Analysis of Proposed Income Tax Credit for Hydrogen Fueling Infrastructure Development

June 2021

Prepared For:
California Hydrogen Coalition

Prepared By:
Brad Williams
Capitol Matrix Consulting

About the Author

Brad Williams joined Capitol Matrix Consulting (CMC) in 2011 after serving in various positions in California state government for nearly 33 years. During the past ten years at CMC, Mr. Williams has been involved in hundreds of projects covering energy and regulatory policy, economic forecasting, economic impact analysis, and state and local government taxation and finance. During his prior three decades in state government, Mr. Williams served in key positions in the State Treasurer's office, Assembly Appropriation Committee, and the Legislative Analyst's Office, where he was chief economist and Director of Budget Overview and Fiscal Forecasting. During his government career, Mr. Williams was regarded as one of the state's top economic and fiscal experts, and he was recognized by The Wall Street Journal as the most accurate forecaster of the California economy in the 1990s.

Table of Contents

Executive Summary

To help achieve its carbon emission reduction goals, California has set ambitious targets for increased reliance on zero emission vehicles (ZEVs) over the next 25 years. These include 5 million light-duty ZEVs on the road by 2030, and, under Governor Newsom's September 2019 executive order, a requirement that 100 percent of light vehicle sales be ZEVs starting in 2035, and that 100 percent of heavy-duty trucks on the road be ZEVs by 2045.

While most ZEVs sold to date have been battery-powered electric vehicles (BEVs), state leaders have recognized the important and complementary role that hydrogen-powered fuel cell electric vehicles (FCEVs) can play in California's carbon-free future. As a result, California has embraced ambitious goals for FCEVs, including a 20 percent share of the ZEV market by 2030 and construction of 1,000 fueling stations to fuel these vehicles.

Initial development of a hydrogen fueling infrastructure has been supported primarily by AB 8 (Perea, 2013), which sets aside $20 million per year for this purpose. These set-asides (allocated through competitive grant programs administered by the California Energy Commission) have contributed to the opening of 46 stations to date, with another 63 in planning, permitting or construction phases. However, the California Air Resources Board indicated in its most recent assessment of hydrogen fueling infrastructure adequacy that the pace of construction needs to increase if California is going to meet its goals for the FCEV market, and that additional state support beyond what is provided in AB 8 will be crucial to achieving those goals.

To this end, the California Hydrogen Coalition is sponsoring legislation (Assembly Bill 1312, Rodriguez) that provides personal and corporate income tax credits for investment in hydrogen fueling stations, production facilities, and distribution assets. These credits would start at 30 percent of costs and decline over time as specific benchmarks are met regarding the number of fueling stations opened and the amount of green hydrogen production in the state. The credit program would expire at the end of 2032. The bill also establishes increasing targets for the share of hydrogen production that must come from renewable resources.

The objective of the tax credit is to accelerate development of a hydrogen fueling infrastructure, stimulate growth in the FCEV market, and help achieve scale economies in the refueling network. The resulting cost-declines and revenue growth will enable the fueling infrastructure to become self-sustaining, no longer needing state support.

The California Hydrogen Coalition commissioned our firm to estimate the job impacts associated with the construction and operation of the hydrogen fueling infrastructure supported by the proposed credit, and to address several other questions related to the tax credit program. Our key findings are:

1. **Proposed tax credit will create thousands of jobs.** Construction of 1,000 stations and associated production facilities will support between 2,280 and 3,720 jobs annually over the 10-year period the credit is in effect (the range depends on how much hydrogen is supplied by production facilities constructed inside versus outside of California). In addition, a growing number of permanent jobs will be created as construction is completed and new facilities come online. Jobs supported by operations and maintenance of the expanded hydrogen fueling infrastructure start at between 1,370 and 1,810 in 2023 and rise to between 12,010 and 13,460 by 2032.

   Importantly, 80 percent to 85 percent of the funding for the jobs over the 10-year period in which the credit is in effect will come from private investors, as opposed to taxpayers or utility ratepayers (which have heavily subsidized battery chargers). Assuming that the credit is successful in making a hydrogen fueling infrastructure development sustainable, job totals for both construction and, especially, operations will grow substantially in the future as the FCEV market continues to expand in line with increasing state targets for ZEVs. These jobs will be 100-percent financed through private investment.

2. **The jobs will be high paying.** The jobs created by the construction and operation of a hydrogen fueling infrastructure would average about $84,000 per year (excluding benefits). Average pay of permanent jobs tied to the operations and maintenance of production hydrogen fueling facilities would be over $91,000 per year. These averages compare favorably to the $71,140 private sector average wage for all industries in California. The above-average rate reflects the large number of good-paying jobs involved in engineering, construction, installation, equipment maintenance, and hydrogen testing.

3. **An income tax credit is a cost-effective tool for incentivizing development of a hydrogen fueling infrastructure.** This is especially the case given the need for a rapid acceleration in the pace of construction. Key features making the credit an attractive option are: it is simple to administer and avoids costly and time-consuming paperwork involved in competitive grant programs; it is market-driven, with developers having incentives to minimize costs and maximize usage of the stations in order to achieve positive returns on investment; the declining rate structure provides incentives for developers to "get in early," thereby accelerating the pace of construction and driving down costs; and the credit has a successful precedent in the solar industry – specifically, the California Solar Initiative (discussed below).

4. **California's positive experience with solar incentives holds promise for the proposed credit.** In the year following federal adoption of a solar tax credit, California enacted the California Solar Initiative (CSI). This was a $3.3 billion utility-ratepayer funded incentive program with the goals of (1) installing 3,000 megawatts (MW) of new distributed solar generation between 2007 and 2016, and (2) creating a self-sustaining solar industry free from ratepayer subsidies by the conclusion of the 10-year period. Although not an income tax credit, the CSI rebate program shared similar features, including relative simplicity, certainty, results-orientation, and a declining rebate amount as energy production goals were achieved.

The results of the CSI program were extremely positive. The 3,000-megawatt goal was met in 2015 – a year early – and solar installations continued to expand after the rebate ended, suggesting that developers were fully weaned of additional state assistance by the end of the program (though they continued to be eligible for the federal income tax credit). Overall, combined state and federal incentives have resulted in over $60 billion in private investment in solar (total includes both "rooftop" solar systems and larger utility scale commercial systems), or about 2 dollars of private investment per dollar of (primarily) federal and state-combined funding.

5. **The $20 million annual AB 8 set-aside has yielded strong private investment.** To date, the California Energy Commission has allocated $165 million for hydrogen stations. About $155 million of this total has been allocated through grant solicitations for light vehicle stations in 2015 and 2019. These state grants attracted $284 million in private investment – or more than $1.80 of private investment for each $1.00 spent by the state.

   Also of note is the major decline in the state funding percentage between the first grant solicitation in 2015, when the state's share was almost two-thirds of total investment costs, and the second grant solicitation in 2019, when the state's contribution dropped to less than one-third of total costs. The declining state share reflects major progress made by station developers in reducing costs and increasing station capacity. One company representative reported that their per-station costs fell by nearly one-half while fueling capacity nearly doubled between the 2015 and 2019 grant offerings. These declining cost trends bode well for the success of the proposed tax credit program. This is because declining costs enable private investors to attain positive returns on investment even as state support diminishes.

6. **Private investment resulting from the proposed tax credit will be even higher.** We estimate that the proposed credit will result in investments of $2.4 billion in fueling stations and $4.4 billion in production facilities and distribution assets, for a combined total of $6.8 billion. The state's share of the combined total will range from 15 percent to 20 percent. The range depends on how much investment in new hydrogen facilities serving California markets will occur inside California (thereby receiving a tax credit) versus outside of California (thereby not receiving a tax credit). Each $1.00 of state funds would leverage between $5.00 and $6.70 of private investment.

7. **State's cost per vehicle for hydrogen fueling infrastructure will drop sharply.** Based on fueling capacity of hydrogen stations funded to date, we estimate that the state costs of fueling infrastructure is currently about $5,320 per FCEV. This cost will fall to between $1,120 and $1,440 per vehicle by the conclusion of the 10-year period.

8. **Most taxpayer/ratepayer support for infrastructure to date has been for battery chargers.** We estimate that combined (public and private) investment allocated for battery charging and hydrogen fueling infrastructure has totaled about $4 billion over the past decade. Of this total, slightly less than $3.6 billion has been for the battery charging infrastructure and about $450 million has been for hydrogen fueling

stations. We estimate that taxpayer and utility ratepayer support for the battery charging infrastructure has been roughly $2.3 billion to date, which implies a subsidy rate of 64 percent. State spending for hydrogen fueling stations has totaled $165 million to date, representing a subsidy rate of about 37 percent.

9. **Increased public support for hydrogen fueling infrastructure is important.** An expanded FCEV market will be necessary in order for all Californians to have viable options for meeting their transportation needs. For example, BEV charging infrastructure has not fully reached the millions of California families living in multifamily units where there is a lack of dedicated space – and in some cases a lack of adequate electrical infrastructure – for overnight charging. For these families, a network of hydrogen fueling stations would offer the same advantage as gasoline stations do today – specifically, the ability to quickly refuel at an offsite location.

10. **Costs for BEV charging and related infrastructure will rise sharply as state moves toward zero-emission transportation goals.** Based on projections of charging needs made by the California Energy Commission, along with our own projections of costs for battery chargers, we estimate that investment in battery charging would need to expand by about $7.5 billion beyond what is currently allocated through the end of this decade to meet the state's goals of 5 million ZEVs on the road by 2030. Cumulative costs would further rise to over $45 billion by 2045 to accommodate demand from future growth in ZEVs on the road under the Governor's 2019 executive orders.

    A shift to an all-electric energy system would also require major upgrades to the electrical grid. A report issued jointly by the CPUC, Energy Commission, and Air Resources Board found that, under its "high electrification" scenario (which is consistent with the Governor's executive order for an all-electric transportation system), California would incur additional investment requirements of $28 billion relative to the baseline. We estimate that $15 billion of the total would be due to electrification of the state's transportation system, while the remainder would be for electrification of buildings throughout the state.

11. **Taxpayer/ratepayer costs could be minimized by an expansion of the FCEV market.** Potentially significant savings would occur for several reasons:

    - Hydrogen fueling technology is in its early stages of development and thus can be expected to experience major cost-declines in the future as technology advances and scale economies are attained. As one example of these potential savings, a major study of comparative costs of battery and hydrogen fuel technologies deployed in Germany (and discussed in the main report) found that at a high degree of ZEV market penetration, hydrogen fuel infrastructure costs could be 20 percent less than BEV infrastructure costs.

- Hydrogen production facilities have the ability to ramp and down quickly, enabling them to take advantage of surplus renewable electricity generated at certain times of the day and over the course of the year. This, in combination with the ability to store hydrogen fuel for lengthy periods, would result in cost-efficient utilization of otherwise surplus power in the electrical grid.
- A more balanced mix of FCEVS and BEVs would also enable California to scale back costly investments that would otherwise be needed in an all-BEV system, such as in the above-mentioned dense urban multifamily units where charging is constrained by lack of space and electrical infrastructure.
- With declining costs, investment in hydrogen fueling stations can become self-sustaining, meaning that costs are internalized through the fuel prices paid by drivers as opposed to subsidies from taxpayers and utility ratepayers.

Background

California has set forth ambitious goals for reducing greenhouse gas emissions over the next 25 years. These include a 40 percent reduction in carbon emissions relative to 1990 levels by 2030, carbon neutrality by 2045, and a requirement that 100 percent of its electricity retail sales be from zero-carbon sources by 2045.

About 41 percent of carbon emissions is attributable to transportation sources, including 28 percent from light-duty vehicles, 9 percent from medium- and heavy-duty vehicles, and 4 percent from off-road vehicles. To reduce emissions from mobile sources, California has established targets for increased reliance on zero emission vehicles (ZEVs).

As indicated in Figure 1, these include 5 million light-duty ZEVs and 100,000 medium- and heavy-duty ZEVs to be on the road by 2030, and 100 percent of transit bus sales to be ZEVs by 2029. Governor Newsom's September 2020 executive order (EO N-79-20) further requires that (1) 100 percent of light-duty vehicle sales are ZEVs by 2035, (2) 100 percent of drayage trucks on the road are ZEVs by 2035, and (3) that 100 percent of all medium- and heavy-duty trucks on the road are ZEVs by 2045.

Figure 1
Current California ZEV Goals

Provision	Requirement for ZEVs and Infrastructure
Light-Duty Vehicles	
Chapter 530/2017 (SB 1275, de León)	1 million on road by 2023
Executive Order B-16-12	1.5 million on road by 2025
CARB's 2017 Scoping Plan	4.2 million on road by 2030
Executive Order B-48-18	5 million on road by 2030; 200 hydrogen fueling stations and 250,000 charging stations in place by 2025.
Executive Order N-79-20	100 percent sales by 2035
Medium- and Heavy-Duty Vehicles	
Sustainable Freight Action Plan (Authorized by Executive Order B-32-15)	100,000 ZEVs on road by 2030
Innovative Clean Transit regulation	100 percent transit bus sales by 2029.
Advanced Clean Trucks regulation	30 percent to 75 percent of truck sales depending on class, by 2035.
Executive Order N-79-20	100 percent of drayage trucks on road by 2035 and 100 percent of all trucks on road by 2045.

Main Types of ZEVs

The two primary types of ZEVs are battery electric vehicles (BEVs) and fuel cell electric vehicles (FCEVs). Both are powered by electricity, but BEVs store energy as electricity in a battery, whereas FCEVs store energy as hydrogen and convert it to electricity via a fuel cell. The two technologies have complementary strengths. Battery-powered transportation works especially well in cases where daily routes are predictable and relatively short, where an inexpensive recharging infrastructure is accessible, and where lengthier recharging periods can be incorporated into daily driving routines. FCEV technology offers advantages for vehicles having high usage rates (e.g., app-based drivers) and larger payloads (e,g., freight haulers); for vehicles needing more range (e.g., long distance commuters); or where flexibility is needed in terms of timing, routing and distances of trips (e.g., family cars, app-base drivers). FCEV fueling stations are capable of fueling times that match those of internal combustion vehicles – often 3-4 minutes as opposed to BEV recharging times of 30 minutes (for rapid charge) up to 8 hours. And each fueling stop can provide up to 400 miles of range.[1]

In recognition of their complementary strengths, California has set forth targets for both battery-charging and hydrogen fueling infrastructures. For example:

- Former Governor Brown's Executive Order B 48-18 set targets for construction and installation of 200 hydrogen fueling stations and 250,000 vehicle battery chargers by 2025.
- In its 2018 evaluation of FCEV deployment, the California Air Resources Board (CARB) cited the California Fuel Cell Partnership goal that one-fifth of the 5 million ZEVs on the road by 2030 be FCEVs, and it indicated that 1,000 strategically placed hydrogen fueling stations would be sufficient to provide fueling coverage in over 93 percent of the state.[2]
- In its November 2020 report on AB 8, CARB stated that that FCEVs can be a viable option for broad segments of California citizens, and that hydrogen fueling network development could provide multiple benefits, including "growth in the FCEV market so that it may contribute upwards of 20 percent of broader zero-emission vehicle deployment targets."[3]

[1] Source: Hydrogen Council. "Path to Hydrogen Competitiveness, a Cost Perspective." January 2020.

[2] California Air Resources Board. "2018 Annual Evaluation of Fuel Cell Electric Vehicle Deployment & Hydrogen Fuel Station Network Development." July 2018. https://ww2.arb.ca.gov/sites/default/files/2019-11/AB8_report_2018_print_ac.pdf

[3] California Air Resources Board. "Hydrogen Station Network Self-Sufficiency Analysis per Assembly Bill 8." November 2020. Page 9.

California Financial Support for Hydrogen Fueling Infrastructure

California has allocated slightly over $7 billion in ZEV development to date. This includes about $4.5 billion focused on vehicles – primarily purchase subsidies and $2.5 billion focused on charging/fueling infrastructure. The great majority of funds dedicated to charging/fueling infrastructures has been for battery charging, mostly funded through utility ratepayer charges. State support for hydrogen fueling infrastructure is provided through AB 8 (Perea, Chapter 401, Statutes of 2013) and recent modifications to the Low Carbon Fuel Standard (LCFS) program.

AB 8 (Perea, 2013). This measure established the Clean Transportation Program (CTP) – also known as Alternative and Renewable Fuel and Vehicle Technology Program – which invests up to $100 million annually in clean energy transportation and fuel transportation projects throughout the state. AB 8 directed that $20 million of this total be annually appropriated through 2024 for the construction of hydrogen-fueling stations. About $155 million has been allocated for this purpose to date. As indicated in Figure 2, the California Energy Commission (CEC), which is responsible for allocating CTP funds, has completed two rounds of competitive grant offerings focused on retail light-duty vehicle fueling stations (GFO 15-605 and GFO 19-602). These incentive grants have contributed to the opening of 46 fueling stations, with another 63 stations in construction, permitting, or planning stages.[4] In addition, the CEC has allocated, or is in the process of allocating, $18 million through competitive grant programs for the design and production of green hydrogen production facilities, and a portion of $50 million for medium- and heavy-duty vehicle hydrogen fueling stations.

Figure 2
Recent Grant Programs for Hydrogen Fueling

GFO	Description	Funding Status
Funded through AB 8 $20 Million Set-Aside		
15-605	Grant incentives for light-duty vehicle stations	$39.3 million awarded.
19-602	Grant incentives for light-duty vehicle stations	$115.7 million awarded.
Funded from Other CTP Sources		
17-602	Grant incentives for small green hydrogen production	$11.9 million awarded
20-603	Grant incentives for medium- and heavy-duty ZEV refueling. Includes both chargers and refueling stations.	Up to $50 million to be awarded. (Initial tranche of $17 million.)
20-609	Grant incentives for hydrogen facilities in California that will produce 100 percent renewable hydrogen from in-state renewable resource(s).	$7 million to be awarded.

[4] California Fuel Cell Partnership. "Hydrogen Stations List, May 2021." https://cafcp.org/resources

Low Carbon Fuel Standard (LCFS) Program. The LCFS is a program designed to reduce the carbon content of transportation fuels. The carbon intensity of a fuel is determined by measuring emissions over the life cycle of its production and use. Fuels having carbon intensity below specific targets generate credits, which are then sold to producers of fuels with above-target fuel intensity (such as gasoline). Fuels generating credits include, among others, ethanol, biodiesel, hydrogen, and electricity for electric vehicles.

To encourage early deployment of hydrogen fuel dispensing stations and rapid chargers, the 2018 amendments to the LCFS program included a zero-emission vehicle infrastructure crediting provision. Under this provision, hydrogen fueling stations and direct-current fast chargers can generate LCFS credits based on the *capacity* of the station or charger as opposed to quantity of hydrogen fuel or electricity dispensed. The additional credits reduce the financial risk associated with low utilization rates of a ZEV fueling infrastructure during early stages of market development.

Further Support Needed

Expansion of the hydrogen fueling network is foundational to future growth in the FCEV vehicle market. In its November 2020 hydrogen fueling network self-sufficiency analysis, the California Air Resources Board concluded that while AB 8 and the LCFS changes have enabled the launch of the FCEV market, additional state funding will be needed to expand the hydrogen fueling network to the point of self-sufficiency.[5] A self-sufficient statewide network of fueling stations will be crucial if FCEVs are to contribute meaningfully to the state's ambitious emissions-reduction goals.

California Hydrogen Coalition Proposal

In order to facilitate the rapid development of the FCEV market, the California Hydrogen Coalition is proposing AB 1312 (Rodriguez, 2021), which creates a personal income and corporate income tax credit for costs associated with the construction of hydrogen fueling and production facilities, as well as costs incurred for assets that enable the movement of hydrogen fuel between production and fueling facilities.

As outlined in Figure 3, the credit for fueling stations would start at 30 percent of qualified costs, dropping to 25 percent the year after 400 stations become operational, then to 20 percent the year after 600 stations become operational, and 15 percent the year after 800 stations are in operation. The credit would cease the year after 1,000 stations are in operation. Credits would be available for up to 700 light-duty stations, 200 heavy-duty vehicle stations, and 100 transit stations, and would be limited to $500 million in any one year.

[5] Supra note 3, California Air Resources Board, page 8.

Figure 3
Key Provisions of California Hydrogen Coalition Proposal (AB 1312, Rodriguez)

Provision	Details
Income tax credit for fueling station construction.	• Starts at 30 percent of costs and declines as number of hydrogen stations increases. • Expires when state year after state reaches 1,000 stations or in 2032 • Available for up to 700 light-duty stations, 200 heavy-duty stations, and 100 transit stations. • Capped at 500 million per year. • Unused portions can be carried forward by investors for 7 years.
Credit for production facilities and distribution assets.	• Starts at 30 percent and declines as in-state production capacity increases. • Expires when 700 kg/day production capacity is attained. • Capped at $1 billion ($900 million for production facilities and $100 million for distribution assets). • Unused portions can be carried forward by investors for 7 years.
Green hydrogen requirements.	• Increases share of total hydrogen produced or dispensed in California for motor vehicles that is required to be produced from renewable resources.

The credit for production facilities and distribution assets is also initially set at 30 percent of costs. They would decline to 25 percent the year following when in-state production of green hydrogen reaches 300,000 kilograms per day (kg/day), and further to 20 percent in the year following when in-state production reaches 500,000 kg/day. The credit would expire the year following when green hydrogen production reaches 700,000 kg/day.

The total amount of production credits would be capped at $1 billion, of which $900 million would be available exclusively for production facilities and $100 million would be available exclusively for distribution assets. The tax credits would be available for tax years beginning January 2023 through December 2032. The credits could be used to offset tax liabilities, and any unused credits could be carried forward to offset future liabilities up to 7 years in the future.

The proposal would also require that increasing percentages of hydrogen produced or dispensed in California for motor vehicles be "green" hydrogen developed from renewable resources. Specifically, it would require the percentage of green hydrogen produced and dispensed to rise from 33.3 percent today to 44 percent by the end of 2024, to 52 percent by the end of 2027, 60 percent by 2030, and 100 percent by the end of 2045.

Analysis of the Proposal

The California Hydrogen Coalition has requested that we analyze the tax credit proposal, focusing on the following issues:

- The jobs and related economic impacts resulting from the proposed tax credit.
- The merits of a credit as a tool to incentivize the buildout of hydrogen stations and production facilities.
- The return-on-investment that California has seen from the $20 million annual AB-8 set-aside to date, and the expected return-on-investment of the proposed tax credit.
- The extent to which California solar incentives were successful in attracting solar investment to California, and the implications of these results for the hydrogen tax credit.
- California state costs of hydrogen fueling infrastructure per vehicle – both today and projected in the future.
- The level of public and private investment that is needed to achieve the Governor's all-ZEV targets established in Executive Order N-79-20, as well as cost-comparisons between hydrogen fueling and battery charging infrastructures.

Jobs and Related Economic Impacts of the Proposed Credits

The main goal of the California Hydrogen Coalition tax credit proposal is to develop the fueling network necessary for the successful development of the FCEV market, which in turn, will provide consumers and business with more vehicle-related choices and opportunities as California moves toward carbon neutrality.

However, accelerated development of a hydrogen fueling infrastructure will also have significant near-term economic benefits, including the creation of thousands of good paying construction-related jobs. We specifically estimate that construction of 1,000 fueling stations and associated production facilities create between 1,300 and 2,250 jobs in 2023, with annual amounts increasing to between 3,070 and 5,060 jobs by 2032 (see Figure 4).

Figure 4
California Jobs Created by the Construction of Hydrogen Fueling Infrastructure

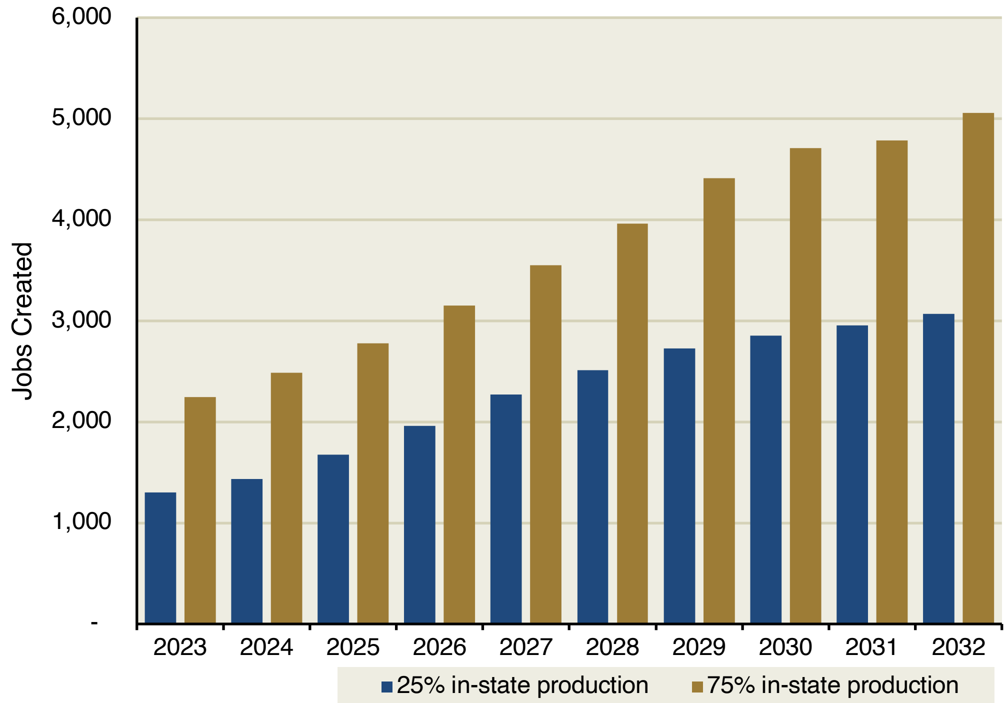


Figure 5 shows provides additional detail for the full 10-year credit period. It shows that the average number of newly created jobs during this period would range from 2,280 to 3,720. Of this total, 1,510 jobs are related to construction of hydrogen fueling stations, and between 770 and 2,210 jobs are related to construction of production facilities.

Figure 5
Jobs Created by Construction of Hydrogen Fueling Facilities and Production Facilities (Annual Average: 2023-2032)

	Fueling Stations	Production Facilities*		Total	
		Low Estimate	*High Estimate*	*Low Estimate*	*High Estimate*
Direct Impacts	820	420	1,230	1,240	2,050
Multiplier Impacts	690	350	980	1,040	1,670
Total	1,510	770	2,210	2,280	3,720

* Includes modest amounts related to purchase of distribution assets (mainly fuel trucks).

These job totals include a large number of California workers involved in the planning, engineering, site preparation, and on-site construction of production and fueling facilities. While most compressors, pumps, tankage, and other major components of fuel production and fueling facilities are currently manufactured out-of-state (and, in fact, outside of the U.S.), a substantial amount of in-state work is nevertheless involved in the distribution, final assembly, and installation of the equipment. In addition, we expect a growing share of replacement parts and equipment to be produced within California as the hydrogen fuel market develops.

Over 80 percent of the funding for these jobs would be from private investors and less than 20 percent would be financed by taxpayers. This is important when considering the net economic impact of the tax credit program. Compared to investments funded through increases in utility rates or taxes, spending financed by private investors is less likely to have offsetting impacts in the form of reduced purchases by households experiencing increases in utility rates or taxes. This is especially the case when investment is coming from multi-national firms that allocate capital spending globally.

Reason for the range in job creation estimates. The range reflects uncertainty regarding how the market for green hydrogen production will develop, and specifically how much of the development will occur in California versus out-of-state. Two general pathways for scaled up hydrogen production are feasible. One is a distributive model – a network of smaller facilities located close to the fueling stations. The other is centralized production, consisting of larger facilities potentially located near to renewable electricity production, along with an extensive system of distribution to fueling stations. In the latter case, the facilities could be located either inside or outside of California, with hydrogen delivered initially by trucks, but potentially through an efficient system of pipelines and bulk terminals in future years as the market expands.

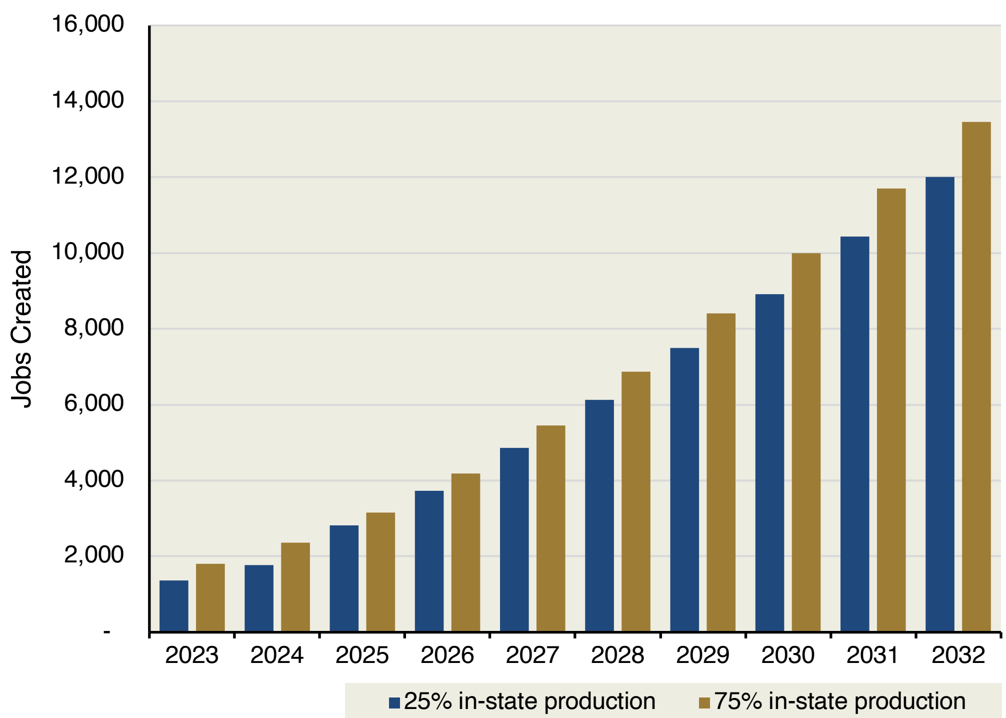
Feedback from industry representatives suggests that the location of hydrogen production facilities is highly sensitive to state and local government policies, and the proposed credit will clearly make in-state production more attractive. At the same time, however, many other factors will also be in play, including costs for land, labor, electricity, scale economies, and state and local tax policies, all of which will have impacts on hydrogen production costs. It is also uncertain whether other states will offer credit incentives to producers of green hydrogen.

To capture the uncertainty regarding how hydrogen production markets will evolve, we prepared two scenarios: one where 25 percent of the hydrogen fuel needed to supply California transportation markets is produced by facilities constructed in California; and the other where 75 percent of hydrogen comes from facilities constructed in the state.

An important caveat to these estimates is that they include impacts only through 2032, the final year of the tax credit program. If the tax credit program is successful in launching the FCEV market, the number of jobs related to hydrogen production, distribution and sales will continue to grow as the hydrogen fueling market scales up in line with California's increased targets for ZEVs.[6]

A growing number of permanent jobs will be created as construction is completed and new facilities come online (see Figure 6). We estimate that jobs connected to the production, distribution and sales of hydrogen will be between 1,370 and 1,810 in 2023, rising over time as more stations and production facilities come online. We estimate that newly created jobs involved in the operations and maintenance of hydrogen fueling stations and production facilities will rise to between 12,010 and 13,460 jobs by the final year of the credit program. These totals include jobs involved in maintenance, repair, hydrogen testing, and trucking of hydrogen from production facilities and management of production facility operations.

Figure 6
Permanent California Jobs Created for Operations and Maintenance of Hydrogen Fueling Infrastructure



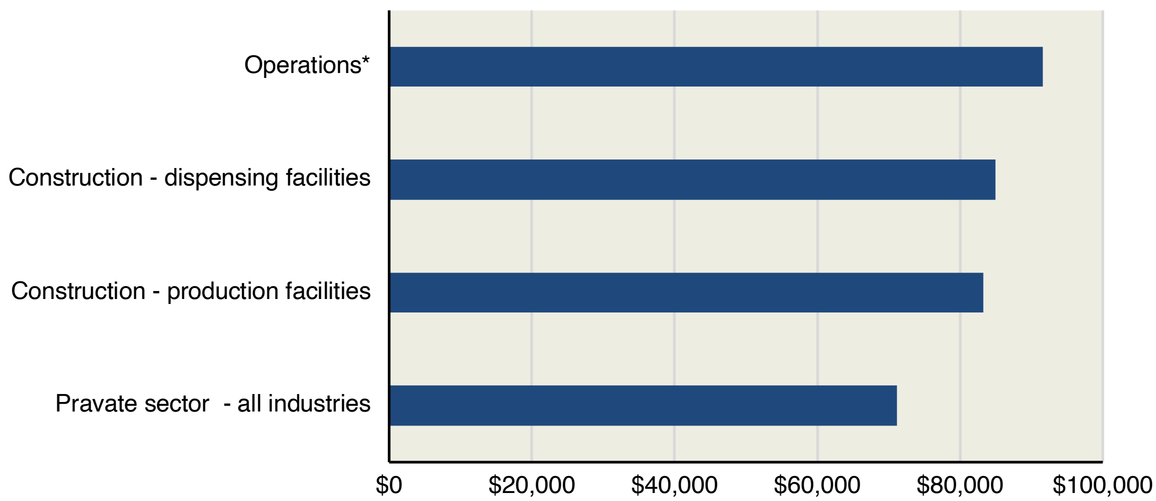
[6] Beyond these impacts, the growth in the FCEV market would support tens of thousands of jobs related to the manufacturing, distribution, sales, and maintenance and repair services for FCEV. These would be offset by declines in jobs related to manufacturing, distribution, sales, maintenance, and repair of internal combustion engine vehicles. These net vehicle-related impacts are not modeled in this report, which is focused on hydrogen fueling infrastructure.

Average Wages of Newly Created Jobs

The jobs created by the construction and operation of hydrogen fueling stations and production facilities would by high paying. As indicated in Figure 7, the average wage of permanent jobs tied to the operations and maintenance of fueling stations and production facilities hydrogen fueling infrastructure would be over $91,000 per year (excluding benefits); jobs during the construction of these facilities would have an average annual salary of around $84,000. These averages compare favorably to the California's economy-wide average of $71,140 per year.

The above-average wages reflect the large number of workers employed in highly paid construction, engineering, managerial, and other professional and skilled technical occupations.

Figure 7
Average Wage of Jobs Created by Hydrogen Fuel Infrastructure Investment



Merits of a Tax Credit Incentive Program

As noted above, in its 2020 AB 8 evaluation, CARB indicated that the grant programs displayed earlier in Figure 2 have enabled the launch of the FCEV market in California, but much more needs to be done. The CARB report emphasized the benefits of policies focused on *rapid development* of the fueling network, which will lead to greater network density, falling costs, and more benefit per investment dollar.[7] In addition, the pace of station development will need to accelerate sharply if California is to achieve the goals of 1,000 stations and 1 million FCEV vehicles within the next decade.

In this context, a simplified tax credit program makes considerable sense for several reasons (see Figure 8 on next page). It is relatively simple to administer for both the state and the project developer. It dispenses with a time-consuming grant process, which

[7] Supra note 3, California Air Resources Board, Page 8

according to industry representatives, added 7 percent to the costs of projects. It is also market-driven, in that the investor retains responsibility for 70 to 85 percent of the project cost and thus has a strong incentive to plan and build the infrastructure in a cost-effective way.

The decline in credit percentages as more fueling and production facilities open creates an incentive to "get in early," thereby expanding the fueling and production networks, promoting rapid integration of technological improvements, moving the overall system toward scale economies, and ultimately lowering costs to investors and FCEV customers.[8]

Finally, the proposed credit has precedent in the renewable energy industry – namely the federal and state incentives that were adopted about 15 years ago, which together launched the solar industry in California.

Figure 8
Advantages of a Tax Credit Incentive Program

Features	Benefits
Simple to administer	Savings to state and investors and, ultimately, hydrogen fuel customers.
Market driven	Investor has strong incentive to complete projects in cost-efficient manner since they bear at least 70 percent of total project costs.
Incentive for accelerated buildout	More rapid achievement of scale economies, reduced costs, and more rapid growth in FCEV market.
Precedent in renewable energy industry	Federal and state programs for renewable energy, built on similar principles, have been successful

Impacts of Solar Incentives on Private Investment

Federal and state incentives have had major impacts on renewable energy investments, particularly solar power. California has been on the forefront of solar energy production since the industry became commercially viable in the 1970s. The state was an early adopter of policies aimed at fostering growth in the industry, such as a property tax exemption for solar equipment installation, net metering (where owners of small "rooftop" systems were able to generate credits for excess energy returned to the electrical grid), and a variety of targeted state and local rebate programs.

These programs contributed to California's leadership in early solar development. However, as of 2006, solar still accounted for less than 1 megawatt of power in California, which was much less than 1 percent of total electrical power generation in the state.

[8] As one example of improved efficiencies and declining costs occurring as the fueling network is built out, fuel station maintenance and repair specialists must currently travel dozens, even hundreds of miles, between fueling stations. With denser networks, less time would be spent on travel and greater time on actual maintenance, testing, and repair activities.

Adoption of solar energy did not accelerate until 2007 following the enactment of the federal solar investment tax credit in 2005 and the California Solar Initiative in 2006.

Federal solar investment tax credit. The Energy Policy Act of 2005 created a 30 percent tax credit for investments in solar energy property. The credit applied to residential and commercial systems and it was available for installations of small distributive rooftop systems as well as large utility scale solar farms. While the credit was originally set to expire in one-year, Congress has repeatedly extended the expiration date, and it remains in effect today. Under the most recent extension, enacted in December 2020, the credit amount was reduced from 30 percent in 2019 to 26 percent in 2020 through 2022, then further to 22 percent in 2023. Unless further extended, the credit will drop to 10 percent for commercial systems, and to zero for residential systems starting in 2024.

California Solar Initiative (SB 1). In 2006, California passed SB 1, a $3.3 billion ratepayer-funded incentive program with the goals of (1) installing 3,000 megawatts (MW) of new distributed solar between 2007 and 2016, and (2) creating a self-sustaining solar industry free from ratepayer subsidies by the conclusion of the 10-year period.

The main incentive under this campaign was the California Solar Initiative (CSI) a rebate program administered by the California Public Utilities Commission for customers of the state's three investor-owned utilities. The rebate took the form of either (1) an upfront payment based on expected performance (using an agreed-upon solar calculator), or (2) a performance-based incentive payment based on metered output over 5 years (which mostly applied to larger commercial systems). The rebate offered for new systems declined in steps over time as more solar systems were installed. For a typical residential system, the initial rebate in 2007 offset roughly 23 percent of solar installation costs; by the end of the program in 2016, the rebate had fallen to about 4 percent of installation costs. Although not an income tax credit, the solar rebate program shared many key features with the California Hydrogen Coalition's tax credit proposal, including simplicity and a declining rebate amount as solar energy production goals were achieved.

Programs had major impacts. The federal and state incentives clearly had a transformative impact on solar energy production in California. The 3,000-megawatt distributed energy goal was met in 2015 – a year early – and solar installations continued to expand, nearly tripling in the three years following the expiration of the rebate in 2016. Total solar production (which includes both smaller distributed generation and large utility scale projects) increased from just under 1,000 MWs in 2006 to 31,288 MWs in 2020, an over 30-fold increase. The incremental impact of California's CSI is difficult to determine. However, it was clearly large, as evidenced by the fact that the federal credit is available in all fifty states, yet California's solar production accounts for 40 percent of the national total.

We estimate that the federal and state incentive programs have stimulated close to $90 billion in solar investment in California over the past 15 years. Net private investment (which "backs out" the offsets from federal and state incentives) has reached approximately $60 million, suggesting a more than 2-to-1 return on public investment.

Implications for hydrogen fueling tax credit. In some important respects, the dynamics that exist today in the FCEV markets are similar to those that existed in 2006 for the solar industry. Like the solar industry in 2006, the development of FCEVs and related fueling infrastructure is in its early stage, and costs are coming down as capacities are increasing. These factors alone indicate that a tax credit will have a strong impact on new investment in a hydrogen fuel infrastructure.

Beyond these similarities, however, is the fact that accessible and reliable hydrogen fuel supplies are crucial prerequisites to expansion of the FCEV market. In this respect, the infrastructure credit will have a *leveraged* impact on the FCEV industry. Expansion of a reliable fuel network will boost consumer confidence and sales of FCEVs, which will lead to greater utilization of the fuel infrastructure, which will lead to further efficiencies and cost reductions.

AB 8 Set-Aside: Return-on-Investment to Date

So far, the state has committed about $165 million to date for construction of fueling facilities. About $155 million of this total has been through two main grant solicitations administered by the CEC. As indicated in Figure 9, these solicitations attracted a combined total of $284 million in private investment funds – or about $1.80 of private funds for each $1.00 of state funds. Also of note is the major decline in the state funding percentage between the first grant solicitation in 2015, when the state's share was almost two-thirds of total investment costs, and the second grant solicitation in 2019, when the state's contribution dropped to less than one-third. The declining state share reflects major progress made by station developers in reducing costs and increasing station capacity. These declining cost trends bode well for the success of the proposed tax credit program. This is because declining costs enable private investors to attain positive returns on investment even as state support diminishes

Figure 9
Estimates of Return-on-Investment for AB 8 Grant Incentive Programs to Date (Millions of Dollars)

Grant Offering	State Funding	Private Funding*	State's Share of Total Investment
2015 (GFO 15-605)	$39.3	$21.6	65 percent
2019 (GFO 19-602)	$115.7	$262.0	31 percent
Total	$155.0	$283.6	35 percent

* Includes matching funds as well as estimates of other expenditures for labor and pre-construction site development.

Expected Return-on-Investment of the Tax Credit Proposal

We estimate that the state will contribute between 15 percent and 20 percent of total expenditures for hydrogen fueling infrastructure development under the California Hydrogen Coalition's income tax credit proposal, depending on how much hydrogen production is sourced inside versus outside of California. This implies that $1.00 of public investment will draw between $5.00 and $6.70 of private investment under the proposed credit.

Figures 10 and 11 provide detail behind our estimates. Figure 10 shows the calculations assuming that 25 percent of new hydrogen production is located inside of California, while Figure 11 shows the same calculations assuming that 75 percent of hydrogen production is located inside the state. As the figures show, investment in fueling stations is estimated to total $2.39 billion over the 10-year period under both scenarios, with $580 million provided by the state and $1.81 billion provided by private investors.

On the combined production and distribution side, we estimate that total investment will be $4.36 billion, with either 25 percent or 75 percent of that total being spent in California, depending on the scenario. California's contribution to the total would range from $420 million under the 25-percent in-state production scenario to $750 million under the 75-percent in-state production scenario. (The state contribution does not increase proportionally under the second scenario because the credit rate drops as more in-state hydrogen production capacity is installed.)

The combined total investment generated by the tax proposal is $6.8 billion, with the state's contribution ranging from $1.0 billion to $1.3 billion.

Figure 10
Cumulative Public vs. Private Investment by End of a 10-year Credit Period – 25 Percent of Hydrogen Produced In-State

Hydrogen fueling infrastructure Capital Expenditures	Private Investors	State of CA	Total	State Credit % of Total
Fueling stations	$1.81 billion	$0.58 billion	$2.39 billion	24%
Production + Distribution	$3.94 billion*	$0.42 billion*	$4.36 billion	10%
Total	$5.75 billion	$1.00 billion	$6.75 billion	15%

* Totals for production facilities and distribution assets include all spending generated by California's FCEV market – including investment in production facilities located both inside and outside of CA. The income-tax credit, however, only applies to facilities located in CA, which in this scenario accounts for 25 percent of the total production market generated by expansions of the California FCEV market.

Figure 11
Cumulative Public vs. Private Investment by End of a 10-year Credit Period – 75 Percent of Hydrogen Produced In-State

Hydrogen fueling infrastructure Capital Expenditures	Private Investors	State of CA	Total	State Credit % of Total
Fueling stations	$1.81 billion	$0.58 billion	$2.39 billion	24%
Production + Distribution	$3.61 billion*	$0.75 billion*	$4.36 billion	17%
Total	$5.42 billion	$1.33 billion	$6.75 billion	20%

* Totals for production facilities and distribution assets include all spending generated by California's FCEV market – including investment in production facilities located both inside and outside of CA. The income tax credit, however, only applies to applies only to facilities located in CA, which in this scenario accounts for 75 percent of the total production market generated by expansions of the California FCEV market.

Costs per vehicle. To date, the state has allocated about $165 million of clean transportation funds for hydrogen fueling infrastructure. In its annual evaluation of hydrogen vehicle deployment and fuel network development, CARB estimates 58 hydrogen fueling stations were funded in California as of the end of 2020.[9] The combine capacity of these stations was 23,667 kg/day, which we estimate would support about 31,000 FCEVs. This translates into state support of about $5,320 per vehicle. Based on our cost projections for the proposed credit, by the end of 2032 California will have provided tax credits totaling between $1.0 and $1.3 billion, while the combined capacity of all open stations will be approximately 1.04 million vehicles. When combined with the $165 million spent to date, total state investment for fueling stations as well as production and distribution facilities will be $1,120 to $1,440 per vehicle at the conclusion of the 10-year credit period.

Split Between Private Investment and Taxpayer/Ratepayer Supported Investment to Date

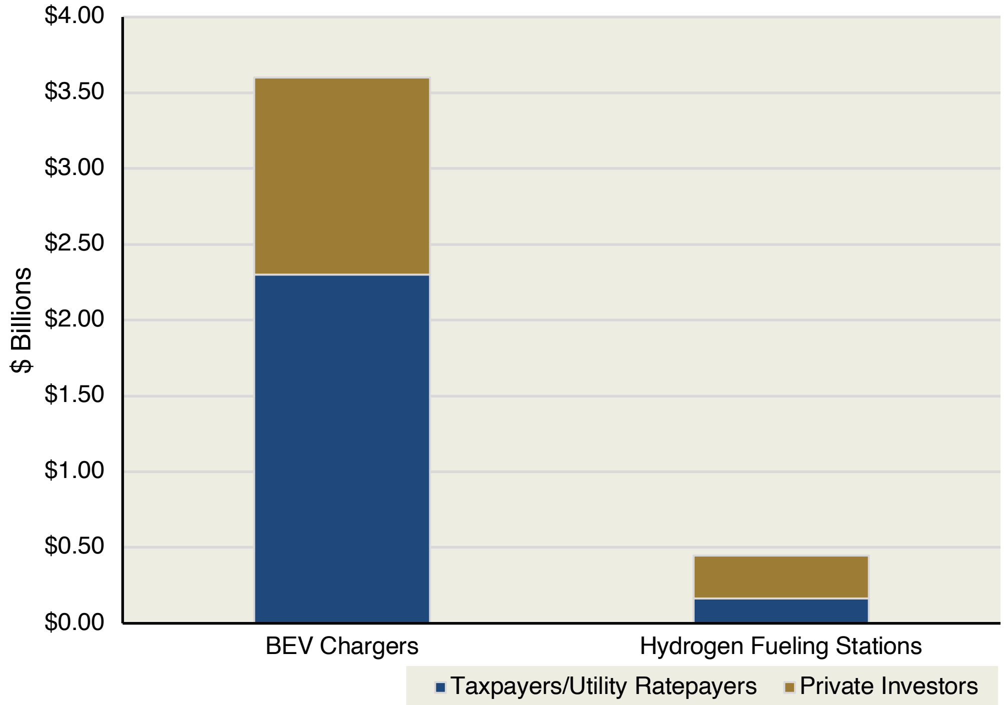
Figure 12 presents our estimates of public and private investment for battery charging and hydrogen fueling infrastructure.[10] We estimate that spending allocated for these purposes over the past decade has totaled about $4 billion. Of this total, slightly less than $3.6 billion has been for battery charging infrastructure and $450 million has been for hydrogen fueling stations. We estimate that combined taxpayer and utility ratepayer subsidies for battery chargers have totaled $2.3 billion, or about 64 percent of total costs to date.[11,] State assistance for hydrogen fuel stations has totaled $165 million to date, resulting in a subsidy rate of about 37 percent.

[9] California Air Resources Board. "2020 Annual Evaluation of Fuel Cell Electric Vehicle Deployment & Hydrogen Fuel Station Network Development. September 2020.

[10] Our estimates are based on information from the CEC and other sources regarding costs for chargers, percentages of charger installed in homes, and the number of public and shared private chargers of that have been installed to date.

[11] The estimate includes funding from state agencies such as the Energy Commission, Air Resources Board, and Caltrans. It also includes funding authorized by the California Public Commission and recovered from ratepayers of California's investor-owned utilities (PG&E, Southern California Edison, and San Diego Gas and Electric). Finally, the

Figure 12
Investment Allocated for BEV Charging and FCEV Fueling Stations



Additional Investment Needed to Achieve Governor's All-Electric Vehicle Goals

Development of detailed projections needed to achieve Governor Newsom's all-electric objectives, set forth in Executive Order N-79-20, is beyond the scope of this report. However, we can make the following general observations based on recent studies released by the California Air Resources Board and the California Energy Commission, as well as other researchers:

Additional Charging Infrastructure Costs Could Exceed $45 Billion

In its 2020 staff report analyzing charging needs to support 5 million zero-emissions vehicles by 2030, the CEC estimated that the number of public and shared private chargers will need to need to increase from 67,000 in 2020 to approximately 965,000 by 2030 to support the state's goal of 5 million ZEVs on the road by 2030.[12] We estimate the additional chargers would require roughly $7.5 billion in combined public-private spending beyond what has been allocated to date. These costs will continue to increase in

estimate includes funding through local programs, such as the City of Los Angeles, which offers rebates of up to $4,000 ($5,000 near a disadvantaged neighborhood) for a standard "level 2" commercial charger, up to $75,000 for a rapid charger, and up to $125,000 for a heavy-duty charging-stations. The program is financed by the Los Angeles Department of Water and Power through ratepayer charges.

[12] California Energy Commission. "Assembly Bill 2127, Electric Vehicle Charging Infrastructure Assessment." January 2021.

subsequent years under Executing Order N 79-20. By 2045, we estimate that cumulative costs for charging infrastructure will have risen to over $45 billion.

Additional Costs for Upgrades to the Electrical Grid – Over $15 Billion

Beyond the costs of chargers, the state will incur expenses for developing additional power generation and upgrading its electrical grid. In March 2021, the CEC, CARB, and CPUC jointly issued an updated analysis on California's progress toward its zero carbon electricity goals.

The report indicated that under a "high electrification scenario," which is consistent with the Governor's ZEV goals, electricity demand from the state's transportation sector will grow from 3,000 Gigawatt-hours in 2020 to an estimated 81,000 Gigawatt-hours in 2045. The report also estimated that the state would need to triple its electricity capacity, from 80 Gigawatts today to 240 Gigawatts by 2045, to meet *all* additional electrical demands resulting under its high electrification scenario, and that the costs for such upgrades would be approximately $28 billion.

We estimate that additional electricity required by the transportation sector would account for slightly over $15 billion of the total, with the remaining $13 billion attributable to costs associated with replacing natural gas with renewable electrical power in homes and businesses.

Expanded FCEV Market Could Lower These Costs Significantly

The scenarios described above are focused on infrastructure needed to support a ZEV market consisting mainly of BEVs. While any path toward an all-ZEV market will include substantial infrastructure costs, these costs can be minimized in a more balanced market that includes a significant number of both BEVs and FCEVs.

A key reason is that increased reliance on FCEVs can bring down costs is that FCEV fueling infrastructure is in an early stage of development with investment and operations costs falling rapidly. Industry representatives we spoke to indicate that their per-station costs fell by one-half and their per-station capacity doubled between the 2015 and 2019 competitive grant programs administered by the CEC. These favorable trends are expected to continue as (1) fueling technology improves, (2) manufacturers open up specialized assembly lines for pumps and other hydrogen station components, and (3) the statewide network of fueling stations fills in.

A recent detailed analysis regarding comparative costs of charging and hydrogen fueling infrastructure development in Germany highlights the magnitude of potential savings that could result FCEVs were to account for 20 percent or more of the market. The analysis was prepared in 2018 by a team of experts from the Institute of Electrochemical Process Engineering in Jülich, Germany. It included a detailed comparison of costs required to build the infrastructure needed to supply energy to between 100,000 to 20 million ZEVs in Germany, with either all-hydrogen or all-battery power vehicles.[13]

The authors found that at low levels of market penetration, the two technologies have similar costs. However, as market size expands, hydrogen fueling infrastructure costs fall by more than battery-charging infrastructure costs, as fueling stations are used more intensively, technological advances occur, and distribution costs fall as transport evolves from trucking to pipelines. The authors specifically estimated that when the ZEV market reaches 20 million, infrastructure costs for an all-FCEV market would be 20 percent less than a comparable battery-charging infrastructure for BEVs.

The report also discusses the advantages of diversification of vehicle technologies in an all-ZEV future, stating that "a smart and complementary combination of the electric charging and the hydrogen refueling infrastructure can join the strengths of both and can avoid non-sustainable solutions with low systems relevance or efficiencies."[14] It found that a key benefit of diversification in a clean-energy electrical power grid is the ability of hydrogen plants to scale up and down to take advantage of surplus power generated by renewable power sources during various times of day and over the course of the year. This flexibility, combined with the ability to store hydrogen over long time periods, would enable otherwise excess electrical generation capacity to be more fully utilized throughout the year.

Although the report is a comparative analysis for Germany, its findings are relevant for California – a state which is moving toward 100 percent reliance on renewable energy and has a diverse population with diverse transportation needs. A complimentary approach in California would ensure these diverse needs are met, and at the same time reduce overall investment expenses that would occur in an all-BEV environment. For example, a more balanced mix of FCEVS and BEVs would enable California to scale back costly investments that would otherwise be needed in an all-BEV system, such as in dense urban multifamily units where space is limited, and expensive electrical system upgrades would be required.

In short, rapid development of a hydrogen fueling infrastructure clearly holds the potential to reduce overall infrastructure costs needed to support combined ZEV fueling and charging. Just as importantly, Californians would benefit from a diversified system having significant numbers of both FCEVs and BEVs. Such a system would leverage the advantages of both power sources for individuals and businesses in the state and reduce systemwide costs.

Comparatively More of Hydrogen Fueling Infrastructure Investment is Likely to be Privately Funded

Policies adopted to date indicate that more costs for a hydrogen fueling infrastructure will be internalized – that is, borne directly by investors and FCEV owners (through costs for

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[13] Institute of Electrochemical Process Engineering (IEK-3) Forschungszentrum Jülich GmbH, Jülich Germany "Comparative Analysis of Infrastructures: Hydrogen Fueling and Electric Charging of Vehicles. 2018.

[14] Ibid, page III.

hydrogen fuel) – than will be the case for a BEV charging infrastructure. As indicated previously, over 50 percent of the battery charging infrastructure to date has been financed through utility ratepayer charges, and all indications are that such policies will continue in the future. The CEC states in its January 2021 report on electric vehicle charging needs that "continued public support for charger deployment is essential to meet state ZEV goals."[15] It also indicates that electricity sales alone may not be enough to maintain sustainable business operations or cover capital costs for planning and constructing charging stations.

In contrast, the intent of the California Hydrogen Coalition's tax credit proposal is to make the hydrogen fueling industry self-sustainable, where private investors are no longer reliant on state funds beyond the 10-year tax-credit period. If current declining cost trends in the industry hold into the future, we believe that self-sustainability is feasible within a decade.

[15] Supra note 12, California Energy Commission, page 2.

Conclusion

California will benefit from growth in complementary ZEV technologies as the state moves toward an all-electric transportation system. The proposed income tax credit sponsored by the California Hydrogen Coalition is an appropriate tool for achieving that objective. AB 8 set-asides have been successful in attracting private investment for the 46 completed and 63 planned hydrogen fueling stations, but more is needed in order for FCEVs to play a meaningful role in meeting California's ZEV targets.

Given the rapid progress made to date with respect to cost declines and capacity improvements in hydrogen fueling stations, we believe that a tax credit will be successful in attracting private investment, accelerating development of the infrastructure needed to grow the FCEV market and wean private investors off of public subsidies altogether. Such investment will have immediate economic impacts, including thousands of good-paying jobs related to the construction, operations, and maintenance of the hydrogen fuel network. Just as importantly, it will provide the fueling infrastructure needed to give all Californians access to workable options as the state moves toward a zero-emissions transportation market.

Appendix – Methodology and Assumptions Behind Our Job Impact Estimates

Overview of Approach

Our economic impact estimates started with the assumption that the credit will generate 1,000 new fueling stations by 2032, which will support 1,000 FCEV light-duty vehicles, 30,000 FCEV heavy-duty vehicles 10,000 FCEV transit busses. (Our estimates assume that some of the heavy-duty fueling stations are dual use.)

Based on the assumptions regarding annual hydrogen fuel consumption by type of vehicle (0.7 kg/day for light vehicle, 10.81 kg/day for heavy duty vehicle, and 6.44 kg/day for a transit vehicle) we then developed estimates of hydrogen production needed to serve California's expanding FCEV markets. We prepared alternative estimates assuming that 25 percent of new production is sourced in California (with the balance coming from out-of-state sources), and again assuming that 75 percent of new hydrogen production is supplied from production facilities constructed in California. As noted in the main text, we prepared these scenarios to account for the considerable uncertainty regarding how future growth in hydrogen production will evolve.

Based on public information in applications for CEC's GFOs 15-605, 17-602 and 19-602, we developed information regarding (1) costs of construction for fueling stations and production facilities, and (2) the allocation of these costs between materials, equipment, engineering, construction, and other spending categories. We then developed job and related economic impact estimates using the IMPLAN input-output modeling and database system (described below).

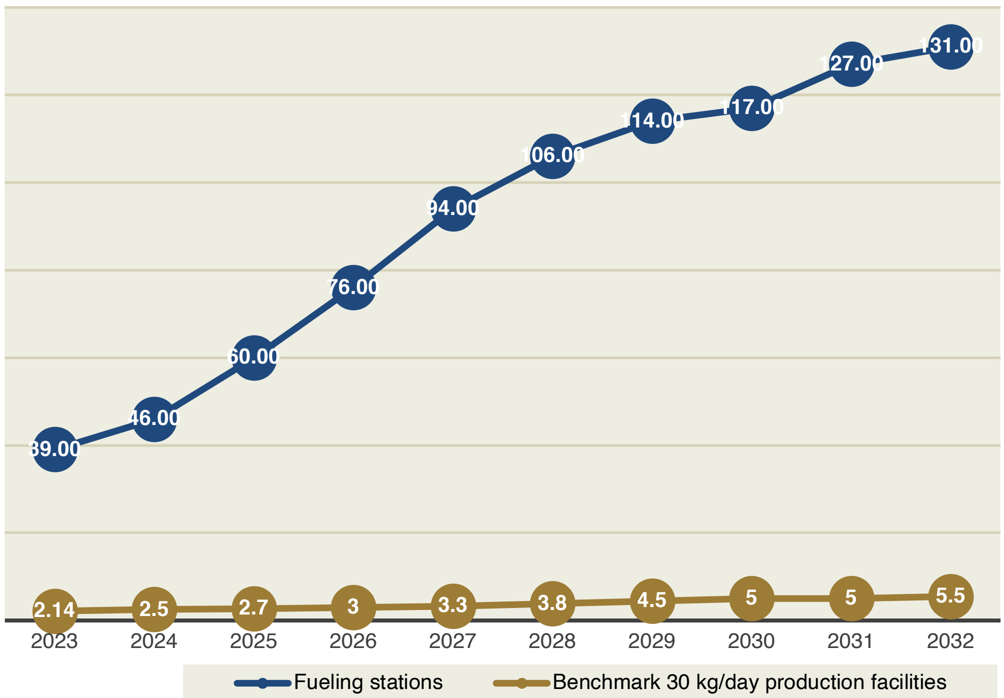
Selected Key Assumptions

In the following sections provide additional detail on key assumptions.

Number of Fueling Facilities Constructed by Year

As shown in Appendix Figure 1, we assume that the credit will result in the construction of 39 facilities in 2023, with the annual number of facilities rising to 94 stations by 2027, and further to 131 stations by 2032. Increased annual construction occurs as more developers secure permits; installation and operational costs drop; buyers gain more confidence in the fueling network; and the FCEV market expands. We also estimated that the number of benchmark 30 kg/day production facilities needed to meet growing fueling demand will increase from 2.14 per year to 5.5 per year over the 10-year period. We then calculated costs and job impacts assuming that, alternatively, 25 percent or 75 percent of the facilities are built in California.

Appendix Figure 1
Number of Credits Claimed Per Year



Average Per-Facility Costs for Fueling Stations and Production Facilities

Our cost assumptions are presented in Appendix Figure 2. We assumed the average cost of fueling stations start at $2.5 million in 2023 for light-duty stations, $7.7 million for heavy-duty stations, and $3.9 million for transit stations. Average costs for production facilities start at $150 million for a standardized facility capable of producing 30,000 kg/day of hydrogen. The cost estimates for stations are based primarily on project information provided in the applications for the Energy Commission's GFOs 15-605 and 19-602, while our estimates for production facilities are based on public project cost information for the Air Liquide liquid hydrogen production plant being constructed in Nevada.

Appendix Figure 2
Cost Assumptions
(Constant 2021 dollars)

Type of Facility	Capacity	Initial Cost	Cost in 2027	Cost in 2032
Light-Duty Vehicle Stations	800 kg/day	$2.5 million	$1.8 million	1.5 million
Heavy-Duty Vehicle Stations	2,500 kg/day	$7.7 million	$5.5 million	4.7 million
Transit Bus Stations	1,250 kg/day	$3.9 million	$2.8 million	$2.4 million
Production Facility	30,000 kg/day	$150.0 million	$108.0 million	93.0 million
Truck/Trailer	4,000 kg	$1.7 million	$1.7 million	$1.7 million

The average costs for both fueling stations and production facilities are assumed to decline over time as hydrogen fueling technology advances, dedicated manufacturing lines for hydrogen fueling equipment open, and scale economies are achieved. Specifically, costs for fueling stations are projected to fall by about 40 percent between 2023 and 2032. Our estimates of cost declines are based on the methodology described in CARB's Hydrogen Station Network Self Sufficiency Analysis.[16]

Regarding spending on distribution assets, we assumed costs for a tractor-trailer capable of hauling 4,000 kilograms of hydrogen would be about $1.7 million per year, holding steady (in constant dollar terms) over the 10-year credit period.

Allocation of Expenditures Between In-State and Out-of-State Suppliers

In addition to the total cost per project, two other factors affecting the California economic impacts of hydrogen fueling station and production facility construction are (1) the allocation of expenditures among various types of business (i.e., engineering, manufacturing, and construction, and (2) the share of expenditures to each business type that goes to in-state versus out-of-state businesses. Our estimates for both are guided by information contained in project applications for the CEC's GFOs 15-605, 17-602 and 19-602, as well as feedback from industry representatives. Overall, we estimate that about 55 percent of total spending would go to businesses and labor located inside California – mainly those involved in engineering, assembly, construction, and on-site installation. These expenditures would support jobs and wages in California. The other 45 percent would go to businesses located outside of California – mainly manufacturers of compressors, pumps, tankage, and other equipment that is primarily produced abroad. These expenditures would support jobs in other states and other countries, but are not included in our totals, which focus on California jobs.

[16] California Air Resources Board. "Hydrogen Station Network Self-Sufficiency Analysis per Assembly Bill 8." November 2020. Discussion starts on page 50.

Ongoing Costs for Operations

We based estimates of ongoing operational costs on information provided in CARB's November 2020 report on Hydrogen Station Network Self-Sufficiency.[17] We estimated initial operations and maintenance costs (excluding procurement) of about $400,000 per year, declining about 3 percent per year, to $320,000 by 2032. The cost declines occur as increased network density results in higher productivity related to maintenance, repair, and testing activities. We assumed wholesale hydrogen prices start at $8/kg, declining by 5 percent per year, to $4.80/kg by 2032 as the result of technological advances and declining costs of manufacturing for key production components.

Direct and multiplier impacts. We translated project expenditures into job and related economic estimates by using the IMPLAN input-output model and database system.[18] The IMPLAN model generates estimates of employment, output, income and value added of employees and companies supplying products or services needed to construct fueling stations and production facilities. These are referred to as *direct* impacts.

In addition, the model estimates secondary impacts relating to purchases made by the main suppliers from subcontractors and other businesses, as well as subsequent rounds of purchases by subcontractors from their suppliers. These subsequent rounds of business-related purchases and jobs are collectively referred to as *indirect* impacts.

Finally, the model estimates business activity that is generated by purchases of goods and services by the *households* of employees working for the prime and sub-contractors, which are collectively referred to as *induced* impacts. These expenditures boost sales, jobs and wages in a wide range of industries, including restaurants, retail establishments, real estate offices, entertainment venues, and professional services. In this report we have combined the indirect and induced effects into a single value, which we refer to as multiplier impacts. In the case of operational expenditures, we have included spending for fixed and variable operations and maintenance as well as procurement of wholesale hydrogen. Spending for hydrogen procurement triggers output, jobs, and wages in the hydrogen production and distribution industries.

[17] Ibid, page 52.

[18] IMPLAN and input-output modeling system widely used by academic institutions, federal, state, and local government agencies, and private companies for economic impact analyses. The model is based on benchmark U.S. input-output accounts produced by the U.S. Bureau of Economic Analysis (BEA). These accounts describe commodity inputs that are used by each industry to produce its output, the commodities produced by each industry, and the use of commodities by final consumers. The relationships in the national accounts are then modified by IMPLAN for each local region to take into account such factors as the relative size of the region's various industrial sectors. Based on these inter-industry tables, IMPLAN calculates a total requirements table, which estimates the full impacts (including multiplier effects) of a given change in sales output in one industry on all other industries in the economy.