CALIFORNIA ENERGY COMMISSION

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California Energy Commission

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# Joint Agency Staff Report on Assembly Bill 8: 2020 Annual Assessment of Time and Cost Needed to Attain 100 Hydrogen Refueling Stations in California

**Gavin Newsom, Governor**

**December 2020 | CEC-600-2020-008**

# California Energy Commission

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# ACKNOWLEDGEMENTS

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# ABSTRACT

The *Joint Agency Staff Report on Assembly Bill 8: 2020 Annual Assessment of Time and Cost Needed to Attain 100 Hydrogen Refueling Stations in California* is in accordance with Assembly Bill 8 (Perea, Chapter 401, Statutes of 2013), which requires the California Energy Commission (CEC) and California Air Resources Board (CARB) 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." Since 2010, the CEC's Clean Transportation Program has invested nearly $166 million in hydrogen infrastructure to support the fuel cell electric vehicle (FCEV) market.

As of December 1, 2020, California's 45 open retail hydrogen refueling stations provide enough hydrogen to support nearly 20,000 light-duty FCEVs. The network is expected to reach 105 stations by the end of 2023, reaching the Assembly Bill 8 goal of achieving at least 100 publicly available stations, and having the capacity to support nearly 150,000 light-duty FCEVs. Planned projects should result in as many as 179 stations, leaving a 21-station gap to reach the 200-stations-by-2025 goal of Governor Edmund G. Brown Jr.'s Executive Order B-48-18. Up to 13 stations should be ready to serve medium- and heavy-duty fuel cell trucks.

The CEC zero-emission vehicle data portal shows cumulative sales or leases of 8,486 light-duty FCEVs through the third quarter of 2020. The CARB survey of auto manufacturers anticipates that 48,900 light-duty FCEVs will operate in California by 2026. The population of medium- and heavy-duty fuel cell truck is expected to grow to more than 60 by 2023.

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

Please use the following citation for this report:

Baronas, Jean, Gerhard Achtelik, et al. 2020. *Joint Agency Staff Report on Assembly Bill 8: 2020 Annual Assessment of Time and Cost Needed to Attain 100 Hydrogen Refueling Stations in California.* California Energy Commission and California Air Resources Board. Publication Number: CEC-600-2020-008.

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# EXECUTIVE SUMMARY

The *Joint Agency Staff Report on Assembly Bill 8: 2020 Annual Assessment of Time and Cost Needed to Attain 100 Hydrogen Refueling Stations in California* (2020 Joint Report) describes the investment, planning and development of hydrogen refueling stations to provide hydrogen to fuel cell electric vehicles (FCEVs) in California. Assembly Bill (AB) 8 (Perea, Chapter 401, Statutes of 2013) directs 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 hydrogen refueling stations until there are at least 100 publicly available stations in California.

Governor Gavin Newsom's Executive Order N-79-20 directly addresses the present-day climate change crisis and the impact of transportation to California's greenhouse gas emissions. The executive order exemplifies California's leadership in deploying zero-emission vehicles (ZEVs), including cars, trucks, buses, freight-related vehicles, and off-road equipment. The executive order sets a goal 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. This goal underscores the importance of the Clean Transportation Program and will influence the tangible outcomes of policies, requirements, and investments planned by numerous California agencies and municipalities, including the CEC and the California Air Resources Board (CARB).

In 2020, just as it did almost every other facet of life, the COVID-19 pandemic disrupted hydrogen station and FCEV deployment plans. The shelter-in-place orders from state government, as well as the additional orders issued in many cities and counties throughout the state, halted much of station permitting, construction, testing, and commissioning that was underway in mid-March. Local authorities had to adjust, including prioritizing essential functions and transitioning to online or tele-based processes for planning and permitting services that had been conducted in person.

### KEY TAKEAWAYS

- **California has developed 45 open retail stations to date.**
- **Fifty-two percent of disadvantaged community residents live within a 15-minute drive of an open retail or planned station.**
- **About 8,486 FCEVs have been sold or leased in California, and the latest auto manufacturer survey anticipates 27,000 FCEVs in California by 2023 and 48,900 by 2026.**
- **Decarbonization drives the planning and adoption of hydrogen and fuel cells in transportation applications, but the COVID-19 pandemic slowed this year's progress.**

In early 2020, pre-COVID-19, one new hydrogen refueling station supported with Clean Transportation Program funds opened. Since then, 2 more stations opened, bringing the total number of open retail hydrogen refueling stations developed in California to 45 as of December 1, 2020.

The CEC evaluates its investments according to several metrics, including the benefit to disadvantaged communities, which are communities throughout California that suffer most from a combination of economic, health, and environmental burdens. About 52 percent of disadvantaged community residents live within a 15-minute drive of an open retail or planned station. By working with diverse stakeholders, the CEC is striving to continuously expand the investment of Clean Transportation Program funds in projects, such as those that reduce emissions from medium- and heavy-duty vehicles, that will result in cleaner air and economic opportunity for disadvantaged communities.

According to the CEC ZEV data portal, cumulative sales or leases of FCEVs in California were 8,486 as of the third quarter of 2020. Moreover, the latest auto manufacturer survey, administered and analyzed by CARB, anticipates 27,000 FCEVs in California by 2023 and 48,900 FCEVs by 2026. Those 48,900 FCEVs would consume about 34,000 kilograms of hydrogen per day. If FCEV numbers grow according to these survey results, the estimated greenhouse gas emissions reductions from operating these vehicles, refueled at the existing hydrogen refueling station network, would be nearly 102,000 metric tons of carbon dioxide equivalent per year by 2026. The growing fleets of medium- and heavy-duty FCEVs in California will help reduce emissions further.

California's network capacity of the 45 stations is 14,500 kilograms per day, enough to support nearly 20,000 light-duty FCEVs. The 16 stations under development from previous solicitations plus the 30 stations initially funded under the most recent solicitation, Grant Funding Opportunity (GFO) 19-602, will add nearly 54,000 kilograms per day of capacity. When all these stations are open, the network will have nearly 69,000 kilograms per day of capacity, enough to support nearly 98,000 FCEVs. For the first time, with the GFO-19-602 stations, the state has more forecasted fueling capacity than the forecasted need in 2026. The additional capacity generates a vehicle deployment opportunity that has not existed previously in the state.

Released December 26, 2019, GFO-19-602 offered funding for up to $110.7 million in Clean Transportation Program grant funding and $5 million from the Volkswagen (VW) Mitigation Trust Fund. GFO-19-602 provided funding for recipients to commission and open publicly available hydrogen refueling stations. These additional stations will accelerate FCEV deployment such that these vehicles can provide significant emissions reductions and help achieve the goals of having 5 million ZEVs in California by 2030 (established in Governor Edmund G. Brown Jr.'s Executive Order B-48-18) and all passenger vehicle sales be zero-emission by 2035, established by Governor Gavin Newsom's Executive Order N-79-20. Of the stations resulting from GFO-19-602, at least 13 stations should be capable of fueling light-, medium-, and heavy-duty vehicles, thereby leveraging infrastructure to address multiple markets and accelerating the development of commercial fuel cell electric trucks with the potential to reduce local air pollution from the goods movement sector.

Significantly, the stations resulting from GFO-19-602 will help industry advance toward developing economies of scale. For this solicitation, the average CEC award amount per station for eligible equipment costs was about $1.3 million for stations sized between 770 and 1,600 kilograms per day (kg/day). Staff expects the addition of effective new critical milestones in GFO-19-602 to result in reduced development time compared to previous solicitations.

As noted in the Clean Transportation Program Investment Plan, the CEC has allocated $20 million per year or 20 percent of the total Investment Plan allocation each year and plans to continue allocating funding through FY 2022–23. In the final half-year covered by the Investment Plan, the CEC plans to split funding for hydrogen infrastructure between light-duty and medium- and heavy-duty hydrogen infrastructure. The CEC will reevaluate whether the proposed $5 million allocation for light-duty public fueling infrastructure for 2023 is enough to meet the needs of the FCEV market and will adjust as needed in annual revisions to the plan.

The Clean Transportation Program investment in hydrogen refueling stations thus far is $166 million. With the future allocation plans, Clean Transportation Program investment in hydrogen refueling stations will total nearly $252 million over the life of the program, from program creation in 2008 through the January 1, 2024, expiration date. CEC grant recipients have also contributed match funding to station development. As of May 1, 2020, the CEC grant recipients contributed $92 million in matching funding, and grant recipients will contribute another $99 million by the end of the GFO-19-602 agreements. These amounts bring the total public and private investment in hydrogen refueling stations under the Clean Transportation Program to nearly $440 million.

With some of the stations resulting from GFO-19-602 planned to become open retail in the next few years, staff estimates that California will have 105 open retail stations before 2024, meeting the AB 8 100-station goal. At the end of 2023, California's network of hydrogen refueling stations will have the fueling capacity to support nearly 150,000 light-duty FCEVs. Also, at the end of 2023, as many as 13 stations in the network will be ready to serve the estimated 13 to 18 operational medium- and heavy-duty FCEVs in California today and the fuel cell electric trucks, totaling 65, that are already funded or in production. Both the Clean Transportation Program and the California Climate Investments Program fund medium- and heavy-duty FCEVs. Staff estimates that by 2027, the network will have 179 stations that can support more than 200,000 FCEVs. These stations include 16 that are privately funded under the CEC agreement with FirstElement Fuel, Inc., and 7 privately funded stations by Iwatani Corporation of America.

# CHAPTER 1: Introduction

Assembly Bill (AB) 118 (Núñez, Chapter 750, Statutes of 2007) created the Clean Transportation Program (formerly known as the Alternative and Renewable Fuel and Vehicle Technology Program).[1] AB 8 (Perea, Chapter 401, Statutes of 2013) reauthorized the Clean Transportation Program until January 1, 2024, and 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] CEC staff estimates that California will have 105 open retail stations before 2024, meeting the AB 8 100-station goal. Staff further estimates that the network will have 179 stations by 2027.

AB 8 requires annual review and reporting by the CEC and California Air Resources Board (CARB). The *Joint Agency Staff Report on Assembly Bill 8: 2020 Annual Assessment of Time and Cost Needed to Attain 100 Hydrogen Refueling Stations in California* (2020 Joint Report) is the sixth such annual report. In September 2020, CARB published the *2020 Annual Evaluation of Fuel Cell Electric Vehicle Deployment and Hydrogen Fuel Station Network* (2020 Annual Evaluation), also required by AB 8.[3] References for the previous reports are in Appendix D.

Governor Edmund G. Brown Jr.'s Executive Order B-16-12 directed state agencies to promote the rapid commercialization of zero-emission vehicles (ZEVs), set a target for the number of ZEVs in California by 2025 at 1.5 million, and set a greenhouse gas (GHG) emissions reduction target for 2050 from the transportation sector equaling 80 percent less than 1990 levels.[4] 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.[5] On September 23, 2020, Governor Gavin Newsom's Executive Order N-79-20 set a goal that, by 2035, all passenger cars and trucks sold in California be zero-emission, all medium- and heavy-duty trucks and buses operated in California be zero-emission by 2045 everywhere feasible, and all drayage trucks be

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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. September 2020. *2020 Annual Evaluation of Fuel Cell Electric Vehicle Deployment and Hydrogen Fuel Station Network Development.* http://ww2.arb.ca.gov/resources/documents/annual-hydrogen-evaluation.

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

5 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.

zero-emission by 2035. All three imperatives strengthen California's focus and activities for hydrogen refueling.

As summarized in Table 1, the CEC released a grant funding opportunity, GFO-19-602, offering up to $110.7 million in Clean Transportation Program grant funding and $5 million from the Volkswagen (VW) Mitigation Trust Fund[6] on December 26, 2019.[7] On December 9, 2020, three awards were approved at the CEC business meeting for up to $115.7 million to develop more stations. Initially, these awardees will develop a total of 30 stations, 8 of which are counted in Table 1 as privately funded because they are not allocated to receive any grant funding. Subsequent batches of stations may be approved for each of the recipients depending on performance, funding availability, and Clean Transportation Program Investment Plan funding allocations.

**Table 1: Hydrogen Refueling Stations in California**

| Station Status | Number of Stations | Public Funding Source |
|---|---|---|
| Open Retail | 45 | Clean Transportation Program |
| In Development Funded Prior to GFO-19-602 | 16 | Clean Transportation Program |
| In Development Funded By GFO-19-602 | 22 | Clean Transportation Program and the VW Mitigation Trust Fund |
| Potential From Future GFO-19-602 Allocations | 73 | Clean Transportation Program |
| Expected From Private Funding | 23 | N/A |
| **Total Number of Stations** | **179** | |

Source: CEC

As many as 179 stations will be completed, leaving a 21-station gap to reach the 200-station goal of Executive Order B-48-18. The 45 open retail stations include those in Ontario and Riverside that are under repair and currently unavailable to customers.

Table 2 shows how the hydrogen refueling network has grown substantially over time. At the time the CEC and CARB published the first joint report in 2015, California had six open retail

6 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.

7 California Energy Commission. [GFO-19-602 – Hydrogen Refueling Infrastructure.](https://www.energy.ca.gov/solicitations/2019-12/gfo-19-602-hydrogen-refueling-infrastructure) https://www.energy.ca.gov/solicitations/2019-12/gfo-19-602-hydrogen-refueling-infrastructure.

stations, and as of December 1, 2020, there are 45.[8] The reduction in the amount of fuel dispensed between 2019 and 2020 is mostly due to the lockdowns associated with COVID-19 that reduced overall vehicle miles traveled. The pace of fuel cell electric vehicle (FCEV) sales and leases also slowed in 2020, and one station closed permanently. California continues to make progress in developing stations that are beneficial to residents of disadvantaged communities and convenient to FCEV drivers.

**Table 2: Growth in Hydrogen Refueling Population**

| Year-to-Year Growth | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|
| Open retail stations | 25 | 31 | 39 | 43 | 45 |
| Average daily hydrogen dispensed (refueling demand)[9] | 340 kg | 1,400 kg | 2,700 kg | 3,400 kg | 2,800 kg |
| Percentage of disadvantaged community population that live within 15 minutes of an open retail station | 12.8% | 18.6% | 23.0% | 23.3% | 23.5% |
| Cumulative light-duty FCEV sales or leases in California | 1,148 | 3,271 | 5,667 | 7,751 | 8,486[10] |

Source: CEC

The CEC Fuels and Transportation Division and CARB program staffs collaborate with many experts to plan and encourage development of hydrogen refueling infrastructure, 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).

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8 Open retail stations are "publicly available hydrogen-refueling stations" as defined in AB 8 and GFO-19-602. California Energy Commission. GFO-19-602 – Hydrogen Refueling Infrastructure. https://www.energy.ca.gov/solicitations/2019-12/gfo-19-602-hydrogen-refueling-infrastructure. One station (West L.A.) has closed and has been removed from the open retail station count. Overall, 46 have become open retail, but the one closed station reduces the number to 45. Two other stations (Ontario and Riverside) that have become open retail are not in operation at the time of publication.

9 The dispensing average is an average for Quarter 3.

10 Through the third quarter of 2020. California Energy Commission. "Zero Emission Vehicle and Infrastructure Statistics." https://www.energy.ca.gov/zevstats.

- Industry stakeholder groups, including the Center for Hydrogen Safety under the auspices of the American Institute of Chemical Engineers (AiCHe).[11]
- California Fuel Cell Partnership (CaFCP), the 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. The public is encouraged to visit the following web pages to become involved in CEC activities:

- Listservers: https://ww2.energy.ca.gov/listservers/index_cms.html
- Events: https://www.energy.ca.gov/events
- Solicitations: https://www.energy.ca.gov/funding-opportunities/solicitations

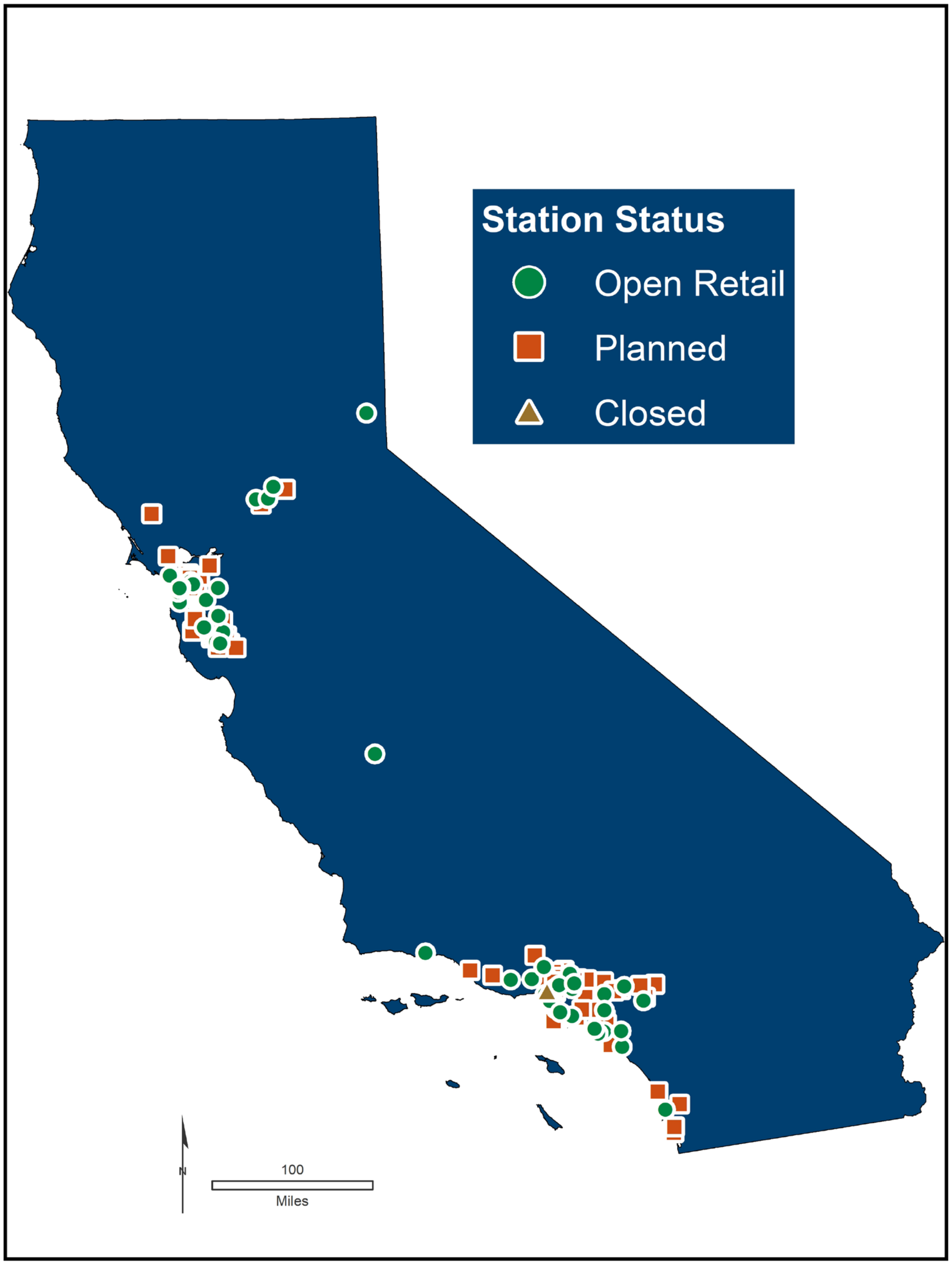
This report continues with analyses for the coverage and capacity of the hydrogen refueling station network, the time it is taking to develop stations and related cost, and the current and future projections of FCEVs and station implementation in California. CEC and CARB staffs review the year's refueling trends and describe other hydrogen and fuel cell projects that are expanding the potential for FCEVs, including buses and trucks, to serve multiple functions in transitioning to a national and international zero-emission transportation system.

11 AiChE®. Center for Hydrogen Safety (CHS). https://www.aiche.org/CHS.

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

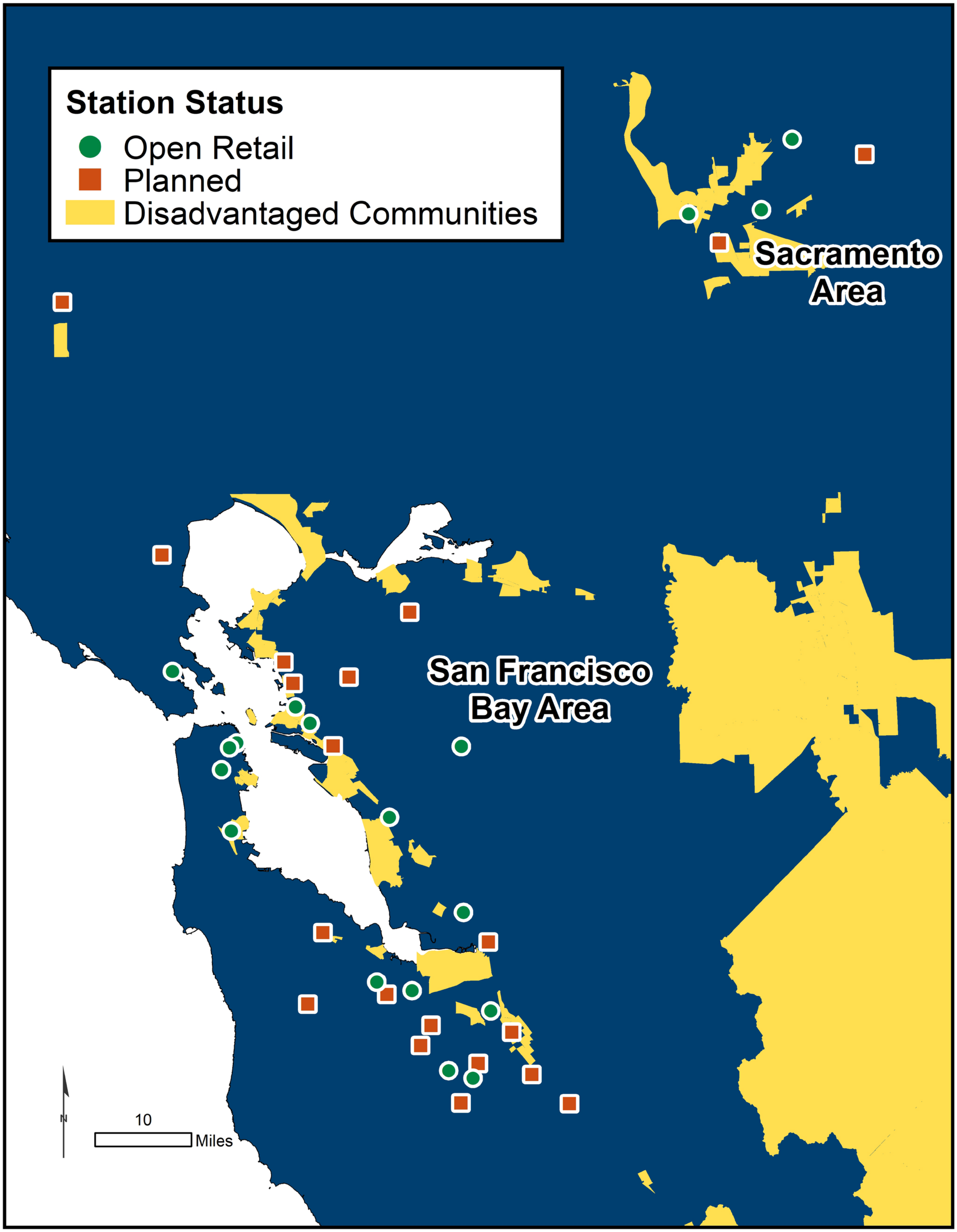
The locations of stations in California's hydrogen refueling station network are shown in Figures 1 through 3. Appendix B lists the actual addresses. Appendix C shows a chronological list of changes to the station network over recent years.

**Figure 1: Hydrogen Refueling Stations in California**



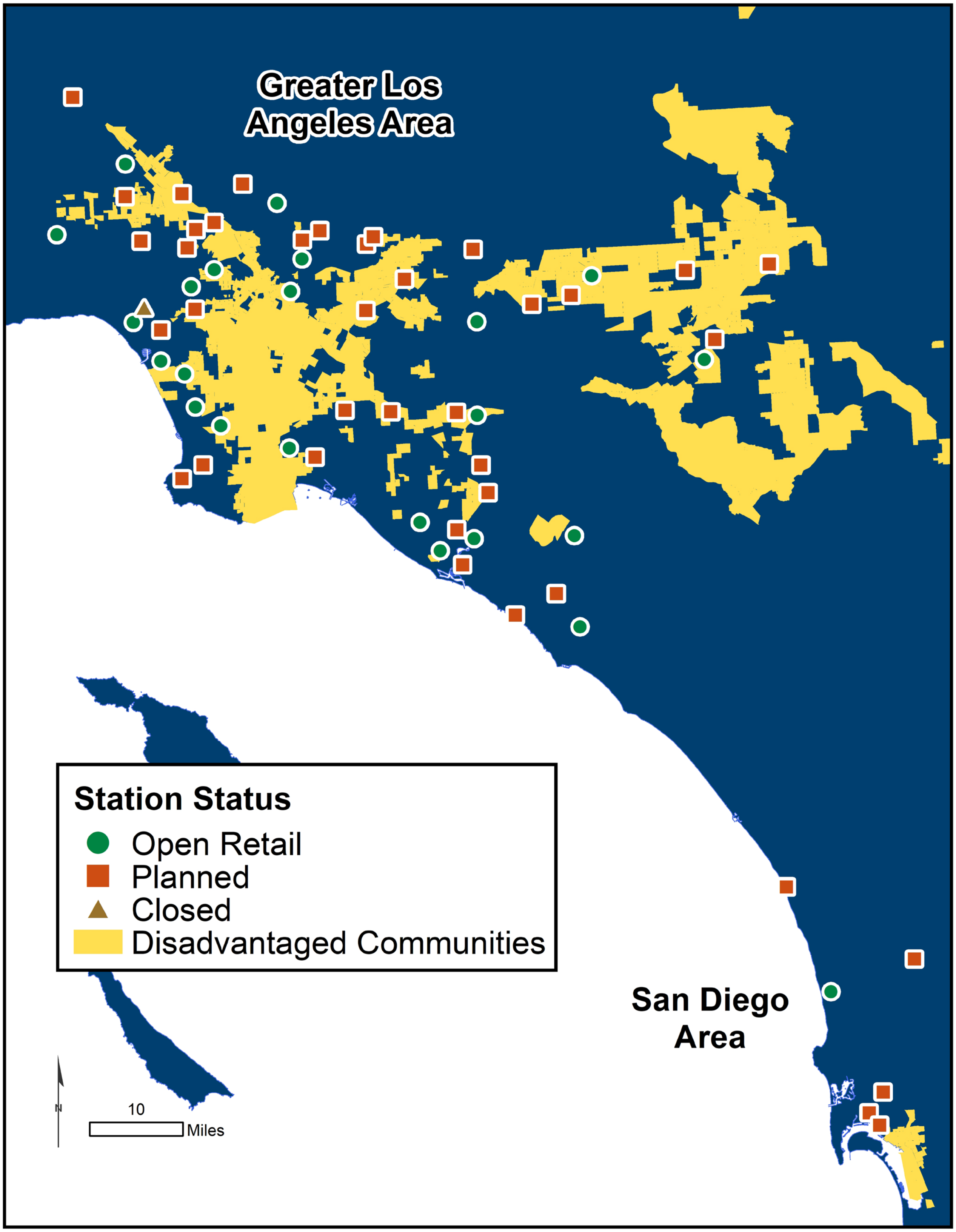

Source: CEC

**Figure 2: Hydrogen Refueling Stations in Northern California With Disadvantaged Communities Highlighted**




Source: CEC

**Figure 3: Hydrogen Refueling Stations in Southern California With Disadvantaged Communities Highlighted**




Source: CEC

## Station Placement in Disadvantaged Communities

Consistent with Senate Bill (SB) 350, the Clean Energy and Pollution Reduction Act of 2015 (De León, Chapter 547, Statutes of 2015),[12] and CARB's guidance to provide access to clean transportation to individuals in disadvantaged communities,[13] the CEC continues to emphasize the importance of serving disadvantaged communities in its solicitations.

The stations resulting from GFO-19-602, the most recent solicitation, include six stations planned to be in disadvantaged communities. These stations will be in the initial batch of stations, which is the first grouping of stations receiving GFO-19-602 funding. More stations will likely be in disadvantaged communities in subsequent batches, pending funding appropriations and Clean Transportation Program Investment Plan allocations. The solicitation encouraged station developers to choose projects that provide employment and air quality benefits to disadvantaged communities. Benefits described by these station developers include air quality benefits, in addition to financial benefits through local property tax fees, business license fees, permitting fees, and employment by hiring in disadvantaged communities.

As shown in Table 3, including stations funded before GFO-19-602, 17 stations will be in disadvantaged communities. Nearly $25 million of Clean Transportation Program funding has been allocated to stations in disadvantaged communities. In previous solicitations, the private sector contributed nearly $4.5 million to stations in disadvantaged communities. Based on the agreements resulting from GFO-19-602, this contribution will increase to nearly $13 million in private sector match funding for stations in disadvantaged communities.

**Table 3: Stations in Disadvantaged Communities**

| | Number of Stations in Disadvantaged Communities | Clean Transportation Program Funding (Capital Expenditure Only) | Match Funding |
|---|---|---|---|
| Solicitations and contracts prior to GFO 19-602 | 11 | $16,880,932 | $4,499,931 |
| GFO 19-602 (Initial Batches of Stations) | 6 | $7,896,888[14] | $8,265,632 |
| **Totals** | **17** | **$24,777,820** | **$12,765,563** |

Source: CEC

12 SB 350 establishes the reduction of greenhouse gases as a state priority through the promotion of various clean energy policies, including widespread transportation electrification. SB 350 information is available at California Energy Commission, Clean Energy and Pollution Reduction Act – SB 350. https://www.energy.ca.gov/sb350/.

13 Disadvantaged communities are identified using the California Office of Environmental Health Hazard Assessment's CalEnviroScreen™. Information is available at OEHHA, CalEnviroScreen. https://oehha.ca.gov/calenviroscreen. The CARB guidance is available at California Air Resources Board, CARB Barriers Report – Final Guidance Document, https://ww2.arb.ca.gov/resources/documents/carb-barriers-report-final-guidance-document.

14 Includes VW Mitigation Trust funds.

## California Hydrogen Infrastructure Tool (CHIT) Analysis of the Network Coverage

Figure 4 displays the coverage provided by the stations identified in the CEC agreements under GFO-19-602. As awarded station developers notify CEC of addresses for additional locations, the evaluation of coverage is expected to change. The figure was produced by the CARB California Hydrogen Infrastructure Tool (CHIT).[15] Areas on the map without color are not within a 15-minute drive from any hydrogen refueling station.[16] In the coverage map, the areas shown with the red shading have the highest degree of coverage. These often have multiple 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.

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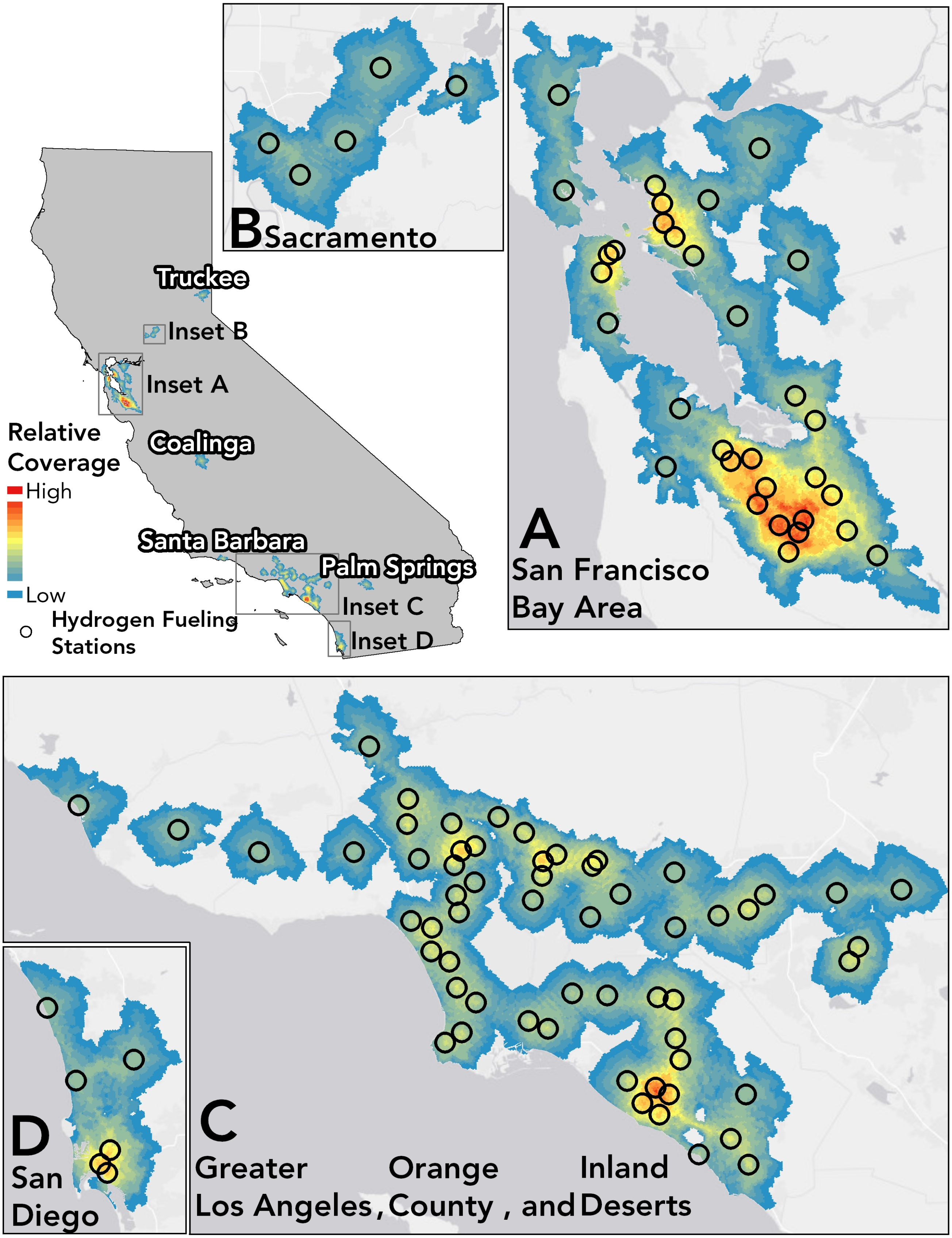
15 Information on CHIT is available at California Air Resources Board, Hydrogen Refueling Infrastructure Assessments. https://ww2.arb.ca.gov/our-work/programs/advanced-clean-cars-program/hydrogen-infrastructure/hydrogen-refueling.

16 California Air Resources Board. September 2020. *2020 Annual Evaluation of Fuel Cell Electric Vehicle Deployment and Hydrogen Fuel Station Network Development*. http://ww2.arb.ca.gov/resources/documents/annual-hydrogen-evaluation.

**Figure 4: Coverage Map**




Source: CARB

## The Fueling Capacity of California's Hydrogen Refueling Station Network

Using 0.7 kilograms as the average amount of fuel used per FCEV per day,[17] today's network of 91 funded stations resulting from CEC agreements will be able to support nearly 98,000 FCEVs, although in practice the number depends on actual FCEV geographical distribution relative to station locations and FCEV driver habits, vehicle miles traveled, and routes traveled.

**Table 4: Hydrogen Refueling Station Network Quantity and Capacity**

| Station Status | Northern California Station Quantity | Northern California Station Capacity (kg/day) | Southern California Station Quantity | Southern California Station Capacity (kg/day) | Connector/ Destination Station Quantity | Connector/ Destination Station Capacity (kg/day) | Statewide Station Quantity | Statewide Station Capacity (kg/day) |
|---|---|---|---|---|---|---|---|---|
| Open Retail | 18 | 6,700 | 24 | 7,000 | 3 | 800 | 45 | 14,500 |
| Planned | 14 | 17,280 | 32 | 36,910 | 0 | 0 | 46 | 54,190 |
| ***Totals*** | ***32*** | ***23,980*** | ***56*** | ***43,910*** | ***3*** | ***800*** | ***91*** | ***68,690*** |

Source: CEC

Table 4 includes the capacity of the 30 initial stations awarded under GFO-19-602. The table does not include the capacity for the West L.A. station, which closed. As awardees meet the requirements and complete the milestones specified in GFO-19-602, subject to future Clean Transportation Program appropriations and Investment Plan allocations, they may develop in total up to 111 new stations and three upgrades over the next seven years. These additional stations not included in Table 4 may add nearly 94,000 kilograms of daily capacity to the California network, bringing the total to more than 160,000 kilograms (160 metric tons[18]) per day, which could support more than 200,000 FCEVs. Staff also estimates up to 16 metric tons per day may be needed in the 2020–2025 time frame for the other various transport projects funded by the Clean Transportation Program and the CEC Electric Program Investment Charge.[19]

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17 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.

18 A unit of weight equal to 1,000 kilograms.

19 These include light-duty and heavy-duty FCEVs, commuter rail, ports (including ancillary equipment), and freight (locomotive) projects. CEC staff analysis for projects in California. 5/1/2020.

Table 5 summarizes the stations awarded under GFO-19-602. They include at least 13 that could serve light-, medium-, and heavy-duty vehicles, thereby leveraging infrastructure to address multiple markets and accelerating the deployment of fuel cell electric trucks.

**Table 5: Summary of Stations Awarded Under GFO-19-602**

| Awardee | # of Stations in Tranche | # Stations in Initial Batches | Average Station Capacity | Average Award Per Station[20] |
|---|---|---|---|---|
| FirstElement Fuel | 49 | 21 | 1,610 kg/day | $1,322,040 |
| Shell | 50 (plus one station upgrade) | 8 | 770 kg/day | $801,334 |
| Iwatani | 12 (plus two station upgrades) | 1 | 1,420 kg/day | $1,807,839 |
| **Totals** | **111 (plus three station upgrades)** | **30** | **1,267 kg/day** | **$1,310,040** |

Source: CEC

## Hydrogen Dispensing

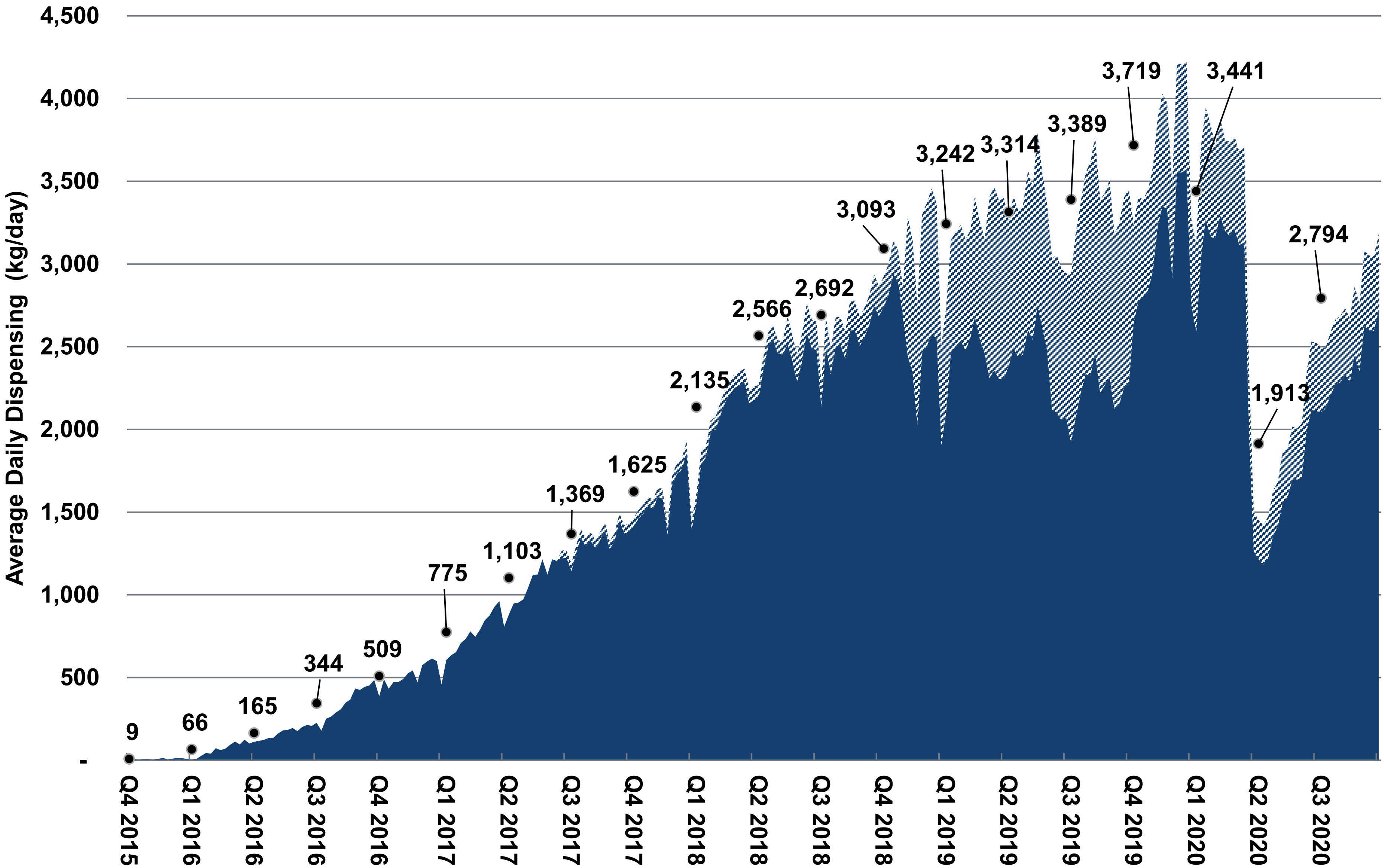
In most cases, station operators report dispensing data to the CEC as required by their grant agreements. Some station operators stopped reporting data once their grant agreements ended, and some have continued reporting voluntarily.

Figure 5 shows the average daily hydrogen dispensing in California. In cases where the CEC stopped receiving data for a station because the required reporting term ended, staff estimated the average daily dispensing per nonreporting station based on the daily regional dispensing (Greater Los Angeles Area, San Francisco Bay Area, San Diego Area, Sacramento Area, and Connector) where that nonreporting station is located. The dispensing shown in solid color in Figure 5 is the amount of dispensed fuel that participating station operators reported to the CEC directly. The estimated dispensing is shown using a patterned color labeled "estimate" in the legend of Figure 5. The figure shows the impact of COVID-19 on hydrogen dispensing with the significant dip at the end of the first quarter of 2020.

Figure 6 shows the percentage of hydrogen dispensed (actual and estimated) in each region from the fourth quarter of 2019 to the third quarter of 2020. About two-thirds of all hydrogen dispensed in California is in the Greater Los Angeles Area.

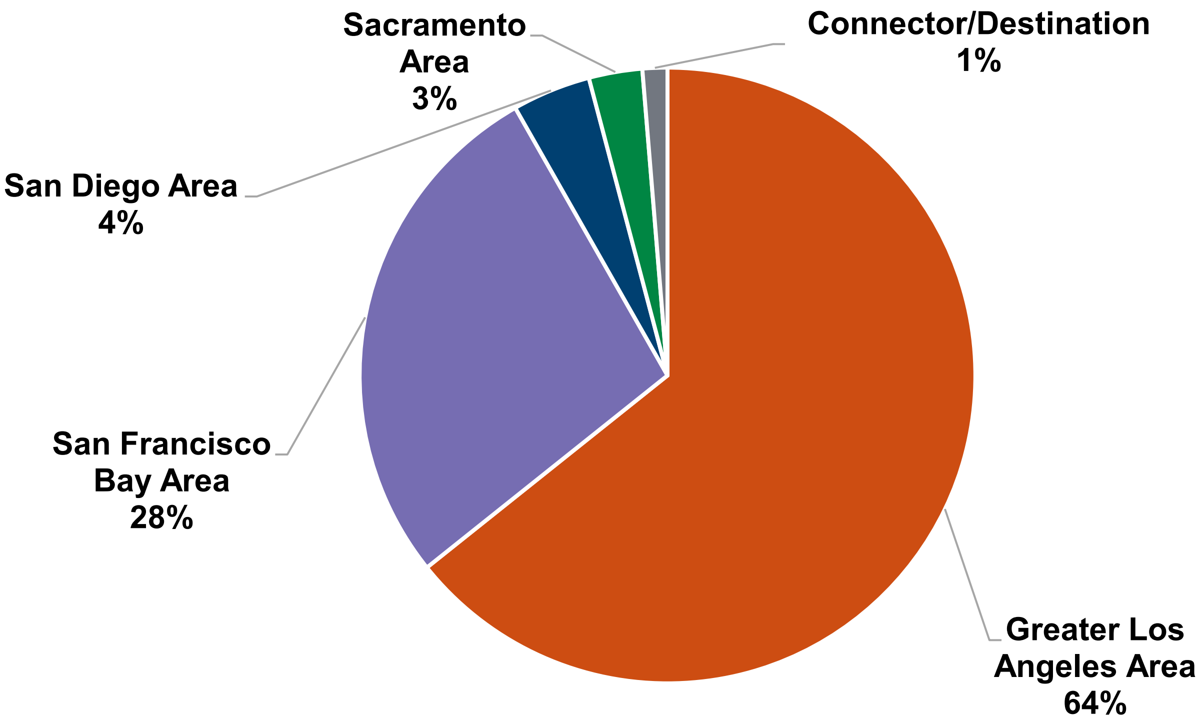
20 Includes $5 million in VW Mitigation Trust Fund.

**Figure 5: Average Daily Hydrogen Dispensing**




Source: CEC

**Figure 6: Percentage of Hydrogen Dispensing in Each Region**




Source: CEC

## Emission Reductions

Hydrogen refueling stations contribute to emissions reductions in greenhouse gases (GHGs), oxides of nitrogen ($NO_x$), and particulate matter 2.5 ($PM_{2.5}$) by providing fuel to FCEVs in California.[21] Figure 6 shows carbon dioxide equivalent ($CO_2e$) emissions reductions resulting from dispensed hydrogen by FCEVs from 2016 to today and projected through 2025.

Staff calculates the overall reduction by considering the efficiency of an FCEV. The projected reductions shown in Figures 7, 8, and 9 are based on the station use; projected growth of FCEVs in California from CARB's 2020 Annual Evaluation, as estimated from an auto manufacturer survey of future FCEV deployment administered by CARB; and the nameplate capacity of stations resulting from CEC agreements.[22] The extent of the emission reductions depends on the local fuel demand based on CARB's evaluation of the auto manufacturer survey and local fuel supplies.

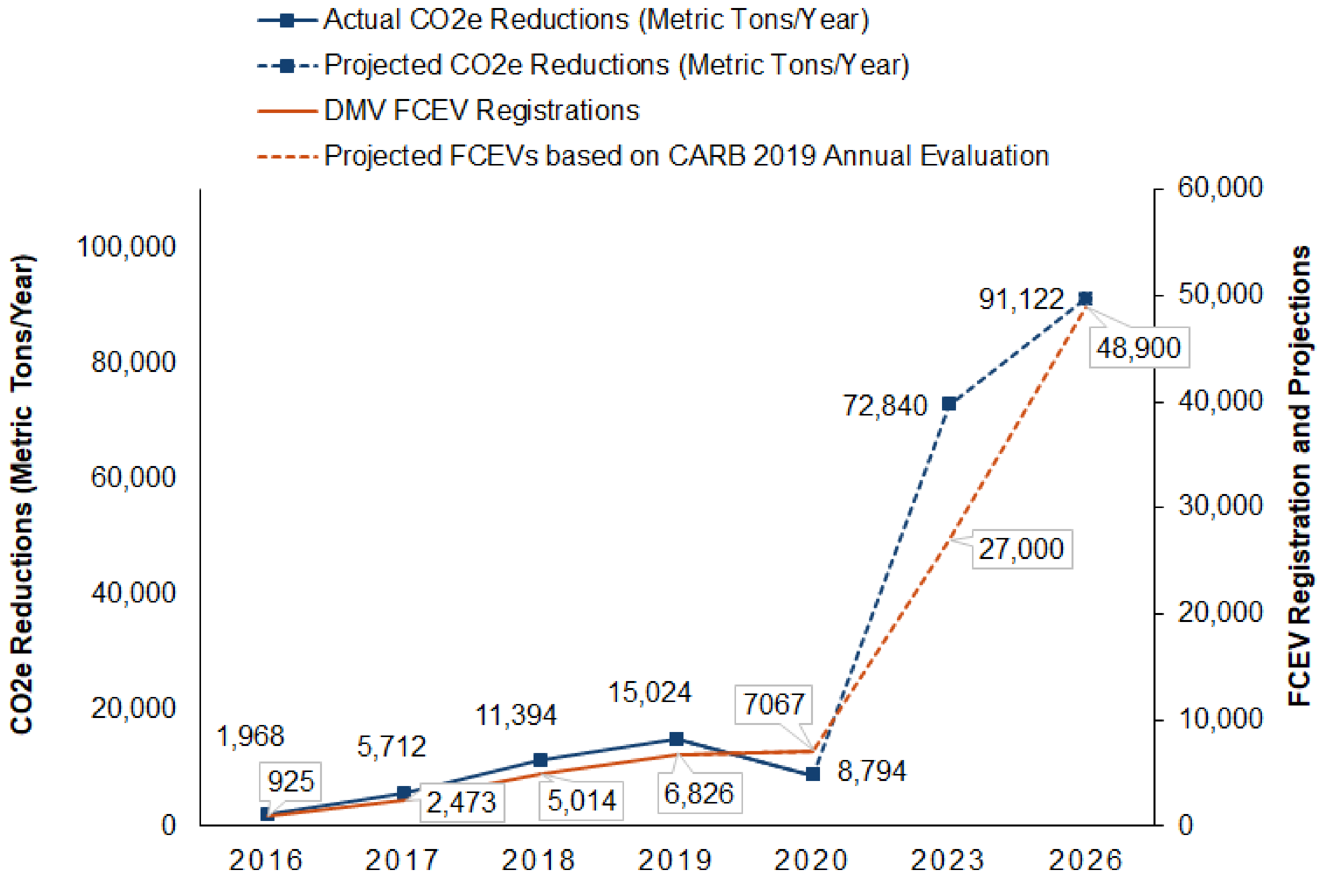
Given these assumptions, the projected GHG emissions reductions from FCEVs is 102,000 metric tons $CO_2e$ per year by 2026. The reductions represent the difference between the emissions from producing, distributing, and consuming gasoline in a "baseline" gasoline

21 "Particulate matter 2.5" is fine inhalable particles, with diameters that are generally 2.5 micrometers and smaller. Source: U.S. Environmental Protection Agency. "Particulate Matter (PM) Pollution." https://www.epa.gov/pm-pollution/particulate-matter-pm-basics.

22 The calculations for GHG reductions include only hydrogen refueling stations that receive public funding.

vehicle, and the emissions from producing and distributing hydrogen and consuming hydrogen in an FCEV. The calculations apply the carbon intensity (CI) of hydrogen and gasoline of each station based on the Low Carbon Fuel Standard (LCFS) methods for determining $CO_2e$ emissions reductions.[23]

**Figure 7: $CO_2e$ Emissions Reductions From Hydrogen Refueling in California**




Source: CEC

In Figures 7, 8, and 9, the estimated emissions reductions, up to 2020, are based on the actual dispensing data for stations still reporting fueling data, with estimates for nonreporting stations, as done in Figure 5. In 2019, the GHG emissions reductions were 14,265 metric tons $CO_2e$ per year, exceeding the 2018 reductions of 11,347 metric tons $CO_2e$ per year. The dip in emissions savings observed in 2020 is due to the reduced amount of driving, which in turn reduced the amount of hydrogen dispensing, due to COVID-19.

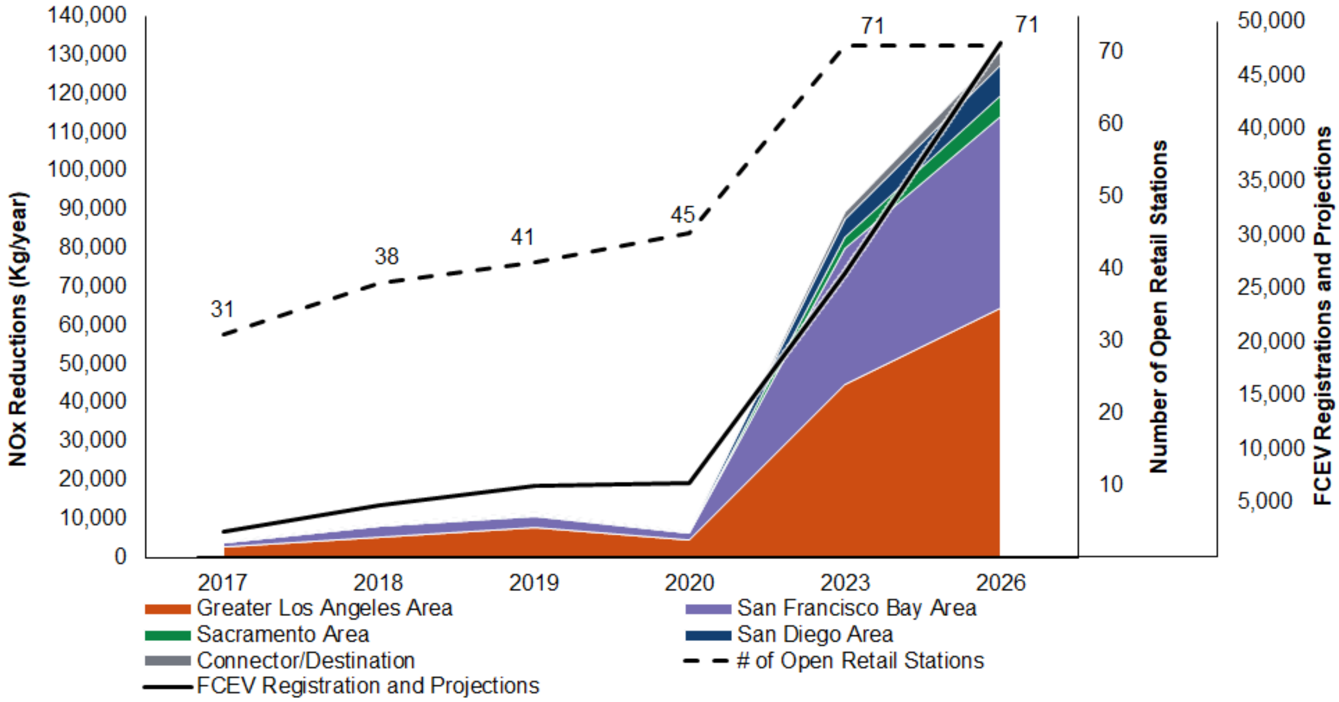
The use of light-duty FCEVs instead of gasoline vehicles results in criteria air pollutant emissions reductions. Staff estimated $NO_x$ and $PM_{2.5}$ emissions reductions using:

23 The calculations use the Low Carbon Fuel Standard current regulation, effective January 2019. The Low Carbon Fuel Standard Final Regulation Order.
https://ww3.arb.ca.gov/fuels/lcfs/fro_oal_approved_clean_unofficial_010919.pdf.

- Fuel economy of 74 miles per gallon gasoline equivalent (mpgge) for light-duty FCEVs and 25 miles per gallon (mpg) for the gasoline vehicle.[24]
- Well-to-wheel emissions, meaning the total emissions resulting from when the fuel is produced to when it is used in a vehicle, of 0.106 g $NO_x$/mile and 0.0140 g $PM_{2.5}$/mile for light-duty FCEVs and 0.279 g $NO_x$/mile and 0.0196 g $PM_{2.5}$/mile for gasoline vehicles.[25]

Figures 8 and 9 show the $NO_x$ and $PM_{2.5}$ emissions reductions projected to 2026 that result from driving zero-emission FCEVs instead of gasoline vehicles. The figures show the time scale increments changing from annual for the actual dispensed hydrogen to every three years starting in 2020 for the CARB survey results projections. Although the amounts of $NO_x$ and $PM_{2.5}$ avoided to date in the regions are relatively modest, the future emissions reductions could be substantial.

**Figure 8: $NO_x$ Emissions Reductions by Region**

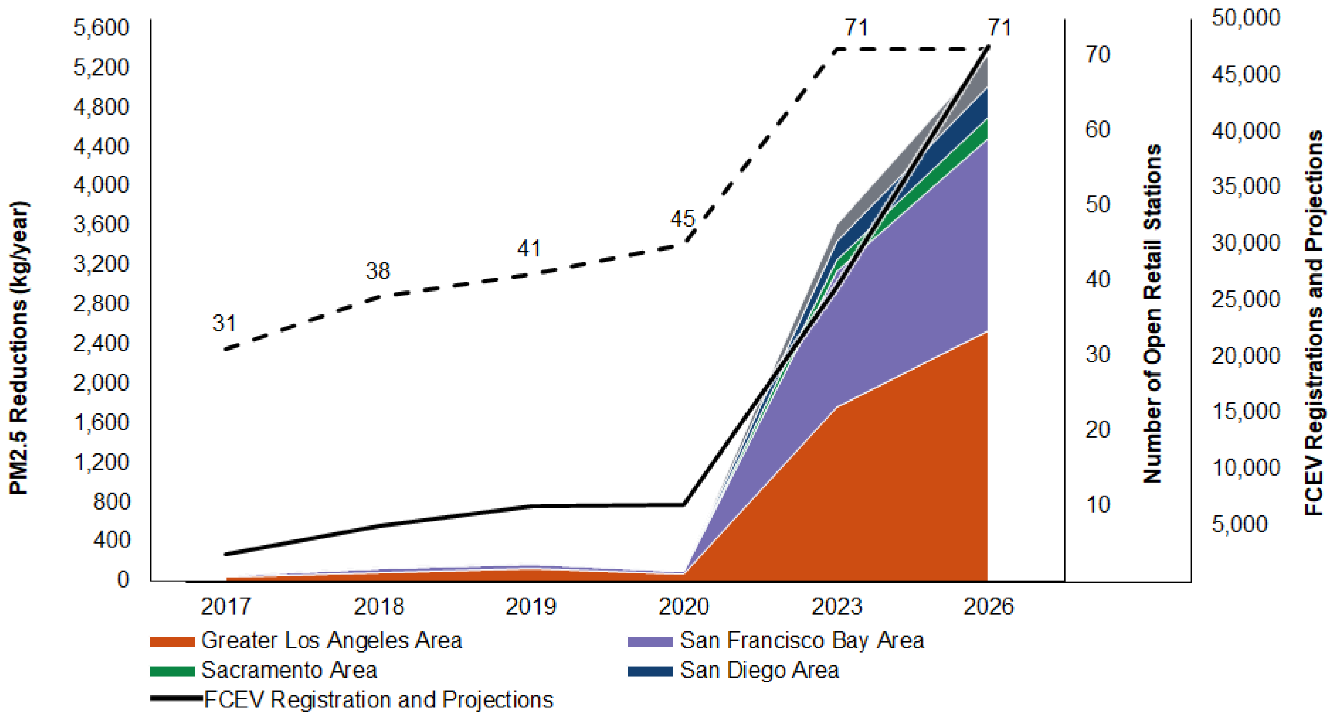



Source: CEC

24 California Air Resources Board. January 2019. The Low Carbon Fuel Standard current regulation, effective January 2019. The Low Carbon Fuel Standard Final Regulation Order. https://ww3.arb.ca.gov/fuels/lcfs/fro_oal_approved_clean_unofficial_010919.pdf.

25 The emissions reductions account for oil refinement in the production of gasoline and the associated use in the gasoline automobile, the manufacture of hydrogen through steam methane reformation, and a few electrolyzer stations within the network. Elgowainy, A., et al. 2017. *Life-Cycle Analysis of Air Pollutants Emission for Refinery and Hydrogen Production from SMR.* Argonne National Laboratory. pp 22-24. https://www.hydrogen.energy.gov/pdfs/review17/sa066_elgowainy_2017_o.pdf.

**Figure 9: $PM_{2.5}$ Emissions Reductions by Region**




Source: CEC

## Global Hydrogen Decarbonization Strategy

Hydrogen producers can make hydrogen from fossil fuels or renewable sources. The magnitude of the emissions reductions from hydrogen displacing gasoline and diesel use in vehicles will increase as the carbon intensity of hydrogen decreases.

The Hydrogen Council, a CEO-led global initiative of 81 leading energy, transport, and industry companies with a united vision for hydrogen to foster the energy transition, has committed to fully decarbonizing the hydrogen used in transportation by 2030.[26]

Released in January 2020, the Hydrogen Council report *Path to Hydrogen Competitiveness: A Cost Perspective*[27] anticipates there will be an international energy market for buying and selling renewable hydrogen. The report expects this international trade to proliferate because the places where it is cheapest to make renewable hydrogen are not the places that need it most: urban, industrial places. For example, the report finds that renewable hydrogen production in locations within Saudi Arabia, Chile, and Australia could produce renewable hydrogen cost effectively today. It may be cost-beneficial for consumers in Asia, Europe, and

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26 The Hydrogen Council has 81 members as of January 2020. https://hydrogencouncil.com/en/newmemberannouncement2020/. In September 2018, the Hydrogen Council announced its plan for 100 percent decarbonization of hydrogen used in transport by 2030. https://hydrogencouncil.com/en/our-2030-goal/.

27 The Hydrogen Council. *Path to Hydrogen Competitiveness: A Cost Perspective*. https://hydrogencouncil.com/en/path-to-hydrogen-competitiveness-a-cost-perspective/.

the United States to buy renewable hydrogen from supply locations such as these rather than produce it locally. The report findings also suggest that scale-up will be the biggest driver of cost reduction, notably in the production and distribution of hydrogen and the manufacturing of system components. The report finds that the expected growth in global hydrogen production capacity from electrolysis is from 15 gigawatts available from projects in development to 50 gigawatts in planned projects.

The Green Hydrogen Coalition, based in the United States, has the mission to promote policies and practices to advance the production and use of green hydrogen, meaning renewable hydrogen, or that which is produced, isolated, or captured without the use of fossil fuels, in all sectors. It supports the Intermountain Power Project in Utah, which is converting a coal-fired plant to a cleaner, gas-fired plant for California utilities. The project goal is to leverage curtailed and low-cost, purpose-built wind and solar energy to produce green hydrogen, store it onsite in the salt dome formation under the plant, and use it in place of natural gas to ultimately enable carbon-free, dispatchable electric generation.[28] With these types of projects being pursued around the world, the cost of renewable hydrogen is falling rapidly because of the combined effects of reduced electrolyzer cost and cheaper renewable power. The 2020 *Global Renewables Outlook* from the International Renewable Energy Agency states that, because of falling cost, renewable hydrogen could be cost-competitive with hydrogen made using fossil fuels in the near future.[29] The Clean Transportation Program has supported renewable hydrogen production in California and will continue to fund and support renewable hydrogen production in future funding opportunities to help achieve this end.[30]

28 Green Hydrogen Coalition. https://www.ghcoalition.org/green-hydrogen-at-scale.

29 International Renewable Energy Agency (IRENA). Global Renewables Outlook, 2020 Edition. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Apr/IRENA_Global_Renewables_Outlook_2020.pdf.

30 The CEC Clean Transportation Program funded hydrogen production plants in GFO-17-602: Renewable Hydrogen Transportation Fuel Production Facilities and Systems. https://energyarchive.ca.gov/contracts/transportation.html.

# CHAPTER 3: Fuel Cell Electric Vehicle Deployment

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. To that end, the CEC recently released a light-duty ZEV data portal[31] so that the public can readily access this information. The portal includes tallies of battery-electric vehicle (BEVs), plug-in hybrid electric vehicle (PHEVs), and FCEV sales and population. The portal shows that FCEVs comprise more than 1 percent of the total 2019 light-duty ZEV population of more than 500,000 vehicles. The data portal is at https://www.energy.ca.gov/zevstats. According to the data portal, 6,933 FCEVs were on California's roads as of the end of 2019. The data portal also provides cumulative sales and leases of light-duty FCEVs in California, which are 8,486 as of the end of the third quarter of 2020, but likely includes FCEVs no longer in use.

CARB also collects and reports the number of FCEVs deployed, per AB 8, to evaluate the need for additional hydrogen refueling stations. To meet this requirement, CARB also evaluates data from the California DMV and surveys auto manufacturers on their FCEV production plans for the near future. The CARB analysis finds that the current stock of registered FCEVs in California totals 7,067 as of October 2020. The economic effect of COVID-19 affected vehicle sales across the country.[32] However, Governor Gavin Newsom's recent Executive Order N-79-20, which sets a goal for all new passenger cars and trucks sold in California be zero-emission by 2035, will likely increase the number of FCEVs sold and leased in the long term.[33]

The 2020 Joint Report uses the projections based on the auto manufacturers' responses to CARB's annual survey for analyses. Figure 10 updates Figure ES-3 in CARB's 2020 Annual Evaluation[34] with FCEV data from October 2020.

Data in Figure 10 are based on two sources: 1) analysis of DMV registration status for FCEVs and 2) an annual survey of auto manufacturers that addresses projected deployments of FCEVs and other ZEVs. Active DMV registrations reported in the figure are as assessed by CARB at the time of reporting, based on matching vehicle identification number patterns in the registration data to those of all FCEV models that have been sold or leased in California.

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

32 *The New York Times*. May 11, 2020. Car sales picked up at the end of April, AutoNation says. https://www.nytimes.com/2020/05/11/business/stock-market-today-coronavirus.html#link-77ffa0fa.

33 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-text.pdf.

34 California Air Resources Board. September 2020. *2020 Annual Evaluation of Fuel Cell Electric Vehicle Deployment and Hydrogen Fuel Station Network Development*. http://ww2.arb.ca.gov/resources/documents/annual-hydrogen-evaluation.

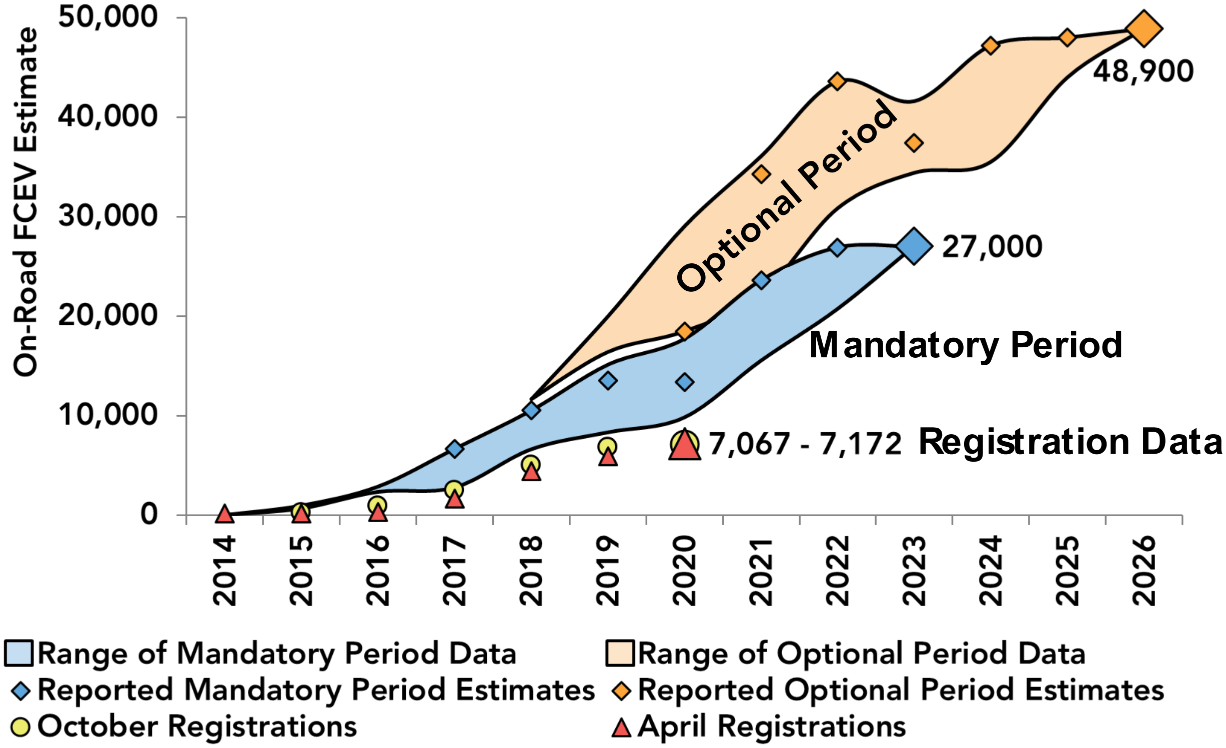
Vehicles with invalid or out-of-state ZIP codes or with registration status codes that do not indicate current active registration at the time of analysis are not included in these counts.

CARB's annual survey of auto manufacturers requests data for future vehicle deployments based on model and model year at the statewide aggregate level. Model years are not matched to the January–December calendar year. In addition, CARB performs geospatial analyses on resolutions finer than the statewide basis. Thus, CARB also completes a series of data processing steps for the auto manufacturer survey responses. Based on prior investigation of historical DMV registration data, CARB translates model year into calendar year by assuming one-third of all vehicles of a given model year become registered and are in use during the preceding calendar year. The remaining two-thirds of vehicles are assumed to be placed on the road in the calendar year matching the model year.

Next, CARB estimates the geospatial distribution of all vehicles indicated on the auto manufacturer survey by blending the stations currently open and in development with the future station network scenario shown in Appendix D of the 2018 Annual Evaluation and described in the California Fuel Cell Partnership's *Revolution* document.[35] Future deployment of new vehicles is distributed to counties proportionally to the percentage of statewide capacity in each year according to this blended scenario. Finally, for all projections of future on-the-road FCEV counts, CARB assumes an attrition rate matching its EMissions FACtor (EMFAC) model of a 15-year half-life for all vehicles. This assumption accounts for the typical rate of vehicles falling out of the on-road fleet because of external causes like accidents or owners transferring the vehicle out of state.

35 California Fuel Cell Partnership. "Resources." https://www.cafcp.org/resources.

**Figure 10: FCEV Projections From Auto Manufacturer Survey**




Source: CARB

Figure 10 presents FCEV projections in the CARB mandatory reporting period (shown in blue, which is the next three model years at the time of survey) and the optional reporting period (shown in orange, which is the following three model years after the mandatory period) for auto manufacturers. In the optional period, some auto manufacturers may not have provided data. The FCEV counts shown in Figure 10, represented by the diamond-shaped icons, are the end-of-period values from the estimates CARB received from auto manufacturers in each survey year.

In 2020, the end-of-period years were 2023 for the mandatory period and 2026 for the optional period. In Figure 10, the areas shown in blue and orange represent the range of survey responses obtained from auto manufacturers for each year. For example, 2020 shows several data points which were populated over time. In the 2014 survey, 2020 was the last year of the optional period. It was the last year of the mandatory period in the 2017 survey.

Figure 10 shows the 2017 estimate for 2020 (blue diamond) was more than 10,000 FCEVs. All of CARB's surveys conducted since 2014 also collected data on 2020, and the vertical spread of the area in blue represents the range of vehicle projections from mandatory periods in all survey years.

Mandatory period estimates for on-the-road FCEVs by 2020 have ranged from 9,800 to fewer than 17,700. The latest projections based on the 2020 survey indicate 27,000 FCEVs on the road by 2023 and 48,900 FCEVs by 2026. These projections imply that auto manufacturers plan to dispatch similar numbers of vehicles as they had stated for 2022 and 2025 last year. As CARB discussed in the 2020 Annual Evaluation, this shift in auto manufacturer projections may be due to uncertainty resulting from COVID-19 in future station development timelines.[36] It may also be due to other challenges in deploying FCEVs, including expectations based on automakers' product announcements that small numbers of vehicle models will be available, in limited vehicle classes; high vehicle purchase and lease costs and high fuel costs; and fuel supply disruptions that make ownership challenging.

California is also working on deploying other types of FCEVs (commercial and pilot): buses, medium- and heavy-duty trucks, portside equipment, a locomotive, and a commuter rail system. At the end of 2023, California's FCEV projects will likely yield as many as 65 fuel cell electric trucks, with 13 to 18 trucks currently operational in the state. The Clean Transportation Program and the California Climate Investments Program fund medium- and heavy-duty fuel cell electric vehicles.[37]

## International Distribution of Fuel Cell Electric Vehicles

Countries around the world are pursuing hydrogen as a solution to decarbonizing the transportation sector.[38] This pursuit is advancing in many applications, including people and goods movement, and for many types of vehicles, including light-, medium-, and heavy-duty on-road vehicles, trains, oceangoing vessels, and material-handling equipment at ports. The international adoption of hydrogen refueling infrastructure is growing, and the global population of light-, medium-, and heavy-duty FCEVs is increasing. But to rapidly scale, greater progress is needed globally. Today, passenger vehicles are sold only in relatively small quantities.

The International Energy Agency (IEA) reported about 600 operational light-duty FCEVs in 2014 and about 13,000 operational light-duty FCEVs in 2018 in North America, Asia, and Europe.[39]

The CEC staff evaluated public studies to obtain information about the global adoption and use of FCEVs. Table 6 summarizes the evaluation, including light-duty FCEVs and the estimated deployment of other types of FCEVs by 2025, unless stated otherwise.

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36 California Air Resources Board. September 2020. *2020 Annual Evaluation of Fuel Cell Electric Vehicle Deployment and Hydrogen Fuel Station Network Development*. http://ww2.arb.ca.gov/resources/documents/annual-hydrogen-evaluation.

37 Baronas, Jean, Gerhard Achtelik, et al. 2019. *Joint Agency Staff Report on Assembly Bill 8: 2019 Annual Assessment of Time and Cost Needed to Attain 100 Hydrogen Refueling Stations in California.* California Energy Commission and California Air Resources Board. Publication Number: CEC-600-2019-039. https://ww2.energy.ca.gov/publications/displayOneReport_cms.php?pubNum=CEC-600-2019-039.

38 Ibid, pp. xi-xii.

39 International Energy Agency Advanced Fuel Cell Technology Collaboration Programme, "ACT TCP 2019 Survey on the Number of Fuel Cell Vehicles, Hydrogen Refueling Stations and Targets," International Energy Agency, 2019. Please see other IEA reports listed in References for earlier year information.

**Table 6: Estimated Light-Duty and Other FCEV Deployment**

For 2025 unless stated otherwise

| Countries | Light-Duty FCEVs | Buses, Medium- and Heavy-Duty Trucks, Portside Equipment, Freight, Commuter Rail, Trains, and Trams |
|---|---|---|
| China | 80,000–100,000 | vehicles expected.[40] |
| Japan[41] | 200,000 | • Buses: by 2030, up to 1,200 |
| South Korea | Up to 200,000[42] | • Buses: by 2022, up to 2,000[43]<br>• Trucks: by 2040, up to 30,000[44] |
| Germany | ZEV targets only[45] | • Buses: between 50 and 100[46]<br>• Train and Trams: 2[47] |
| United States[48] | 48,900 | • Buses: between 40 and 370<br>• Medium-duty trucks: between 40 and 400<br>• Heavy-duty trucks: between 10 and 50<br>• Portside equipment: ten pilot<br>• Rail freight (locomotives): one locomotive<br>• Commuter rail: one commuter rail system |

Source: CEC

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40 The lower bound of the estimate is based on data compiled by the International Council on Clean Transportation from 15 potential FCEV pilot program cities within China, as of December 2020. The higher bound is based on a press release from the Chinese Society of Automotive Engineering. "Energy-saving and New Energy Vehicle Technology Roadmap 2.0." http://www.sae-china.org/news/activities/202010/3957.html.

41 Hydrogen and Fuel Cell Strategy Council. March 2019. *The Strategic Road Map for Hydrogen and Fuel Cells*. https://www.meti.go.jp/english/press/2019/pdf/0312_002b.pdf.

42 Teter, Jacob. "Hydrogen and Fuel Cells Considerations for the California Energy Commission." IEA. Presentation at the July 2, 2020, IEPR workshop on Hydrogen and Fuel Cell Electric Vehicle Market Status. https://efiling.energy.ca.gov/getdocument.aspx?tn=233701. Also, South Korea Ministry of Economy and Finance press release. July 28, 2020. "Government Releases an English Booklet on the Korean New Deal." http://english.moef.go.kr/pc/selectTbPressCenterDtl.do?boardCd=N0001&seq=4948.

43 Fuel Cell & Hydrogen Energy Association. "South Korean Fuel Cell Industry Developments." http://www.fchea.org/in-transition/2019/2/19/south-korean-fuel-cell-industry-developments.

44 Netherlands Enterprise Agency. January 2019. "Hydrogen Economy Plan in Korea." https://www.rvo.nl/sites/default/files/2019/03/Hydrogen-economy-plan-in-Korea.pdf.

45 Germany has targets of 1 million ZEVs by 2020 and 7 million–10 million by 2030. However, the targets are not broken down among BEV, FCEV, and PHEVs. Markus Becker, German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety. December 8, 2020.

46 Fuel Cell & Hydrogen Energy Association. March 2019. "Germany Fuel Cell Industry Developments." http://www.fchea.org/in-transition/2019/3/18/germany-fuel-cell-industry-developments.

47 Ibid.

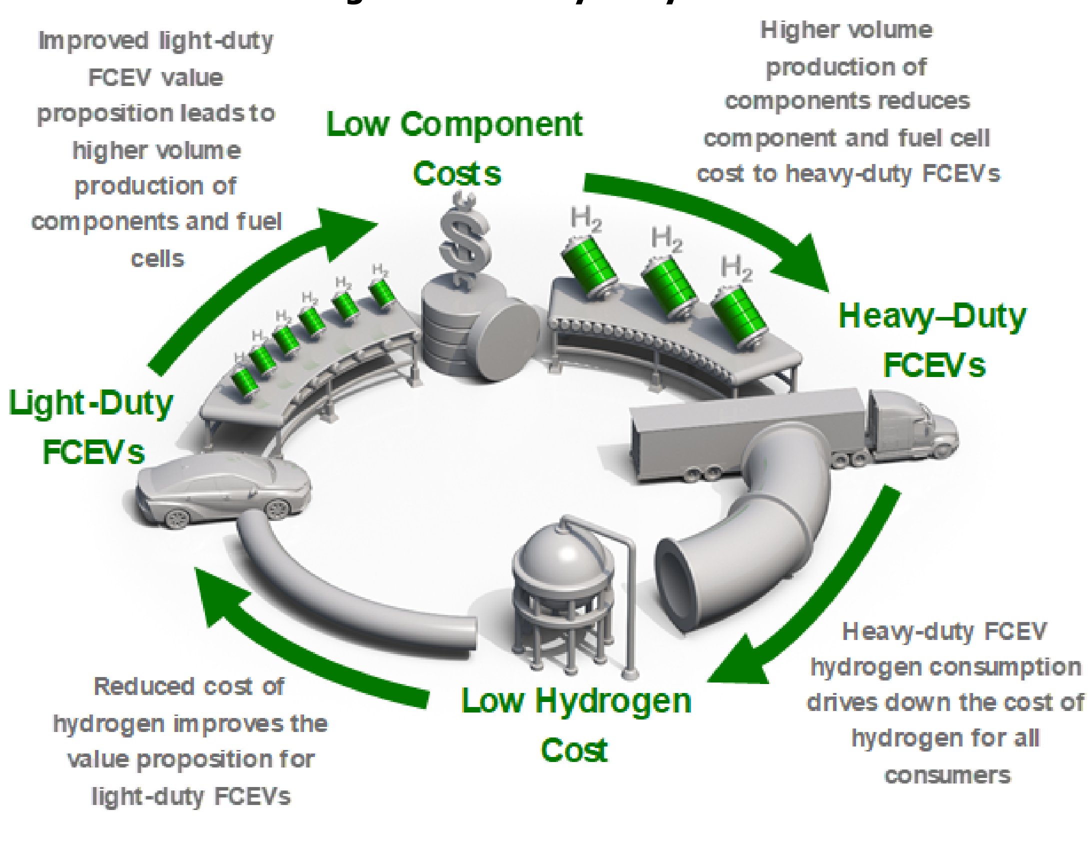
48 CEC staff analysis of hydrogen projects in California. 5/1/2020.

## Interdependencies of Light- and Heavy-Duty Vehicle Investments

The growing global investment in all types of FCEVs will most likely contribute to innovations and economies of scale that lead to cost reductions that benefit all customers. Speaking to this issue, in a presentation to the 2019 Fuel Cell & Hydrogen Energy Association Fuel Cell Seminar, the National Renewable Energy Laboratory (NREL) presented the mutually beneficial relationship with light-duty and heavy-duty FCEVs, shown in Figure 11.[49] The graphic conveys the interdependencies and mutual benefits of light- and heavy-duty vehicle investments. In the early days of establishing a hydrogen fueling market, mass-produced passenger vehicles will be most helpful in reducing fuel cell and component costs. Furthermore, larger vehicles, with larger tank sizes and more demanding duty cycles, require larger quantities of fuel production that should reduce the retail price of hydrogen.

In addition to the funding for public hydrogen refueling stations, the Clean Transportation Program is supporting nonpublic hydrogen infrastructure for freight and transit vehicles, which positions California to benefit from the virtuous circle shown in Figure 11. GFO-19-602, the most recent hydrogen refueling infrastructure solicitation, adopted the same synergy with the goal of funding multipurpose stations for light-duty and medium-duty vehicles.

**Figure 11: Depiction of the Interdependencies of the Cost of Components Between Light- and Heavy-Duty FCEVs**




Source: NREL (formatting modified by the authors of this report)

49 Peters, Michael and Jake Thornson. 2019. "Fuel Cell Seminar, H2@Scale Session." November 19, 2019, Long Beach, CA. https://www.energy.gov/sites/prod/files/2019/12/f69/fcto-fcs-h2-scale-2019-workshop-15-peters.pdf.

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

Unforeseeable events, such as the COVID-19 pandemic, affect station development time. Likewise, foreseeable activities, such as negotiating leases with site owners and navigating the planning and permitting processes of authorities having jurisdiction (AHJs), can vary in the length of time to complete. To motivate prospective station developers to plan appropriately for these foreseeable events such that they will reduce the likelihood of delays, the CEC has instituted "critical milestones" in recent hydrogen refueling infrastructure solicitations.

The most recent CEC solicitation, GFO-19-602, included four critical milestones to increase station developer readiness for foreseeable activities including AHJ approvals, safety planning, site control, utility connection, and hydrogen supply. Table 7 lists the critical milestones in GFO-19-602.[50]

**Table 7: Critical Milestones for Station Development in GFO-19-602**

| Critical Milestones | When Required |
|---|---|
| 1: Formal or informal preapplication meeting for permits with AHJs, with a representative of the Office of the Fire Marshal, or other similar fire control office in the AHJ, and a representative of the Pacific Northwest National Laboratory Hydrogen Safety Panel | At the time of application for stations for which applicants are submitting addresses, except if meetings have been delayed because of COVID-19 public measures. For the remaining stations, due on or before the date when addresses for the remaining stations are submitted to CEC. |
| 2: Site control and possession | At the time of application for stations for which applicants are submitting addresses. For the remaining stations, due on or before the date when addresses for the remaining stations are submitted to the CEC. |
| 3: Meeting(s) with the utility company | On or before the date specified in the agreement Schedule of Products and Due Dates. |
| 4: Meeting(s) with the hydrogen supply company | On or before the date specified in the Schedule of Products and Due Dates. |

Source: CEC

50 California Energy Commission. GFO-19-602 – Hydrogen Refueling Infrastructure. https://www.energy.ca.gov/solicitations/2019-12/gfo-19-602-hydrogen-refueling-infrastructure.

Table 8 describes the station development phases that can be shortened with these critical milestones in place.

**Table 8: 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 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 |
| **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

As reported in the 2019 Joint Report, the hydrogen supply disruption that began in June 2019 extended the time it took station developers to complete some of the development phases, particularly for stations funded under GFO-15-605. Shortly after the supply disruption ended, the COVID-19 pandemic began, affecting station development time even further. In some areas in California, local ordinances halted construction. Moreover, the pandemic affected station testing. For these reasons, not many stations funded under GFO-15-605 have progressed into further phases in 2020.

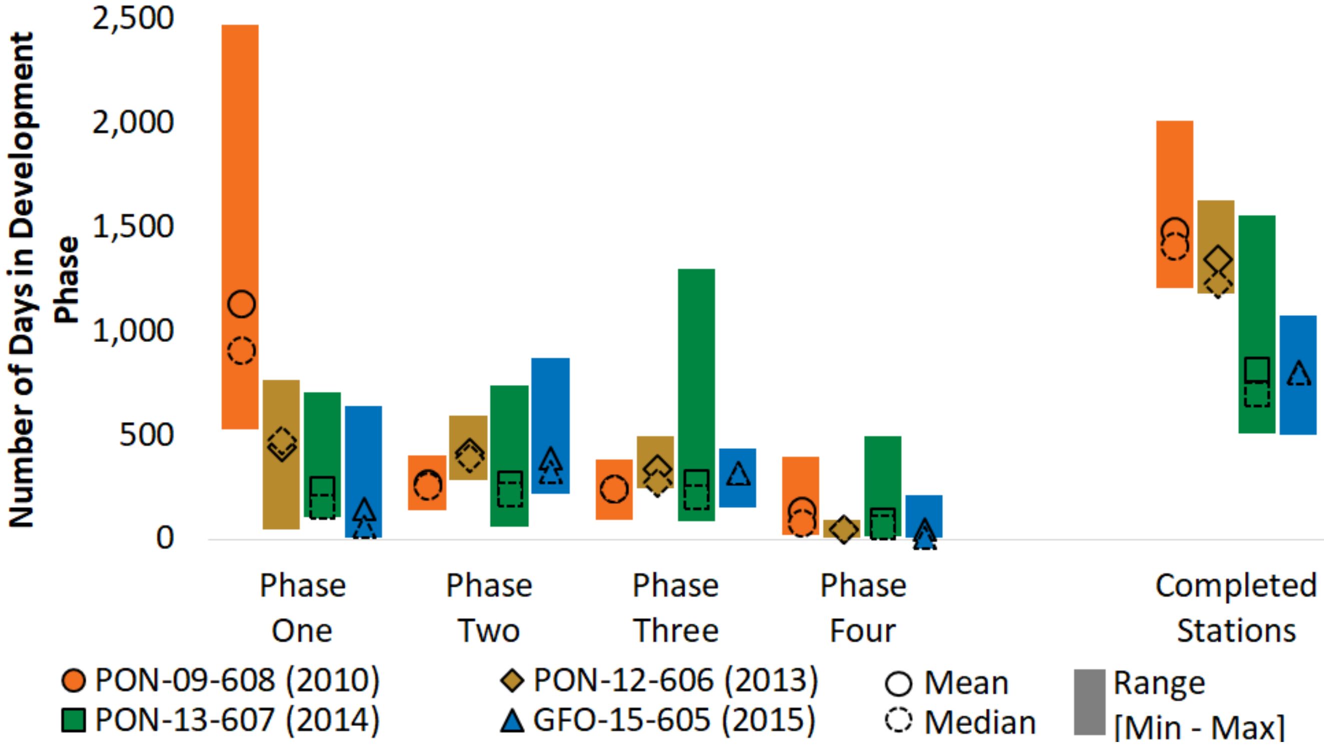
In this year's report, station development time is presented in Figure 12 showing mean, median, minimum, and maximum number of days for each phase and solicitation. A mean number of days simply represents the average number of days for all stations that completed each phase. Mean numbers could contain skewed numbers by stations that experienced unforeseeable and unusual circumstances that led 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 numbers spent in each phase. 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 the phases.

The figure shows an overall decrease in station development time with the more recent solicitations. Phase One decreased significantly after 2010. This decrease is partially due to the emphasis the newer solicitations placed on station developer readiness. The newer solicitations required applicants to hold a pre-application meeting with the AHJ and secure the station site. So far, Phase Two and Phase Three are making the mean and median numbers for GFO-15-605 a little higher than PON-13-607, but the high end of the total station development time for GFO-15-605 is still well below PON-13-607. The high values in GFO-13-607 and GFO-15-605 are most likely outliers, given that the associated means and medians are far below the earlier two solicitations.

The stations resulting from GFO-19-602 are expected to maintain the trend of decreased development time, especially with the benchmarks included in the solicitation: receiving approval to build from the respective AHJ within 18 months of the CEC approving the station, and becoming open retail within 30 months of the CEC approving the station. Added to the CEC's benchmarks is the second edition of the *Hydrogen Station Permitting Guidebook*.[51] The station developers, local government officials, and planners can reference the guidebook, which is based on significant progress made in the industry. The guidebook will help station developers navigate the permitting processes and potentially reduce time spent in the processes.

51 California Governor's Office of Business and Economic Development (GO-Biz). *Hydrogen Station Permitting Guidebook.* September 2020. https://cdn.businessportal.ca.gov/wp-content/uploads/2020/09/GO-Biz_Hydrogen-Station-Permitting-Guidebook_Sept-2020.pdf.

**Figure 12: Mean, Median, Minimum, and Maximum Days of Each Station Development Phase by Solicitation**




**Overall, the time spent in Phase One and the means and medians of station development times decreased significantly after 2010. The high values in PON-13-607 and GFO-15-605 are most likely outliers, given that the associated means and medians are far below the earlier two solicitations.**

Source: CEC and CARB

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

This chapter analyzes how the growth in the hydrogen refueling station network is keeping pace with FCEV deployment and anticipates future station capacity needs to 2026. This year, this chapter is expanded to include an international perspective about hydrogen refueling station deployment and highlights some of the common discussions and policy choices being considered related to hydrogen transport around the globe.

CEC and CARB staff evaluated the FCEV projections and the need for fuel to determine the amount and timing of the needed growth of the hydrogen refueling network regionally. Table 9 shows that, with stations resulting from CEC agreements under GFO-19-602, the four major urban regions evaluated in this report should have enough capacity to serve the number of FCEVs that auto manufacturers expect to bring to market in coming years. In fact, the network capacity now far exceeds the FCEV estimates for 2026, the furthest future year for which there are 2020 survey results available from auto manufacturers. This finding of having a network capacity surplus is a significant difference from the findings of past years' reports, in which this same analysis forecasted near-term shortfalls in fueling capacity in many regions.

This progress in hydrogen fuel availability is due in large part to GFO-19-602, which has awarded a new collection of stations for development. The Clean Transportation Program annual funding allocation of $20 million for hydrogen refueling stations has helped create certainty of future investments in stations. The CEC decided previously to reexamine the best way to support and structure hydrogen solicitations, which meant that no new station awards were made for several years. However, this reexamination allowed stakeholder collaboration and resulted in the CEC deciding to design future solicitations to focus on cost reduction in station equipment by enabling industry to advance toward developing economies of scale. GFO-19-602 aimed to produce this outcome by offering several years of funding at once for station developers to propose a tranche of stations and by including the opportunity to add future years' funding allocations to projects once available.

Now that the CEC has made funding awards under GFO-19-602, the result is many more funded stations. While industry stakeholders have been closely involved in this solicitation in which the CEC made a large amount of Clean Transportation Program funding available for hydrogen refueling stations, actually having the GFO-19-602 projects awarded and able to commence[52] provides greater certainty that the stations will indeed materialize. With this confirmation that the CEC is investing the funds as anticipated, auto manufacturers and hydrogen suppliers should, in turn, have greater confidence to make additional investments and deployments in the California FCEV market throughout the state and regionally.

52 CEC grant agreement projects begin at the agreement start date or at the date at which the agreement is signed by all parties, whichever is later.

The regional analysis in this section includes all open retail and planned stations under previous solicitations, the stations resulting from CEC agreements under GFO-19-602 in each station developer's initial batch, and the stations in potential later batches for which the developer provided an address. In providing addresses, developers met various milestones to confirm location viability. These stations with addresses (all batches) funded under GFO-19-602 total 46, fewer than half of the expected 111 new stations to result from the full tranches awarded under this solicitation. The locations of the remaining stations are to be determined by the station developers and approved by the CEC following a process described in the GFO. When these remaining stations are added, the statewide capacity will almost double.

While the GFO-19-602 results are significant, there are still a few areas of concern in terms of the station network supporting FCEV deployment. As evidenced in the figures in this section, some regions, particularly San Diego, are near capacity today, meaning there is not much excess hydrogen supply in the current open retail station network to support many more FCEVs. This situation is partially explained by COVID-19 and the reduced number of stations opened this year because of limited development and construction activity. If station developers can complete the number of stations scheduled to open in 2021, this capacity constraint should be alleviated quickly.

Another potential concern that developers should consider when planning the locations of the remaining GFO-19-602 stations is the need to support FCEV deployment in additional areas, including the Central Valley (cities such as Stockton, Fresno, and Bakersfield) and the Central Coast (Monterey, San Luis Obispo, and so forth), as shown in Table 9. Not only can stations in these areas support local market development, they can also enable long-distance travel between larger urban areas and to recreational destinations. Developers should also consider reaching new disadvantaged communities that have no local fueling opportunity in these additional areas.

Table 9 shows the number of FCEVs anticipated in each region in 2026 based on auto manufacturer survey results, and the amount of hydrogen needed daily to sustain that number of vehicles. The table then compares that needed amount of hydrogen to the anticipated amount of hydrogen available in the region's station network in 2026. This anticipated capacity is calculated by using 80 percent of nameplate station capacity of all stations (for GFO-19-602, this means all stations for which an awarded developer has provided an address) to represent a sustainable level of refueling at each station, such that a station is not completely empty at the end of each day or has waiting lines for fueling.

**Table 9: Regional Projection for Fuel Demand**

| Region | Projected # of FCEVs in 2026 | H2 Needed for Projected FCEVs in 2026 (kg/day) | H2 Capacity of Stations in 2026 (kg/day) | Additional # of FCEVs That Stations Could Support in 2026 |
|---|---|---|---|---|
| Greater Los Angeles Area | 22,700 | 15,900 | 40,800 | 35,600 |
| San Francisco Bay Area | 15,700 | 11,000 | 21,900 | 15,600 |
| Sacramento Area | 1,900 | 1,300 | 2,300 | 1,400 |
| San Diego Area | 2,600 | 1,800 | 5,700 | 5,600 |
| Remainder of the State | 6,000 | 4,200 | 600 | (5,100) |
| **Total** | **48,900** | **34,200** | **71,300** | **53,100** |

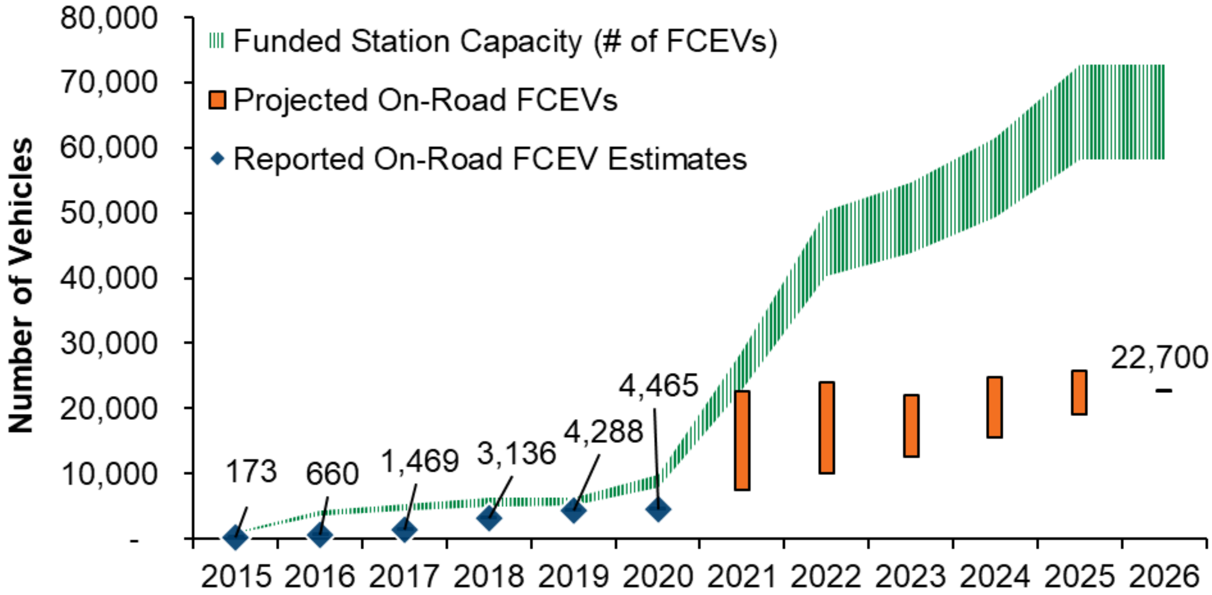
Source: CEC

Figures 13 through 16 compare the estimated FCEV rollout, shown in Figure 10 (FCEV Projections from Auto Manufacturer Survey), to the estimated, regional station deployment based solely on the station network described earlier in this chapter. The orange bars in Figures 13 through 16 show the range of CARB-estimated FCEVs from auto manufacturer surveys. The figures assume that stations will open according to station developers' timelines.

The analyses use 0.7 kilogram per day of hydrogen consumed per FCEV to convert station capacity into the estimated number of FCEVs supported. The green lines in the figures indicate the estimated number of FCEVs that could be supported by a region's stations. 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).

Figure 13 shows that the Greater Los Angeles Area has thus far seen FCEV deployment paralleling but lower than station capacity. Stations opened in 2020 have brought some additional fueling capacity to the region. With many stations proposed in this region in the GFO-19-602 initial batches, by the end of 2022, the available capacity should be nearly quadruple what it is today. By 2026, the region's station network should be able to support more than double the 22,700 FCEVs estimated.

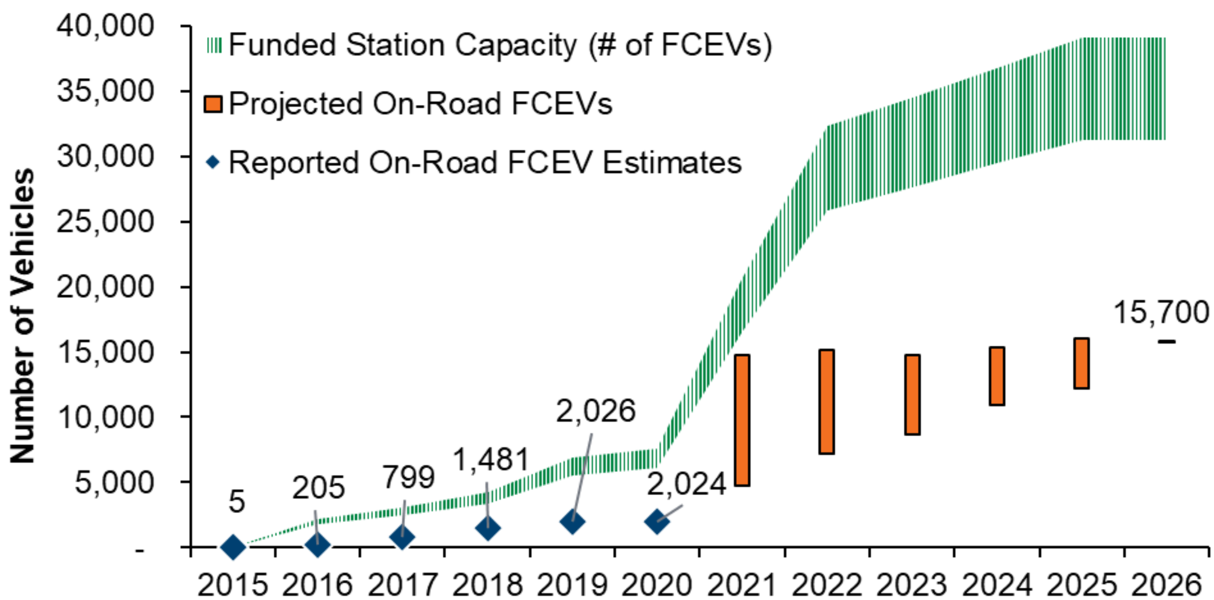
**Figure 13: Greater Los Angeles Area Station Capacity and Number of Vehicles**




Source: CEC

Figure 14 shows that the network capacity in the San Francisco Bay Area can likely support the anticipated FCEV rollout through 2026. After 2022, the region is well positioned to accept more than 30,000 FCEVs.

**Figure 14: San Francisco Bay Area Station Capacity and Number of Vehicles**

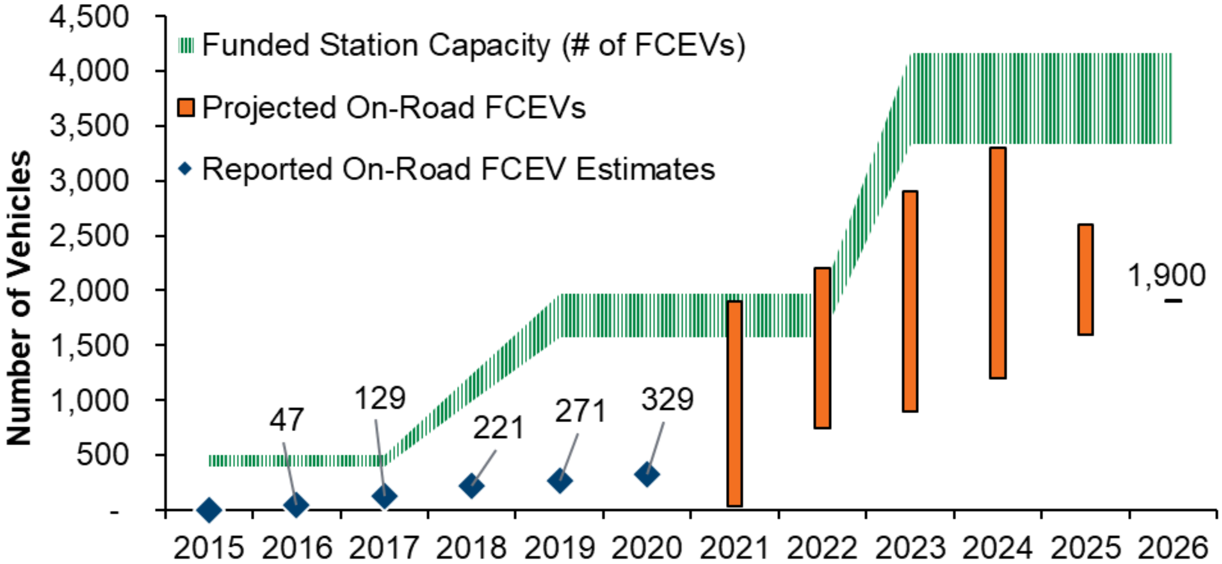



Source: CEC

Figure 15 shows that the current network capacity of the Sacramento region is enough to allow the market to grow from nearly 300 to more than 1,500 FCEVs in the coming years. However, Sacramento may approach available fueling capacity in 2021 or 2022 if FCEV rollout is as robust as manufacturers project because no new stations are planned to open until 2023.

Once those stations are open, the region should again be able to support substantial FCEV market growth.

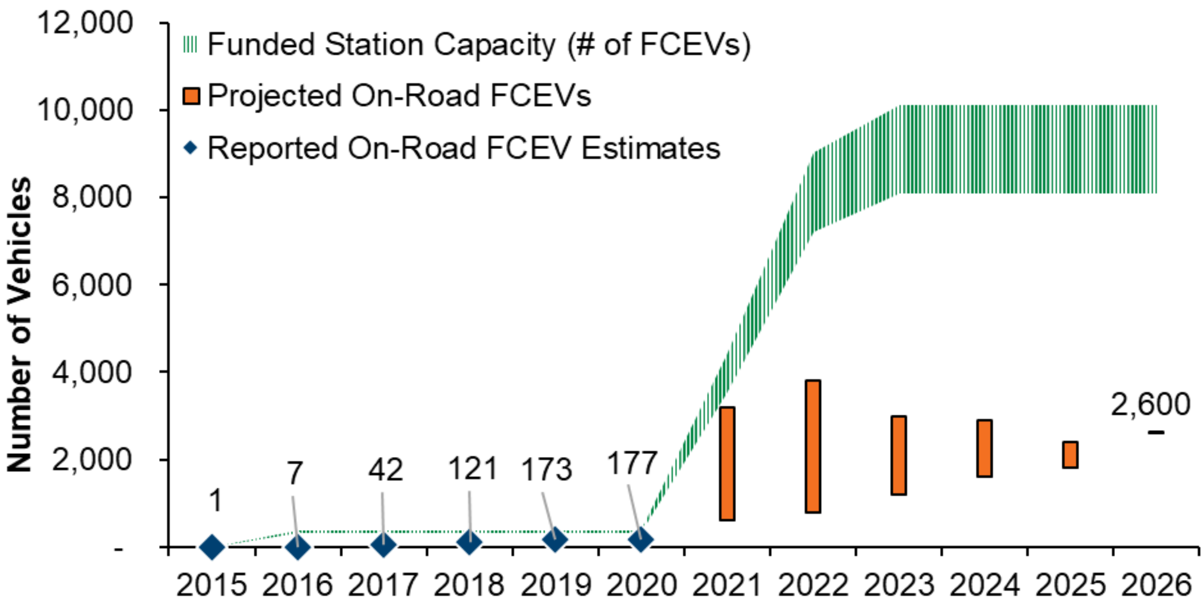
**Figure 15: Sacramento Area Station Capacity and Number of Vehicles**




Source: CEC

Figure 16 shows San Diego's network is operating near capacity and will continue to do in 2021 but should have the capacity needed to grow the market from 2022. Station developers are responding to the need for additional stations in San Diego by locating four stations resulting from GFO-19-602 in this area thus far.

**Figure 16: San Diego Area Station Capacity and Number of Vehicles**




Source: CEC

## International Station Development and Capacity

CEC staff evaluated the quantity of hydrogen stations that are reported for other countries. As shown in Table 10, there are nearly 500 hydrogen stations around the world, according to the data available on the International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE) website.[53] The IPHE numbers are the most consistent source available to staff. However, staff recognizes the numbers as "ballpark." Table 10 includes a few exceptions to the IPHE numbers.

Except for the United States, where the total stations resulting from CEC agreements in California are used, staff used the IPHE data. Japan has more hydrogen refueling stations than any other nation, and Germany has more than double the stations most countries do; however, these countries have fewer FCEVs than California. Japan has fewer than 4,000 FCEVs (including buses), and Germany has fewer than 600 FCEVs (including buses and trucks). These numbers indicate that station quantity and the related fueling capacity are not the only barriers to FCEV deployment. Other barriers could include several factors such as the small number of FCEV models available to consumers, high vehicle purchase and lease costs, high cost of hydrogen as a transportation fuel, and lack of consumer awareness. Many of the other regions where hydrogen stations have been built have relied on GHG-based automotive regulations, which are also in place in California. However, most of these regions do not also have a mechanism like the California Zero-Emission Vehicle regulation, which requires increasing proportions of auto manufacturers' sales to be zero-emission options like FCEVs, BEVs, and PHEVs.

53 Information was reported under the PARTNERS tab on the IPHE website. https://www.iphe.net/.

**Table 10: Reported National Quantities of Hydrogen Refueling Stations**

| Country | Hydrogen Refueling Stations[54] |
|---|---|
| Japan | 133 |
| Germany | 76 |
| United States | 47[55] |
| France | 37 |
| China | 35 |
| South Korea | 34 |
| United Kingdom | 13 |
| Canada | 9 |
| Norway | 6 |
| Austria | 5 |
| Netherlands | 5 |
| Italy | 4 |
| Brazil | 2 |
| Czech Republic | 2[56] |
| India | 2 |
| **Total** | **410**[57] |

Source: CEC and IPHE

## Common Themes Around the World

Throughout 2020, CEC staff discussed with representatives of public agencies around the world plans for FCEVs, hydrogen station development, and hydrogen production to serve the transportation sector. CEC and CARB staffs participate in the U.S. Department of Energy's (DOE's) Hydrogen and Fuel Cells Program strategy formation. This effort accelerates research, development, and demonstration to enable the commercialization of hydrogen and fuel cell technologies by the private sector. The DOE "H2@Scale" initiative, as covered in previous joint

54 Data are from "International Partnership for Hydrogen and Fuel Cells in the Economy," except for the number for the United States. https://www.iphe.net/. Staff assumed the numbers reported are for open retail stations unless noted otherwise.

55 The U.S. number includes 45 open retail stations resulting from CEC agreements in California, 1 station in Hawaii, and 1 station in Connecticut. There are 91 stations funded under CEC agreements total.

56 FuelCellWorks. "ORLEN Invests in the First Hydrogen Stations in the Czech Republic." https://fuelcellsworks.com/news/orlen-invests-in-the-first-hydrogen-stations-in-the-czech-republic/.

57 The total number of stations differs slightly from the number reported in CARB's 2020 Annual Assessment, potentially because of the variability of the responses from the IPHE participants.

reports, sets forth the cross-sectoral production, use, and distribution of hydrogen in manufacturing, chemical and food processing, transportation, and other industries.[58]

CEC stakeholders and experts highlighted the role of hydrogen and fuel cells in helping integrate renewable energy resources, provide long-term energy storage, and add resilience to the grid in workshops for the CEC *Integrated Energy Policy Report (IEPR)*. The *IEPR* notes that the comments provided useful data for consideration about hydrogen as a possible decarbonized resource for industrial energy and building heat and power.[59]

The U.S. and California efforts join those of several nations, regions, and jurisdictions to raise common themes in their policies and strategies. Many have established technology-neutral policies to support zero-emission transportation to meet emissions reductions targets to combat climate change. Some have prepared or are preparing specific hydrogen strategies within these broad energy strategies and systems. As examples:

- China: The State Council issued a circular on November 2, 2020, a new development plan for new energy vehicles from 2021 to 2035. New energy vehicles include BEVs, PHEVs, and FCEVs. The circular calls for "efforts to seize opportunities, consolidate development momentum, make the most of infrastructure and information technology, reinforce core competitiveness and facilitate the high-quality and sustainable development of the sector."[60]
- International Energy Agency (IEA): During its presentation on the "Future of Hydrogen" to the G20, the IEA emphasized how hydrogen can bring great technological and economic contributions to the continued acceptance of renewable energy across the globe. Although the presentation described the expense of producing hydrogen using renewable electricity as a significant barrier at present, the IEA explained how the cost of hydrogen production could fall by as much as 30 percent by 2030 because of anticipated decreased renewable energy costs and the scale-up of hydrogen.[61]
- The European Union (EU): The European Commission states in the *Hydrogen Strategy for a Climate-Neutral Europe* that hydrogen has a major role as an energy

58 U.S. Department of Energy. Office of Energy Efficiency & Renewable Energy. "H2@Scale." https://www.energy.gov/eere/fuelcells/h2scale.

59 California Energy Commission staff. *Final 2019 Integrated Energy Policy Report*. California Energy Commission. Publication Number: CEC-100-2019-001-CMF. https://www.energy.ca.gov/data-reports/reports/integrated-energy-policy-report/2019-integrated-energy-policy-report.

60 The State Council. The People's Republic of China. November 2020. "New development plan for NEVs unveiled." english.www.gov.cn/policies/latestreleases/202011/02/content_WS5f9ff225c6d0f7257693ece2.html

61 International Energy Agency (IEA) report prepared for the G20 in Karuizawa, Japan. June 2019. "The Future of Hydrogen." https://www.iea.org/reports/the-future-of-hydrogen.

carrier in mobility (long-haul, heavy-duty, and commercial vehicles), industry, and heating applications.[62]

- Germany: In its *National Hydrogen Strategy*, Germany's Federal Ministry of Economic Affairs and Energy emphasizes hydrogen as pivotal to achieving GHG neutrality by 2050. The strategy incorporates hydrogen in transport, synthetic gas production, and chemical and industrial processes. It identifies hydrogen as a sector coupler in decarbonized energy sources.[63]
- New Zealand: New Zealand published "A Vision for Hydrogen in New Zealand" in September 2019, stating that green hydrogen is a tool that will help reduce global emissions to achieve a carbon-neutral economy by 2050, and that New Zealand is partnering with Japan to develop hydrogen technology.[64]
- Japan: Japan established a basic hydrogen strategy in April 2017 to accomplish a world-leading hydrogen-based society. The strategy includes key points such as realizing low-cost hydrogen use; developing international hydrogen supply chains; expanding renewable energy in Japan; using hydrogen in power generation, mobility, and industrial processes; using fuel cell technologies; using innovative technologies for hydrogen production, highly efficient energy carriers, and low-cost fuel cells; leading international standardization; and promoting citizens' understanding and regional cooperation.[65]

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62 European Commission. July 2020. Communication for the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of Action: *Hydrogen Strategy for a Climate-Neutral Europe*. https://ec.europa.eu/energy/sites/ener/files/hydrogen_strategy.pdf.

63 Federal Ministry of Economic Affairs and Energy. June 2020. *National Hydrogen Strategy*. https://www.bmwi.de.

64 New Zealand Government. September 2019. *Green Hydrogen Strategy: a vision for hydrogen in New Zealand*. https://www.mbie.govt.nz/dmsdocument/6798-a-vision-for-hydrogen-in-new-zealand-green-paper.

65 Ministry of Economy, Trade and Industry. "Basic Hydrogen Strategy (key points)." https://www.meti.go.jp/english/press/2017/pdf/1226_003a.pdf.

# CHAPTER 6: Remaining Cost and Time Required to Establish a Network of 100 Publicly Available Hydrogen Refueling Stations

CARB reported in the 2020 Annual Evaluation that a greater acceleration in new station development will be necessary to achieve the goal of at least 100 publicly available stations by 2024 based on the historical development rates. Now, California is positioned to meet this goal because of the proposed awards under the GFO-19-602[66] using $110.7 million in Clean Transportation Program funding and $5 million in VW Mitigation Trust funding. As CARB expected, these proposed awards will achieve the acceleration necessary to reach more than 100 publicly available stations by 2024. Staff expects all 61 funded stations to be open retail and an additional 44 stations resulting from GFO-19-602 to become open retail before 2024. Combining these numbers will result in 105 open retail stations before 2024.

As of today, the Clean Transportation Program has invested nearly $166 million to fund hydrogen refueling stations to support the fuel cell electric vehicle market in California, with 91 stations resulting from CEC agreements in California. For station projects that the CEC funded between 2010 and 2014, developers contributed more than $36 million in required match funding.[67] Between 2015 and 2019, developers contributed another $24 million in match funding. Such costs relate to the cost of civil engineering, landscaping, equipment, and design to meet local governmental requirements. For the stations resulting from GFO-19-602, staff anticipates the station developers plan to contribute up to $32 million in match funding for the initial batches of stations. Combined, the total match funding contributions reach nearly $92 million or about 36 percent of the total public and private investment of $258 million.

## Economies of Scale for Hydrogen Refueling Station Equipment

GFO-19-602 offered to fund the hydrogen refueling station equipment, in contrast to previous solicitations that funded labor, materials, and supplies. The goal was to help industry advance toward developing economies of scale for hydrogen refueling station equipment.

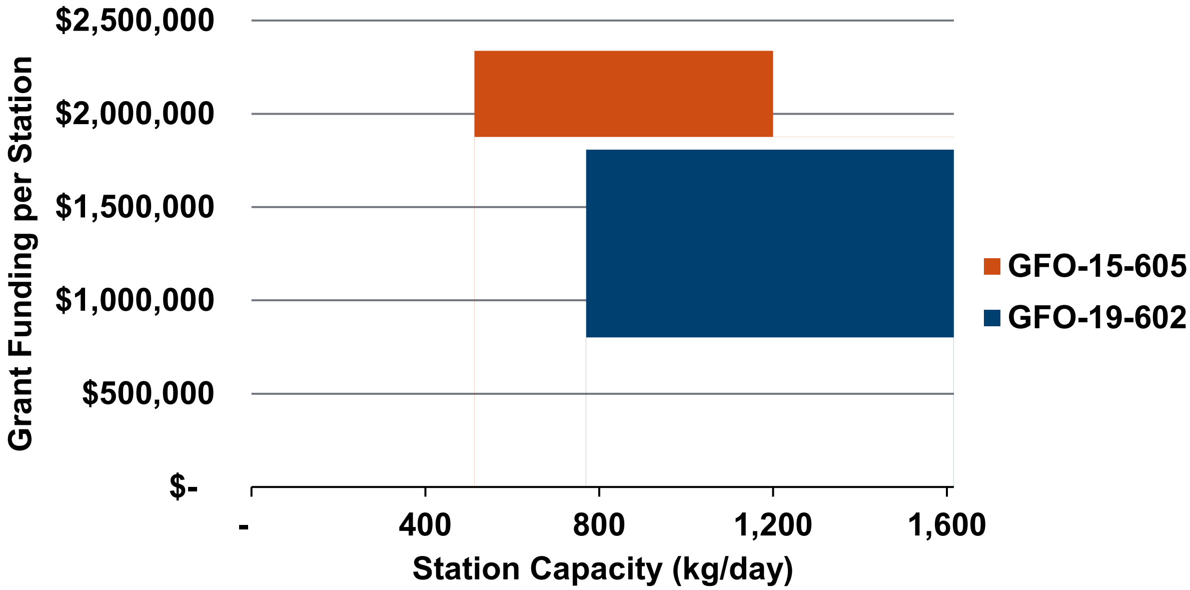
For the stations funded under GFO-15-605, the average CEC award amount per station was about $2 million for stations that dispense between 500 and 1,200 kilograms (kg) of hydrogen daily. The initial batch of stations awarded in 2020, under GFO-19-602, helped develop economies of scale for hydrogen refueling station equipment, as shown in Figure 17. Under GFO-19-602, the average proposed award amount per station is about $1.3 million for stations

66 California Energy Commission. GFO-19-602 Hydrogen Refueling Infrastructure. https://www.energy.ca.gov/solicitations/2019-12/gfo-19-602-hydrogen-refueling-infrastructure.

67 Baronas, Jean, Gerhard Achtelik, et al. *Joint Agency Staff Report on Assembly Bill 8: 2016 Annual Assessment of Time and Cost Needed to Attain 100 Hydrogen Refueling Stations in California*. California Energy Commission. Publication Number: CEC-600-2017-002. https://ww2.energy.ca.gov/2017publications/CEC-600-2017-002/CEC-600-2017-002.pdf.

sized between 770 and 1,600 kg per day. This trend of station costs decreasing while station capacity is increasing demonstrates how the Clean Transportation Program public dollars are going further than they once were.

**Figure 17: Grant Funding and Station Capacity for GFO-15-605 and GFO-19-602**

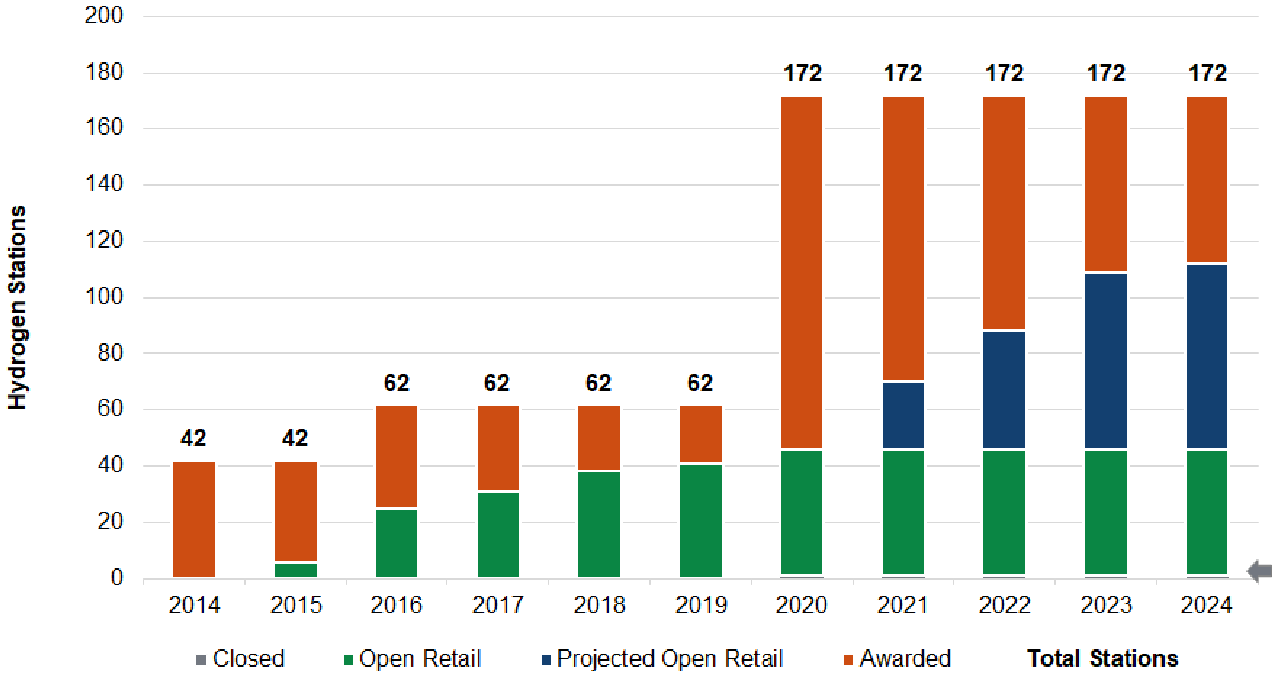



Source: CEC

## Meeting the Goal of 100 Hydrogen Refueling Stations

The Clean Transportation Program funding combined with the supplemental VW Mitigation Trust Funding is expected to deliver 111 new stations, plus three upgrades. Figure 18 shows the past progress, current position, and anticipated future of hydrogen refueling stations becoming open retail in California through 2024. In 2020, one station closed but is reported here as a CEC-funded station, and 30 stations were proposed for award under the initial batches of stations under GFO-19-602. The stations shown in Figure 18 are funded from the Clean Transportation Program and the VW Mitigation Trust Fund.

**Figure 18: Number of Hydrogen Refueling Stations Resulting From the Clean Transportation Program and VW Mitigation Trust Fund**




Source: CEC

In last year's joint report, before the COVID-19 pandemic and without the outcome of GFO-19-602, staff assumed 15 stations would become open retail per year. After speaking with station developers during the COVID-19 shelter-in-place orders to reassess current station development schedules, and by analyzing the schedules they submitted for station development for GFO-19-602, staff estimates that the station development time for the remaining stations will not be constant. Staff estimates that all the 61 funded stations[68] and 8 stations from GFO-19-602 will be open retail in 2021, and 36 stations from GFO-19-602, which includes stations proposed in the second batches under GFO-19-602, will become open retail between 2022 and 2023, as shown in Figure 18. This finding means staff estimates California will have 105 open retail stations before 2024.

Staff also estimates that the network will have 179 stations either open or in development by 2027. This includes 16 privately funded stations resulting from CEC agreements and 7 privately funded stations not connected to CEC agreements for a total of 23 privately funded stations.

## Meeting the Goal of 200 Hydrogen Refueling Stations

Despite the growth in the network, additional private sector funding will be necessary to meet the goal of 200 hydrogen refueling stations set forth by Governor Edmund G. Brown Jr.'s Executive Order B-48-18. As shown in Table 11, an updated version of the table from the

68 The West L.A. station achieved open retail and is now closed.

*2020–2023 Investment Plan Update for the Clean Transportation Program*,[69] a gap of 21 hydrogen stations will remain after 179 stations are opened. However, not all 179 stations may be built by 2025, which is the deadline for meeting the 200-station goal, which means the gap could be higher than 21 stations without additional private investments.

**Table 11: Existing Refueling Stations and the Gap to Achieve the 200 Station Goal**

| Category | Hydrogen Refueling Stations |
|---|---|
| Open Retail Stations | 45 |
| Additional Refueling Stations for Which Funding Has Been Allocated (includes anticipated funding from Clean Transportation Program) | 111 |
| Anticipated Privately Funded Stations | 23 |
| **Total** | **179** |
| 2025 Goal (from Executive Order B-48-18) | 200 |
| **Gap From the 200 Station Goal** | **21** |

Source: CEC

Based on the momentum of station rollout and the amount of match funding contributed by the private sector to the cost of designing, building, and commissioning stations thus far, the potential of the 21-station gap becoming filled by private sector funding is highly likely. Notably, the 179 stations include 16 that are privately funded under the CEC agreement with FirstElement Fuel and 7 privately funded stations under development by Iwatani, which are not connected to CEC agreements. Future stations will potentially receive credits from the Hydrogen Refueling Infrastructure provision of the CARB Low Carbon Fuel Standard program. These are encouraging signs that public investments are helping move the industry toward a sustainable model.

69 Brecht, Patrick. 2020. *2020-2023 Investment Plan Update for the Clean Transportation Program*. California Energy Commission. Publication Number: CEC-600-2020-003-REV. https://efiling.energy.ca.gov/getdocument.aspx?tn=234959.

# CHAPTER 7: Conclusions

California has developed 45 open retail hydrogen refueling stations as of December 1, 2020. The total number of stations that will result from CEC agreements, if all are funded through future appropriations and Clean Transportation Program funds, is 172. The CEC included critical milestones in GFO-19-602 to increase station developer readiness for the AHJ approvals, safety planning, site control, utility connection, and hydrogen supply. As a result, the CEC staff expects the average development time for the stations resulting from GFO-19-602 agreements to be less than two years.

The Clean Transportation Program emphasizes the importance of projects and funding activities in or near disadvantaged communities. This emphasis is shown by 52 percent of disadvantaged community residents living within a 15-minute drive time of an open retail or planned station.

Despite the effect of COVID-19 that slowed some station development, California's hydrogen refueling station network largely met the needs of FCEV drivers in the state. Hydrogen fuel demand fell markedly between the first quarter and second quarter of 2020 because of COVID-19 lockdown orders. The average amount of hydrogen dispensed per day was 3,441 kilograms in the first quarter of 2020 and only 1,913 kilograms in the second quarter. Dispensing has increased in the third quarter of 2020, to an average of 2,794 kilograms per day, but has not fully recovered to pre-COVID-19 levels.

California is not alone in its commitment to hydrogen. Countries around the world are pursuing hydrogen as a solution to decarbonize the transportation sector and other sectors of the worldwide economy. Agencies across the world, including those in Asia, North America, and Europe, report opportunities for using hydrogen-powered vehicles for people and goods movement, including light-, medium-, and heavy-duty on-road vehicles, trains, oceangoing vessels, and material-handling equipment at ports and warehouses.

The fueling capacity of today's 45 stations is 14,500 kilograms per day. The future network capacity of stations for which funding has been allocated will be nearly 160 metric tons per day. The state will have more fueling capacity than will be needed by the number of FCEVs that are projected for 2026. This additional capacity generates an FCEV deployment opportunity that has not existed in California previously. This potential for growth in FCEV fueling demand also presents new business opportunities for the production and distribution of hydrogen, preferably renewably sourced and low-to-zero-carbon hydrogen, to serve the vehicle fueling market in California.

At the end of 2023, the network of hydrogen refueling stations in California will have enough hydrogen to support nearly 150,000 light-duty fuel cell electric vehicles. As many as 13 stations in the California network will also be ready to serve the estimated 13 to 18 operational medium- and heavy-duty fuel cell trucks in California today and the other trucks that will use fuel cells and hydrogen, totaling an estimated 65, that are already funded or are in production.

California is expected to meet the AB 8 goal of at least 100 publicly available stations by January 1, 2024 with some of the stations resulting from GFO-19-602 becoming open retail before 2024. The solicitation puts California on a trajectory toward meeting the 200-station goal in Executive Order B-48-18 by increasing the number of stations to 172 which includes 16 that are privately funded under the CEC agreement with FirstElement Fuel, Inc. With the 7 anticipated privately funded stations by Iwatani Corporation of America, staff expects the hydrogen network in California to reach 179 stations. Filling the remaining gap to 200 stations is achievable with additional private sector investment and continued economies of scale for station equipment. Encouraging signs indicate that the hydrogen refueling market is moving toward a sustainable privately funded market. These achievements will be made possible through public investments and support.

# GLOSSARY

California Hydrogen Infrastructure Tool (CHIT) — a geographical information system-based tool developed in the ArcGIS environment 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.

Carbon intensity (CI) — The amount of carbon by weight emitted per unit of energy consumed. A common measure of carbon intensity is weight of carbon per British thermal unit (Btu) of energy. When there is only one fossil fuel under consideration, the carbon intensity and the emissions coefficient are identical. When there are several fuels, carbon intensity is based on the combined emissions coefficients weighted by the associated energy consumption levels.

Chevron profile — the hourly variation in gasoline sales that reflects the influence of commuter patterns on refueling.

Disadvantaged community — a community specifically targeted for investment of proceeds from the state's Cap-and-Trade Program. These investments are aimed at improving public health, quality of life, and economic opportunity in California's most burdened communities while reducing pollution that causes climate change. Disadvantaged communities are defined in CalEnviroScreen. https://oehha.ca.gov/calenviroscreen.

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

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.

Initial batch of stations — the first set of stations that an applicant proposes to deliver under GFO-19-602.

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

Sacramento Area — the counties of El Dorado, Placer, Sacramento, 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.

Tranche of stations — a collection of hydrogen refueling stations that an applicant proposes to deliver under GFO-19-602.

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

# APPENDIX A: Refueling Trends

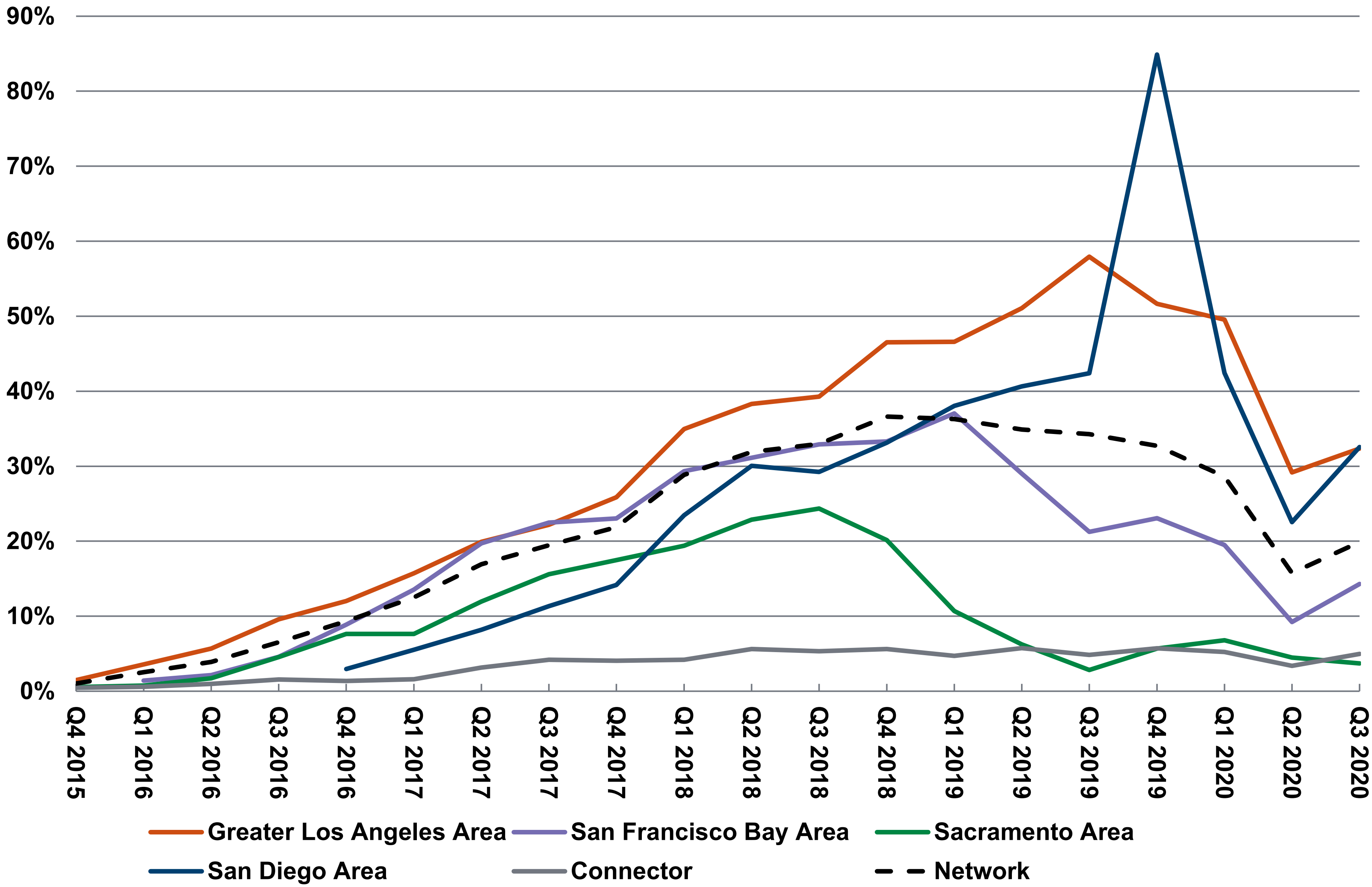
This appendix presents refueling trends from open retail stations. The CEC obtains quarterly data from station operators, and CEC staff compiles and analyzes the data. In most cases, station operators report dispensing data to the CEC through grant agreements. Some station operators stopped reporting data once their grant agreement ended, in which case CEC staff calculated the average dispensing per station for each region (Greater Los Angeles Area, San Francisco Bay Area, San Diego Area, and Sacramento Area) and assumed that the calculated average was the amount dispensed for any station in that region that did not report.

## Quarterly Trends

Figure A-1 shows the quarterly hydrogen station utilization rates for the Greater Los Angeles Area, San Francisco Bay Area, Sacramento Area, San Diego Area, and connector stations. By the end of the third quarter of 2020, the Greater Los Angeles Area's utilization is 32 percent, the San Francisco Bay Area's utilization was 14 percent, the Sacramento Area's utilization was 4 percent, the San Diego Area's utilization was 33 percent, and the connector/destination station utilization was 5 percent. The overall network utilization was 20 percent.

The overall network utilization shows a recovery from the previous drop in utilization due to the coronavirus pandemic. Furthermore, California saw a utilization percentage spike in the San Diego Area at 85 percent during the fourth quarter of 2019 before the coronavirus pandemic occurred. This spike is due to a hydrogen station serving large demand and makes a case for adding stations in the San Diego Area.

**Figure A-1: Quarterly Hydrogen Station Utilization**




Source: CEC

Figure A-2 shows the percentage of the hourly amount of fuel dispensed in the California network in the third quarter of 2020 compared with the Chevron Friday profile.[70] The Chevron Friday profile shows the hourly variation in refueling station demand for gasoline stations.

The hydrogen refueling profile follows the gasoline refueling closely. However, because the California network of open hydrogen stations is small compared with the roughly 8,000 gasoline stations that are reported to be in operation, having one station down for maintenance has a greater effect on the overall hydrogen station network than it would on the larger gasoline station network. In addition, FCEV drivers sometimes do not fuel at the times that they would normally depending on fuel availability. This situation may be one reason that the hydrogen dispensing profile differs a little from the Chevron Friday profile.

Figures A-3 through A-6 show regional analyses of average dispensing by time of day based on data from the fourth quarter of 2019 through the third quarter of 2020.

Figure A-7 shows the percentage of fuel dispensed by day of the week from the fourth quarter of 2019 through the third quarter of 2020.

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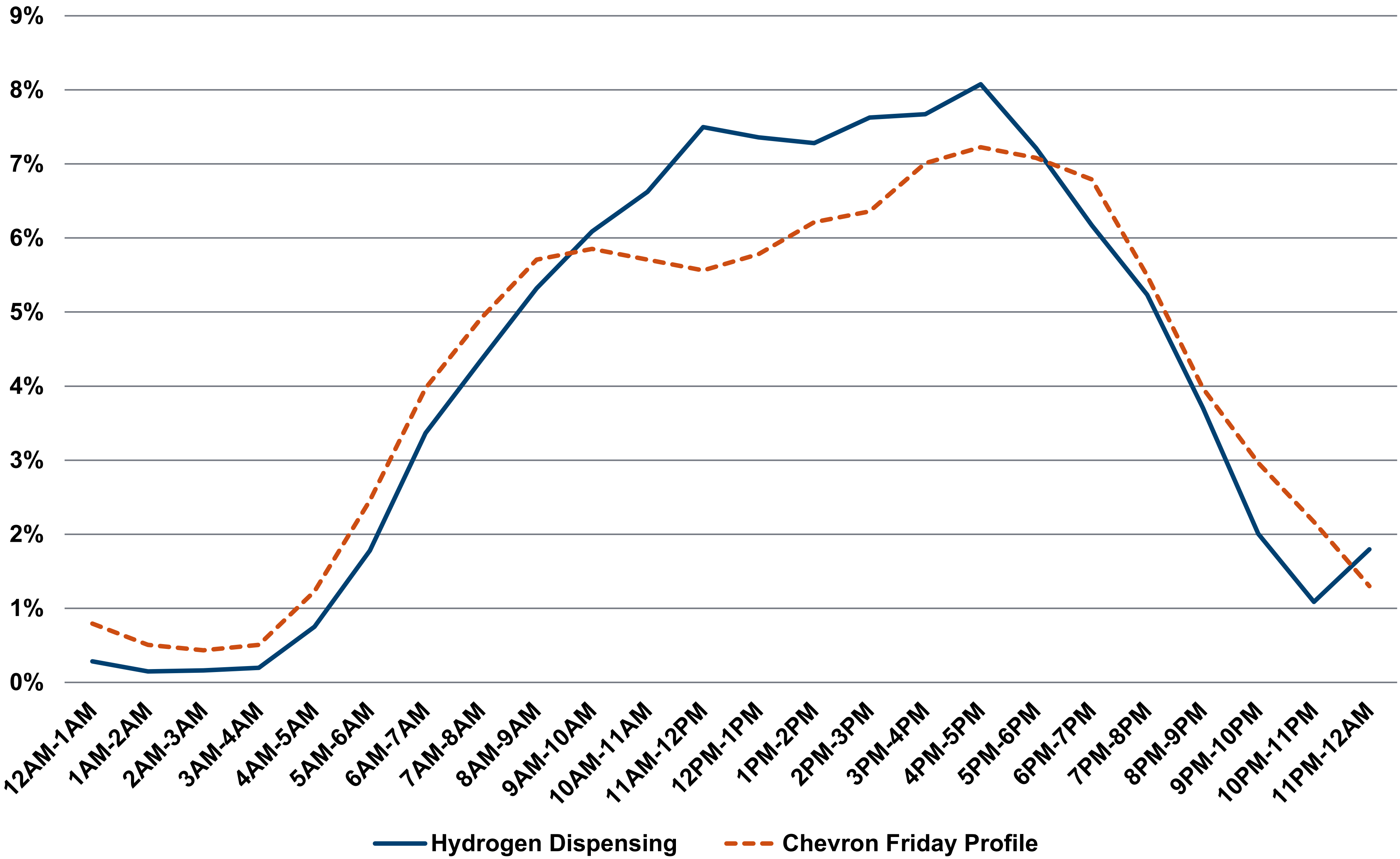
70 The "Chevron profile" is a profile developed based on fuel dispensing data from gas stations provided by Chevron. Source: Chen, Tan-Ping. *Final Report: Hydrogen Delivery Infrastructure Options Analysis*. Nexant. DOE Award Number: DE-FG36-05GO15032. http://energy.gov/sites/prod/files/2014/03/f11/delivery_infrastructure_analysis.pdf.

**Figure A-2: Network Utilization Percentage by Time of Day**




Source: CEC

**Figure A-3: Greater Los Angeles Area Refueling by Time of Day**

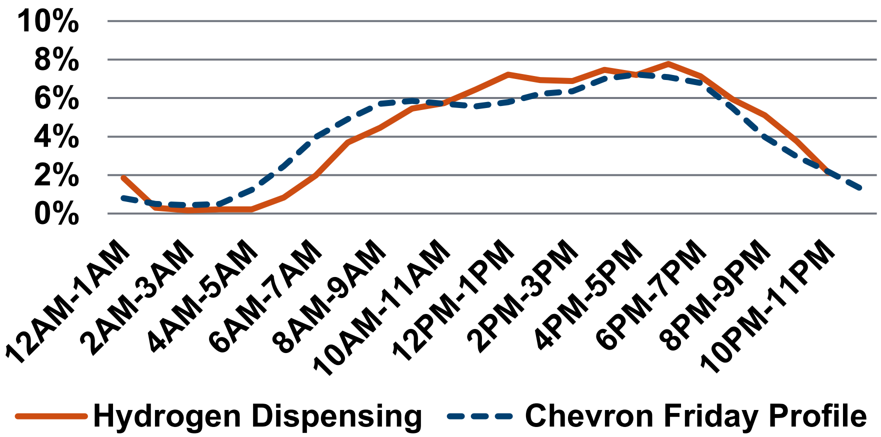



**Figure A-4: San Francisco Bay Area Refueling by Time of Day**

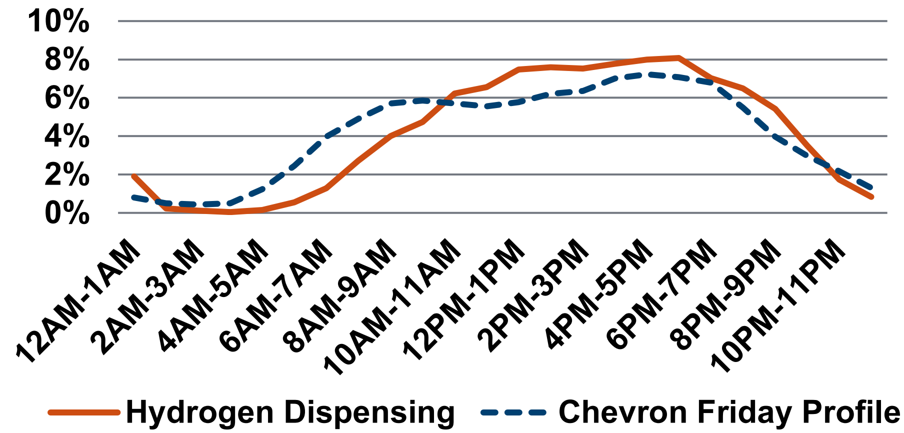



**Figure A-5: San Diego Area Refueling by Time of Day**

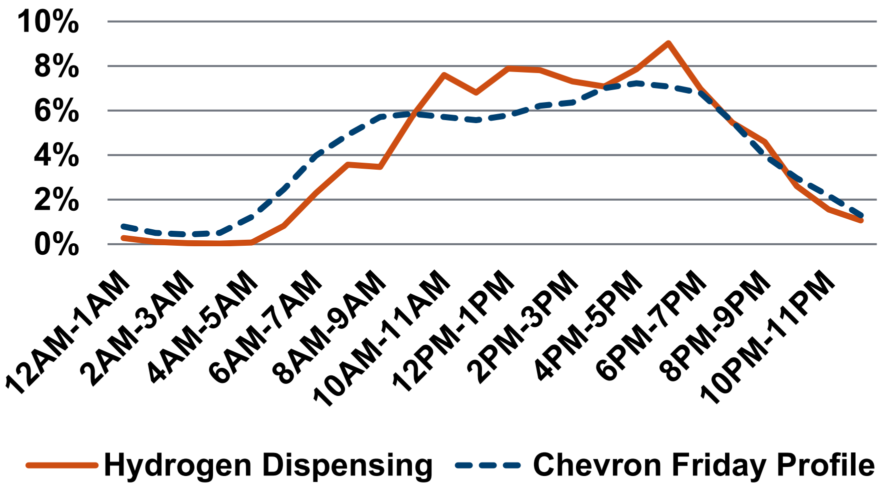
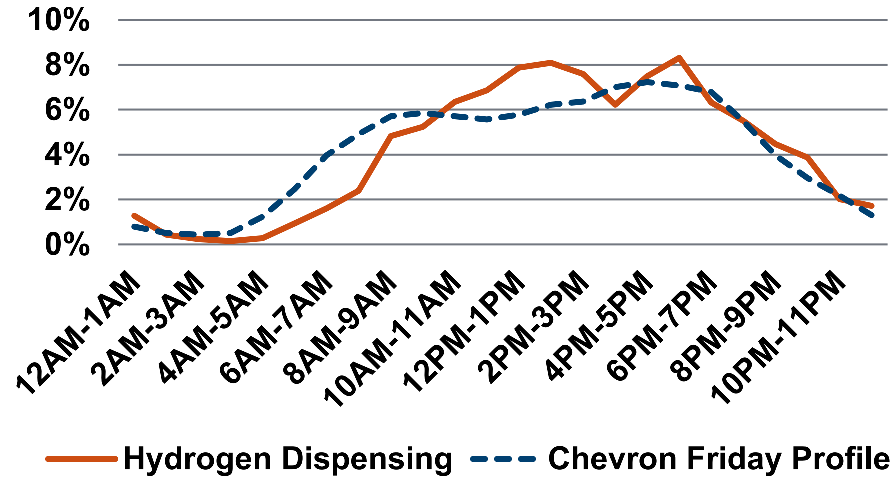
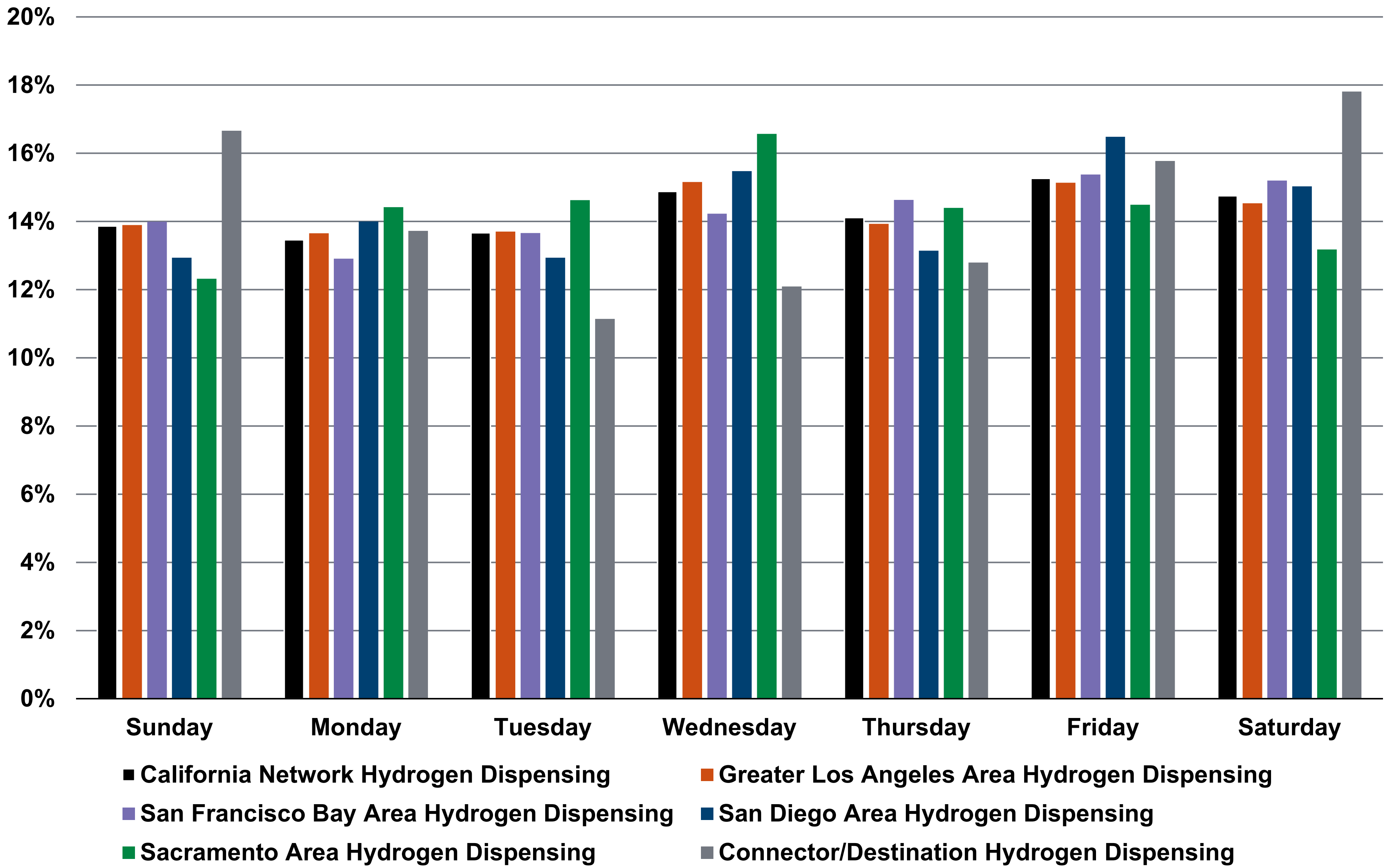



**Figure A-6: Sacramento Area Refueling by Time of Day**




Source: CEC

**Figure A-7: Percentage of Fuel Dispensed by Day of Week**




Source: CEC

# APPENDIX B: List of Hydrogen Refueling Stations in California

Table B-1 lists the 45 open retail hydrogen refueling stations, with photo, street address, open retail date, and funding solicitation, resulting from the Clean Transportation Program. CEC staff took the photo if no photo credit is listed. Table B-2 lists the stations that are in the process of becoming open retail.

**Table B-1: Open Retail Stations Resulting From Clean Transportation Program**

| | | |
|---|---|---|
|  Photo Credit: Air Liquide |  |  Photo Credit: California Fuel Cell Partnership |
| Anaheim | Campbell | Citrus Heights |
| 3731 East La Palma Avenue | 2855 Winchester Boulevard | 6141 Greenback Lane |
| 11/29/2016 | 6/9/2016 | 12/18/2018 |
| PON-12-606 | PON-13-607 | GFO-15-605 |
|  Photo Credit: FirstElement Fuel |   |   Photo Credit: California Fuel Cell Partnership |
| Coalinga | Costa Mesa | CSULA |
| 24505 West Dorris Avenue | 2050 Harbor Boulevard | 5151 State University Drive |
| 12/11/2015 | 1/21/2016 | 11/20/2019 |
| PON-13-607 | PON-13-607 | PON-13-607 (Operation and Maintenance Only) |

Source: CEC, photo credit: CEC unless otherwise stated

| | | |
|---|---|---|
|  |  |  Photo Credit: Linde |
| Del Mar (San Diego) | Diamond Bar | Emeryville[71] |
| 3060 Carmel Valley Road | 21865 East Copley Drive | 1172 45th Street |
| 12/2/2016 | 8/18/2015 | 11/19/2018 |
| PON-13-607 | PON-09-608 | PON-13-607 |
|  Photo Credit: Air Products and Chemicals, Inc. |  Photo Credit: FirstElement Fuel |  Photo Credit: FirstElement Fuel |
| Fairfax (Los Angeles) | Fountain Valley | Fremont |
| 7751 Beverly Boulevard | 18480 Brookhurst Street | 41700 Grimmer Boulevard |
| 5/2/2016 | 7/6/2020 | 9/7/2017 |
| PON-09-608 | GFO-15-605 | PON-13-607 |

Source: CEC, photo credit: CEC unless otherwise stated

71 Messer Group and CVC Capital Partners Fund VII acquired Linde's gases business in North America on March 1, 2019. The Emeryville station, which Linde developed and operated, now is recognized as a Messer station.

| | | |
|---|---|---|
|  |  |  |
| Hayward | Hollywood (Los Angeles) | La Cañada Flintridge |
| 391 West A Street | 5700 Hollywood Boulevard | 550 Foothill Boulevard |
| 4/27/2016 | 11/10/2016 | 1/25/2016 |
| PON-13-607 | PON-13-607 | PON-13-607 |
| <br>Photo Credit: FirstElement Fuel | <br>Photo Credit: Air Products and Chemicals, Inc. | <br>Photo Credit: Air Liquide |
| Lake Forest | Lawndale | LAX (Los Angeles) |
| 20731 Lake Forest Drive | 15606 Inglewood Avenue | 10400 Aviation Boulevard |
| 3/18/2016 | 6/22/2017 | 12/21/2018 |
| PON-13-607 | PON-09-608 | SCAQMD Contract |

Source: CEC, photo credit: CEC unless otherwise stated

| | | |
|---|---|---|
|  | <br>Photo Credit:<br>FirstElement Fuel | <br>Photo Credit:<br>FirstElement Fuel |
| Long Beach | Mill Valley | Mission Hills |
| 3401 Long Beach Boulevard | 570 Redwood Highway | 15544 San Fernando Mission Blvd |
| 2/22/2016 | 6/16/2016 | 10/26/2020 |
| PON-13-607 | PON-13-607 | GFO-15-605 |
| <br>Photo Credit:<br>Iwatani Corporation | <br>Photo Credit: California Fuel Cell Partnership | <br>Photo Credit:<br>Ontario Station |
| Mountain View | Oakland | Ontario |
| 830 Leong Drive | 350 Grand Avenue | 1850 E. Holt Boulevard |
| 2/28/2018 | 9/20/2019 | 4/24/2018 |
| PON-12-606 | GFO-15-605 | PON-13-607 |

Source: CEC, photo credit: CEC unless otherwise stated

| | | |
|---|---|---|
|  Photo Credit: Air Liquide |  Photo Credit: FirstElement Fuel |  Photo Credit: ITM Power |
| Palo Alto | Playa Del Rey (Los Angeles) | Riverside |
| 3601 El Camino Real | 8126 Lincoln Boulevard | 8095 Lincoln Avenue |
| 12/20/2018 | 8/18/2016 | 3/8/2017 |
| PON-13-607 | PON-13-607 | PON-13-607 |
|  |  Photo Credit: California Fuel Cell Partnership |  Photo Credit: California Fuel Cell Partnership |
| Sacramento | San Francisco Harrison Street | San Francisco Mission Street |
| 3510 Fair Oaks Boulevard | 1201 Harrison Street | 3550 Mission Street |
| 5/22/2019 | 12/2/2019 | 2/14/2020 |
| GFO-15-605 | GFO-15-605 | GFO-15-605 |

Source: CEC, photo credit: CEC unless otherwise stated

| | | |
|---|---|---|
|  Photo Credit: California Fuel Cell Partnership |  Photo Credit: FirstElement Fuel |  Photo Credit: Iwatani Corporation |
| San Francisco Third Street | San Jose | San Juan Capistrano |
| 551 Third Street | 2101 North First Street | 26572 Junipero Serra Road |
| 11/6/2019 | 1/15/2016 | 12/23/2015 |
| GFO-15-605 | PON-13-607 | PON-09-608 |
|  Photo Credit: Iwatani Corporation |  Photo Credit: FirstElement Fuel |  |
| San Ramon[72] | Santa Barbara | Santa Monica |
| 4475 Norris Canyon Road | 150 South La Cumbre Road | 1819 Cloverfield Boulevard |
| 7/26/2017 | 4/9/2016 | 2/1/2016 |
| PON-13-607 | PON-13-607 | PON-09-608 |

Source: CEC, photo credit: CEC unless otherwise stated

72 Iwatani Corporation of America acquired four hydrogen refueling stations that were previously owned by Messer (formerly Linde, LLC) as announced on May 13, 2019. The four stations are Mountain View, San Juan Capistrano, San Ramon, and West Sacramento.

| | | |
|---|---|---|
|  | <br>Photo Credit:<br>FirstElement Fuel |  |
| Saratoga | South Pasadena | South San Francisco |
| 12600 Saratoga Avenue | 1200 Fair Oaks Avenue | 248 South Airport Boulevard |
| 3/14/2016 | 4/10/2017 | 2/12/2016 |
| PON-13-607 | PON-13-607 | PON-13-607 |
|  | <br>Photo Credit: SCAQMD | <br>Photo Credit:<br>FirstElement Fuel |
| Thousand Oaks | Torrance | Truckee |
| 3102 Thousand Oaks Boulevard | 2051 West 190th Street | 12105 Donner Pass Road |
| 3/30/2018 | 8/18/2017 | 6/17/2016 |
| PON-13-607 | SCAQMD Contract | PON-13-607 |

Source: CEC, photo credit: CEC unless otherwise stated

| | | |
|---|---|---|
|  |  | Photo Credit:<br>Iwatani Corporation |
| UC Irvine | West LA<br>(CLOSED) | West Sacramento |
| 19172 Jamboree Road | 11261 Santa Monica Boulevard | 1515 South River Road |
| 11/12/2015 | 10/29/2015 | 7/7/2015 |
| PON-09-608 | PON-09-608 | PON-09-608 |

| |
|---|
| Photo Credit: Air Products and Chemicals, Inc. |
| Woodland Hills |
| 5314 Topanga Canyon Road |
| 10/5/2016 |
| PON-12-606 |

Source: CEC, photo credit: CEC unless otherwise stated

Table B-2 lists the locations of stations resulting from CEC agreements under the Clean Transportation Program in planning, permitting, or under construction. The stations are listed in alphabetical order by city. Also provided is the CEC solicitation or contract under which the station received funding.

**Table B-2: Stations Resulting From Clean Transportation Program in Development**

| Station Address (A to Z by city) | Solicitation or Contract |
|---|---|
| 26813 La Paz Road, Aliso Viejo, CA 92656 | GFO-19-602 |
| 102 East Duarte Road, Arcadia, CA 91006 | GFO-19-602 |
| 17325 Pioneer Boulevard, Artesia, CA 90701 | GFO-19-602 |
| 14477 Merced Avenue, Baldwin Park, CA 91706 | GFO-19-602 |
| 1250 University Avenue, Berkeley, CA 94702 | GFO-15-605 |
| 6392 Beach Boulevard, Buena Park, CA 90621 | GFO-19-602 |
| 145 W. Verdugo Avenue, Burbank, CA 91502 | 600-12-018 |
| 800 North Hollywood Way, Burbank, CA 91505 | GFO-19-602 |
| 2911 Petit Street, Camarillo, CA 93012 | GFO-19-602 |
| 337 E. Hamilton Avenue, Campbell, CA 95008 | GFO-15-605 |
| 7170 Avenida Encinas, Carlsbad, CA 92011 | GFO-19-602 |
| 12610 East End Avenue, Chino, CA 91710 | PON-12-606 |
| 2600 Pellissier Place, City of Industry, CA 90601 | GFO-19-602 |
| 605 Contra Costa Boulevard, Concord, CA 94523 | GFO-15-605 |
| 2995 Bristol Street, Costa Mesa, CA 92626 | GFO-19-602 |
| 11284 Venice Boulevard, Culver City, CA 90230 | GFO-15-605 |
| 21530 Stevens Creek Boulevard, Cupertino, CA 95014 | GFO-19-602 |
| 3160 Carlson Boulevard, El Cerrito, CA 94530 | GFO-19-602 |
| 13397 Folsom Boulevard, Folsom, CA 95630 | GFO-19-602 |
| 16880 Slover Avenue, Fontana, CA 92337 | GFO-19-602 |
| 47700 Warm Springs Boulevard, Fremont, CA 94539 | GFO-19-602 |
| 3402 Foothill Boulevard, Glendale, CA 91214 | GFO-19-602 |
| 104 North Coast Highway, Laguna Beach, CA 92651 | GFO-15-605 |
| 2589 North Lakewood Boulevard, Long Beach, CA 90815 | GFO-19-602 |
| 988 North San Antonio Road, Los Altos, CA 94022 | GFO-19-602 |
| 5164 West Washington Boulevard, Los Angeles, CA 90016 | GFO-19-602 |
| 666 North Santa Cruz Avenue, Los Gatos, CA 95030 | GFO-19-602 |
| 705 West Huntington Drive, Monrovia, CA 91016 | GFO-19-602 |
| 1600 Jamboree Boulevard, Newport Beach, CA 92660 | GFO-19-602 |
| 5821 Nave Drive, Novato, CA 94949 | GFO-19-602 |
| 4280 Foothill Boulevard, Oakland, CA 94601 | GFO-19-602 |
| 2160 South Euclid Avenue, Ontario, CA 91762 | GFO-19-602 |

| Station Address (A to Z by city) | Solicitation or Contract |
|---|---|
| 615 South Tustin Street, Orange, CA 92866 | GFO-19-602 |
| 67 Moraga Way, Orinda, CA 94563 | GFO-19-602 |
| 290 South Arroyo Parkway, Pasadena, CA 91105 | GFO-19-602 |
| 475 North Allen Avenue, Pasadena, CA 91106 | GFO-19-602 |
| 313 West Orangethorpe Avenue, Placentia, CA 92870 | GFO-19-602 |
| 28103 Hawthorne Boulevard, Rancho Palos Verdes, CA 90275 | PON-09-608 |
| 503 Whipple Avenue, Redwood City, CA 94063 | GFO-15-605 |
| 3505 Central Avenue, Riverside, CA 92506 | GFO-19-602 |
| 5551 Martin Luther King Jr. Boulevard, Sacramento, CA 95820 | 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 |
| 1666 1st Avenue, San Diego, CA 92101 | GFO-19-602 |
| 1832 West Washington Street, San Diego, CA 92103 | GFO-19-602 |
| 5494 Mission Center Road, San Diego, CA 92108 | GFO-15-605 |
| 1110 West Gladstone Street, San Dimas, CA 91773 | GFO-19-602 |
| 101 Bernal Road, San Jose, CA 95119 | GFO-15-605 |
| 3939 Snell Avenue, San Jose, CA 95136 | GFO-19-602 |
| 510 East Santa Clara Street, San Jose, CA 95112 | GFO-19-602 |
| 24551 Lyons Avenue, Santa Clarita, CA 91321 | PON-09-608 |
| 266 College Avenue, Santa Rosa, CA 95401 | GFO-19-602 |
| 14478 Ventura Boulevard, Sherman Oaks, CA 91423 | GFO-15-605 |
| 3780 Cahuenga Boulevard, Studio City, CA 91604 | GFO-15-605 |
| 10908 Roscoe Boulevard, Sun Valley, CA 91352 | GFO-19-602 |
| 1296 Sunnyvale Saratoga Road, Sunnyvale, CA 94087 | GFO-15-605 |
| 24505 Hawthorne Boulevard, Torrance, CA 90505 | GFO-19-602 |
| 14244 Newport Avenue, Tustin, CA 92780 | GFO-19-602 |
| 15710 Roscoe Boulevard, Van Nuys, CA 91406 | GFO-19-602 |
| 2121 Harbor Boulevard, Ventura, CA 93001 | GFO-19-602 |
| 17287 Skyline Boulevard, Woodside, CA 94062 | PON-13-607 |

Source: CEC

# APPENDIX C: Cumulative Number of Stations and Capacity

Since 2017, the cumulative number of stations and associated cumulative capacity changed with new funding solicitations, station replacements, stations that did not reach completion, and station closures. Table C-1 shows the changes in the cumulative number of stations and nameplate capacity for the stations network over time. The 50 stations shown in 2017 were funded under previous solicitations and contracts.

**Table C-1: Cumulative Number and Capacity of Stations Resulting From Clean Transportation Program (Since 2017)**

| Year | Description | Cumulative Number of Stations | Total Nameplate Capacity of Stations (kg/day) |
|---|---|---|---|
| 2017 | Clean Transportation Program provided Operations and Maintenance funds to CARB-funded CSULA station (60 kg/day), so the station was added to the Clean Transportation Program-funded stations. | 50 | 9,365 |
| 2017 | The stations planned for Encinitas (180 kg/day), and 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 | 8,485 |
| 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 | 13,665 |
| 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 | 13,275 |
| 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 | 14,875 |

| Year | Description | Cumulative Number of Stations | Total Nameplate Capacity of Stations (kg/day) |
|---|---|---|---|
| 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 | 17,235 |
| 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 | 16,875 |
| 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 | 16,650 |
| 2019 | Station capacities were updated with the numbers reported to the CARB LCFS Hydrogen Refueling Infrastructure (HRI) credit program.[73] | 62 | 24,327 |
| 2020 | Two more stations (Concord and Redwood City) were approved for HRI credits and station capacities were updated using the numbers reported to the HRI credit program. (+1,400 kg/day) | 62 | 25,727 |
| 2020 | West Los Angeles station (180 kg/day) closed. The map in Figure 1 and Figure 3 depicts the West Lost Angeles station as a red dot in the map to convey the closure of the station. | 61 | 25,547 |
| 2020 | 30 stations were approved at the CEC business meeting in December. | 91 | 68,690 |

Source: CEC

73 California Air Resources Board. "LCFS ZEV Infrastructure Crediting." https://ww3.arb.ca.gov/fuels/lcfs/electricity/zev_infrastructure/zev_infrastructure.htm.

# APPENDIX D: References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