updated HyStEP 2.0 device. CARB and the CEC had agreed on a competitive request for proposals (RFP) process administered by CARB to award the funds to a third party to design, construct, test, validate, and deliver the new device to California. CARB first released the RFP on April 14, 2023, and hosted an online webinar for prospective applicants on May 2, 2023. Final applications were due June 14, 2023. CARB did not receive any applications by the original deadline.

Since no applications were received, CARB staff have reassessed various aspects of the RFP, including the allocated budget and the timeline for application submittal. CARB staff made several changes, including increasing the allocated budget from $850,000 to $1,050,000[42], and re-released the RFP on October 18, 2023. Applications are due to CARB by January 24, 2024, with selection of an awardee anticipated by March 13, 2024.

41 The current HyStEP device was not originally designed with medium- and heavy-duty station testing in mind. However, it has been used to provide limited testing capability to some of these types of stations. A new device that is designed from the beginning with this capability in mind may provide more opportunities for testing these kinds of stations in the future.

42 CARB staff determined that a budget increase was required to generate broader interest and elicit a larger number of applications. The original budget of $850,000 had been determined in 2019 based on the best-known information at the time. As discussed elsewhere in this report, the effects of the COVID-19 pandemic and recent inflation have been cited by many station developers as increasing costs in the hydrogen fueling industry. Given the similarities in equipment, labor force, and industry, CARB staff anticipate that similar factors impact the budget for the HyStEP 2.0 RFP.

Courtesy of Iwatani Corporation

Conclusions and Recommendations

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

CARB Actions: Recommend station network development targets for next CEC program. Recommend priority locations to meet coverage needs in next CEC program. Recommend minimum operating requirements and station design features to incentivize in next CEC program.

Over the past 10 years, the CEC's Clean Transportation Program has made significant progress toward California state government goals for hydrogen fueling infrastructure development. The CEC ensured that more than 100 hydrogen fueling stations (a key milestone referenced in AB 8) were awarded co-funding for development earlier than the program's January 1, 2024 sunset date. In addition, the CEC has implemented new grant funding solicitations to continue advancing network planning toward the 200-station target of EO B-48-18.

At the same time, progress on the ground has been slow throughout the duration of the Clean Transportation Program. While more than 100 stations have been awarded co-funding, the 100th station is now projected to open in 2025 at the earliest, assuming optimistic station development timelines in the next two years. In addition, a large number of station projects have recently been cancelled. Although some of the funds from the cancelled stations will be available for new station grant awards, and the California legislature has ensured the extension of hydrogen station funding via the Clean Transportation Program though 2030, there is currently no clear path to establishing 200 total hydrogen fueling stations in California. Given typical timelines for committing funds, developing grant solicitation guidelines, awarding grants, signing contracts, and building stations, it is clear that any potential future public and private efforts to close the gap to 200 stations will not achieve that milestone by 2025.

Station developers annually face more challenges and barriers than anticipated to quickly develop new hydrogen stations. Operating hydrogen stations have faced challenges with equipment and hydrogen fuel supply. Broader economic factors like COVID-19, inflation, and Russia's actions stemming from the war in Ukraine have impacted the industry and challenged the operating finances of stations. Challenges faced in the past year have especially had a strong impact on the pace of new station development, station operational reliability, and the consumer experience.

As station development timelines have continually extended beyond prior expectations, projections for future FCEV sales have been pushed later multiple times over the course of the past 10 years. Despite long-term projections for installed network capacity larger than projected hydrogen demand, auto manufacturers continue to report that uncertainty in network development timelines is one factor limiting long-term FCEV sales projections to one-third of the funded network's ultimate capacity. Low station reliability also plays a role limiting projections of future FCEV sales, and with recent station reliability averaging near 60 percent, long-term network capacity provides a slim margin over projected demand. Unless reliability improves, new stations are funded, or both, the network in 2029 will only have a useable fueling capacity 80 percent above projected demand. This leaves little room for further FCEV sales growth in the next decade. Improvements in planned network capacity and individual station reliability are clearly critical to fostering the growth of the FCEV on-road fleet beyond current projections.

CARB continues to see a potential role for hydrogen-fueled FCEVs in the future ZEV fleet, especially as the market evolves to reach the 100 percent ZEV sales goals of the Advanced Clean Cars II program. The investments made through the Clean Transportation Program and the support provided by the LCFS program are critical pieces to launch the hydrogen fueling market in California and support its development toward the ultimate goal of financial self-sufficiency. Despite the challenges, these programs remain focused on those goals and there is significant opportunity remaining in these programs to continue working to resolve challenges and expand the hydrogen fueling network so that larger numbers of consumers can reasonably and reliably choose to drive an FCEV as their ZEV of choice.

Given the developments over the past year and the experiences of CARB staff and collaborating staff at the CEC and other agencies over the past ten years, CARB staff make the following recommendations for hydrogen station support through the Clean Transportation Program and potential parallel efforts:

- **Collaborate through public-private efforts to understand the root causes of recent slower station development pace and identify strategies to avoid these causes in the future.** California's hydrogen station developers and operators have reported multiple and varied challenges faced during the station financing, siting, design, permitting, construction, and commissioning phases over the past several years. These considerations may often affect stations on a case-by-case basis, but others may be more systemic and apply not only to all stations within a single developer's portfolio but across multiple developers. To date, there is not yet a comprehensive understanding of the individual and aggregate root causes of the drivers of station development timelines beyond individual anecdotes. Public agencies will likely need to collaborate more closely with the private station developer industry to develop a deep understanding of these driving factors to co-develop solutions (whether public policy, private business practice, or both).
- **Leverage the upcoming hydrogen fuel customer outreach event to help identify prioritization for potential public support programs.** The CEC is currently planning to host at least one event that will provide an opportunity for hydrogen fuel consumers to provide direct feedback and perspective on their experiences with California's hydrogen fueling network. This feedback may be a useful resource for determining the appropriate prioritization of funding and other program development among the multiple goals of new station construction, reliability improvement, station upgrade and refurbishment, and hydrogen station economics (especially reducing price paid at the pump). This can help ensure that CEC funding decisions and other public programs to support hydrogen fueling stations appropriately consider public consumer priorities and perspectives.
- **Convene station operators and developers to help solidify priorities and identify pathways to solutions. As priorities are identified, the next key step will be the identification and development of viable and effective solutions that can sustainably address the current challenges.** CARB, the CEC, and other public agency collaborators will likely need to reach out to private industry members to gather information and understand perspectives on the types of solutions that could be addressed with existing support programs, planned funding, and potentially new support program concepts. In particular, public financial investment may not be the most effective means to address some of these challenges and public-private conversations should help identify these cases and alternative strategies to resolve the challenges in these cases.
- **Continue to monitor developments in the renewable hydrogen market and seek solutions that will incentivize business practices to build economies of scale.** Trends in LCFS program data demonstrate that California's hydrogen fueling station operators have recently begun to reduce the sourcing of renewable and clean hydrogen to sell at their stations. While the individual sources have significantly reduced carbon intensity over the past several years, the volume of hydrogen purchased from these low-carbon and renewable sources appears to have significantly declined. This trend runs counter to the long-term goal of helping to establish a widespread production and distribution system based on renewable and low-carbon hydrogen. CARB and other California state agency partners will need to monitor this developing situation, especially as the economics of hydrogen fueling stations continue to evolve in the future.

New policies or programs may need to be considered that incentivize expansion, rather than contraction, of renewable hydrogen implementation and enable growth of economies of scale in California's renewable hydrogen production and distribution market.

- **Continue to ensure that new station funding addresses gaps in established markets while maintaining a focus on establishing and reinforcing new markets, especially in rural and disadvantaged communities.** New hydrogen fueling station grant awards made through the CEC's GFO-22-607 have successfully brought hydrogen fueling station plans to new markets that were previously unaddressed, especially in the San Joaquin Valle. At the same time, ongoing network development and new station proposals continue to support the need for reinforcing coverage and expanding available hydrogen fueling capacity in some of the largest potential hydrogen demand markets that have historically been the focus of developers' efforts. It appears that the hydrogen fueling market is ready for even more emphasis on this dual approach to build new hydrogen fueling stations both in the core early markets and in new markets across the state, including rural and disadvantaged communities that have not yet been addressed by planned hydrogen network development. As new funding allocations are made through the Clean Transportation Program as a result of AB 126, opportunities arise for hydrogen station funding through the newly awarded ARCHES hydrogen hub, and the CEC determines the best path for new station grant awards from the funds in Shell's recent grant agreement cancellation, a strategy similar to GFO-22-607 should be considered to help expand the geographic reach of network coverage and capacity.

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Appendix A: Assembly Bill 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

Table 7: List of Hydrogen Fueling Station Data as of August 10, 2023

Name	Address	City	Capacity (kg/day)	Retail Open	County	Renewable %
Coalinga	24505 W Dorris Ave	Coalinga	266	2015	Fresno	40%
Diamond Bar	21865 E Copley Dr	Diamond Bar	180	2015	Los Angeles	33%
San Juan Capistrano	26572 Junipero Serra Rd	San Juan Capistrano	394	2015	Orange	33%
UC Irvine	19172 Jamboree Rd	Irvine	180	2015	Orange	33%
West Sacramento	1515 S River Rd	West Sacramento	394	2015	Yolo	33%
Anaheim	3731 E La Palma Ave	Anaheim	180	2016	Orange	33%
Campbell	2855 Winchester Blvd	Campbell	266	2016	Santa Clara	40%
Costa Mesa	2050 Harbor Blvd	Costa Mesa	266	2016	Orange	40%
Del Mar	3060 Carmel Valley Rd	San Diego	266	2016	San Diego	40%
Fairfax	7751 Beverly Blvd	Los Angeles	180	2016	Los Angeles	33%
Hayward	391 West A St	Hayward	266	2016	Alameda	40%
Hollywood	5700 Hollywood Blvd	Los Angeles	266	2016	Los Angeles	40%
La Cañada-Flintridge	550 Foothill Blvd	La Canada Flintridge	266	2016	Los Angeles	40%
Lake Forest	20731 Lake Forest Dr	Lake Forest	266	2016	Orange	40%
Long Beach	3401 Long Beach Blvd	Long Beach	266	2016	Los Angeles	40%
Mill Valley	570 Redwood Hwy	Mill Valley	266	2016	Marin	40%
Playa Del Rey	8126 Lincoln Blvd	Los Angeles	266	2016	Los Angeles	40%
San Jose	2101 North First St	San Jose	266	2016	Santa Clara	40%
Santa Barbara	150 S La Cumbre Rd	Santa Barbara	266	2016	Santa Barbara	40%
Santa Monica	1819 Cloverfield Blvd	Los Angeles	180	2016	Los Angeles	33%

Name	Address	City	Capacity (kg/day)	Retail Open	County	Renewable %
Saratoga	12600 Saratoga Ave	Saratoga	198	2016	Santa Clara	40%
South San Francisco	248 S Airport Blvd	South Francisco	266	2016	San Mateo	40%
Truckee	12105 Donner Pass Rd	Truckee	266	2016	Nevada	40%
Woodland Hills	5314 Topanga Canyon Blvd	Woodland Hills	180	2016	Los Angeles	33%
Fremont	41700 Grimmer Blvd	Fremont	266	2017	Alameda	40%
Lawndale	15606 Inglewood Ave	Lawndale	180	2017	Los Angeles	33%
Riverside	8095 Lincoln Ave	Riverside	100	2017	Riverside	33%
San Ramon	2451 Bishop Dr	San Ramon	393	2017	Contra Costa	33%
South Pasadena	1200 Fair Oaks Ave	South Pasadena	206	2017	Los Angeles	40%
Torrance	2051 W 190th St	Torrance	200	2017	Los Angeles	33%
Citrus Heights	6141 Greenback Ln	Citrus Heights	513	2018	Sacramento	40%
Emeryville	1152 45th St	Emeryville	350	2018	Alameda	100%
LAX	10400 Aviation Dr	Los Angeles	200	2018	Los Angeles	40%
Mountain View	830 Leong Dr	Mountain View	349	2018	Santa Clara	33%
Ontario	1850 Holt Blvd	Ontario	100	2018	San Bernardino	100%
Palo Alto	3601 El Camino Real	Palo Alto	136	2018	Santa Clara	40%
Thousand Oaks	3102 Thousand Oaks Blvd	Thousand Oaks	266	2018	Ventura	40%
CSULA	5151 State University Dr	Los Angeles	51	2019	Los Angeles	100%
Oakland	350 Grand Ave	Oakland	808	2019	Alameda	40%
Sacramento	3510 Fair Oaks Blvd	Sacramento	513	2019	Sacramento	40%
San Francisco-Harrison Street	1201 Harrison St	San Francisco	513	2019	San Francisco	40%
San Francisco-Third Street	551 Third St	San Francisco	513	2019	San Francisco	40%
Fountain Valley	18480 Brookhurst St	Fountain Valley	1212	2020	Orange	40%

Name	Address	City	Capacity (kg/day)	Retail Open	County	Renewable %
Mission Hills	15544 San Fernando Mission Rd	Mission Hills	1212	2020	Los Angeles	40%
San Francisco-Mission Street	3550 Mission St	San Francisco	513	2020	San Francisco	40%
Aliso Viejo	26813 La Paz Rd	Aliso Viejo	1616	2021	Orange	40%
Berkeley	1250 University Ave	Berkeley	513	2021	Alameda	40%
Campbell-Hamilton	337 E Hamilton Ave	Campbell	1212	2021	Santa Clara	40%
Concord	605 Contra Costa Blvd	Concord	1212	2021	Contra Costa	40%
Costa Mesa-Bristol	2995 Bristol St	Costa Mesa	1616	2021	Orange	40%
Placentia	313 West Orangethorpe Ave	Placentia	1616	2021	Orange	40%
Sherman Oaks	14478 Ventura Blvd	Sherman Oaks	808	2021	Los Angeles	40%
Studio City	3780 Cahuenga Blvd	North Hollywood	808	2021	Los Angeles	40%
Sunnyvale	1296 Sunnyvale Saratoga	Sunnyvale	1212	2021	Santa Clara	40%
Baldwin Park	14477 Merced Ave	Baldwin Park	1616	2022	Los Angeles	40%
Burbank-Hollywood	800 N. Hollywood Wy	Burbank	1616	2022	Los Angeles	40%
Cupertino	21530 Stevens Creek Blvd	Cupertino	1616	2022	Santa Clara	40%
Hawaiian Gardens	11807 Carson St	Hawaiian Gardens	808	2022	Los Angeles	40%
Orange	615 South Tustin St	Orange	1616	2022	Orange	40%
Pasadena-Allen	475 N. Allen Ave	Pasadena	1469	2022	Los Angeles	40%
San Jose-Bernal	101 Bernal Rd	San Jose	513	2022	Santa Clara	40%
San Jose- Snell	3939 Snell Ave	San Jose	1616	2022	Santa Clara	40%
Seal Beach	13980 Seal Beach Blvd	Seal Beach	808	2022	Orange	40%
Anaheim-Euclid	1100 North Euclid St	Anaheim	808	2023	Orange	40%
Burbank	145 W Verdugo Rd	Burbank	100	2023	Los Angeles	33%
Chino Hills	3260 Chino Ave	Chino Hills	808	2023	San Bernardino	40%

Name	Address	City	Capacity (kg/day)	Retail Open	County	Renewable %
Corona	616 Paseo Grande	Corona	808	2023	Riverside	40%
Fontana	16880 Slover Ave	Fontana	1616	2023	San Bernardino	40%
La Mirada	13550 South Beach Blvd	La Mirada	808	2023	Los Angeles	40%
Oakland-Foothill	4280 Foothill Blvd	Oakland	1616	2023	Alameda	40%
Redwood City	503 Whipple Ave	Redwood City	1212	2023	San Mateo	40%
Riverside-Central	3505 Central Ave	Riverside	1616	2023	Riverside	40%
San Bernardino	1930 South Waterman Ave	San Bernardino	1616	2023	San Bernardino	40%
San Diego	5494 Mission Center Rd	San Diego	1212	2023	San Diego	40%
Santa Ana	2120 East McFadden Ave	Santa Ana	808	2023	Orange	40%
Woodside	17287 Skyline Blvd	Woodside	68	2023	San Mateo	33%
Buena Park	6392 Beach Blvd	Buena Park	1616	2024	Orange	40%
Camarillo	2911 Petit St	Camarillo	1520	2024	Ventura	40%
El Cerrito	3160 Carlson Blvd	El Cerrito	1616	2024	Contra Costa	40%
Fremont- Warm Springs	47700 Warm Springs Blvd	Fremont	1616	2024	Alameda	40%
Madera	18463 Road 23	Madera	519	2024	Madera	40%
Orinda	67 Moraga Wy	Orinda	1616	2024	Contra Costa	40%
Oxnard	3402 E Vineyard Ave	Oxnard	519	2024	Ventura	40%
Rancho Bernardo	11030 Rancho Carmel Dr	Rancho Bernardo	1616	2024	San Diego	40%
Rancho Cordova	3329 Mather Field Rd	Rancho Cordova	519	2024	Sacramento	40%
Riverside Upgrade	8095 Lincoln Ave	Riverside	708	2024	Riverside	40%
San Diego-Washington	1832 West Washington St	San Diego	1616	2024	San Diego	40%
San Jose- Santa Clara	510 E. Santa Clara St	San Jose	1616	2024	Santa Clara	40%
San Ramon Upgrade	2451 Bishop Dr	San Ramon	807	2024	Contra Costa	40%

Name	Address	City	Capacity (kg/day)	Retail Open	County	Renewable %
Ventura	2121 Harbor Blvd	Ventura	1616	2024	Ventura	40%
Visalia	6422 Betty Dr	Visalia	519	2024	Tulare	40%
Bellflower	9409 Alondra Blvd	Bellflower	1616	2025	Los Angeles	40%
Fairfield	2595 N Texas St	Fairfield	1616	2025	Solano	40%
Fresno	4163 S Chestnut Ave	Fresno	1616	2025	Fresno	40%
Galt	Carol Dr and Amador Ave	Galt	1616	2025	Sacramento	40%
Kettleman City	33252 Hubert Wy	Kettleman City	1616	2025	Kings	40%
Lakewood	5500 South St	Lakewood	1616	2025	Los Angeles	40%
Livermore	7810 National Dr	Livermore	1616	2025	Alameda	40%
Los Angeles-Santa Monica	10867 Santa Monica Blvd	Los Angeles	1616	2025	Los Angeles	40%
McClellan Park	4785 Bailey Loop	McClellan Park	1616	2025	Sacramento	40%
Moreno Valley	12520 Graham St	Moreno Valley	1616	2025	Riverside	40%
Palm Springs	E Vista Chino & N Gene Autry Trail	Palm Springs	1616	2025	Riverside	40%
Rosemead	939 San Gabriel Blvd	Rosemead	1616	2025	Los Angeles	40%
San Jose-Capitol	1898 N Capitol Ave	San Jose	1616	2025	Santa Clara	40%
San Jose-Redmond	1331 Redmond Ave	San Jose	1616	2025	Santa Clara	40%
San Jose-Union	3707 Union Ave	San Jose	1616	2025	Santa Clara	40%
Vallejo	10 Sage St	Vallejo	1616	2025	Solano	40%
Los Altos	988 N. San Antonio Rd	Los Altos	1616	2026	Santa Clara	40%
Los Gatos	666 N. Santa Cruz Ave	Los Gatos	1616	2026	Santa Clara	40%
Ontario- Euclid	2160 S. Euclid Ave	Ontario	1616	2026	San Bernardino	40%
Torrance-Hawthorne	24505 Hawthorne Blvd	Torrance	1616	2026	Los Angeles	40%
Tustin	14244 Newport Ave	Tustin	1616	2026	Orange	40%

Appendix C: Station Status Definition Details

The new awards for station development made by the CEC through GFO-19-602 have significantly expanded the outlook of hydrogen fueling network development in California. This *Annual Evaluation* adopts a set of station status definitions designed to reflect the current state of the operating and planned hydrogen fueling network. Definitions remain aligned with those adopted by the Governor's Office of Business and Economic Development and other stakeholders, though this report has re-grouped some of these definitions into new categories in order to streamline reporting.

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 California Code of Regulations 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 the Hydrogen Fuel Cell Partnership.

The remainder of the status definitions are as follows:

- **Temporarily Non-Operational:** These stations have previously achieved Open-Retail status in California's hydrogen fueling network, but have not been available to customers for fueling for an extended period of time. The reasons for the change in operating status vary for each station in this group. These stations are currently expected to return to Open-Retail status in the future, but the timeline is unknown.
- **Fully Constructed:** Construction is complete at these stations and the station developer has notified the appropriate authority having jurisdiction.
- **Continuing Development:** These stations initiated development as a result of efforts prior to awards made through GFO-19-602. These stations were initiated through prior grant funding administered by the CEC or began development as they received approval to participate in the LCFS HRI program.
- **Newly Under Development:** Most of the stations in this group are part of batch one in awardees' planned networks of stations through grant awards made in GFO-19-602. This group also includes stations that developers are currently building without funding through GFO-19-602.
- **Future Known Locations:** These stations are part of batch two in awardees' planned networks of stations through grant awards made in GFO-19-602. Per the requirements of GFO-19-602, station developers must first complete batch one stations before being eligible for reimbursement on development of batch two stations. Even though these locations are known via applications to GFO-19-602, construction is not expected to begin until a future date.
- **Future Unknown Locations:** These stations are all part of awards made through GFO-19-602. These stations are included in batch two or later of awardees' station development plans. Awardees were not required to provide addresses for these stations at the time of application, but will determine and share the specific locations with the CEC as they complete each sequential batch in their station construction plans.

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