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Joint Agency Staff Report on Assembly Bill 8: 2023 Annual Assessment of the Hydrogen Refueling Network in California

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California Energy Commission

Miki Crowell, California Energy Commission
Andrew Martinez, California Air Resources Board
Primary Authors

Tomas Ortiz
Project Manager

Elizabeth John
Branch Manager
MEDIUM- AND HEAVY-DUTY ZERO EMISSION TECHNOLOGIES BRANCH

Hannon Rasool
Director
FUELS AND TRANSPORTATION DIVISION

Drew Bohan
Executive Director

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The following individuals and organizations contributed to this report:

California Energy Commission
- Jane Berner
- Miki Crowell
- Magdulin Dwedari
- Andrew Hom
- Mark Johnson
- Vivian Nguyen
- Tomas Ortiz
- Sebastian Serrato
- Kristi Villareal

California Air Resources Board
- Andrew Martinez

Governor's Office of Business and Economic Development
- Gia Brazil Vacin

ABSTRACT

The Joint Agency Staff Report on Assembly Bill 8: 2023 Annual Assessment of the Hydrogen Refueling Network in California is in accordance with Assembly Bill 8 (Perea, Chapter 401, Statutes of 2013). This bill required the California Energy Commission (CEC) and California Air Resources Board to 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 CEC's Clean Transportation Program has allocated nearly $257 million in public hydrogen infrastructure primarily for light-duty vehicles. California is expected to have 130 hydrogen refueling stations by 2027 with at least 7 stations capable of fueling medium- or heavy-duty vehicles. Last year's report expected 175 stations, but a grant recipient cancelled a 2021 grant agreement to develop 50 new stations. As of November 6, 2023, 66 stations achieved open retail status, with 4 stations opening since the last report.

The 66 open retail stations can serve nearly 58,000 fuel cell electric vehicles (FCEVs) when operating at capacity, more than the fueling needs of 14,809 light-duty FCEVs estimated to be on the road as of September 30, 2023. However, station downtime and recent hydrogen price spikes undermine the customer experience. Of the 66 open retail stations, 12 have been offline for more than 30 days. These open stations have operated at around 60 percent of their full capacity on average, due to maintenance, equipment failures, supply chain constraints, and hydrogen supply disruptions. The CEC is acting to address each of these barriers and improve station reliability.

The CEC estimates 130 fully operational stations will have the capacity to serve nearly 188,000 light-duty FCEVs, which is sufficient to support projected FCEVs by 2029. Auto manufacturers have delayed their FCEV deployment projections by one year partially because of the factors cited above undermining the customer experience, decreases in the station count for the planned network, and lack of robust sales in California and globally. But there are new signs for hydrogen station development in the European Union, which harbor the potential for increased global FCEV sales. CEC and CARB staffs intend to continue evaluating the FCEV market as it evolves.

Keywords: Assembly Bill 8, California Air Resources Board, California Energy Commission, Clean Transportation Program, fuel cell electric vehicle, hydrogen refueling station

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EXECUTIVE SUMMARY

The *Joint Agency Staff Report on Assembly Bill 8: 2023 Annual Assessment of the Hydrogen Refueling Network in California.* (2023 Joint Report) describes the investment, planning, development, and use of hydrogen refueling stations to support fuel cell electric vehicles (FCEVs) in California as directed by Assembly Bill (AB) 8 (Perea, Chapter 401, Statutes of 2013). AB 8 further directed the California Energy Commission (CEC) to allocate $20 million annually, not to exceed 20 percent of the funds appropriated by the Legislature, from the Clean Transportation Program toward public hydrogen refueling stations until there are at least 100 publicly available stations in California. Governor Edmund G. Brown Jr.'s Executive Order B-48-18 set a goal of 200 hydrogen refueling stations by 2025.

In October 2023, Assembly Bill 126 (Reyes, Chapter 319, Statutes of 2023) reauthorized the Clean Transportation Program until July 1, 2035 and directed the CEC to allocate no less than 15 percent of the amount of funds appropriated by the Legislature to fund hydrogen refueling stations for light-, medium-, or heavy-duty vehicles until July 1, 2030. AB 126 removed the requirement for a joint assessment of the time and cost needed to attain 100 hydrogen refueling stations. Instead, the CEC and CARB are required, on an annual basis, to 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. While this current report is meeting the former requirements of AB 8, future reports will meet the requirements of AB 126.

Governor Gavin Newsom's Executive Order N-79-20 sets goals for all new passenger cars and trucks sold in California to be zero-emission by 2035, all medium- and heavy-duty trucks and buses operated in California to be zero-emission by 2045 everywhere feasible, and all drayage trucks to be zero-emission by 2035. The goals will influence the policies, requirements, and investments planned by numerous California agencies and municipalities, including the CEC and California Air Resources Board (CARB).

The objective of the Clean Transportation Program solicitations has been for the fueling capacity of the station network to stay well ahead of hydrogen fuel demand so that consumers can have confidence in fuel availability if they choose to drive a FCEV. Since last year's joint report, 4 hydrogen refueling stations opened,

KEY TAKEAWAYS

California is meeting the former 100-station goal pursuant to AB 8 with expended and committed funds (a combination of public and private funding) supporting 130 stations, and California continues its efforts to expand the hydrogen refueling network.

California has 66 open retail stations, with 12 of these stations nonoperational for over 30 days. Station reliability, hydrogen supply disruptions, and spiking hydrogen prices have undermined the customer experience. The CEC is taking actions to address each of these challenges.

Cumulative sales or leases of light-duty FCEVs in California since 2010 have been 17,442, while 14,809 FCEVs are estimated to be on California's roads as of the end of the third quarter of 2023.

Global inflation, labor and material shortages, and supply chain interruptions continue to affect station development.

The average rate of growth in dispensing is now increasing at a higher rate

bringing the total number of stations that have achieved open retail status in California to 66, as of November 6, 2023.

In addition, the average daily dispensing level across the network appears to be increasing at a higher rate than before the COVID-19 pandemic. The average rate of growth prepandemic (the second quarter of 2017 to the first quarter of 2020) was about 18 percent per quarter. The average rate of growth from the second quarter of 2017 to the second quarter of 2023 is about 21 percent per quarter. These 66 open retail stations have the capacity to support nearly 58,000 light-duty FCEVs, while 14,809 FCEVs are estimated to be on California's roads as of the end of the third quarter of 2023, according to CEC analysis of California Department of Motor Vehicles data on the Zero Emission Vehicle (ZEV) Dashboard (Zero Emission Vehicle and Infrastructure Statistics, https://www.energy.ca.gov/data-reports/energy-insights/zero-emission-vehicle-and-charger-statistics). The average daily hydrogen dispensing per FCEV in the second quarter is estimated to be about 0.5 kilograms.

This network of 66 open retail stations includes 12 stations that are considered temporarily nonoperational (TNO). The TNO stations previously achieved open retail status but have been unavailable for customer fueling for a period greater than 30 days for various reasons, including the time needed for mechanical upgrades or repairs, station testing, and reviews by local officials. TNO stations do not include stations that are affected by fuel supply disruptions. These TNO stations are expected to become available for customer fueling again in the future. The remaining 54 open retail stations are available for customer fueling with the exception of downtime events that can last for periods up to 30 consecutive days due to hydrogen supply issues, maintenance, equipment failures, and supply chain constraints.

The *2023 Annual Evaluation of Fuel Cell Electric Vehicle Deployment and Hydrogen Fuel Station Network Development* (2023 Annual Evaluation) by CARB found that the network of open retail stations, not including TNO stations, have operated at around 60 percent of full capacity on average from the third quarter of 2022 to the second quarter of 2023. Reducing the network capacity of open retail stations using the 60 percent availability percentage reported by CARB shows that the network can support about 34,800 FCEVs. This number is further reduced to about 31,000 FCEVs when TNO stations are removed; this is almost half of what the nameplate capacity of 66 open retail stations can support. Therefore, increased station reliability and uptime are imperative to protect public funds and support the driver experience.

Through 2022, the Clean Transportation Program allocated funding sufficient to support 168 stations (including 16 stations included in a CEC agreement funded fully by match share). With the private sector announcing an additional 7 privately funded stations, the state expected at least 175 stations to be open retail by 2027 as reported in the 2022 Joint Report. However, the latest grant funding opportunity, GFO-22-607, which was released October 21, 2022, with the intent of reaching California's 200-station goal, was undersubscribed. The CEC received four qualifying applications, and only three of those applications received passing scores, resulting in 6 stations rather than the anticipated 27.

In addition, in June 2023, Shell, a grant recipient under GFO-19-602, requested to cancel its $41 million grant agreement, which would have developed 50 new stations. Two months later, Shell announced it would close five existing light-duty hydrogen stations temporarily to conduct a safety

assessment with no expected date for reopening the stations. And another agreement expired without completing a station. These circumstances reduced the expected total number of stations to 130. The CEC will continue to explore ways to expand the network and ensure current and future FCEV drivers have sufficient, convenient, and reliable refueling options.

When all 130 stations are open, the network will be capable of supporting nearly 188,000 light-duty FCEVs when assuming operation at 100 percent capacity. When assuming 80 percent of nameplate capacity (more realistic and sustainable level of fueling when considering the ability for neighboring stations to provide coverage for a station outage and demand variability during travel seasons), these stations are capable of supporting nearly 150,000 FCEVs. CARB reported in the 2023 Annual Evaluation that the FCEV population in California could grow to 34,900 FCEVs by 2026 and 62,600 FCEVs by 2029. CARB bases these projections on the latest auto manufacturer survey responses. The projected rates of growth show that auto manufacturers anticipate a one-year delay in the FCEV sales projection relative to the previous survey. Actual FCEV sales have historically been lower than auto manufacturer projections.

The 2029 projected FCEV population of 62,600 is nearly one-third of the 188,000 FCEVs that the anticipated fueling network of 130 stations could support based on the nameplate capacity of the stations, and more than double assuming that stations would dispense no more than 80 percent of nameplate capacity. However, factors such as reliability and availability of existing stations and the development speed of new stations, in addition to the recent cancellation of stations, are expected to continue to lag the station and FCEV deployment projections. Despite the network having fewer stations and lower capacity numbers than previously reported, the CEC still expects to have more nameplate fueling capacity than the projected light-duty FCEV need for the foreseeable future. The amount of extra capacity between the expected capacity availability in the network and the amount of capacity needed to sustain light-duty FCEVs remain high, due in part to auto manufacturers scaling back their FCEV sales projections.

Beyond expanding the network of stations, there are barriers that need to be addressed to give FCEV drivers confidence in the refueling network. Barriers to FCEV market growth include spiking prices of hydrogen and station reliability and availability that are caused by supply chain constraints, hydrogen supply disruptions, and equipment failures. Actual network fueling capacity depends on the reliability of hydrogen supply and station uptime. Improving station reliability and availability are key to providing all stakeholders, most notably FCEV drivers and auto manufacturers, confidence in the FCEV market such that it can grow to the full potential. In addition, the price of hydrogen reached an all-time high of $36 per kilogram in August 2023, which is comparable to paying about $14.40 for a gallon of gasoline (when accounting for the improved efficiency of a FCEV compared to a gasoline-powered vehicles). This price is more than a doubling of historical prices; the average price of hydrogen in the second quarter of 2022 was $14.95.

The CEC is taking actions to address each of these barriers. To improve station reliability, the CEC released a solicitation, GFO-23-604, on November 3, 2023, providing nearly $11 million to support operations and maintenance of existing stations. The CEC is requiring commitment to achieving 95 percent uptime as a condition for receiving a grant. The CEC will require that any future hydrogen stations provide data on downtime related to maintenance, equipment failures, or hydrogen fuel supply issues to understand the reliability of the network from a customer experience. The CEC

provided a $7.7 million manufacturing grant to FirstElement Fuel Inc. to produce hydrogen refueling equipment in California, which could help ease supply chain constraints.

The 2022 Budget Act provides $100 million to the CEC to distribute grants for producing clean hydrogen in-state through electrolysis or biofuels using renewable energy, which, in addition to private investments, should help ensure a more reliable hydrogen supply and could help stabilize prices. Finally, in collaboration with other agencies and industry stakeholders, the CEC held a joint-agency workshop November 6, 2023, to discuss the light-duty FCEV customer experiences at hydrogen refueling stations in California and identify new strategies to overcome key barriers. State officials and industry stakeholders must continue to work together to address these barriers.

In addition, the pace of building out new hydrogen stations has slowed. The station development pace depends not only on the amount of funding available but also on the number of station equipment vendors and the number of station developers available to deploy stations. Station development times were decreasing until the COVID-19 pandemic slowed many station development activities. The median total station development time was decreasing from about four years to two years for stations that opened before the pandemic. The median total station development time increased to about three years for those stations that completed during the pandemic, and the number will likely increase for stations that began development during the pandemic (only 10 of 22 stations have completed). Global inflation, labor and material shortages, and supply chain interruptions continue to affect station development. CEC staff is learning more about these issues from station developers and plans to incorporate feedback from workshops in future solicitations.

The CEC and CARB also evaluate fueling needs regionally to analyze if the specific areas where vehicles are being sold and leased are adequately served by stations. This analysis is particularly important during early market development, as having infrastructure in places where potential customers need it can influence the decision to adopt FCEV technology. The largest urban areas of the state will continue to have sufficient network capacity capable of supporting more than projected FCEVs in California; however, station reliability and availability affect the actual capability of the refueling network to be able to support FCEVs. The Sacramento Area will be almost at capacity in 2024 until more stations open in 2025. The San Diego Area received much needed additional capacity because of the opening of one more station in May 2023 and will have sufficient capacity to support projected FCEVs when two more planned stations open, but additional fueling locations in this region are needed to provide wider coverage.

About 67 percent of California's residents who live in disadvantaged communities are within a 15-minute drive time of an open retail or planned hydrogen station. This percentage is similar to 61 percent of the general statewide population being in the same drive distance to a station. However, rural disadvantaged communities and disadvantaged communities with lower population density still tend to be farther than a 15-minute driving distance to any hydrogen refueling station.

In addition to light-duty FCEVs, the state is working to support the demonstration and deployment of medium- and heavy-duty FCEVs. At least 7 of the 130 projected stations should be capable of fueling medium- or heavy-duty vehicles in addition to light-duty ones, thereby leveraging infrastructure to address multiple markets and accelerating the development of commercial fuel cell electric trucks. This number decreased from 15 reported in last year's joint report because of the cancellation of Shell's agreement.

According to the CEC ZEV Dashboard where vehicle and infrastructure statistics are compiled at https://www.energy.ca.gov/zevstats, there were 134 medium- and heavy-duty FCEVs (all buses) registered in the state at the end of 2022. The CEC ZEV Dashboard shows 2,186 electric medium- and heavy-duty vehicles. The CEC has published *2023 Staff Report on Senate Bill 643: Clean Hydrogen Fuel Production and Refueling Infrastructure to Support Medium-and Heavy-Duty Fuel Cell Electric Vehicles and Off-Road Applications* on September 25, 2023, that discusses medium- and heavy-duty FCEVs along with off-road non-transportation vehicles that use hydrogen as fuel in more depth.

As directed in AB 8, the CEC has allocated $20 million per year or 20 percent of the total Clean Transportation Program Investment Plan allocation each year for public hydrogen stations and focused on light-duty stations with that funding. The Clean Transportation Program has allocated about $257 million to light-duty hydrogen refueling station projects through fiscal year 2022-2023. This total allocation includes $41 million from the agreement recently cancelled by Shell, of which more than $7 million cannot be reallocated to projects because the encumbrance deadline for this funding has passed. This total allocated amount is smaller than what was reported in the 2022 AB 8 Joint Report ($279 million) because GFO-22-607 was undersubscribed and did not fund as many stations as anticipated. The remaining funds from GFO-22-607 were reallocated to other non-light-duty projects. Another $4 million of the remaining unawarded GFO-22-607 funds went to GFO-22-502 to fully fund one of the recipients for their heavy-duty hydrogen station. Moreover, the revised staff draft of the *2023–2024 Investment Plan Update for the Clean Transportation Program* does not allocate any new funding to light-duty hydrogen refueling infrastructure because the program has unspent funding that was previously allocated to Shell's cancelled agreement.

The private sector has contributed match funding to station development. Industry has made independent investments in hydrogen refueling stations and production plants that are outside CEC agreements. As of November 6, 2023, grant recipients have contributed nearly $100 million in match funding and will contribute another $59 million by the end term (in 2026) of the CEC grant agreements funded under GFO-19-602. Staff also anticipates receiving another $4 million in match for remaining four stations under GFO-22-607. These contributions will bring the total public and private investment in hydrogen refueling stations under the Clean Transportation Program to nearly $420 million. These numbers reflect the reduced match funding because of the recent agreement cancellation.

There are new signs for hydrogen station development in the European Union (EU) which harbor the potential for increased global FCEV sales. In March 2023, the EU countries agreed to build hydrogen refueling stations in all major cities and at least every 200 kilometers along the core Trans-European Transport Network linking these cities. According to *Deployment of Fuel Cell Vehicles in Road Transport and the Expansion of the Hydrogen Refueling Station Network: 2023 Update* by the Technology Collaboration Programme on the Research, Development and Demonstration on Advanced Fuel Cells (AFC TCP), more than 70,000 FCEVs (light-, medium-, and heavy-duty) and more than 1,000 hydrogen refueling stations (both public and private) are in the world.

More than 90 percent of all FCEVs in operation are in California and three other countries: South Korea, China, and Japan. On a per capita basis, California ranks second after Korea for FCEV deployments. While the on-road fleet of hydrogen fuel cell vehicles is dominated by passenger FCEVs, the report found that the number of buses and commercial trucks increased at a higher rate than

passenger cars in 2022 and made up about 20 percent of global FCEVs. Also according to the report, in 2022 sales of passenger FCEVs declined slightly, despite 2022 being the second highest year for FCEV sales on record. For the first time China took the global lead in the number of hydrogen stations (320) in 2022 and continued its leadership in the deployment of bus and commercial FCEVs. South Korea is second with 213 stations, followed by Japan at 164, Germany at 95, and California with at least 72 stations (66 open retail public light-duty stations and at least 6 medium and heavy-duty stations). Continued global efforts in vehicle and station deployment will help bring down the costs of technologies and build robust supply chains.

Despite recent reductions in the number of stations and station network capacity, California continues to support the current and future FCEV population by providing funding for hydrogen refueling infrastructure that exceeds current and projected vehicle demand at least through 2029. However, the deployment of refueling infrastructure and FCEVs must accelerate to enable the scale of FCEV sales needed to make a mature market. To support this effort, having a reliable refueling network is essential. CEC and CARB staffs' joint evaluation of the FCEV market will continue to guide future funding decisions, including assessing an appropriate funding amount per station given inflation, supply chain challenges, and uncertainty around the future fuel demand from light-duty FCEVs. With the enactment of AB 126, the state will continue to provide support to expand a hydrogen refueling station network that will provide the reliable coverage and the capacity to support light-, medium-, and heavy-duty FCEVs.

CHAPTER 1: Introduction

Assembly Bill (AB) 118 (Núñez, Chapter 750, Statutes of 2007) created the Clean Transportation Program.[1] Assembly Bill 8 (Perea, Chapter 401, Statutes of 2013) reauthorized the Clean Transportation Program until January 1, 2024. AB 8 also directed the California Energy Commission (CEC) to allocate $20 million annually, not to exceed 20 percent of the amount of funds appropriated by the Legislature, toward at least 100 publicly available hydrogen refueling stations.[2] AB 8 required annual review and reporting by the CEC and California Air Resources Board (CARB). The *Joint Agency Staff Report on Assembly Bill 8: 2023 Annual Assessment of the Hydrogen Refueling Network in California* (2023 Joint Report) is the ninth annual report. CARB published the *2023 Annual Evaluation of Fuel Cell Electric Vehicle Deployment and Hydrogen Fuel Station Network* (2023 Annual Evaluation) on December 6, 2023, also required by AB 8.[3] Appendix C lists references for previous reports.

In October 2023, Assembly Bill 126 (Reyes, Chapter 319, Statutes of 2023) reauthorized the Clean Transportation Program until July 1, 2035, and directed the CEC to allocate no less than 15 percent of the amount of funds appropriated by the Legislature to fund hydrogen refueling stations until July 1, 2030. AB 126 removed the requirement for a joint assessment of the time and cost needed to attain 100 hydrogen refueling stations. Instead, the CEC and CARB are required, on an annual basis, to 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. While this current report is meeting the former requirements of AB 8, future reports will meet the requirements of AB 126.

This report will review progress toward establishing a hydrogen refueling network that provides the coverage and capacity to support light-duty fuel cell electric vehicles (FCEVs) requiring hydrogen fuel that are being placed into operation in the state. The report will also assess whether funding from the Clean Transportation Program remains necessary to achieve the former 100-station goal per AB 8.[4] This report is organized with five analytical chapters:

- Chapter 2: The Coverage and Capacity of the Hydrogen Refueling Station Network
- Chapter 3: Fuel Cell Electric Vehicle Deployment
- Chapter 4: Time Required to Permit and Construct Hydrogen Refueling Stations

1 California Legislative Information. Assembly Bill 118 (Núñez, Chapter 750, Statutes of 2007). https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=200720080AB118.

2 California Legislative Information. Assembly Bill 8 (Perea, Chapter 401, Statutes of 2013). https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201320140AB8.

3 California Air Resources Board. December 2023. *2023 Annual Evaluation of Fuel Cell Electric Vehicle Deployment and Hydrogen Fuel Station Network Development*. https://ww2.arb.ca.gov/sites/default/files/2023-12/AB-8-Report-2023-FINAL-R.pdf.

4 California Legislative Information. Assembly Bill 8 (Perea, Chapter 401, Statutes of 2013). https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201320140AB8.

- Chapter 5: Amount and Timing of the Growth of the Hydrogen Refueling Network
- Chapter 6: Remaining Cost and Time Required to Establish a Sufficient Network of Refueling Stations

Governor Edmund G. Brown Jr.'s Executive Order B-16-12 directed state agencies to promote the rapid commercialization of zero-emission vehicles (ZEVs) and set a target of 1.5 million ZEVs in California by 2025.[5] Governor Brown's Executive Order B-48-18 established goals of achieving 200 hydrogen stations by 2025 and 5 million ZEVs in California by 2030.[6] On September 23, 2020, Governor Gavin Newsom's Executive Order N-79-20 set goals that all new passenger cars and trucks sold in California be ZEVs by 2035, all medium- and heavy-duty trucks and buses operated in California be ZEVs by 2045 everywhere feasible, and all drayage trucks be ZEVs by 2035.[7] All three imperatives strengthen California's focus and activities for hydrogen refueling infrastructure and ZEVs. CARB adopted the Advanced Clean Cars II regulations in 2022 that requires all new cars and light-duty trucks sold in California to be ZEVs, including plug-in hybrid electric vehicles, by 2035, effective on November 30, 2022.[8]

The CEC Fuels and Transportation Division and CARB program staffs collaborate with experts, market participants, and stakeholders to plan and encourage development of hydrogen refueling infrastructure and deployment of fuel cell electric vehicles, including:

- The Governor's Office of Business and Economic Development (GO-Biz) and the California Department of Food and Agriculture, Division of Measurement Standards (CDFA/DMS).
- The South Coast Air Quality Management District (SCAQMD), Bay Area Air Quality Management District (BAAQMD), and other air districts.
- Local agencies, including planning, building, and safety officials.
- The United States Department of Energy (U.S. DOE) and national laboratories, including the National Renewable Energy Laboratory (NREL) and Pacific Northwest National Laboratory (PNNL).
- Industry stakeholders, including the Center for Hydrogen Safety under the auspices of the American Institute of Chemical Engineers (AiCHe), Hydrogen Fuel Cell Partnership, California Hydrogen Business Council, SAE International, and the CSA Group.

Staff also considers input from public comments received in workshops and submitted to the docket to develop grant solicitations and analyses. For example, the CEC relied on industry stakeholder

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5 Office of Governor Edmund G. Brown Jr. Executive Order B-16-2012. https://www.ca.gov/archive/gov39/2012/03/23/news17472/index.html.

6 Office of Governor Edmund G. Brown Jr. Executive Order B-48-18. https://www.ca.gov/archive/gov39/2018/01/26/governor-brown-takes-action-to-increase-zero-emission-vehicles-fund-new-climate-investments/index.html. The Governor's Interagency Working Group on ZEVs released a *2018 ZEV Action Plan Priorities Update* in response to the executive order. http://business.ca.gov/Portals/0/ZEV/2018-ZEV-Action-Plan-Priorities-Update.pdf.

7 Office of Governor Gavin Newsom. Executive Order N-79-20. https://www.gov.ca.gov/wp-content/uploads/2020/09/9.23.20-EO-N-79-20-Climate.pdf.

8 California Air Resources Board. "Advanced Clean Cars II Regulations: All New Passenger Vehicles Sold in California to be Zero Emissions by 2035." https://ww2.arb.ca.gov/our-work/programs/advanced-clean-cars-program/advanced-clean-cars-ii.

comments and requests[9] for greater certainty in public funding programs when designing GFO-19-602. This included industry feedback such as, "Industry applauds the CEC's approach to the Draft Solicitation Concepts for the next round of light-duty Fuel Cell Electric Vehicle (FCEV) hydrogen station grant funding. The CEC has responded positively to industry comments from 2017 and this latest proposed draft Grant Funding Opportunity (GFO) structure is innovative, potentially transformative, and could result in a large number of hydrogen refueling stations to be built over a multi-year period in Tranches and Batches through the remaining duration of the AB8 authorization. We believe that many of the new CEC draft GFO approaches can help further advance FCEV market adoption." A separate industry stakeholder stated that "the majority of the hydrogen community asked the Energy Commission to rethink the structure of [sic] its hydrogen refueling infrastructure solicitation to adapt to the improved market conditions and learnings that have taken place over the past several years. On this front, FirstElement Fuel wishes to congratulate the CEC for putting forth draft solicitation concepts that very accurately capture the industry asks."

The CEC released GFO-19-602 in 2019, which was proceeded by solicitations: public opportunity notice (PON)-09-608 in 2010 (notice of proposed awards (NOPA) in 2010), PON-12-606 in 2012 (NOPA in 2013), PON-13-607 in 2013 (NOPA in 2014), and GFO-15-605 in 2016 (NOPA in 2017). GFO-19-602 was also proceeded by the development of CARB's Low Carbon Fuel Standard (LCFS) hydrogen refueling infrastructure (HRI) program, which became effective on January 1, 2019. LCFS HRI credits fund and support hydrogen stations, in particular for operations and maintenance. GFO-19-602 requires hydrogen station developers to develop stations in batches. The developers are working on their first and second batches and will be able to access the third batch of funding upon successful completion of the milestones specified in GFO-19-602. Appendix A shows a list of stations that are in development and corresponding grant funding opportunity that funded those stations.

The public is encouraged to visit the following web pages to become involved in CEC activities:

- Subscriptions: https://www.energy.ca.gov/subscriptions
- Events: https://www.energy.ca.gov/events
- Solicitations: https://www.energy.ca.gov/funding-opportunities/solicitations

CEC and CARB staffs review the year's refueling trends and describe other hydrogen and fuel cell projects that are expanding the potential for FCEVs, including buses and trucks, to serve several functions in transitioning to a national and international zero-emission transportation system. The data this joint report uses, unless otherwise noted, are:

- From the third quarter of 2022 through the second quarter of 2023 for hydrogen refueling station related analyses.
- Through the end of the third quarter of 2023 for the latest number of FCEVs.
- As of November 6, 2023, for reporting new station openings.

9 California Energy Commission. "Docket Log for Draft Solicitation Concepts for Light-Duty Hydrogen Refueling Infrastructure." https://efiling.energy.ca.gov/Lists/DocketLog.aspx?docketnumber=18-HYD-04.

CHAPTER 2:
The Coverage and Capacity of the Hydrogen Refueling Station Network

This chapter discusses the progress toward establishing a hydrogen refueling network to provide the coverage (the placement of stations) and capacity (the number of FCEVs stations and the network can support) needed to fuel FCEVs that are on the road in California. The chapter also discusses station statistics such as hydrogen dispensed, utilization, retail price of hydrogen, station reliability and availability, and hydrogen supply to analyze whether the current network of stations is sufficient to serve on-road FCEVs.

The coverage and capacity of the open retail hydrogen refueling station network continue to grow in California in spite of some recent setbacks. The recent solicitation, GFO-22-607, which was expected to help close the gap to the 200-station goal, was undersubscribed and did not fund as many stations as anticipated because the CEC received four qualifying applications and only three of those applications received passing scores, resulting in 6 stations rather than the anticipated 27. In addition, one of the grant recipients, Shell, that was funded under GFO-19-602 requested to cancel its $41 million grant agreement, which would have funded 50 new stations and one upgrade, in June 2023. And another agreement expired without completing a station. As a result of these setbacks, the expected total number of stations (open retail stations and planned stations combined) in California is now 130.

The main factors that contributed to the agreement cancellation were "difficulties permitting, obtaining decarbonized hydrogen, construction cost escalation, supply chain, global inflation, and overall challenges with project execution" and "political and economic uncertainty."[10] Although Shell's shift away from renewables likely also played a role.[11] Therefore, this joint report uses the 130-station network for evaluating coverage and capacity.

Figures 1 through 3 show the locations of stations in the hydrogen refueling station network in California. Planned stations that do not have locations yet are not shown in these figures. The California network includes 66 open retail stations and 64 planned stations. Appendix A lists 110 stations with addresses. Appendix B lists the changes in the station network from 2017 to 2023.

The network of open retail stations includes 66 stations; 54 of these stations are available for customer fueling with the exception of brief downtime events, and 12 stations are considered temporarily nonoperational (TNO),[12] as they have previously achieved open retail status but have

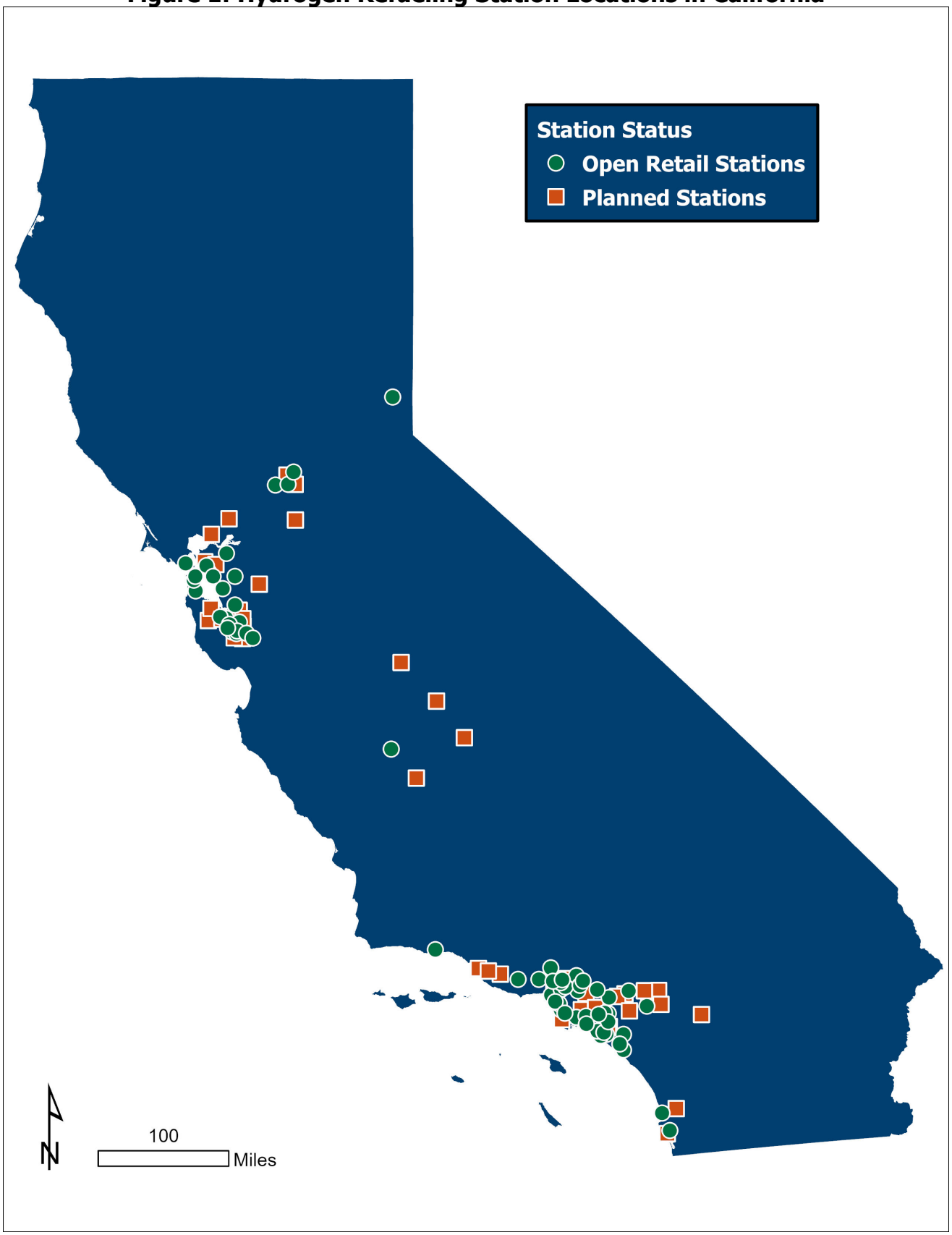
10 An email from a Shell representative on July 10, 2023.

11 Reuters. June 9, 2023. "Exclusive: Shell Pivots Back to Oil to Win Over Investors." https://www.reuters.com/business/energy/shell-pivots-back-oil-win-over-investors-sources-2023-06-09/.

12 A TNO station in Riverside is available for FCEV drivers to fuel by reservation. Stations in Berkeley, Citrus Heights, Sacramento, San Francisco – 3rd Street, and San Francisco – Harrison Street are offline to address the station operator's safety standards. Stations located in Anaheim – E. La Palma, LAX, and Palo Alto are offline and are awaiting station upgrades. The Ontario, CSULA, and Anaheim – N. Euclid stations are offline and awaiting necessary repairs.

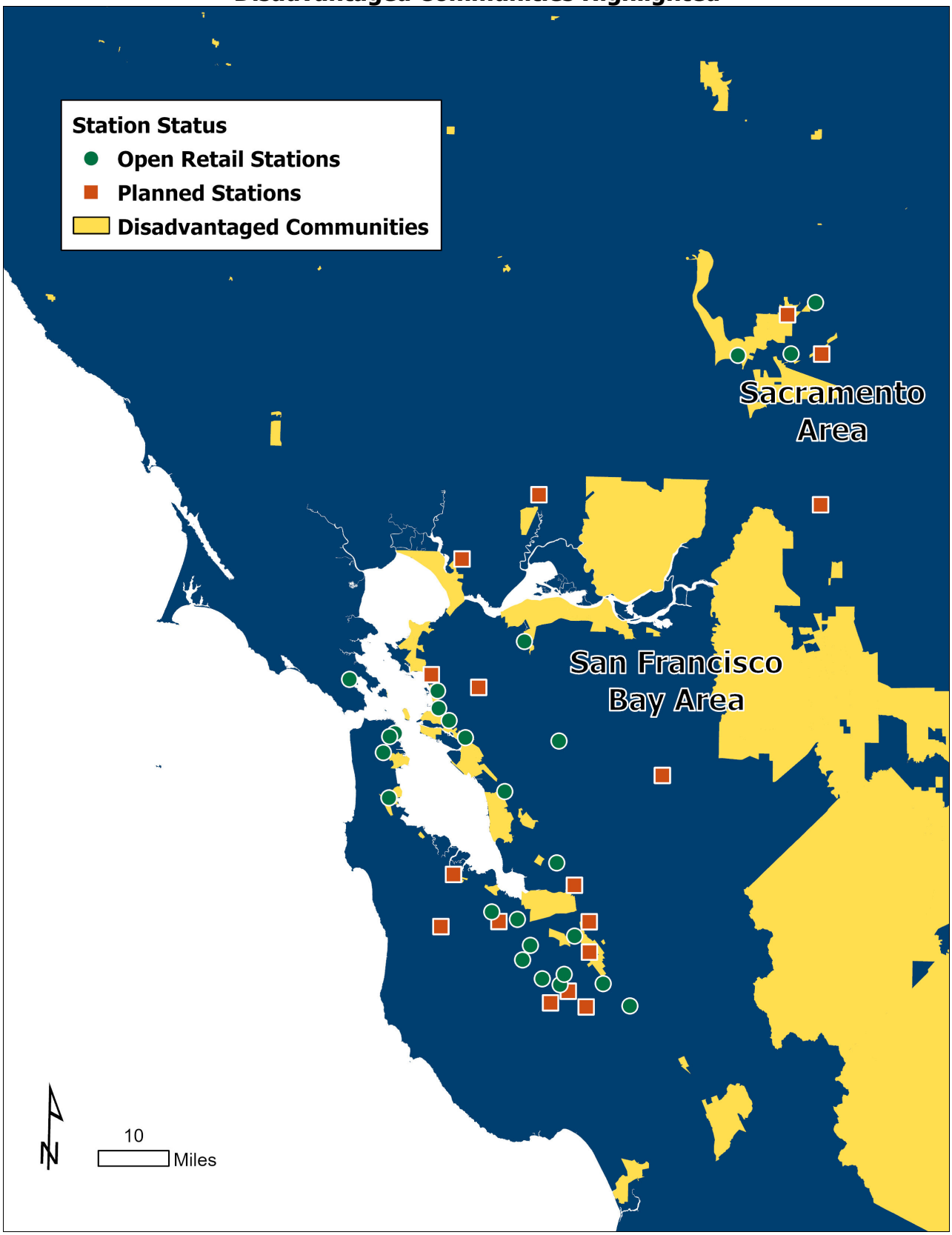
been unavailable for customer fueling for a period greater than 30 days for various reasons. TNO stations do not include stations that are affected by fuel supply disruptions. These TNO stations are expected to become available for customer fueling again in the future and are shown as open retail stations in Figures 1 through 3. However, station operators do not have estimated time frame for when these TNO stations will reopen.

Figure 1: Hydrogen Refueling Station Locations in California



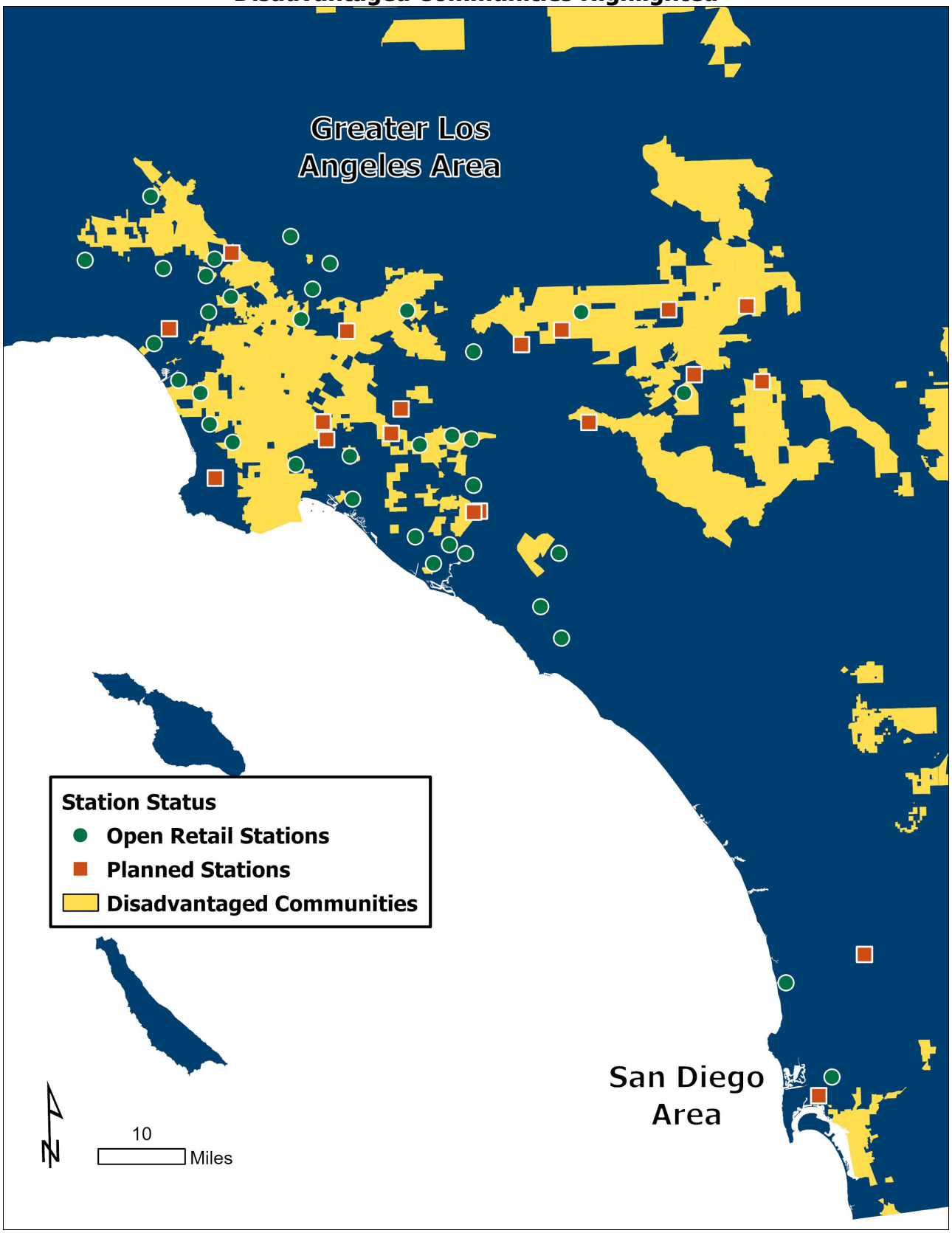
Source: CEC

Figure 2: Hydrogen Refueling Station Locations in Northern California With Disadvantaged Communities Highlighted



Source: CEC

Figure 3: Hydrogen Refueling Station Locations in Southern California With Disadvantaged Communities Highlighted



Source: CEC

The CEC continues to emphasize the importance of serving disadvantaged communities in its solicitations. The last solicitation, GFO-22-607, promoted disadvantaged communities with low access to a hydrogen refueling station as eligible areas to site new hydrogen refueling station projects. As a result, five of six stations are in disadvantaged communities. With all the stations with known addresses under GFO-19-602, new stations funded under GFO-22-607, and privately funded stations that are proposed for development, 38 stations will be in disadvantaged communities.[13] The proposed refueling network will provide coverage so that 67 percent of the disadvantaged community population and 61 percent of the general population of California will be within a 15-minute driving distance to a hydrogen refueling station. These numbers could increase as addresses for stations in future batches funded under GFO-19-602 are announced. However, as observed in the past, rural disadvantaged communities and disadvantaged communities with lower population density still tend to be farther than a 15-minute driving distance to any hydrogen refueling station. The CEC and CARB will continue to promote equity in their investments and explore options to expand hydrogen refueling network benefits to as many disadvantaged communities as possible.

Coverage Map Using California Hydrogen Infrastructure Tool

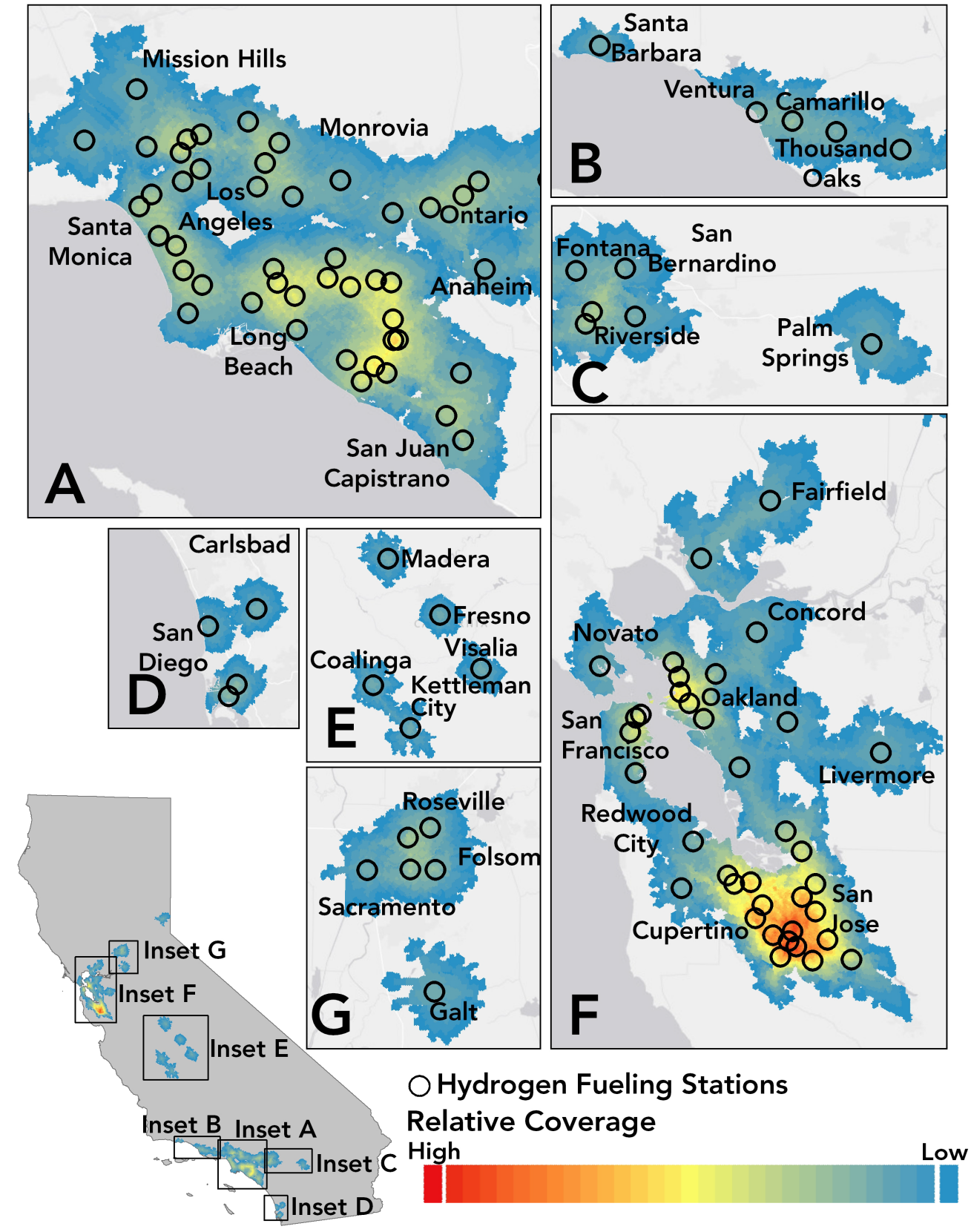
Figure 4 displays the coverage provided by all stations in the 130-station network with known addresses. As awarded station developers notify the CEC of addresses for additional locations, or possible station relocations and other changes, the evaluation of coverage is expected to change. The figure was produced by the CARB California Hydrogen Infrastructure Tool (CHIT).[14] Areas on the map without color are not within a 15-minute drive from any hydrogen refueling station. In the coverage map, the areas shown with the red shading have the highest degree of coverage. These areas often have several stations providing coverage to neighborhoods and communities in the nearby area. The blue areas have less fueling coverage; these areas typically have a small number of available stations or are farther away from the fueling station network.

The stations are generally concentrated in the San Francisco Bay Area, the Greater Los Angeles Area, the Sacramento Area, and the San Diego Area. There are a few connector stations in the Central Valley and a few destination stations. The highest degree of coverage is in the southwest side of the San Francisco Bay Area around San Jose, Cupertino, and other nearby cities with additional hot spots in San Francisco, Oakland, Emeryville, Orange County between Irvine and Costa Mesa, and in a few spots around Los Angeles County.

13 *Disadvantaged communities* are identified using the California Office of Environmental Health Hazard Assessment's CalEnviroScreen 4.0. Information is available at OEHHA, CalEnviroScreen. https://oehha.ca.gov/calenviroscreen.

14 California Air Resources Board. "Hydrogen Refueling Infrastructure Assessments." https://ww2.arb.ca.gov/resources/documents/california-hydrogen-infrastructure-tool-chit.

Figure 4: Coverage Map



Source: CARB

Quantity of FCEVs Supported by Hydrogen Refueling Station Network

Table 1 summarizes the coverage and capacity of the hydrogen refueling station network in California by showing the station quantity and fueling capacity in terms of the quantity of FCEVs that the network can support when operating at capacity. Staff used the assumption of 0.7 kilogram per day of hydrogen consumed per FCEV to convert the station nameplate capacity into the estimated number of FCEVs supported (by dividing the fueling capacity by 0.7).[15] This network summary includes the Clean Transportation Program-funded and privately funded stations. Including all currently known publicly and privately funded stations, the projected network will contain 130 stations.

These 130 known planned stations will have the capacity to support nearly 188,000 FCEVs when assuming operation at 100 percent availability, which is nearly triple the fueling needs of the projected FCEV population in 2029, according to the 2023 Annual Evaluation. Even when assuming 80 percent of nameplate capacity (more realistic and sustainable level of fueling),[16] these stations are capable of supporting nearly 150,000 FCEVs, which is more than double the fueling needs of the projected FCEV population in 2029.

However, the projected FCEV population has not changed much since 2021, which is helping keep the buffer between the fueling capacity of the network and the fueling demand. There could be many factors affecting auto manufacturers' projections, but the recent network developments may be playing a role in auto manufacturers' decision to roll back their FCEV sales projections. The recent changes in the projected size of the hydrogen refueling network due to Shell's exit, ongoing station reliability issues and price spikes (discussed later in this chapter) that undermine the customer experience, and lack of robust sales in California and globally may have affected the auto manufacturers' FCEV sales projections (indicated in Chapter 3).

FCEV drivers continue to suffer from lack of confidence in fuel availability because of stations being unavailable and unreliable. In fact, CARB's 2023 Annual Evaluation found that the network of open retail stations, not including TNO stations, has operated at around 60 percent of capacity on average from the third quarter of 2022 to the second quarter of 2023 because of maintenance, equipment failures, supply chain constraints, and hydrogen supply disruptions. Station reliability and availability are discussed later in this chapter. Overall, the current 66 open retail stations can support nearly 58,000 FCEVs when operating at capacity, which is nearly quadruple the estimated 14,809 FCEVs on the road as of the third quarter of 2023. However, reducing the network capacity of open retail stations using this availability percentage shows that the network can support about 34,800 FCEVs.

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15 Pratt, Joseph, Danny Terlip, Chris Ainscough, Jennifer Kurtz, and Amgad Elgowainy. 2015. *H2FIRST Reference Station Design Task, Project Deliverable 2-2.* National Renewable Energy Laboratory and Sandia National Laboratories. https://www.osti.gov/biblio/1215215.

16 The 2023 Joint Report and past joint reports have used an assumption of 80 percent of nameplate capacity for some analyses as a more realistic and sustainable level of fueling. This assumption allows for neighboring stations to cover for stations that need to go offline temporarily because of mechanical issues or scheduled maintenance. If all stations were operating at 100 percent of nameplate capacity, neighboring stations would not be able to cover for other stations during outage or maintenance. In addition, accounting for variability of demand throughout the year is important. For example, if a station was operating at nameplate capacity daily, then the station would not be able to accommodate any increased demand during busy travel seasons.

This number is further reduced to about 31,000 FCEVs when TNO stations are removed. To help make the existing stations more reliable, the CEC has released a solicitation, GFO-23-604, on November 3, 2023, providing nearly $11 million to support operations and maintenance of existing stations. The CEC is requiring commitment to achieving 95 percent uptime as a condition for receiving a grant.

This report uses the assumption of 0.7 kg of hydrogen per FCEV per day for all the analyses; however, other factors can influence the quantity of FCEVs that can be supported. These factors include the interdependency of the actual FCEV geographical distribution relative to stations, driver habits, vehicle miles traveled, and routes traveled. The number of connector stations and destination stations can affect these factors, which is expected to improve with four stations from GFO-22-607 planned along the Interstate 5 and State Route 99.

Table 1: Hydrogen Refueling Station Network and Quantity of FCEVs Supported

Station Status	Station Quantity	FCEVs Stations Can Support
Open Retail	66	58,000
Planned	64	130,000
Total Funded	***130***	***188,000***

Source: CEC

Hydrogen Dispensing and Station Utilization

Although the COVID-19 pandemic affected hydrogen dispensing and station utilization, the average daily hydrogen dispensing across the network appears to be increasing at a higher rate than prepandemic. The average rate of growth before the pandemic (the second quarter of 2017 to the first quarter of 2020) was about 18 percent per quarter. The average rate of growth from the second quarter of 2017 to the second quarter of 2023 is about 21 percent per quarter. These data show that the average rate of growth in dispensing has increased since the pandemic occurred. The average daily hydrogen dispensing per FCEV in the second quarter is estimated to be about 0.5 kilograms.

Factors affecting the number of kilograms dispensed across the network may include fluctuations in commuting and daily driving, extended time frames for planned and unscheduled maintenance at the stations, and the availability of delivered hydrogen. Increased FCEV sales and registrations have resulted in increased demand for hydrogen from existing stations. CARB's 2023 Annual Evaluation reported that the growth in FCEV registrations with an increase of 1,859 FCEVs between April 2022 and April 2023 was the third highest growth rate for new registrations since reporting began in 2014. The existing network of hydrogen refueling stations in California has ample fueling capacity to support the on-road light-duty FCEVs because the average utilization[17] of the overall network is 17 percent. Many of the older legacy stations funded before 2014 are operating close to capacity because the nameplate capacity of those stations is small. The newer generation stations, which were funded after 2014, have been operating at a lower utilization rate because they are four times

17 The term "utilization" is used in this joint report to align with the industry norm to describe the ratio of fuel throughput to the nameplate capacity of the station or the network of stations.

larger than the stations built before the end of 2014. Newer generation stations are used at about 25 percent of capacity even on the most heavily trafficked days.

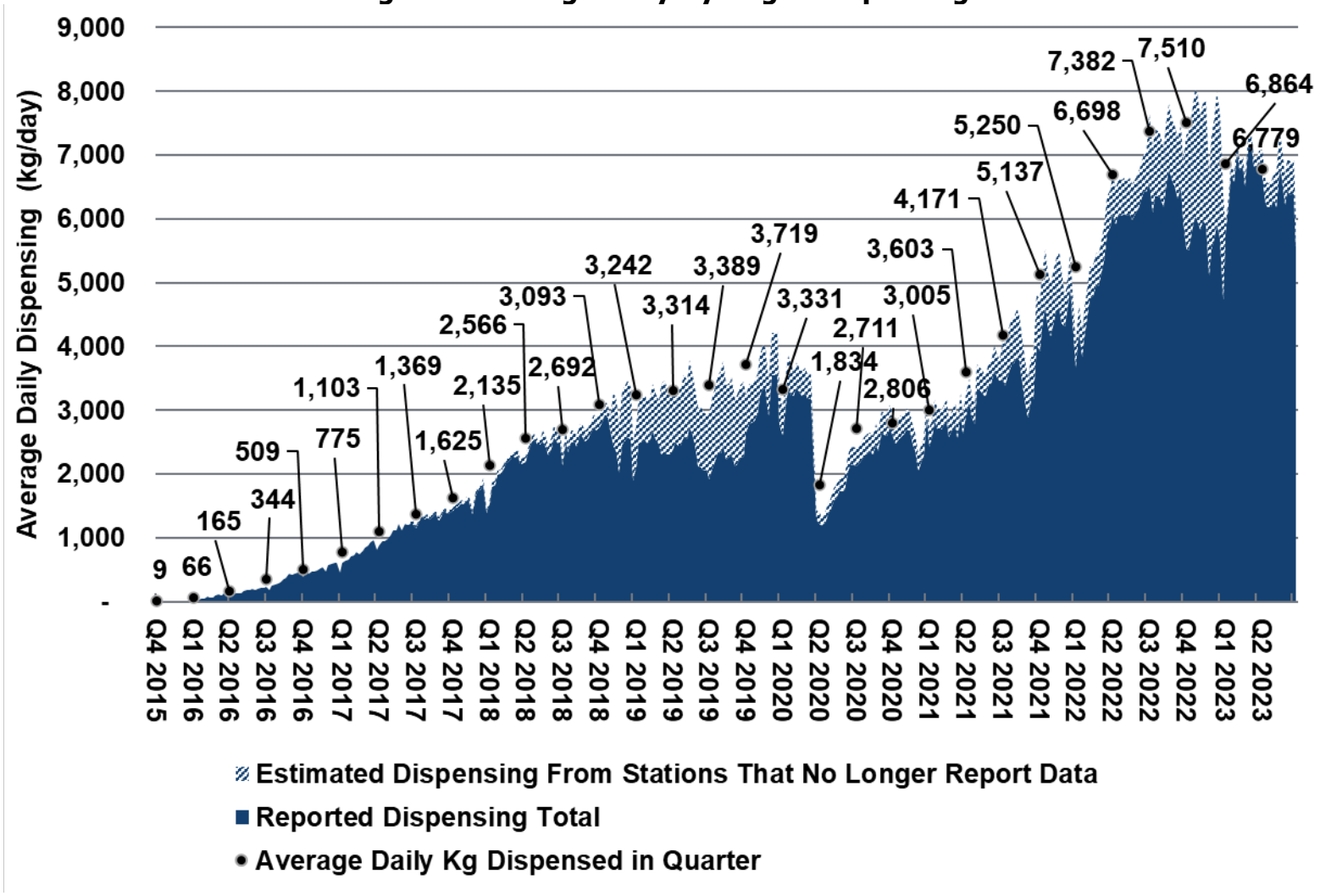
The CEC requires grant recipients to report hydrogen dispensing data during the term of their grant agreements. Once an agreement term ends, some station operators continue reporting data voluntarily. Figure 5 shows the average daily hydrogen dispensing in California based on the station operators' reports. For stations that do not report, staff estimated the average daily dispensing based on the daily regional dispensing (Greater Los Angeles Area, San Francisco Bay Area, San Diego Area, Sacramento Area, and connector area outside the four other areas) where each nonreporting station is located. Of 66 open retail hydrogen refueling stations, CEC staff received data from 61 stations and estimated dispensing for 4 stations in the second quarter of 2023. The TNO stations are assumed to have dispensed zero kilograms of hydrogen for the quarter that they are categorized as TNO. This figure does not include one open retail station because it became open for retail after the first quarter of 2023.

The average weekly dispensed fuel, shown in solid color in Figure 5,[18] is reported by station operators. The patterned area shows the estimated dispensing for stations that do not report to the CEC.[19] Above each quarter, the quarterly average daily dispensing is shown. Figure 5 shows that in the second quarter of 2023, average daily dispensing has increased to about 6,800 kg/day, about 1 percent over the daily average dispensing reported in the 2022 Joint Report. Figure 6 shows the percentage of hydrogen dispensed (actual and estimated) in each region from the beginning of the third quarter of 2022 to the end of the second quarter of 2023. About two-thirds of all hydrogen dispensed in California was in the Greater Los Angeles Area.

18 Estimated dispensing fluctuates since reporting requirements vary according to CEC agreements.

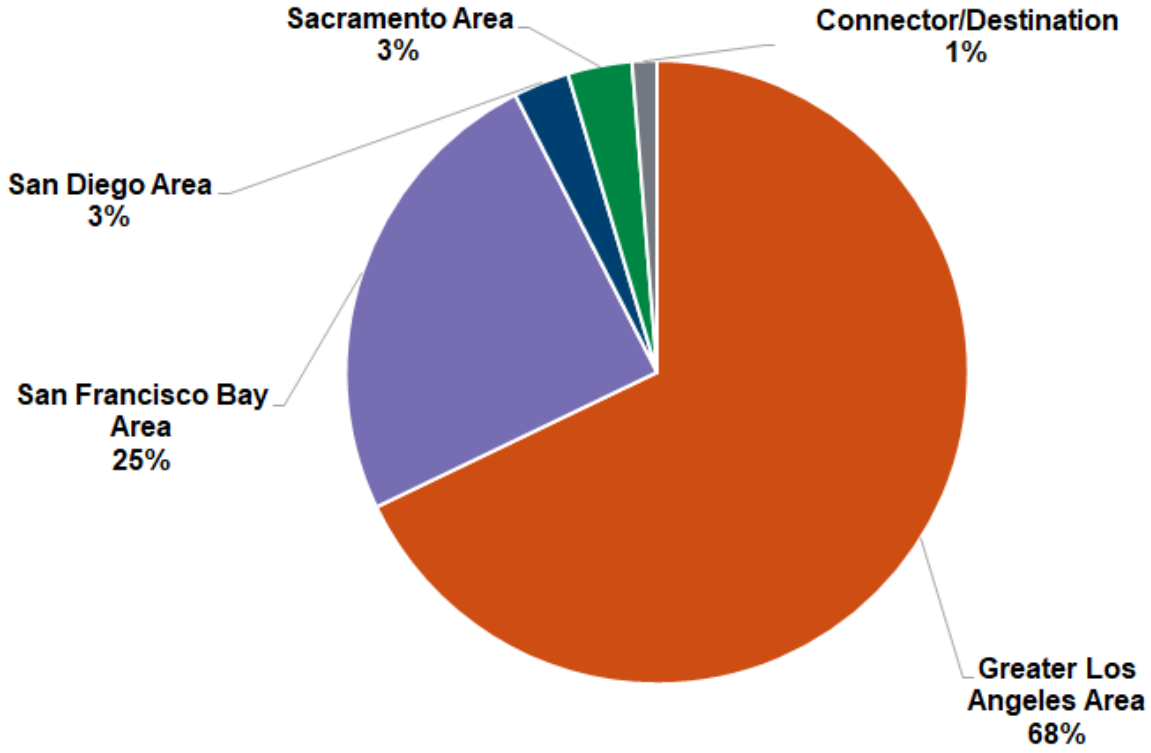
19 In 2019, many agreements ended and many of those stations discontinued reporting fueling data to the CEC; hence, the patterned line is larger in that year. However, starting in 2020, many station operators have agreed to provide the CEC with an abbreviated amount of fueling data for stations that are no longer part of CEC agreements to allow the CEC to do this reporting.

Figure 5: Average Daily Hydrogen Dispensing



Source: CEC

Figure 6: Percentage of Hydrogen Dispensing by Region (Q3 2022–Q2 2023)



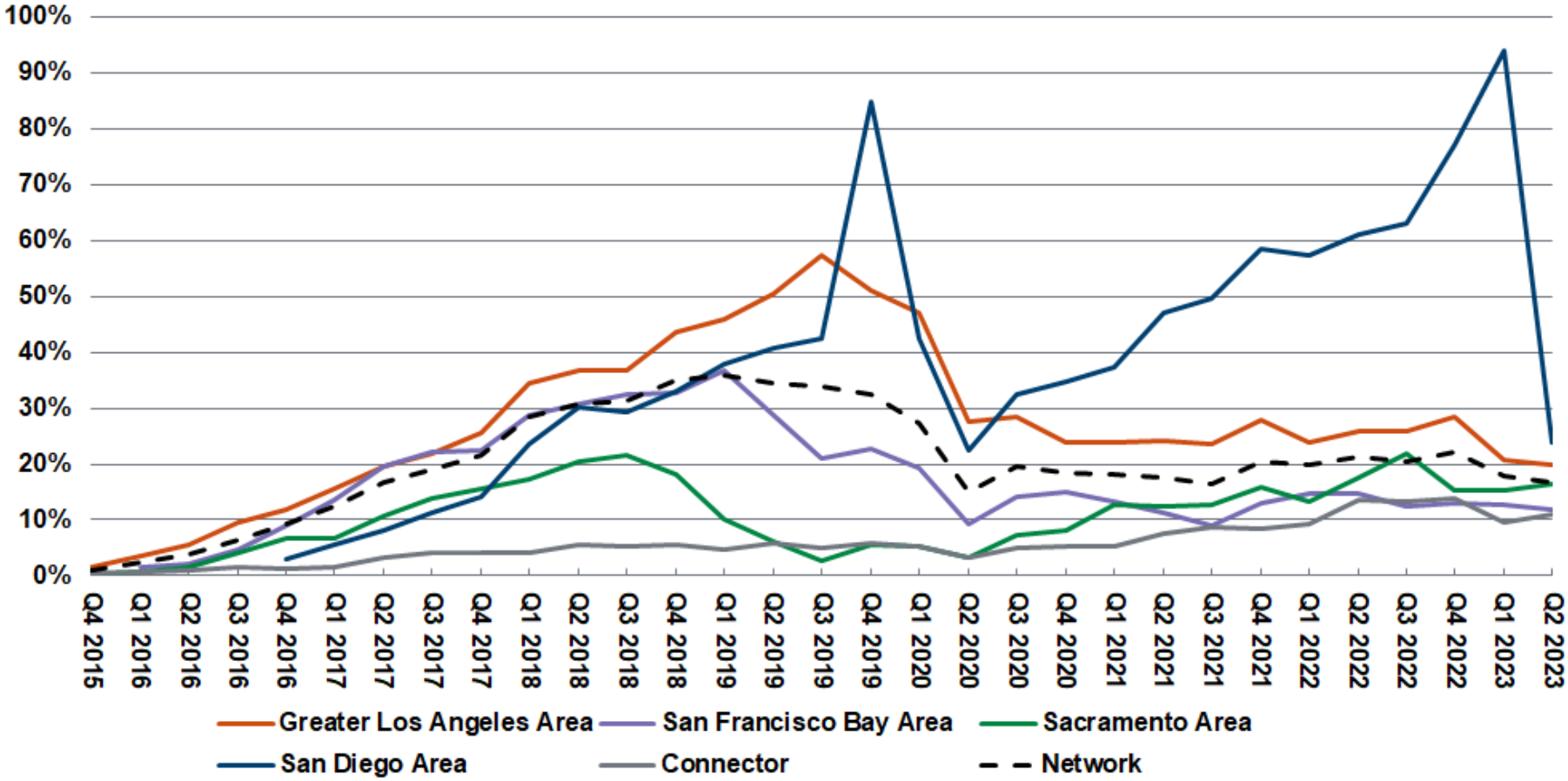
Source: CEC

Figure 7 shows the quarterly hydrogen station utilization rates statewide. Staff calculated the utilization rate by dividing the total quarterly amount dispensed by the overall quarterly nameplate capacity of the open retail station network. If a station is designated as TNO or down for maintenance, the station is considered to have dispensed zero for the period that it is offline. The overall network utilization was 17 percent in the second quarter of 2023. The utilization percentage has been hovering around 20 percent consistently since the first quarter of 2020 because fueling capacity and fueling demand have grown at a similar rate.

The San Diego Area had the highest average utilization rate, more than 90 percent in the first quarter of 2023. In the second quarter of 2023, the San Diego-Mission Center station opened with more than 1,200 kg/day capacity, causing the overall utilization rate in that area to decline to 23 percent. The Greater Los Angeles Area is the region with the next highest average utilization rate, 20 percent.

These trends shown in Figures 6 and 7 help inform stakeholders where future stations are needed.

Figure 7: Hydrogen Station Utilization by Quarter



Source: CEC

Retail Price of Hydrogen

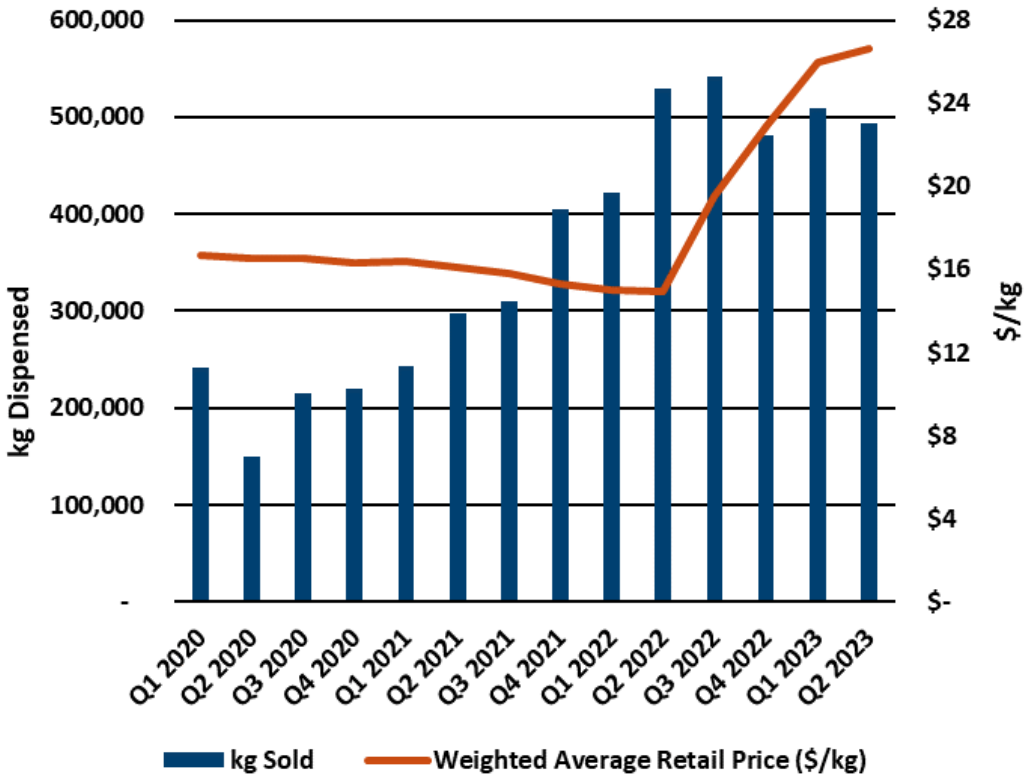
Figure 8 shows the weighted average retail price of hydrogen and the total kilograms of hydrogen sold per quarter for hydrogen stations that report dispensing data to the CEC. The weighted average retail price of hydrogen is the quarterly revenue generated by hydrogen sales in the network divided by the total kilograms dispensed by the network in the quarter. This sample represents all stations that have agreements with the CEC and are required to report their fueling data and stations that voluntarily submit data to the CEC. The samples for the latest quarter account for about 70 percent of currently open retail stations in the state.

Figure 8 shows that the average price of dispensed hydrogen increased from $14.95 per kilogram in the second quarter of 2022 to $26.64 in the second quarter of 2023. In the third and fourth quarters of 2022, most open retail stations in California increased the hydrogen fuel prices at the pump to between nearly $19 and $25 per kilogram, tax included. Many stations have increased the prices at the pump further to between nearly $24 and $36 per kilogram, tax included. FCEVs are about 2.5 times more efficient than gasoline-powered vehicles.[20] Therefore, in terms of driving range obtained from the fuel, $24 per kilogram of hydrogen is equivalent to paying about $9.60 for a gallon of gasoline, and $36 per kilogram of hydrogen is equivalent to paying about $14.40 for a gallon of gasoline. FCEV drivers could be paying up to $180 to fill an empty tank at $36 per kilogram. Station developers have cited that these price increases are due to increasing energy costs for natural gas, increasing labor and materials costs due to inflation, and lower value of CARB LCFS credits traded on the market, meaning station operators are earning fewer dollars per credit. LCFS revenue can help offset the costs of operations and maintenance of stations, which has helped keep prices paid by FCEV drivers at the pump lower in the past.

The CEC, CARB, GO-Biz, and station developers have been searching for ways to improve the current situation and reduce the prices paid by FCEV drivers. The CEC released the solicitation, GFO-23-604, on November 3, 2023, providing nearly $11 million to support operations and maintenance of existing stations, which may help lower the prices paid by FCEV drivers. Also, the 2022 Budget Act provides $100 million to the CEC to distribute grants for producing clean hydrogen in-state through electrolysis or biofuels using renewable energy, which, in addition to private investments, should help ensure a more reliable hydrogen supply and could help stabilize prices.

20 California Air Resources Board. July 2020. *Unofficial Electronic Version of the Low Carbon Fuel Standard Regulation*. https://ww2.arb.ca.gov/sites/default/files/2020-07/2020_lcfs_fro_oal-approved_unofficial_06302020.pdf.

Figure 8: Weighted Average Price of Hydrogen and Total Kilograms Sold Per Quarter



Source: CEC

Hydrogen Dispensed

Most of the hydrogen dispensed in the California station network has been produced using fossil gas steam methane reformation (SMR).

The CARB LCFS Program allows program participants to meet the renewable requirements by using either direct renewable content or purchasing renewable attributes, or credits. The CARB LCFS Program uses the definition of renewable hydrogen as hydrogen derived from electrolysis of water or aqueous solutions using renewable electricity, catalytic cracking or steam methane reforming of biomethane, or thermochemical conversion of biomass, including the organic portion of municipal solid waste.[21] The LCFS Program explains how indirect accounting may be used for renewable natural gas to produce hydrogen for transportation purposes by obtaining environmental attributes.[22] Renewable electricity, for renewable hydrogen production by electrolysis, means electricity derived from sources that qualify as eligible renewable energy resources as defined in California Public Utilities Code Sections 399.11–399.36.[23] These code

21 California Code of Regulations Title 17, Division 3, Chapter 1, Subchapter 10, Article 4, Subarticle 7, §95481.

22 California Air Resources Board. July 2020. *Unofficial Electronic Version of the Low Carbon Fuel Standard Regulation.* https://ww2.arb.ca.gov/sites/default/files/2020-07/2020_lcfs_fro_oal-approved_unofficial_06302020.pdf.

23 California Code of Regulations Title 17, Division 3, Chapter 1, Subchapter 10, Article 4, Subarticle 7, §95481.

sections define renewable electricity as electricity produced via many renewable pathways, including solar, wind, geothermal, biomass, landfill gas, municipal solid waste, tidal energy, and others.[24]

The CEC used to receive data on the kilograms of hydrogen dispensed at stations and the percentage of renewable hydrogen dispensed in attestations provided by station developers, per CEC agreements. However, many agreements have ended, so the CEC does not have a meaningful sample size to report the renewable hydrogen content. For stations reporting to the CARB LCFS Program under the HRI provision,[25] the CARB 2023 Annual Evaluation estimates 53 percent renewable content in 2022 and 49 percent renewable content in the first quarter of 2023 using data available through the LCFS program for all reporting hydrogen stations. Book and claim accounting is likely used to reach those levels of renewable content.

The analysis shows that the renewable content continued to decrease over the last two years. The CARB 2023 Annual Evaluation suspected that increased economic pressures may have been a factor for this recent decrease in the renewable content.

The CEC will continue to explore ways to help increase the renewable content of hydrogen directly produced in-state that is used in vehicles.

Station Reliability and Availability

Although the nameplate dispensing capacity of the hydrogen network exceeds the current reported hydrogen demand, the availability of stations in the network continues to be a problem. CARB's 2023 Annual Evaluation discussed station availability, finding that the network of open retail stations, not including TNO stations, operated at around 60 percent of capacity on average from the third quarter of 2022 to the second quarter of 2023. Actual network fueling capacity depends on the reliability of hydrogen supply and station uptime. As discussed earlier in this chapter, when considering the 60 percent availability and number of TNO stations, the current network of open retail stations can support only about 31,000 FCEVs, almost half of what the nameplate capacity of 66 open retail stations can support. Thus, improving station reliability is key to providing all stakeholders, most notably FCEV drivers and auto manufacturers, confidence in the FCEV market.

Hydrogen station developers are responsible for maintaining stations reliably and predictably. The CEC solicitations that funded most of the existing and planned stations in the state required applicants to discuss operation and maintenance procedures and plans. Applications were scored based on the information related to how applicants planned to maximize station uptime, meet customer fill requests, optimize the response process and time needed to address a station outage, and coordinate repairs and maintenance with nearby stations.

Recent station unavailability has been caused mostly by unexpected equipment failure, spare parts shortages, and hydrogen supply disruptions. For example, a supply service disruption affected 10 stations in Southern California in August 2023 for about one week and has been

24 California Public Utilities Code §§399.11–399.36 and California Public Resources Code §25741.

25 California Code of Regulations Title 17, Division 3, Chapter 1, Subchapter 10, Article 4, Subarticle 7, §95481.

affecting these 10 stations again since September 2023. During the one-week supply disruption in August 2023, station operator FirstElement Fuel secured a temporary emergency supply of hydrogen for five stations within a few days to rectify station closures due to lack of fuel. Unfortunately, this emergency supply of hydrogen resulted in a temporary price increase. However, these same 10 stations in Southern California have remained closed since September 2023 due to hydrogen supply disruptions. Separately from the supply disruptions in Southern California, some stations experienced reduced fuel deliveries in 2023 preventing stations from serving FCEV drivers once onsite hydrogen supply was exhausted.

Shell closed five stations temporarily in August 2023 to conduct a safety assessment with no estimated timeline for restoration. The closure of Shell stations has left the Sacramento Area with one open station. The remaining station serving the Sacramento Area is one of the oldest stations in the state and cannot handle the increased demand without requiring a mandatory 10-minute wait time between fills to avoid equipment failure. As a result, drivers could spend hours waiting for an opportunity to refuel. Toyota has provided rental cars and reimbursement for fuel to those affected drivers; however, these provisions mean many of these drivers are driving cars with tailpipe emissions instead of ZEVs.

The CEC released a solicitation, GFO-23-604, on November 3, 2023, providing nearly $11 million to help the existing open retail station network become more reliable by supporting operations and maintenance of these stations. The CEC is requiring commitment to achieving 95 percent uptime as a condition for receiving a grant. The CEC also provided a $7.7 million manufacturing grant to FirstElement Fuel Inc. to produce hydrogen refueling equipment in California, which could help ease supply chain constraints.

Expanding Options for Hydrogen Supply for California

Diversifying the supply of hydrogen for FCEVs will be significant for increasing the reliability of refueling stations and decreasing the cost of hydrogen. The state of California, in partnership with industry stakeholders, applied to the U.S. DOE for federal funding for a hydrogen hub. On October 13, 2023, the U.S. DOE announced $7 billion to launch seven regional clean hydrogen hubs, including up to $1.2 billion for the California hydrogen hub called the Alliance for Renewable Clean Hydrogen Energy Systems or "ARCHES."[26] This hydrogen hub will increase the sources and the amount of hydrogen available in California.

Meanwhile, the Clean Transportation Program has funded three new renewable hydrogen production plants and two upgrade projects to existing plants, with a combined daily nameplate capacity of nearly 24,000 kg.[27] One of these plants started production in June

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26 U.S. DOE. October 13, 2023. "Biden-Harris Administration Announces $7 Billion For America's First Clean Hydrogen Hubs, Driving Clean Manufacturing and Delivering New Economic Opportunities Nationwide." https://www.energy.gov/articles/biden-harris-administration-announces-7-billion-americas-first-clean-hydrogen-hubs-driving.

27 Two production plants were funded by GFO-17-602, Renewable Hydrogen Transportation Fuel Production Facilities and Systems, released December 2017. Two additional plants and a plant upgrade were funded by GFO-20-609, Renewable Hydrogen Transportation Fuel Production, released April 9, 2021.

2023.[28] The rest of the plants are still in early stages of development. Four of these projects use electrolyzers to produce hydrogen.

The CEC's Energy Research and Development Division (ERDD) also has a program called the Clean Hydrogen Program,[29] which was established by Assembly Bill 209 (The Energy and Climate Change budget bill, Chapter 251, Section 12, Chapter 7.6, Article 4, enacted in September 2022). The Clean Hydrogen Program provides financial incentives ($100 million) to eligible in-state projects to demonstrate or scale-up hydrogen projects that produce, process, deliver, store, or use clean hydrogen.

Other hydrogen production updates since the 2022 Joint Report, including projects that will serve transportation uses and those that will not, are summarized in the following list.

- Linde announced its plans to increase its green hydrogen production capacity in Ontario (San Bernardino County) based on the growing demand from the mobility market.[30]
- SGH2 Energy received permits from the City of Lancaster, and its project that is funded by the CEC was approved at the CEC's business meeting May 31, 2023. The project is expected to start producing roughly 3,800 metric tons[31] of renewable hydrogen annually using waste in 2025 to support FCEVs.
- The City of Lancaster released an update about Element Resources planning to build a renewable hydrogen production plant in the city. The plant is expected to produce 20,000 metric tons of renewable hydrogen annually.[32]
- Raven SR Inc., Chevron New Energies, and Hyzon Motors Inc., announced January 9, 2023, that they are collaborating for a green waste-to-hydrogen production plant in Richmond (Contra Costa County) to supply transportation markets in Northern California. The production plant is expected to divert up to 99 wet tons of green and food waste a day and to produce up to 2,400 metric tons of renewable hydrogen annually.[33] The project received CEQA approval in May 2023.[34]

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28 H2B2. June 15, 2023. "H2B2's SoHyCal Project in California Has Started Hydrogen Production." https://www.h2b2.es/h2b2s-sohycal-project-in-california-has-started-hydrogen-production/.

29 California Energy Commission. Clean Hydrogen Program. https://www.energy.ca.gov/programs-and-topics/programs/clean-hydrogen-program.

30 Linde. January 31, 2023. "Linde to Increase Green Hydrogen Production in California." https://www.linde.com/news-media/press-releases/2023/linde-to-increase-green-hydrogen-production-in-california.

31 The metric ton is a unit of mass and defined as 1,000 kilograms.

32 The City of Lancaster. January 24, 2023. "Element Resources to Build One of California's Largest Renewable Hydrogen Production Facilities in the City of Lancaster, CA." https://www.cityoflancasterca.org/Home/Components/News/News/9889/.

33 Chevron Corporation. January 9, 2023. "Raven SR, Chevron and Hyzon Motors Collaborate to Produce Hydrogen From Green Waste in Northern california." https://www.chevron.com/newsroom/2023/q1/raven-sr-chevron-hyzon-motors-collaborate-to-produce-hydrogen-from-green-waste.

34 Raven. May 24, 2023. "Raven SR Bioenergy Project Receives Environmental Approval From City of Richmond, Calif." https://ravensr.com/richmmond-bioenergy-project-approved/.

- Yosemite Clean Energy LLC announced that its project has been awarded funding from the CEC to build a hydrogen production plant in Oroville (Butte County) by converting forest biomass into green hydrogen. Using wood waste will also help reduce the risk of wildfire. The project is expected to be completed in the first quarter of 2026 and produce 7,000 metric tons of hydrogen annually.[35]

The total fueling capacity of the 130-station network is nearly 132,000 kg/day (130 metric tons/day), or enough hydrogen fuel for nearly 188,000 light-duty FCEVs. The combined daily production capacity of existing and new production plants that will supply hydrogen to the transportation sector is about 108,000 kg/day, most of which can be available to use in California. This amount is about 80 percent of the capacity of the future light-duty fueling network (though more than double the anticipated demand of the latest light-duty FCEV projection by auto manufacturers of 62,600 FCEVs on the road by 2029). However, all of this production capacity is not necessarily dedicated to light-duty vehicles, and continuing to focus on increasing hydrogen production for the California mobility market, with a focus on clean hydrogen and low carbon intensities, should remain a priority. In addition, more hydrogen production projects, even the ones that will not supply the transportation sector, will help advance technologies and reduce the costs of hydrogen.

Medium- and Heavy-Duty Hydrogen Infrastructure

Station developers are designing at least 7 of the 130 projected stations to be capable of fueling medium- or heavy-duty vehicles in addition to light-duty ones, thereby leveraging infrastructure to address multiple markets and accelerating the development of commercial fuel cell electric trucks. This development includes two multiuse stations that serve light-, medium-, and heavy-duty vehicles awarded under GFO-22-607.

The CEC has published *2023 Staff Report on Senate Bill 643: Clean Hydrogen Fuel Production and Refueling Infrastructure to Support Medium-and Heavy-Duty Fuel Cell Electric Vehicles and Off-Road Applications* [36] (2023 SB 643 Staff Report) on September 25, 2023, that discusses medium- and heavy-duty FCEVs, along with off-road nontransportation vehicles that use hydrogen as fuel, in more depth.

35 *Biomass Magazine*. July 12, 2023. "Yosemite Clean Energy Receives $5 Million Grant." https://biomassmagazine.com/articles/20207/yosemite-clean-energy-receives-5-million-grant.

36 Villareal, Kristi. 2023. *2023 Staff Report on Senate Bill 643: Clean Hydrogen Fuel Production and Refueling Infrastructure to Support Medium-and Heavy-Duty Fuel Cell Electric Vehicles and Off-Road Applications.* California Energy Commission. Publication Number: CEC-600-2023-053. https://www.energy.ca.gov/sites/default/files/2023-09/CEC-600-2023-053_0.pdf.

CHAPTER 3:
Fuel Cell Electric Vehicle Deployment

This chapter discusses the estimated number of FCEVs currently in the state and the projected FCEV population, along with barriers to widespread FCEV adoption.

The cumulative sales and leases of light-duty FCEVs are increasing. Annual sales have generally been between 2,000 and 3,200 per year for the last five years, with 3,205 FCEVs sold or leased in 2021, 2,574 sold or leased in 2022, and about 3,500 could be sold or leased in 2023 at the current 2023 pace.

The current network nameplate fueling capacity could support more deployment of FCEVs. However, actual network fueling capacity depends on the availability of hydrogen supply and the availability of the stations themselves. As noted earlier, concerns with reliability and TNO stations reduce the availability of the stations. The station developers and operators must improve the operations and maintenance of these stations to support FCEVs.

Both the CEC and CARB publish FCEV deployment numbers. The CEC Energy Assessments Division collects and analyzes California Department of Motor Vehicles (DMV) data about the trends in ZEV sales and population. CARB also collects and reports the estimated number of FCEVs on the road in April and October each year based on the analysis of DMV data, including removing vehicles that appear to be no longer registered in the state.

The CEC publishes "Zero Emission Vehicle and Infrastructure Statistics,"[37] which offer a collection of dashboards for ZEV sales, ZEV population, school buses, and corresponding infrastructure information. The New ZEV Sales in California dashboard reports that the on-road population of FCEVs was 11,897 at the end of 2022, and the dashboard reports the new FCEV sales for 2023, through the end of the third quarter, as 2,912 FCEVs. With this information, staff estimates the total on-road FCEV population to be 14,809, the summation of 11,897 and 2,912.[38]

The dashboard shows cumulative light-duty ZEV sales, including FCEV, BEV, and plug-in hybrid electric vehicles, of 1,742,801 in California as of the third quarter of 2023. The dashboard also shows 134 fuel cell electric buses at the end of 2022. The 2023 SB 643 Staff Report discusses medium- and heavy- duty vehicles in more detail.

CARB's analysis of DMV data found the population of FCEVs was 12,993, as of April 2023. Per the provision set forth by AB 8, CARB is "to aggregate and make available to the public, no later than June 30, 2014, and every year thereafter, the number of hydrogen-fueled vehicles that motor vehicle manufacturers project to be sold or leased over the next 3 years, as

37 California Energy Commission. "Zero Emission Vehicle and Infrastructure Statistics." https://www.energy.ca.gov/zevstats.

38 According to the CEC ZEV Dashboard, cumulative sales or leases of FCEVs in California were 17,442 in the third quarter of 2023; however, the cumulative sales number of FCEVs does not account for those FCEVs no longer in use due to replacement or attrition.

reported to the state board, and the number of hydrogen-fueled vehicles registered with the Department of Motor Vehicles through April 30."[39] AB 8 also requires the CEC and CARB to consider "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, …" and other factors.

Figure 9, reprinted from CARB's 2023 Annual Evaluation, shows data as provided by auto manufacturers for estimates of vehicles on the road and projected for future deployment from all years of reporting in CARB's Annual Evaluations. CEC staff notes that the material in Figure 9 are projections, per AB 8. Estimated numbers of vehicles on the road per CARB's annual analysis of April 2023 DMV registration data are shown by the red triangles, growing to an estimate of 12,993 vehicles.

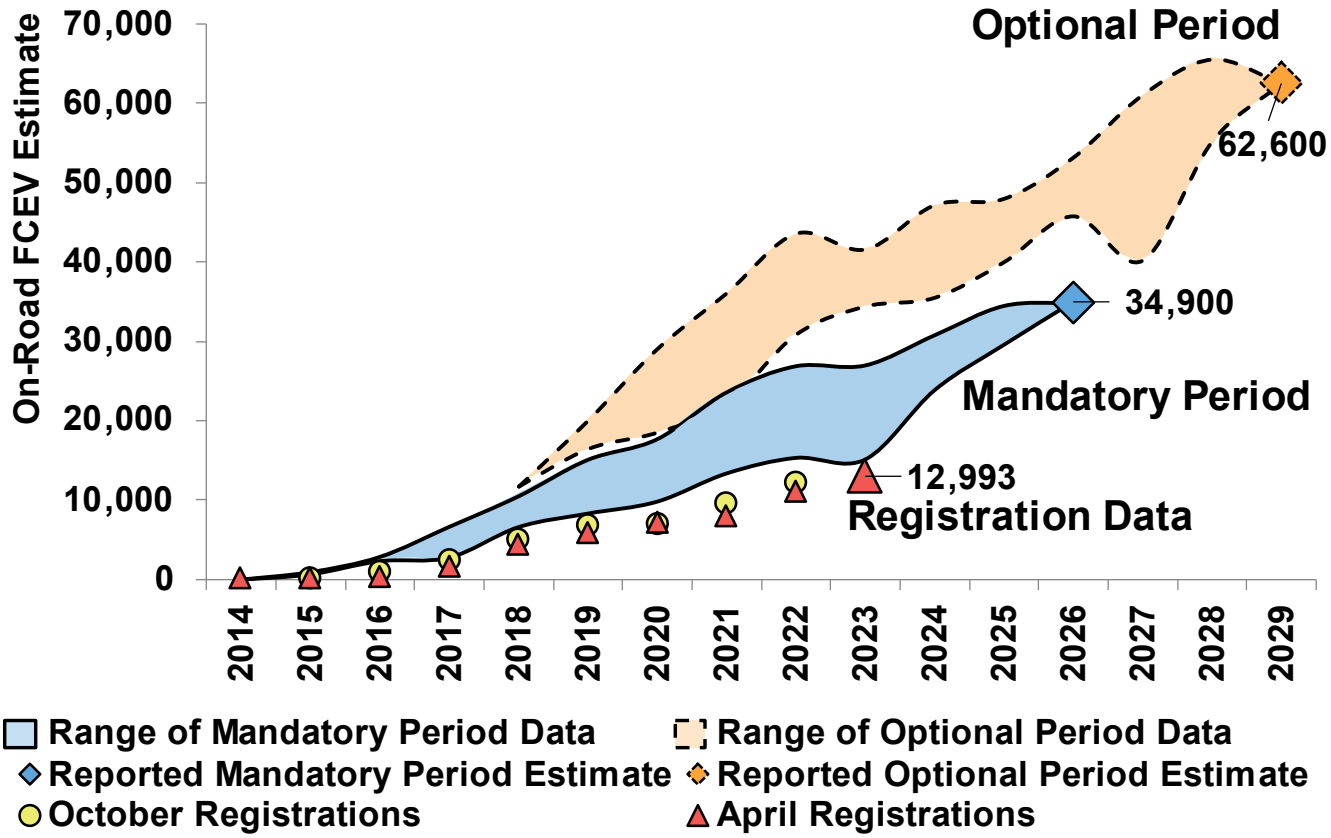
In Figure 9, yellow circles show estimated numbers of vehicles on the road based on October DMV data. Two shaded areas are also shown in the figure, representing projections made by auto manufacturers for future FCEV deployment in all annual evaluations to date. For each annual evaluation, auto manufacturers submit projections to CARB of future FCEV deployment, split into two periods. All auto manufacturers who seek to certify vehicles for sale in California must provide estimates for the mandatory period, which always covers the current model year and the next three model years. Auto manufacturers may also provide responses for the optional reporting period, which extends three further model years. For example, in the 2023 survey, the mandatory survey reporting period covers the Model Years 2023 through 2026, and the optional survey reporting period covers Model Years 2027 through 2029.

In Figure 9, the lower, blue-shaded area displays results for mandatory periods in all past surveys, while the upper, orange-shaded area displays results for optional periods in all past surveys. The information provided on the survey, by auto manufacturers, represents projected FCEV sales or leases in terms of model years. CARB's analysis translates model year into calendar year by assuming that one-third of all vehicles of a given model year are sold or leased in the prior calendar year based on the historical DMV registration data from 2007 to 2012. For example, if an auto manufacturer responds with a projection of 900 FCEVs to be sold in Model Year 2023, CARB's analysis assumes 300 FCEVs will be sold in Calendar Year 2022 and the remaining 600 FCEVs in Calendar Year 2023. CARB's analysis also assumes a standard rate at which FCEVs fall out of the fleet, such as vehicles being moved to another state, accidents, and other causes to estimate the on-road population. This rate is based on similar assumptions in CARB's vehicle fleet modeling tool EMFAC.

Auto manufacturers' deployment plans in the 2023 annual survey would result in 34,900 FCEVs on the road in California in 2026 and 62,600 on the road in 2029. The projected rates of growth show that auto manufacturers anticipate a one-year delay in the FCEV sales projection relative to the previous survey. Auto manufacturer estimates of future FCEV sales have consistently been overestimates relative to actual sales.

39 California Legislative Information. Assembly Bill 8 (Perea, Chapter 401, Statutes of 2013). https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201320140AB8.

Figure 9: FCEV Projections Based on CARB Analysis of Responses to the Annual Auto Manufacturer Survey



Source: CARB

Addressing Barriers to Widespread FCEV Commercialization and Deployment

Beyond expanding the network of stations, there are barriers that need to be addressed to give FCEV drivers confidence in the hydrogen refueling network. These barriers to FCEV market growth relate to station reliability, station availability, and increasing hydrogen prices. Station reliability and availability are affected by station outages due to equipment failures and supply issues as described in the Station Reliability and Availability section in Chapter 2 of this report. Some recent examples of these barriers include supply service disruptions affecting 10 stations in Southern California since September 2023 and station shut downs for safety assessments. Currently, only 54 of 66 open retail stations are available for customer fueling. Even these 54 stations can experience downtime events periodically for planned and unplanned maintenance and supply issues.

As reported in the Retail Price of Hydrogen section in Chapter 2 of this report, hydrogen prices continue to increase to the point where FCEV drivers could be paying up to $180 to fill a tank. Another barrier is the lack of vehicle models and consumer options along with lack of robust sales in California and globally.

Both the state and industry stakeholders must work to address these barriers. As discussed in Chapter 2, the CEC released a solicitation to support operations and maintenance of existing stations and provided a manufacturing grant to produce hydrogen refueling equipment in California. In addition, to gain a better understanding of customer experiences with light-duty hydrogen refueling and hydrogen refueling market potential, the CEC entered into a contract with University of California, Davis (UC Davis), who will conduct a customer survey that will investigate:

- Purchase or lease motivations for FCEVs.
- Driver experiences with FCEVs and hydrogen refueling.
- Whether FCEV buyers will continue with FCEV ownership.
- FCEV owner conversations with other potential buyers about FCEV ownership.

The contract will also investigate experiences surrounding the medium- and heavy-duty fuel cell truck market. UC Davis will conduct interviews with automakers, fleets, fuel suppliers, and equipment providers to investigate:

- Experience with operating medium- and heavy-duty fuel cell trucks.
- Experience providing hydrogen fuel.
- Experience procuring hydrogen fuel.
- Barriers to the adoption of medium- and heavy-duty fuel cell trucks.
- Suggested solutions to those barriers.
- Perceptions regarding the future of medium- and heavy-duty fuel cell trucks.
- Plans of fleet operators on potentially incorporating medium- and heavy-duty fuel cell trucks as part of future fleet procurement.
- Expectations for the necessary hydrogen infrastructure and fuel supply.

The CEC also continues to explore options to enhance the hydrogen station network reliability, resiliency, and availability by working with the industry and setting uptime requirements in future solicitations. The CEC will require that any future hydrogen stations provide data on downtime related to maintenance, equipment failures, or hydrogen fuel supply issues to understand the reliability of the network from a customer experience.

CHAPTER 4:
Time Required to Permit and Construct Hydrogen Refueling Stations

Chapter 4 covers the station development time, shows how the development time has changed over the years, and discusses efforts to help reduce station development time.

Overall station development times were decreasing until the COVID-19 pandemic slowed many station development activities. Time required to permit and construct hydrogen refueling stations observed during and after the pandemic may not be an accurate representation of the progress the industry has made in reducing station development time. In addition to the pandemic-related delays reported in the 2021 and 2022 Joint Reports, station developers continue to experience supply chain issues, including labor and material shortages, and global inflation.

This report breaks down station development time into four phases to analyze the trend. Table 2 lists the phases of station development.

Table 2: Station Development Phases

Phases	Description	Responsible Entity(ies)
Phase One: From start of CEC grant-funded project to initial permit application filing	Begins when the grant-funded project agreement is executed and includes site selection and site control, station planning, participation in prepermitting meetings for confirmation of station design consistency with local zoning and building codes and filing the initial permit application with the authority having jurisdiction (AHJ). Equipment ordering could occur during this phase.	Grant recipient and AHJ
Phase Two: From initial permit application filing to receipt of approval to build	Consists of AHJ review of the application and potential site reengineering/redesign based on AHJ feedback. Minor construction work sometimes begins.	Grant recipient and AHJ
Phase Three: From approval to build to station becoming operational	Includes station construction and meeting operational requirements: fuel supply, hydrogen quality testing, dispensing per standard, successful refueling of one FCEV, and receipt of an occupancy permit from the AHJ.	Grant recipient and AHJ

Phases	Description	Responsible Entity(ies)
Phase Four: From station becoming operational to becoming open retail	The station undergoes accuracy testing with the California Department of Food and Agriculture/Division of Measurement Standards (DMS) and protocol testing with auto manufacturers and the Hydrogen Station Equipment Performance (HyStEP) device. Once the station has been confirmed to meet the refueling protocol, the station is categorized as open retail.	Grant recipient, DMS, CARB (HyStEP), and auto manufacturers

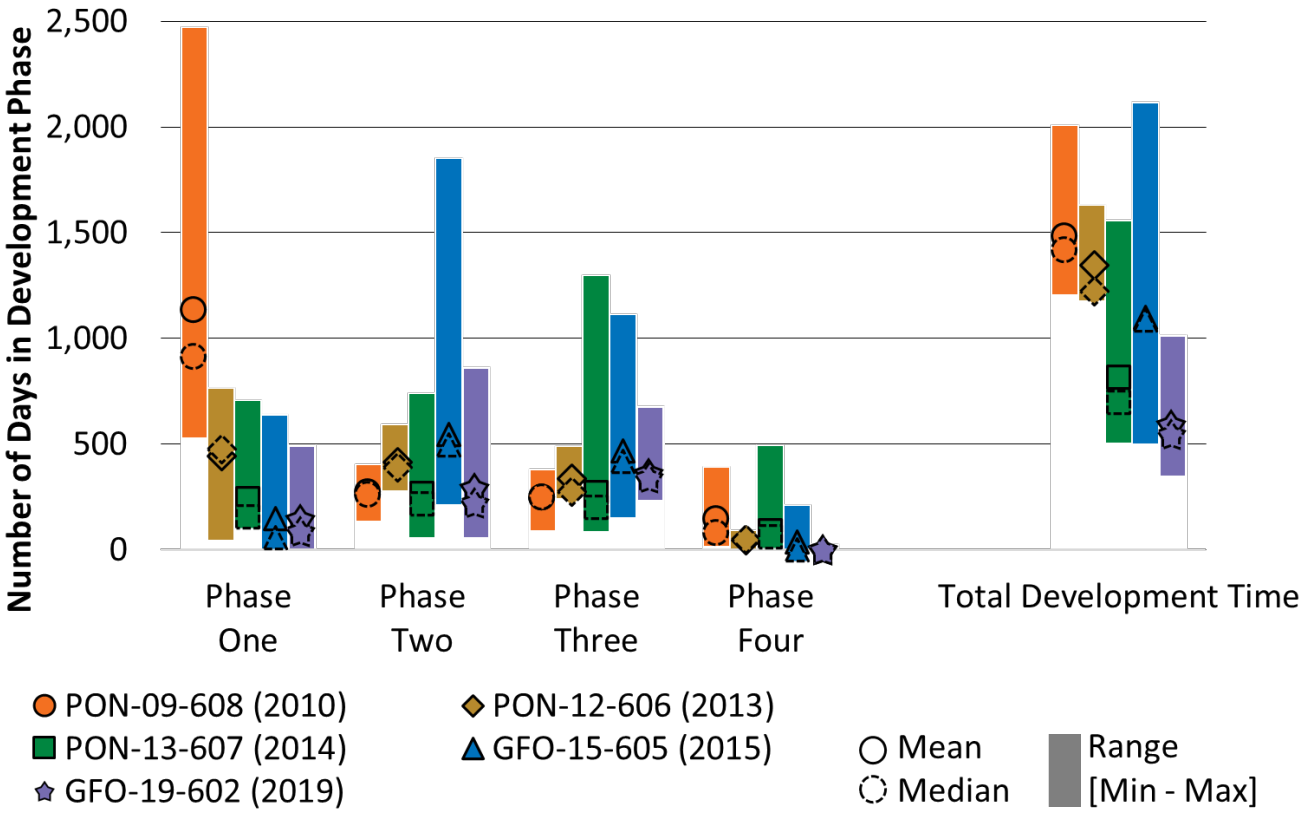
Source: CEC

Figure 10 presents station development time, showing mean, median, minimum, and maximum number of days for each phase with one bar representing all the stations that completed that phase per solicitation. A *mean number of days* simply represents the average number of days for all stations that completed each phase. Mean numbers can be affected by unusual circumstances some stations experience that lead to atypical station development time. A median number of days represents the middle value of the reported number of days for all stations that completed each phase. Median numbers represent more typical station development time. Minimum and maximum numbers of days represent the minimum and maximum time spent in each phase for all stations that completed each phase. The figure includes data from stations that are not yet open for retail fuel sales, but only includes data for those stations for the completed phases. The bars on the far right in the figure show mean, median, minimum, and maximum numbers of days for the *total* station development time for each solicitation and include *only stations that have completed all phases*.

Figure 10 shows, per solicitation, the actual time station projects spent in each phase; therefore, the time spent in development phases includes data of stations that were canceled without completing or stations that have closed. For example, nine projects were either canceled or closed without completing during 2023, but these stations had completed Phase One (and one station project completed Phase Two), and the associated data are included in the corresponding solicitation bars for these phases. The Phase One and Two development times from these stations are *not* represented in the Total Development Time bars because the stations did not complete all phases.

This analysis does not include stations awarded under GFO-22-607 because these stations were recently approved in the summer of 2023 and do not contribute sufficient data to the analysis.

Figure 10: Mean, Median, Minimum, and Maximum Days of Each Station Development Phase by Solicitation



Overall, the time spent in Phase One decreased after 2010 for newer solicitations. The mean, median, and maximum of station development time for newer solicitations continue to increase as more stations are completed. The median total station development time was decreasing from about four years to two years for stations that opened before the pandemic. The median total station development time increased to about three years for those stations that completed during the pandemic (GFO-15-605). The median total station development time for GFO-19-602 is lower than the other solicitations, but only ten stations have completed all phases. The development time for GFO-19-602 is expected to increase because many of the stations are still in development and affected by global inflation and supply chain issues.

Sources: CEC and CARB

As shown in Figure 10, the station development time in Phase Two (mean, median, and maximum) and Phase Three (mean and median) for GFO-15-605 has increased as more stations funded under this solicitation completed since data were last reported in the 2022 Joint Report. One more station remains to be completed under GFO-15-605, which will increase the mean, median, and maximum numbers for this solicitation. In fact, this station received approval to build in April 2023 after five years in the permitting process, which increased the mean, median, and maximum values for Phase Two for this solicitation.

The station development time for GFO-19-602 continues to be updated as more stations complete the development phases. Only ten GFO-19-602 stations have completed all phases. Of these ten stations, seven stations are funded fully by match share in an agreement

resulting from GFO-19-602. These stations opened quickly because the station developer had already begun permitting those stations before applying for GFO-19-602. The station development time in Phase One for GFO-19-602 is less than other solicitations because those stations were in the permitting process before they applied for GFO-19-602. The station development time for GFO-19-602 is expected to continue increasing as more stations are completed.

Station developers shared how supply chain issues and global inflation are affecting their station development. One developer reported that securing funding commitments is more difficult due to inflation increasing the costs to develop stations along with the lower LCFS HRI credit value. They also spend more time trying to negotiate for a better construction contract, which sometimes affect Phase Three. Another developer reported that finding equipment that ensures station uptime has been difficult; the equipment installed at existing stations either cannot maintain sufficient uptime or require station operators to develop their own parts to improve. This developer is carefully selecting equipment for the rest of the stations they develop to meet the customer expectations. Another developer also pointed to construction cost escalation, supply chain, and global inflation. Until global inflation, labor and material shortages, and supply chain interruptions are resolved, staff expects overall station development time for remaining stations to continue to increase.

Efforts to Help Reduce Station Development Time

CEC staff continues to work with station developers to explore ways to overcome the hurdles they are experiencing and expedite station development, including assessing an appropriate funding amount per station given inflation, supply chain challenges, and the uncertainty around the future fuel demand from light-duty FCEVs. Reducing station development time will also give current and future FCEV drivers more confidence in their refueling options.

The time required to complete Phase Four has generally decreased over time. Partly because CARB, the CEC, GO-Biz, and DMS collaborated with public and private stakeholders to develop the HyStEP device and program in the time between PON-13-607 and GFO-15-605. Stations are currently tested using the HyStEP device before becoming open for retail hydrogen sale. The HyStEP tests the ability of hydrogen refueling stations to adhere to the fueling protocols of the industry-adopted SAE J2601 standard. This standard protocol helps ensure fast, safe, and reliable fueling experiences for customers. The HyStEP device accomplishes the task of verifying conformance to the protocol in one to two weeks. Prior efforts that relied on testing via multiple auto manufacturers using test vehicles could require months of scheduling, testing, adjusting, and retesting. However, there is only one HyStEP device in the state, which could slow down station opening if the station development pace improves or if multiple stations are ready for testing simultaneously. Furthermore, the current HyStEP device can only test stations that fuel light-duty vehicles. In the future, a newer HyStEP device will be needed to test medium- and heavy-duty hydrogen stations. The HyStEP program is operated by CARB, with collaborative review of HyStEP testing results among state agencies, the station developer, and auto manufacturers.

CARB has released a request for proposal on October 18, 2023, with $1.05 million available to design, engineer, build, test, and validate the next generation HyStEP 2.0. The HyStEP 2.0

device will include new hardware and capabilities which lead to reduced testing time. These capabilities include simultaneous testing and venting, accommodating back-to-back fueling, and ability to test a larger variety of vehicle tank sizes. HyStEP 2.0 is expected to begin testing hydrogen stations in California by late 2025. Once developed, the original HyStEP and HyStEP 2.0 devices would be used to perform testing at stations across the state.

Both the state and industry stakeholders must collaborate to reduce the station development time as station development depends on several factors including permit timing, public and private funding, the number of station equipment vendors and supply chain, and the number of station developers participating in the market available to deploy stations.

CHAPTER 5:
Amount and Timing of the Growth of the Hydrogen Refueling Network

This chapter analyzes the amount and timing of the growth of the hydrogen refueling network by comparing the anticipated schedule of hydrogen refueling station openings over the next six years to the estimated schedule of FCEV deployment in California. The objective of the Clean Transportation Program solicitations have been for the fueling capacity of the station network to stay well ahead of hydrogen fuel demand so that consumers can have confidence in fuel availability if they choose to drive a FCEV. This chapter also discusses contextual information about station and FCEV deployment in other parts of the world.

This report uses the nameplate capacity of stations to analyze the amount and timing of the growth of the hydrogen refueling network in California, discusses the statewide network of stations, and then evaluates the anticipated growth in greater detail at a regional level. This analysis assumes that stations within the network are operating regularly at their nameplate capacities without significant downtime. The validity of this analysis depends on the degree to which stations are actually functioning this way in the real world — they have hydrogen supply available to dispense and are up and running. If stations are down due to broken equipment or because they have run out of hydrogen fuel, the station network cannot support the number of FCEVs that they should on paper. Chapter 2 already discussed challenges with hydrogen supply and other factors that have at times significantly affected station network performance.

As of November 6, 2023, California has built about four times more dispensing capacity than the demand needed to fuel its population of FCEVs. The station opening timelines provided to the CEC by hydrogen station developers suggest that by 2027, the network of 130 projected stations will have the capacity to serve nearly 188,000 FCEVs. This number is about three times the amount of fuel needed to supply the projected 62,600 FCEVs by 2029 reported in CARB's 2023 Annual Evaluation, based on the latest auto manufacturer survey responses.

Even though the overall network nameplate capacity should still exceed fuel demand, there have been setbacks, such as proposed stations being canceled and existing stations experiencing reliability and availability issues.

Regional Analysis of Network Growth and FCEV Deployment

This section evaluates four major regions of the state: the Greater Los Angeles Area, the San Francisco Bay Area, the Sacramento Area, and the San Diego Area. The regions are defined in the glossary. Also evaluated is the rest of the state, composed of the North Region, Central Coast, Central Valley, Eastern Sierra, and Imperial County.

Table 3 presents the estimate of FCEV registrations per region as of April 2023, the number of FCEVs that the regional capacity of open retail stations with TNO stations removed can support, and the additional number of FCEVs the regional capacity can support. The largest

regions of the Greater Los Angeles Area and the San Francisco Bay Area have more than sufficient fueling capacity for the number of FCEVs registered in the area, although station downtime can mean there are still times when fuel is unavailable. The San Diego Area has more capacity compared to the number of FCEVs than it has in past years due to the opening of one more station.

The region with the most urgent need of additional fueling capacity is the Sacramento Area, because two of the three stations in the area are TNO, with no indication of when they will reopen, at the time of this report's preparation. These two TNO stations must reopen to meet regional fuel demand because, while the Sacramento region has three additional stations in development, the stations are not scheduled to open until 2025.

Table 3: Regional FCEVs and Open Retail Minus TNO Station Capacity

Region	# of FCEV Registrations[40]	Estimated # of FCEVs Open Retail Stations Can Support[41]	Additional # of FCEVs that Open Retail Stations Can Support
Greater Los Angeles Area	8,051	29,400	21,300
San Francisco Bay Area	3,307	16,600	13,300
Sacramento Area	902	600	(300)
San Diego Area	487	2,100	1,600
Rest of State	246	1,100	900
Total	12,993	49,800	36,800

Source: CEC

Table 4 presents projections of vehicle and station rollout in 2029. The stations with known locations that are planned to be opened by 2029 are expected to have sufficient nameplate capacity to serve the number of FCEVs projected to be sold by that year as reported in CARB's 2023 Annual Evaluation based on the latest auto manufacturer survey responses. The total capacity of all 130 anticipated stations will have the nameplate capacity to serve about three times the projected number of FCEVs. As public and private entities work to make this planned station network a reality, the state intends to support the fueling infrastructure that has the capacity to sustain an increased FCEV population to achieve ZEV deployment goals.

In past years, this report has highlighted limited opportunity for FCEV deployment in the rest of the state outside the four main urban regions. The results of GFO-22-607 have added new station projects in Madera, Visalia, and Kettleman City. Furthermore, a station in Fresno is

40 Numbers of FCEVs determined by DMV registration data, April 2023.

41 The estimated numbers of FCEVs supported are displayed with rounding to the nearest hundred in this table to better show regional differences. Elsewhere in this report, the statewide estimates are rounded to the nearest thousand.

planned as part of a GFO-19-602 project. When these newly funded stations open in 2025, several Central Valley communities will have the fueling access needed to support FCEV adoption.

Table 4: Regional Projection of FCEVs and Station Network Capacity in 2029

Region	Projected # of FCEVs in 2029[42]	Estimated # of FCEVs Stations Could Support in 2029	Additional # of FCEVs That Stations Could Support in 2029
Greater Los Angeles Area	32,600	71,400	38,800
San Francisco Bay Area	21,200	50,800	29,600
Sacramento Area	3,200	7,400	4,200
San Diego Area	2,900	6,700	3,800
Rest of State	2,700	7,200	4,500
Total	62,600	143,500	80,900

Source: CEC

The regional analysis in this chapter evaluates all open retail stations, the planned stations under CEC solicitations with confirmed addresses, and planned stations that are privately funded.

To confirm station addresses under GFO-19-602, in which station developers build stations in batches, developers must meet various milestones to prove location viability. There are 41 stations with addresses out of the 61 new stations that the CEC expects to result from GFO-19-602, once fully funded. These stations without confirmed addresses are not part of this analysis. Network nameplate capacity with these stations without locations would be about 30 percent more from the 2029 capacity listed in Table 4.

To calculate the projections presented in Table 4, staff used the daily station capacity as determined by the Hydrogen Station Capacity Evaluation (HySCapE) tool (or the stated nameplate capacity, if HySCapE results are not available). Then, staff used the assumption of 0.7 kilogram per day of hydrogen consumed per FCEV to convert the station nameplate capacity into the estimated number of FCEVs supported.

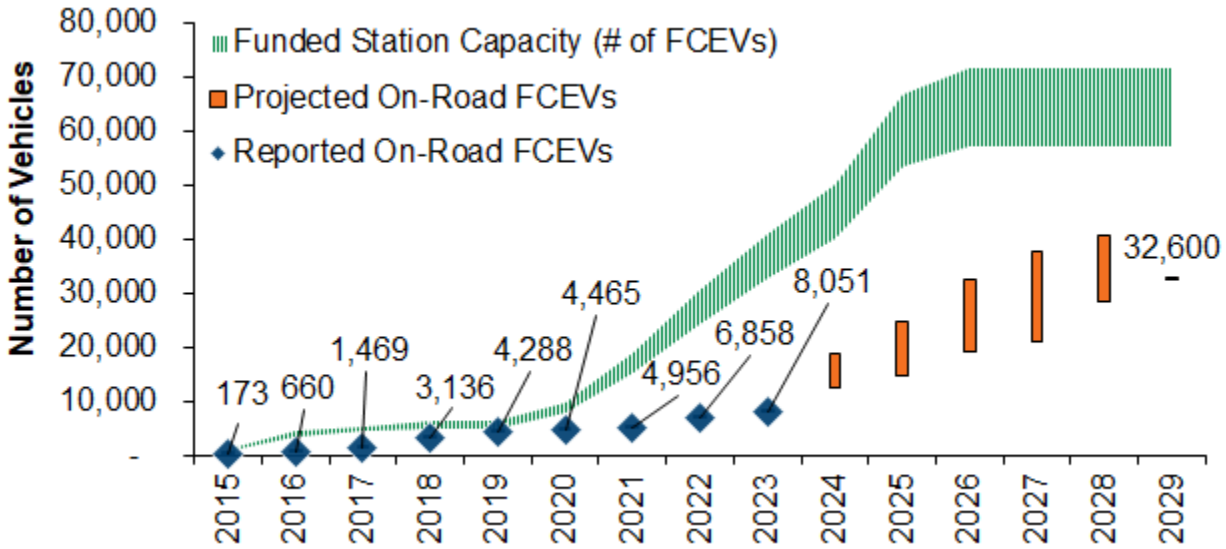
Figures 11 through 13 compare the estimated FCEV rollout to the estimated regional station deployment based solely on the network of stations with known locations. The orange bars in Figures 11 through 13 show the range of FCEVs projected from auto manufacturer surveys. The figures assume that stations will open according to station developers' timelines.

42 CARB assigned the proportion of projected vehicles based on the auto manufacturers survey responses to each county based on the proportion of network capacity among stations located within the county. This method assumed the regional distribution of FCEV deployment will closely follow the regional distribution of the fueling network.

The green lines in the figures indicate the estimated number of FCEVs that could be supported by stations in each region. The width of the green line represents the difference between using 100 percent of the station nameplate capacity to determine the number of FCEVs supported (the upper bound) and using 80 percent (the lower bound, representing a more sustainable level of fueling).

Figure 11 shows that the FCEV population in the Greater Los Angeles Area has largely followed capacity growth, increasing over time at a similar rate. The expected capacity in the region has the potential to sustain projected FCEV deployment, with the ability to support at least 57,000 FCEVs by 2026.

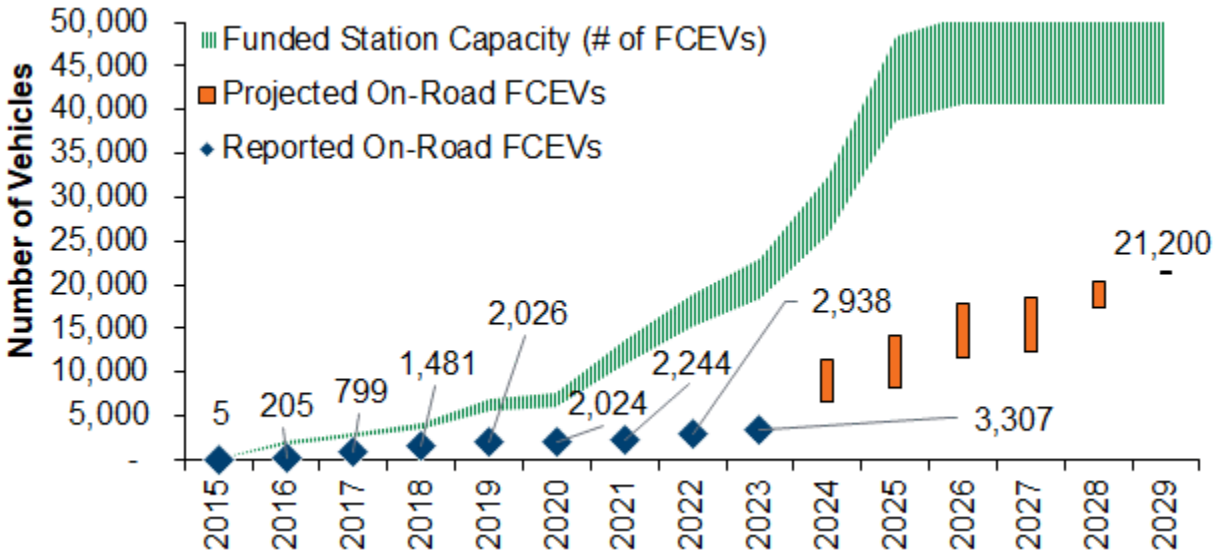
Figure 11: Greater Los Angeles Area Station Capacity and Number of Vehicles



Source: CEC

Figure 12 shows that the network capacity in the San Francisco Bay Area is maintaining a healthy amount of excess capacity to serve FCEVs. The Bay Area expects a jump in network capacity in 2025 and 2026 and should have capacity to serve at least 48,000 FCEVs by the end of 2025. This number of FCEVs supported by the expected capacity is more than tenfold increase from today's number of FCEVs on the road in the Bay Area.

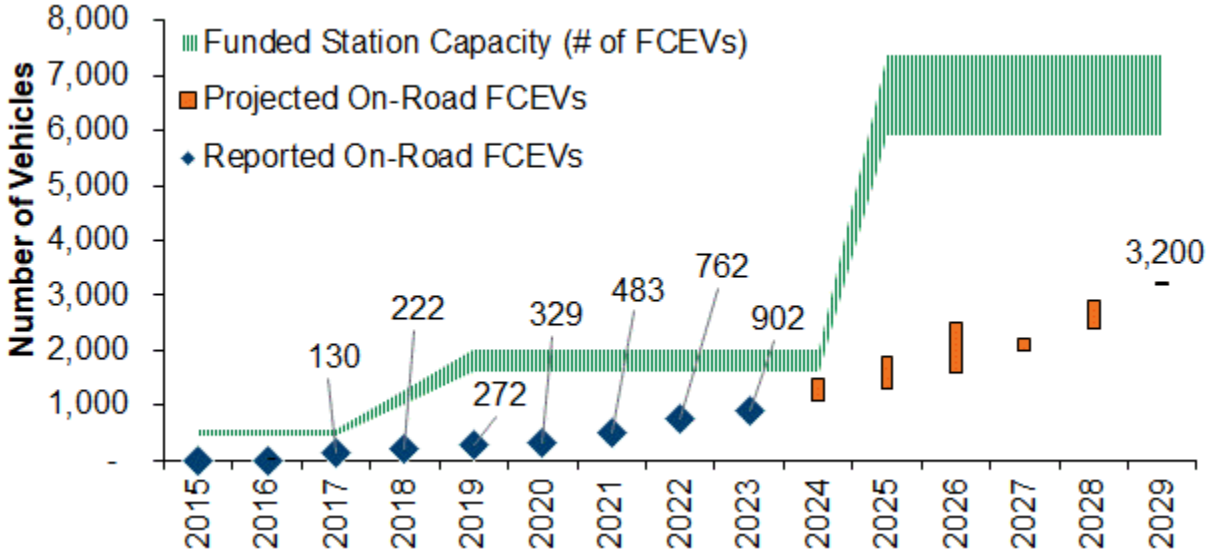
Figure 12: San Francisco Bay Area Station Capacity and Number of Vehicles



Source: CEC

Figure 13 shows that the current network capacity of the Sacramento region is enough to support existing FCEVs, but this figure includes two TNO stations. As shown in Table 3, one open retail station in this region is not sufficient to support existing FCEVs. Even when those two TNO stations come back online, the gap between the expected capacity and the projected number of FCEVs in 2024 could be as small as 100 FCEVs. Three new station locations in the region are not expected until 2025, so drivers will likely continue to experience longer wait times until then.

Figure 13: Sacramento Area Station Capacity and Number of Vehicles

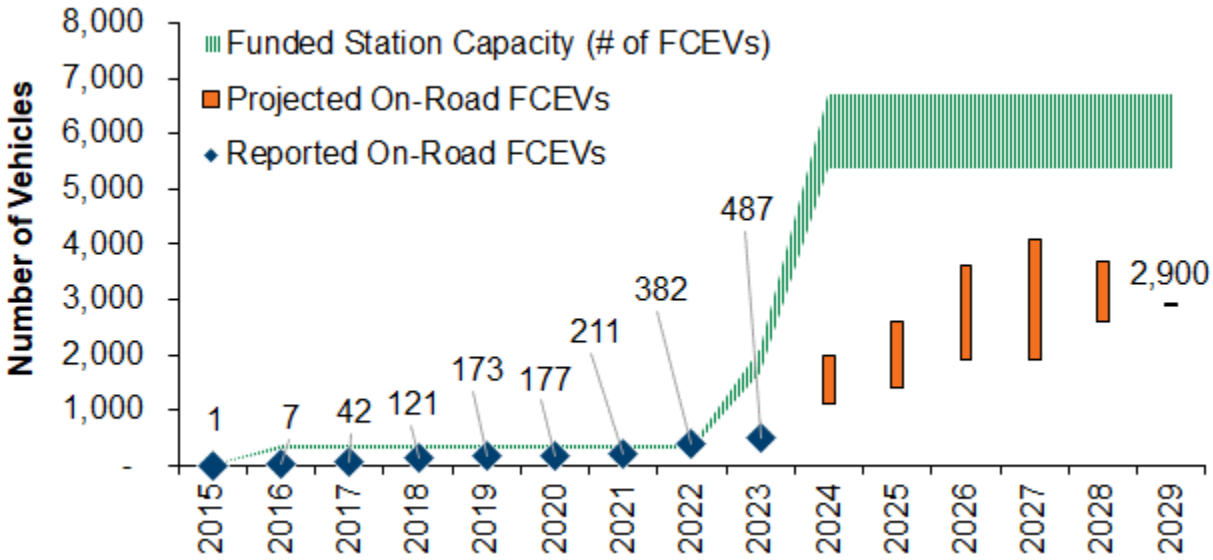


Source: CEC

Figure 14 shows San Diego's network having sufficient capacity to serve existing FCEVs with a second station with 1,212 kg/day capacity that opened in May 2023. Two more stations are

planned for the region in 2024, but additional fueling locations in this region are needed to provide wider coverage.

Figure 14: San Diego Area Station Capacity and Number of Vehicles



Source: CEC

FCEVs and Stations in Other Countries

For FCEVs and hydrogen infrastructure to scale and reduce costs, investments must be made globally. In March 2023, the European Union (EU) countries agreed to build hydrogen refueling stations in all major cities and at least every 200 kilometers along the core Trans-European Transport Network linking these cities.[43] This agreement harbors the potential for developing more robust supply chains for hydrogen refueling equipment and increased global FCEV sales.

According to *Deployment of Fuel Cell Vehicles in Road Transport and the Expansion of the Hydrogen Refueling Station Network: 2023 Update* by the Technology Collaboration Programme on the Research, Development and Demonstration on Advanced Fuel Cells (AFC TCP),[44] more than 70,000 FCEVs (light, medium and heavy-duty) and more than 1,000 hydrogen refueling stations (both public and private) are in the world. More than 90 percent of all FCEVs in operation are in California and three other countries: South Korea, China and Japan. On a per capita basis, California ranks second after Korea for FCEV deployments. While the on-road fleet is dominated by passenger FCEVs, the report found that the number of buses

43 Hydrogen Insight. March 28, 2023. "EU nations agree to install hydrogen fuelling stations in all major cities and every 200km along core routes." https://www.hydrogeninsight.com/policy/eu-nations-agree-to-install-hydrogen-fuelling-stations-in-all-major-cities-and-every-200km-along-core-routes/2-1-1426859.

44 Remzi Can Samsun, Michael Rex. 2023. *Deployment of Fuel Cell Vehicles in Road Transport and the Expansion of the Hydrogen Refueling Station Network: 2023 Update*. Technology Collaboration Programme on the Research, Development and Demonstration on Advanced Fuel Cells. https://www.ieafuelcell.com/fileadmin/publications/2023/2023_Deployment_of_Fuel_Cell_Vehicles_and_Hydrogen_Refueling_Station.pdf.

and commercial trucks increased at a higher rate than passenger cars in 2022 and made up about 20 percent of global FCEVs. While sales of passenger FCEVs declined slightly, 2022 was still the second highest year on record for new FCEV sales. For the first time China took the global lead in total number of hydrogen stations (320) and continued its leadership in the deployment of bus and commercial FCEVs. South Korea has 213 stations, followed by Japan with 164, Germany with 95 and California with at least 72 stations (66 open retail public light duty stations and at least 6 medium and heavy-duty stations). Continued global efforts in vehicle and station deployment will help bring down the costs of technologies and build robust supply chains.

Table 5 summarizes the population of passenger vehicles and other non-passenger vehicles (including buses, commercial vehicles, and trucks) in China, Germany, Japan, and South Korea as reported by the AFC TCP. The vehicle population in these countries increased since last reported in the 2022 Joint Report. Table 6 summarizes the number of hydrogen refueling stations in these countries.

Table 5: FCEVs in Other Countries

Country	Passenger FCEV	Non-Passenger FCEV (buses, commercial vehicles, and trucks)	Total
China	240	13,264	13,504
Germany	2,201	141	2,342
Japan	7,619	124	7,743
South Korea	29,337	286	29,623

Source: Data from the AFC TCP report

Table 6: Hydrogen Stations in Other Countries

Country	Hydrogen Stations
China	320
Germany	95
Japan	164
South Korea	213

Source: Data from the AFC TCP report

Continued global efforts in vehicle and station deployment will help bring down the costs of technologies and build robust supply chains.

CHAPTER 6:
Remaining Cost and Time Required to Establish a Sufficient Network of Hydrogen Refueling Stations

This chapter focuses on the remaining cost and time required to establish a sufficient network of hydrogen refueling stations.

Overall, the CEC's Clean Transportation Program has allocated nearly $257 million through fiscal year 2022-2023. This total allocation includes $41 million from the agreement recently cancelled by Shell, of which more than $7 million cannot be reallocated to any other projects because the encumbrance deadline for this funding has passed. This total allocated amount is smaller than what was reported in the 2022 AB 8 Joint Report ($279 million) because GFO-22-607 was undersubscribed and did not fund as many stations as anticipated. The remaining funds from GFO-22-607 were reallocated to other non-light-duty projects. Another $4 million of the remaining unawarded GFO-22-607 funds went to GFO-22-502 to fully fund one of the recipients for their heavy-duty hydrogen station. Moreover, the revised staff draft of the *2023-2024 Investment Plan Update for the Clean Transportation Program*[45] does not allocate any new funding to light-duty hydrogen refueling infrastructure because the program has unspent funding that was previously allocated to Shell's cancelled agreement.

Of the $257 million, the CEC has awarded about $202 million so far to support 105 stations funded by solicitations. Staff anticipates awarding another $40 million to fund 21 more stations under GFO-19-602 and other hydrogen refueling station projects to be determined for the remaining funds from the cancelled agreement with Shell. Staff also anticipates awarding $4 million to fund the remaining four stations under GFO-22-607. The CEC has released a solicitation to support operations and maintenance of existing hydrogen stations for about $11 million.

Private investment has included nearly $100 million to match public-sector funding to date, and grant recipients will have committed more than $63 million in additional match funding for the remaining stations funded under GFO-19-602 and GFO-22-607, making the total private investment about $163 million. The total reported public and private investment in hydrogen refueling stations is nearly $420 million, although this figure may be higher because some private sector investment has not been reported.

With the 130 stations funded by the combined expended and committed funds, the state has allocated sufficient funds to meet and exceed the former 100-station goal set by AB 8. California also continues to explore ways to expand the network to ensure current and future

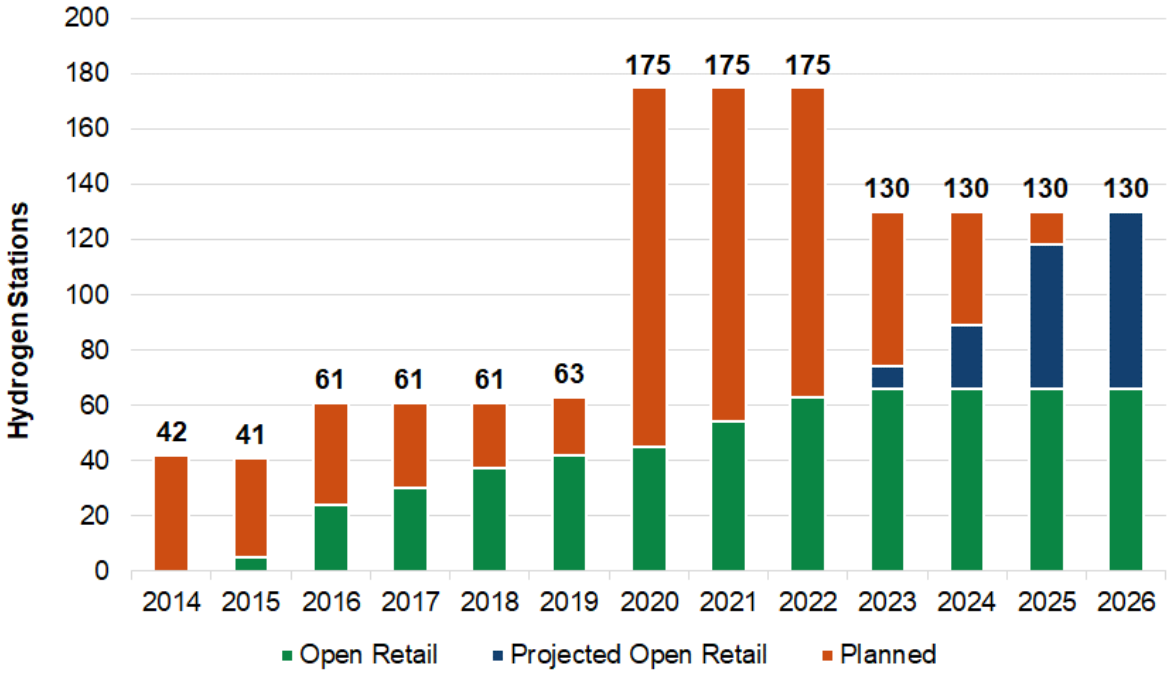
45 Tuggy, Benjamin. 2023. *2023–2024 Investment Plan Update for the Clean Transportation Program*. California Energy Commission. Publication Number: CEC-600-2023-029-SD-REV. https://efiling.energy.ca.gov/GetDocument.aspx?tn=252876&DocumentContentId=88010.

FCEV drivers have sufficient, convenient, and reliable refueling options, though staff does not expect 200 stations in the near future due to the cancellation of $41 million Shell agreement this year (which would have added 50 new stations) and GFO-22-607 not funding as many stations as anticipated.

Figure 17 shows the total estimated stations resulting from the Clean Transportation Program (including $5 million from the Volkswagen Mitigation Trust Fund[46] allocated to GFO-19-602) and private investments. The total estimated stations include 16 stations included in a CEC agreement with FirstElement Fuel funded fully by match share and 7 privately funded stations by Iwatani Corporation of America. Based on the most recent station development schedules shared by station developers, all 130 stations are estimated to be open retail by 2027.

Given inflation, supply chain challenges, and uncertainty around the future fuel demand from light-duty FCEVs, assessment of an appropriate funding amount per station for future stations is important. Other supportive policies, including the CARB LCFS HRI, contribute to the hydrogen refueling station network. Seventy stations have been approved to generate LCFS credits through the HRI provision.[47]

Figure 15: Open Retail, Projected Open Retail, and Planned Hydrogen Refueling Stations by Year



Source: CEC

46 Funding from the Volkswagen Environmental Mitigation Trust is the result of a settlement agreement among Volkswagen Group of America, Inc., the United States Environmental Protection Agency, and CARB following VW's admission that they used illegal software "defeat devices" in certain 2.0-liter and 3.0-liter diesel passenger vehicles sold in the United States and California.

47 California Air Resources Board. "LCFS ZEV Infrastructure Crediting — Approved HRI and FCI Applications." Accessed November 6, 2023. https://ww2.arb.ca.gov/resources/documents/lcfs-zev-infrastructure-crediting.

Further details on the 66 stations that are in various stages of development are as follows:

- GFO-19-602 stations:
    - 31 stations are under development
    - 21 stations are pending for future batches
- GFO-22-607 stations:
    - 2 stations were approved at the CEC business meeting in August 2023
    - 4 stations are pending – waiting for additional information before being considered for approval at a CEC business meeting
- Iwatani private stations:
    - 4 stations are under development
- Stations funded prior to GFO-19-602:
    - 2 stations are under development

In August 2023, Governor Gavin Newsom directed the GO-Biz to develop a new Hydrogen Market Development Strategy to build a clean renewable hydrogen market in California. This effort is aimed to help decarbonize the transportation and industrial sectors in California using hydrogen. The strategy combined with existing efforts may guide the state to expand the hydrogen refueling network.

CHAPTER 7: Conclusions

California is meeting the former 100-station AB 8 goal with nearly $257 million allocated to hydrogen infrastructure by the end of the AB 8 program supporting 130 stations.

California has 66 hydrogen refueling stations open as of November 6, 2023. These stations, when operating at capacity, have excess fueling capacity that is nearly quadruple today's demand needed by the 14,809 FCEVs in California. The hydrogen station network nameplate fueling capacity of today would also be sufficient to meet the 2026 projected demand of 34,900 FCEVs as reported in CARB's 2023 Annual Evaluation. However, 12 of these 66 open retail stations are TNO and have not been operating for more than 30 days. Other stations have downtime periodically due to maintenance, equipment failures, and hydrogen supply issues. As reported in the 2023 Annual Evaluation, the network of open retail stations, not including TNO stations, has operated at around 60 percent of its full capacity on average from the third quarter of 2022 to the second quarter of 2023. When considering this availability percentage and TNO stations, the network of open retail stations can support about 31,000 FCEVs. Thus, these excess capacities appear exaggerated when many stations are unreliable and unavailable in reality.

The state and private market should address barriers that are undermining the customer experience. These barriers include price spiking and station downtime due to equipment failures, supply chain constraints, and hydrogen fuel supply issues. The CEC is taking actions to address each one of these barriers and improve station reliability. As part of the efforts, the CEC released a solicitation, GFO-23-604, on November 3, 2023, to improve uptime of existing stations. The CEC also provided a manufacturing grant to produce hydrogen refueling equipment in California, which could help ease supply chain constraints. In addition, the CEC held a joint-agency workshop on November 6, 2023, to discuss the light-duty FCEV customer experiences at hydrogen refueling stations in California and identify new strategies to overcome key barriers. The CEC also entered into a contract with UC Davis to conduct a customer survey to investigate barriers further.

The 2022 Budget Act provides $100 million to the CEC to distribute grants for producing clean hydrogen in-state, which should help ensure a more reliable hydrogen supply and could help stabilize prices. In addition, the CEC funded renewable hydrogen production plants, and stakeholders in California are planning investments in renewable hydrogen production. Increasing the true renewable content of hydrogen used in vehicles and reducing the reliance on purchasing biogas credits are critical for meeting California's decarbonization goals. There needs to be more transparency by market participants as to the emission impacts and feedstock used to create hydrogen being used today and a pathway to increasing the use of clean hydrogen that does not rely on credits or other accounting mechanisms. Also, in October 2023, the U.S. DOE announced that California will receive up to $1.2 billion to launch a clean hydrogen hub in California, which will increase the sources and the amount of hydrogen available in California.

The 2029 projected FCEV population of 62,600 is nearly one-third of the 188,000 FCEVs that the anticipated fueling network of 130 stations could support based on the nameplate capacity of the stations, and more than double even when assuming that stations would dispense no more than 80 percent of nameplate capacity (more realistic and sustainable level of fueling). But this amount of extra capacity between the expected capacity availability in the network and the amount of capacity needed to sustain light-duty FCEVs remains high due in part to early indications that auto manufacturers may adjust their FCEV sales projections in response to the recent network developments and lack of robust sales in California and globally. These developments include fewer expected stations due to Shell's announcement, ongoing and persistent reliability issues with existing stations, and high hydrogen fuel costs.

About 67 percent of California's residents who live in disadvantaged communities are within a 15-minute drive time of an open retail or planned hydrogen station. This percentage is similar to 61 percent of the general statewide population being in the same drive distance to a station. However, the CEC and CARB will continue to explore options to expand hydrogen refueling network benefits to as many disadvantaged communities as possible because rural disadvantaged communities and disadvantaged communities with lower population density tend to be farther than a 15-minute driving distance to any hydrogen refueling station.

Along with California, other governments, specifically China, Germany, Japan, and South Korea, continue to invest in hydrogen refueling stations and vehicles. Together, California and these four countries have more than 850 open hydrogen refueling stations, including light-, medium-, and heavy-duty hydrogen refueling stations, and have deployed nearly 54,000 light-duty FCEVs and nearly 14,000 buses, commercial vehicles, and medium- and heavy-duty FCEVs. In addition, the new agreement reached in the EU to develop hydrogen stations in all major cities and at least every 200 kilometers to link these cities offers the potential for increased global FCEV sales.

Station development time continues to suffer as the world experiences global inflation and supply chain issues (including labor and material shortages) resulting from the COVID-19 pandemic. Station developers and CEC staff are working together to find ways to overcome these hurdles.

California is advancing the hydrogen market with efforts such as its application to the U.S. DOE's funding for a hydrogen hub and the development of the Hydrogen Market Development Strategy. In collaboration with other agencies and industry stakeholders, the CEC will continue to find ways to provide sufficient, convenient, and reliable refueling options beyond just expanding the refueling network. With the enactment of AB 126, California is committed to continue collaborating with the industry stakeholders to support the expansion of the hydrogen refueling station network and FCEV deployment in the state.

GLOSSARY

Authority Having Jurisdiction (AHJ) — an organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation, or a procedure.

California Hydrogen Infrastructure Tool (CHIT) — a geographical information system-based tool developed using ArcGIS software to assess the spatial distribution of the gaps between the coverage and capacity provided by existing and planned stations and the potential first adopter market for fuel cell electric vehicles.

Disadvantaged community — Defined by Health and Safety Code 39711 as the most burdened census tracts in California. Burden scoring is determined by 20 pollution/health and socioeconomic factors.

Fuel cell electric vehicle (FCEV) — a zero-emission vehicle that runs on compressed hydrogen fed into a fuel cell "stack" that produces electricity to power the vehicle.

Greater Los Angeles Area — the counties of Los Angeles, Orange, Riverside, San Bernardino, and Ventura.

Hydrogen Refueling Infrastructure (HRI) credits — Low Carbon Fuel Standard (LCFS) credits that allow eligible hydrogen stations to generate infrastructure credits based on the capacity of the station minus the quantity of dispensed fuel.

Hydrogen Station Capacity Evaluation (HySCapE) model — a tool for verifying the dispensing capacity of a hydrogen refueling station, based on the Chevron profile. CARB uses HySCapE to verify station capacity for the LCFS HRI program, and the CEC used it to verify station capacity under GFO-19-602.

Hydrogen Station Equipment Performance (HyStEP) device — a device that tests the ability of hydrogen refueling stations to adhere to the fueling protocols of the industry-adopted SAE J2601 standard.

Low Carbon Fuel Standard (LCFS) — Standard developed by CARB to reduce the carbon intensity of transportation fuel used in California.

Nameplate capacity — Rated capacity, nominal capacity, installed capacity, or maximum effect, is the intended full-load sustained output of a hydrogen refueling station.

Sacramento Area — the counties of El Dorado, Placer, Sacramento, Sutter, Yolo, and Yuba.

San Diego Area — the area of San Diego County.

San Francisco Bay Area — the counties of Alameda, Contra Costa, Marin, Napa, San Francisco, San Mateo, Santa Clara, Santa Cruz, Solano, and Sonoma.

Steam methane reformation — a process in which methane molecules are split to extract the hydrogen and carbon dioxide is released into the atmosphere.

Temporarily nonoperational (TNO) station — a hydrogen refueling station that has previously achieved open retail status but has been unavailable for customer fueling for a period greater

than 30 days for various reasons. A TNO station does not include a station that is affected by a fuel supply disruption. A TNO station is expected to become available for customer fueling again in the future.

Zero-emission vehicle (ZEV) — a vehicle that emits no exhaust gas from the onboard source of power.

APPENDIX A:
Hydrogen Refueling Stations in California

Table A-1 lists the 66 open retail hydrogen refueling stations (54 stations available for customer fueling and 12 TNO stations), with street address and open retail date. Table A-2 lists the stations in the process of becoming open retail. These lists include both Clean Transportation Program-funded and privately funded stations. Real-time status is available to drivers via the Station Operational Status System, maintained by the Hydrogen Fuel Cell Partnership and accessible at the website, https://m.h2fcp.org.

Table A-1: Open Retail and Temporarily Nonoperational Stations

Station Address (A to Z by city)	Open Retail Date
2618 La Paz Road, Aliso Viejo, CA 92656	6/22/2021
3731 East La Palma Avenue, Anaheim, CA 92806	11/29/2016
1100 North Euclid Street, Anaheim, CA 92801	4/24/2023
14477 Merced Avenue, Baldwin Park, CA 91706	2/7/2022
1250 University Avenue, Berkeley, CA 94702	1/12/2021
800 North Hollywood Way, Burbank, CA 91505	8/20/2022
337 E. Hamilton Avenue, Campbell, CA 95008	5/24/2021
2855 Winchester Boulevard, Campbell, CA 95008	6/9/2016
6141 Greenback Lane, Citrus Heights, CA 95621	12/18/2018
24505 West Dorris Avenue, Coalinga, CA 93210	12/11/2015
605 Contra Costa Boulevard, Concord, CA 94523	5/28/2021
2995 Bristol Street, Costa Mesa, CA 92626	12/29/2021
2050 Harbor Boulevard, Costa Mesa, CA 92627	1/21/2016
21530 Stevens Creek Boulevard, Cupertino, CA 95014	4/6/2022
21865 East Copley Drive, Diamond Bar, CA 91765	8/18/2015
1172 45th Street, Emeryville, CA 94608	11/19/2018
18480 Brookhurst Street, Fountain Valley, CA 92708	7/6/2020
41700 Grimmer Boulevard, Fremont, CA 94538	9/7/2017
391 West A Street, Hayward, CA 94541	4/27/2016
11807 East Carson Street, Hawaiian Gardens, CA 90716	3/21/2022
19172 Jamboree Road, Irvine, CA 92612	11/12/2015
550 Foothill Boulevard, La Cañada Flintridge, CA 91011	1/25/2016
20731 Lake Forest Drive, Lake Forest, CA 92630	3/18/2016
15606 Inglewood Avenue, Lawndale, CA 90260	6/22/2017
3401 Long Beach Boulevard, Long Beach, CA 90807	2/22/2016
10400 Aviation Boulevard, Los Angeles, CA 90045	12/21/2018
5151 State University Drive, Los Angeles, CA 90032	11/20/2019
5700 Hollywood Boulevard, Los Angeles, CA 90028	11/10/2016

Station Address (A to Z by city)	Open Retail Date
7751 Beverly Boulevard, Los Angeles, CA 90036	5/2/2016
8126 Lincoln Boulevard, Los Angeles, CA 90045	8/18/2016
570 Redwood Highway, Mill Valley, CA 94941	6/16/2016
15544 San Fernando Mission Boulevard, Mission Hills, CA 91345	10/26/2020
830 Leong Drive, Mountain View, CA 94043	2/28/2018
4280 Foothill Boulevard, Oakland, CA 94601	10/18/2023
350 Grand Avenue, Oakland, CA 94610	9/20/2019
1850 E. Holt Boulevard, Ontario, CA 91761	4/24/2018
615 South Tustin Street, Orange, CA 92866	3/23/2022
3601 El Camino Real, Palo Alto, CA 94306	12/20/2018
475 North Allen Avenue, Pasadena, CA 91106	12/16/2022
313 West Orangethorpe Avenue, Placentia, CA 92870	5/7/2021
8095 Lincoln Avenue, Riverside, CA 92504	3/8/2017
3510 Fair Oaks Boulevard, Sacramento, CA 95864	5/22/2019
3060 Carmel Valley Road, San Diego, CA 92130	12/2/2016
5494 Mission Center Road, San Diego, CA 92108	5/9/2023
1201 Harrison Street, San Francisco, CA 94103	12/2/2019
3550 Mission Street, San Francisco, CA 94110	2/14/2020
551 Third Street, San Francisco, CA 94107	11/6/2019
101 Bernal Road, San Jose, CA 95119	6/30/2022
2101 North First Street, San Jose, CA 95131	1/15/2016
3939 Snell Avenue, San Jose, CA 95136	5/27/2022
26572 Junipero Serra Road, San Juan Capistrano, CA 92675	12/23/2015
4475 Norris Canyon Road, San Ramon, CA 94583	7/26/2017
150 South La Cumbre Road, Santa Barbara, CA 93105	4/9/2016
1819 Cloverfield Boulevard, Santa Monica, CA 90404	2/1/2016
12600 Saratoga Avenue, Saratoga, CA 95070	3/14/2016
13980 Seal Beach Boulevard, Seal Beach, CA 90740	10/3/2022
14478 Ventura Boulevard, Sherman Oaks, CA 91423	12/2/2021
1200 Fair Oaks Avenue, South Pasadena, CA 91030	4/10/2017
248 South Airport Boulevard, South San Francisco, CA 94080	2/12/2016
3780 Cahuenga Boulevard, Studio City, CA 91604	4/26/2021
1296 Sunnyvale Saratoga Road, Sunnyvale, CA 94087	2/11/2021
3102 Thousand Oaks Boulevard, Thousand Oaks, CA 91362	3/30/2018
2051 West 190th Street, Torrance, CA 90501	8/18/2017
12105 Donner Pass Road, Truckee, CA 96161	6/17/2016
1515 South River Road, West Sacramento, CA 95691	7/7/2015
5314 Topanga Canyon Road, Woodland Hills, CA 91364	10/5/2016

Source: CEC

Table A-2 lists the locations of stations that are under development. The stations are listed in alphabetical order by city. If the station received Clean Transportation Program funding, the CEC solicitation or contract under which the station received funding is provided.

Table A-2: Stations Under Development

Station Address (A to Z by city)	Solicitation or Contract
9409 Alondra Boulevard, Bellflower, CA 90706	GFO-19-602
6392 Beach Boulevard, Buena Park, CA 90621	GFO-19-602
145 W. Verdugo Avenue, Burbank, CA 91502	600-12-018
2911 Petit Street, Camarillo, CA 93012	GFO-19-602
3260 Chino Avenue, Chino Hills, CA 91709	Privately Funded
616 Paseo Grande, Corona, CA 92882	Privately Funded
3160 Carlson Boulevard, El Cerrito, CA 94530	GFO-19-602
2595 North Texas Street, Fairfield, CA 94533	GFO-19-602
16880 Slover Avenue, Fontana, CA 92337	GFO-19-602
47700 Warm Springs Boulevard, Fremont, CA 94539	GFO-19-602
4163 South Chestnut Avenue, Fresno, CA 93725	GFO-19-602
Northwest Corner of Carol Drive and Amador Avenue, Galt, CA 95632	GFO-22-607
33252 Hubert Way, Kettleman City, CA 93239	GFO-22-607
5500 South Street, Lakewood, CA 90713	GFO-19-602
13550 South Beach Boulevard, La Mirada, CA 90638	Privately Funded
7810 National Drive, Livermore, CA 94550	GFO-19-602
988 North San Antonio Road, Los Altos, CA 94022	GFO-19-602
10867 Santa Monica Boulevard, Los Angeles, CA 90025	GFO-19-602
666 North Santa Cruz Avenue, Los Gatos, CA 95030	GFO-19-602
18463 Road 23, Madera, CA 93637	GFO-22-607
4785 Bailey Loop, McClellan Park, CA 95652	GFO-19-602
12520 Graham Street, Moreno Valley, CA 92553	GFO-19-602
2160 South Euclid Avenue, Ontario, CA 91762	GFO-19-602
67 Moraga Way, Orinda, CA 94563	GFO-19-602
3402 E Vineyard Avenue, Oxnard, CA 93036	GFO-22-607
East Vista Chino & North Gene Autry Trail, Palm Springs, CA 92262	GFO-19-602
3329 Mather Field Road, Rancho Cordova, CA 95670	GFO-22-607
503 Whipple Avenue, Redwood City, CA 94063	GFO-15-605
3505 Central Avenue, Riverside, CA 92506	GFO-19-602
939 San Gabriel Boulevard, Rosemead, CA 91770	GFO-19-602
1930 South Waterman Avenue, San Bernardino, CA 92408	GFO-19-602
11030 Rancho Carmel Drive, San Diego, CA 92128	GFO-19-602

Station Address (A to Z by city)	Solicitation or Contract
1832 West Washington Street, San Diego, CA 92103	GFO-19-602
510 East Santa Clara Street, San Jose, CA 95112	GFO-19-602
1898 North Capitol Avenue, San Jose, CA 95132	GFO-19-602
1331 Redmond Avenue, San Jose, CA 95120	GFO-19-602
3707 Union Avenue, San Jose, CA 95124	GFO-19-602
2120 East McFadden Avenue, Santa Ana, CA 92705	Privately Funded
24505 Hawthorne Boulevard, Torrance, CA 90505	GFO-19-602
14244 Newport Avenue, Tustin, CA 92780	GFO-19-602
10 Sage Street, Vallejo, CA 94589	GFO-19-602
2121 Harbor Boulevard, Ventura, CA 93001	GFO-19-602
6422 Betty Drive, Visalia, CA 93291	GFO-22-607
17287 Skyline Boulevard, Woodside, CA 94062	PON-13-607

Source: CEC

APPENDIX B:
Changes in the Planned Network

Since 2017, the planned network changed due to new funding solicitations, station replacements, stations that did not reach completion, and station closures. Table B-1 shows the changes in the planned network resulting from CEC agreements funded by the Clean Transportation Program and the associated number of FCEVs that could be supported. The 50 stations shown in the first row for 2017 were funded under solicitations and contracts before GFO-15-605, GFO-19-602, and GFO-22-607.

Table B-1: Changes in the Planned Station Network Since 2017

Year	Reasons for Changes	Number of Planned Stations	Number of FCEVs That Could Be Supported
2017	Clean Transportation Program provided Operations and Maintenance funds to CARB-funded CSULA station (60 kg/day), so the station was added to the collection of Clean Transportation Program-funded stations.	50	13,000
2017	The stations planned for Encinitas (180 kg/day), Foster City (350 kg/day), and Los Altos (350 kg/day) were canceled because of lack of clear path to completion, and they were removed from the list of Clean Transportation Program-funded stations.	47	12,000
2017	Sixteen new stations were approved under GFO-15-605 (5,180 kg/day) and added to the list of Clean Transportation Program-funded stations.	63	20,000
2017	Three HyGen Industries stations (130 kg/day each) were addressed at the October 2017 CEC Business Meeting and removed from the list of Clean Transportation Program-funded stations.	60	19,000
2017	Five additional stations (1,600 kg/day) were proposed for funding under GFO-15-605 and added to the list of Clean Transportation Program-funded stations.	65	21,000

Year	Reasons for Changes	Number of Planned Stations	Number of FCEVs That Could Be Supported
2018	FirstElement upgraded 12 stations from 310 kg/day to 500 kg/day liquid technology (+2,280 kg) and the Air Liquide Anaheim station capacity was adjusted in reporting from 100 kg to 180 kg to reflect more realistic operations.	65	25,000
2018	One of the five additional stations proposed for funding under GFO-15-605 did not move forward (360 kg/day) and was removed from the list of Clean Transportation Program-funded stations.	64	24,000
2019	Mobile refueler project (45 kg/day) and Santa Nella (180 kg/day) station ended without completion and were removed from the list of Clean Transportation Program-funded stations.	62	24,000
2019	Station capacities were updated with the numbers reported to the CARB LCFS HRI credit program.	62	35,000
2020	Two more stations (Concord and Redwood City) were approved for HRI credits and station capacities were updated, each using the numbers reported to the HRI credit program. (+1,400 kg/day)	62	37,000
2020	West Los Angeles station (180 kg/day) closed. The station operator lost lease due to redevelopment plans for the site.	61	36,000
2020	30 new stations were approved at the CEC business meeting in December. One of these stations is an upgrade to the station at Torrance.	90	98,000
2021	The station capacities were adjusted using the latest LCFS HRI approved capacities.	90	101,000
2022	Rancho Palos Verdes (180 kg/day) and Santa Clarita (180 kg/day) stations were canceled due to sites becoming unviable.	88	100,000
2022	Culver City (1,616 kg/day) station was canceled due to issues in obtaining site control.	87	98,000

Year	Reasons for Changes	Number of Planned Stations	Number of FCEVs That Could Be Supported
2022	Seven GFO-15-605 station capacities were adjusted from 1,616 kg per day to 1,212 kg/day due to an error in last year's reporting of the number of fueling positions each station contained.	87	94,000
2022	Seven privately funded Iwatani stations that are outside CEC agreement were added to the total planned station count.	94	102,000
2022	Laguna Beach (808 kg/day) station was canceled due to issues in permitting.	93	101,000
2022	Six GFO-19-602 Iwatani Batch 2 stations were approved. (Locations to be determined but two of six are planned to be upgrades of existing stations.)	97	110,000
2023	Fourteen GFO-19-602 FirstElement Fuel Batch 2 stations were approved.	111	142,000
2023	Two new stations were approved under GFO-22-607 at the CEC Business Meeting in August 2023.	113	147,000
2023	Seven Shell stations and an upgrade to the Torrance station through GFO-19-602 were cancelled. All future batch stations proposed under the agreement were also cancelled.	106	139,000
2023	Chino (100 kg/day) station agreement expired. The station will not be completed.	105	139,000
2023	25 stations (21 GFO-19-602 future batch stations and 4 GFO-22-607 stations) are pending and not in CEC agreements yet.	130	188,000

Source: CEC

APPENDIX C: References

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