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STAFF REPORT

Draft Zero-Emission Vehicle Infrastructure Plan (ZIP)

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Thanh Lopez
Madison Jarvis
Primary Authors

Michael Nicholas
Project Manager

Mark Wenzel
Office Manager
LIGHT-DUTY ELECTRIC VEHICLE INFRASTRUCTURE AND ANALYSIS OFFICE

Hannon Rasool
Deputy Director
FUELS AND TRANSPORTATION DIVISION

Drew Bohan
Executive Director

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ABSTRACT

Zero-emission vehicle charging and hydrogen fueling infrastructure are critical to meeting California's clean transportation goals. Public, private, and utility investments have played essential roles in deploying the existing charging and fueling infrastructure. Growth in public and private funding will provide a pathway to success in zero-emission vehicle infrastructure deployment. Private funding has been critical to developing the existing infrastructure and is anticipated to play a large role in the future. There is also an ongoing role for public funding in accelerating deployment and ensuring equitable outcomes. The state is committed to doing its part through policy, targeted investment, and continued coordination across state agencies, utilities, and the private market.

The California Zero-Emission Vehicle Market Development Strategy lays out the overall strategy to meet California's Zero-Emission Vehicle goals. The strategy has four market pillars (vehicles, infrastructure, end users, and workforce). This document, the Zero-Emission Vehicle Infrastructure Plan, or ZIP, developed in collaboration with several state agencies, is intended to support and provide a fuller description of the "infrastructure" pillar. The ZIP describes the state's near- and long-term actions, in collaboration with the private market, to ensure that zero-emission vehicle infrastructure will meet the needs of the growing zero-emission vehicle market.

Keywords: ZIP, zero-emission vehicles, electric vehicle charging, hydrogen fueling

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EXECUTIVE SUMMARY

Greenhouse gas and criteria pollutant emissions from transportation are significant contributors to the climate crisis and to negative health consequences, especially in low-income and disadvantaged communities. Zero-emission vehicle charging and hydrogen fueling infrastructure are critical to meeting California's clean transportation goals. Infrastructure investments increase access and equitable adoption and accelerate the transition away from fossil fuels. The *Zero-Emission Vehicle Infrastructure Plan* seeks to support decision-making in the public and private sectors by describing the state's near- and long-term actions to ensure that zero-emission vehicle infrastructure deployment will meet the needs of the growing zero-emission vehicle market. The *Zero-Emission Vehicle Infrastructure Plan* provides a fuller description of the "infrastructure" market pillar within the California Zero-Emission Vehicle Market Development Strategy.

Pathway to Success for California's ZEV goals

The *Zero-Emission Vehicle Infrastructure Plan* presents a pathway to success for California's zero-emission vehicle goals that includes increasing strategic investments from the private sector, utilities, and the public sector. Public, private, and utility investments have played essential roles in deploying the existing infrastructure, and that will continue. The California Energy Commission has invested over $580 million on zero-emission vehicle infrastructure and has proposed roughly $3 billion over five years. The California Public Utilities Commission has authorized $1.85 billion in spending by the electric utilities it regulates.

There is an ongoing role for public funding in accelerating deployment and ensuring equitable outcomes. The state is committed to doing its part through policy, targeted investment, and continued coordination across state agencies, utilities, and the private market. Actions underway and planned by a range of market participants will ensure the state meets its goals.

The Grid Can Accommodate Near-Term Infrastructure Goals

California's electric grid can accommodate near-term infrastructure goals, and longer-term goals can be achieved with planning, which is already underway. California's existing grid and approved investments in it will allow the state to handle millions of electric vehicles in the next few years. Ongoing planning will help prepare the grid for reliance and reliability in the longer term.

The State Is Taking Action to Meet Its Goals

Informed by the principles of the Zero-Emission Vehicle Market Development Strategy, including "equity in every decision" and "public actions drive greater private investment to scale investable markets," state agencies are accelerating the deployment of zero-emission vehicle infrastructure and preparing for near- and long-term needs.

Charging and Hydrogen Fueling for Medium- and Heavy-Duty Vehicles

State agencies have committed $194 million to medium- and heavy-duty zero-emission vehicle infrastructure and budgeted more than $600 million to support medium- and heavy-duty charging and hydrogen fueling infrastructure needs over the next three years. The California Public Utilities Commission (CPUC) has authorized $864 million for chargers to support 11,500

medium- and heavy-duty vehicles. An emphasis on medium- and heavy-duty vehicles is part of a strategy to increase equity by rapidly transitioning the most polluting vehicles to zero emissions.

Public Hydrogen Fueling for Light-Duty Fuel Cell Electric Vehicles

California Energy Commission (CEC) investments of $279 million for light-duty hydrogen infrastructure are underway with plans to dispatch an additional $27 million to reach 200 stations to serve light-duty fuel cell electric vehicles. Some stations are planned to serve light-, medium-, and heavy-duty fuel cell electric vehicles. Further public light-duty funding depends on demonstrated need through the acceleration of fuel cell electric vehicle deployment. State and private actors will collaborate to address other challenges for light-duty fuel cell electric vehicle such as high prices at the pump, station reliability, fueling standards, and others.

Level 1 and Level 2 Charging for Light-Duty Plug-In Electric Vehicles

The CEC has invested more than $109 million to support Level 1 and Level 2 electric vehicle charging infrastructure, resulting in more than 9,600 chargers for shared-private and public use and nearly 4,000 chargers for private single-family/multifamily use. More than $1.4 billion has been dedicated for Level 1 and Level 2 charging in the near term from state and utility investments. Maximizing access to home charging is a priority for the state equity strategies, including efforts to increase access to charging for multifamily housing residents and proposed funding for incentives for charging at low-income single-family homes.

Fast Charging for Light-Duty Plug-In Electric Vehicles

The CEC has invested $151 million to support the rollout of direct current fast chargers that can charge a plug-in electric vehicle faster than Level 1 and Level 2 chargers. Governor Gavin Newsom's 2022–2023 proposed budget would add $600 million for fast charging across the state. The CPUC has authorized $5 million for fast charging infrastructure. Adapting to market trends will mean phasing out public support for chargers with CHAdeMO connectors and improving on the consumer experience, focusing on charging speeds and costs to drivers. CHAdeMo is a connector standard for fast charging of electric vehicles. Equity strategies for fast charging include ensuring convenient access for priority populations and focusing on costs to drivers.

Emerging Technologies

Battery swapping (where depleted batteries are replaced with charged batteries at swap stations), wireless charging, and mobile charging units are emerging technologies. The state has funded advanced technologies and will monitor the demonstration of these technologies, as well as the incorporation by automakers. Investments in emerging technology help advance the charging market and create opportunities for new solutions designed to improve electric vehicle charging.

Other Challenges and Responses

In collaboration with local governments, businesses, and others, state agencies are working to overcome challenges beyond investments, including improving building codes, building the reliability of charging and hydrogen fueling networks, streamlining permitting, improving interconnection times, and working on the standardization of charging and fueling infrastructure.

CHAPTER 1: Background

California has set goals of high levels of zero-emission vehicle (ZEV) adoption across all mobile sectors including light-duty, medium-duty, heavy-duty, and off-road. Many actors are taking action to support these vehicles with plug-in electric vehicle (PEV) charging and hydrogen fueling infrastructure. Public funding, electric utility investment, and private investment have contributed to California's ZEV charging and fueling infrastructure networks, and all will continue to be essential to meeting future goals. The *California ZEV Market Development Strategy* lays out the overall strategy to meet California's ZEV goals. The strategy focuses on four market pillars (vehicles, infrastructure, end users, and workforce) to inform the roles and responsibilities of each public and private market player to accelerate large scale, affordable, and equitable ZEV market development.[1] This document, the *Zero-Emission Vehicle Infrastructure Plan* (ZIP), supports the "infrastructure" pillar within the *California ZEV Market Development Strategy.* Although policies and actions may impact more than one pillar, the ZIP does not address vehicles, end users, and workforce in detail. The ZIP articulates what California has done and will do in the near and longer term to support ZEV charging and hydrogen fueling infrastructure deployment, electric grid readiness, and sufficient hydrogen supply. California has made significant progress in ZEV infrastructure deployment and preparing the grid for a transition to ZEVs and will continue to do so.

The California Energy Commission (CEC) coordinated with several agencies to develop this plan, including the California Public Utilities Commission (CPUC), California Air Resources Board (CARB), California State Transportation Agency (CalSTA), California Department of Transportation (Caltrans), Governor's Office of Business and Economic Development (GO-Biz), Department of General Services (DGS), Department of Housing and Community Development (HCD), and the California Building Standards Commission (CBSC).

CARB is the lead agency on deployment of ZEVs and equipment, and the CEC is the lead agency on ZEV charging and fueling infrastructure and the energy demand forecast, which anticipates grid impacts from ZEVs. The CPUC sets policy for infrastructure investments by the utilities it regulates. GO-Biz is the lead agency for job growth and economic development with a team specifically dedicated to cultivating opportunities to accelerate ZEV market growth including permit streamlining. CalSTA develops and coordinates the policies and programs of the state's transportation-related departments. Caltrans manages California's highway and freeway lanes, provides intercity rail services, and permits more than 400 public-use airports and hospital heliports. DGS is the lead agency ensuring PEV chargers are strategically installed at state-owned and leased facilities. The CBSC oversees California's comprehensive building codes, and the Department of Housing and Community Development develops building standards for private residences, including multifamily buildings. Coordination among these

1 California Governor's Office of Business and Economic Development. *California Zero-Emission Vehicle Market Development Strategy*. https://static.business.ca.gov/wp-content/uploads/2021/02/ZEV_Strategy_Feb2021.pdf.

agencies has been robust and is crucial to ensure each program is complementary, ensures strategic use of state funds, and maximizes the benefits to all Californians.

The CEC held a public workshop January 20, 2022, to share the purpose, vision, and principles of the ZIP for stakeholder feedback. The workshop drew nearly 300 attendees, and many provided comments. In general, the comments supported the ZIP, voiced concerns with grid readiness for the anticipated load of converting the medium- and heavy-duty (MDHD) sector to electric and supported the inclusion of emerging technologies for ZEV infrastructure.

Structure of the ZIP

Chapter 1 introduces California's ZEV goals, describes the purpose of the ZIP, and outlines ZEV infrastructure efforts to date, including private funding, public and utility funding, and other strategies including building standards and responses to permitting and reliability challenges. Chapter 2 describes the readiness of the electric grid for additional demand from ZEV infrastructure. Chapter 3 describes the projected needs and barriers for infrastructure. Chapter 4 divides ZEV infrastructure into five categories serving vehicle and infrastructure types and provides the current position, private sector actions, and actions the state is taking for each category. Chapter 5 describes near-term and longer-term key strategies for future funding decisions.

California's Zero-Emission Vehicle and Infrastructure Goals

ZEVs and ZEV infrastructure (for PEV charging and fuel cell electric vehicle [FCEV] fueling) will be a key component of achieving California's greenhouse gas (GHG) reduction targets, petroleum reduction goals, and air quality standards. California has specific goals to increase the supply of ZEVs and infrastructure including:

- By 2025:
  - Having at least 1.5 million ZEVs on the road. (Executive Order B-16-12).[2]
  - Installing 200 public hydrogen-fueling stations and 250,000 battery-electric vehicle chargers, including 10,000 direct current fast chargers (DCFC) (Executive Order B-48-18).[3]
- By 2030:
  - Having 5 million ZEVs on the road (Executive Order B-48-18).
- By 2035:
  - Transitioning 100 percent of new sales of passenger vehicles and trucks to ZEVs.
  - Transitioning 100 percent of operating drayage trucks to zero emission.
  - Transitioning 100 percent of operating off-road vehicles and equipment to zero-emission everywhere feasible (Executive Order N-79-20).[4]

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2 Executive Order B-16-12 available at https://www.ca.gov/archive/gov39/2012/03/23/news17472/index.html.

3 Executive Order B-48-18 available at https://www.library.ca.gov/wp-content/uploads/GovernmentPublications/executive-order-proclamation/39-B-48-18.pdf.

4 Executive Order N-79-20 available at https://www.gov.ca.gov/wp-content/uploads/2020/09/9.23.20-EO-N-79-20-Climate.pdf.

- By 2045:
  - Transitioning 100 percent of operating MD/HD trucks and buses to zero emission everywhere feasible (Executive Order N-79-20).

Purpose of the ZIP

The ZIP, along with modeling and analysis efforts such as those in Assembly Bill (AB) 2127 (Ting, Chapter 365, Statutes of 2018), Senate Bill (SB) 1000 (Lara, Statutes of 2018, Chapter 368), and Senate Bill 643 (Archuleta, Chapter 646, Statutes of 2021), will support decision-making in the public and private sectors by documenting what California has done and will do to deploy ZEV infrastructure equitably. The ZIP will also support public discussions of future funding needs and pathways to success in the state's ZEV goals, especially as embodied in proposed vehicle regulations. The ZIP is intended to be updated every two years.

GO-Biz collaborated with several agencies to develop the ZEV Market Development Strategy.[5] The goal of the ZEV Market Development Strategy is to accelerate large-scale, affordable, and equitable ZEV market development. Within the ZEV Market Development Strategy are four pillars: vehicles, infrastructure, end users, and workforce. End users encompasses consumers, riders, fleet operators, transportation network companies, car dealers, drivers, transportation planning agencies, program administrators, ports, regional and local governments and communities, trucking companies, and fuel providers. The ZIP will support the ZEV Market Development Strategy, addressing the "infrastructure" pillar of that strategy. More information on development of the other pillars can be found in the ZEV Market Development Strategy and other related documents.

The ZEV Market Development Strategy identifies five core principles:

1. Equity in every decision
2. California's embrace of all zero-emission pathways
3. Collective problem-solving
4. Public actions that drive greater private investment to scale investable markets
5. Design for resilience and adaptation

The ZIP and the state actions described within it support and use these principles.

Equity strategies include:

1) Weighting more investments for MD/HD ZEV infrastructure while recognizing the need to still make meaningful investments to support infrastructure for passenger vehicles because of the need to swiftly transition the most polluting vehicles toward zero-emission technologies.
2) Ensuring ZEV infrastructure investment benefit those in low-income and disadvantaged communities. For example, the CEC's Clean Transportation Program seeks to invest

5 GO-Biz. February 2021. ZEV Market Development Strategy. February 2021. https://static.business.ca.gov/wp-content/uploads/2021/02/ZEV_Strategy_Feb2021.pdf.

more than 50 percent of funding to benefit low-income and disadvantaged communities.

3) Using ongoing analysis to measure and track progress in serving low-income and disadvantaged communities, such as CEC's reports under SB 1000, and an effort by the CEC to create a plan to define, measure, and track program benefits beyond project location through a public outreach and engagement process in 2022.
4) Funding community-led projects to improve underserved communities' access to clean mobility options, such as the Clean Mobility Options Voucher Pilot Program, implemented by CARB, and funding proposed in the Governor's 2022–2023 Proposed Budget for Community-Based Plans, Projects and Support, and Sustainable Community Strategies.
5) Funding charger deployments in harder to reach segments such as to support PEVs in on-demand transportation services like Uber, Lyft, and DoorDash[6]; and installing chargers serving multifamily housing residents[7]; and installing chargers serving rural drivers.[8]

Private Sector Funding for ZEV Infrastructure

Growth in both public and private funding will provide a pathway to success in ZEV infrastructure deployment. Private funding has been critical to developing the existing ZEV infrastructure and is anticipated to play a large role in the future. As the market for electrification matures, usage of ZEV infrastructure should increase and ZEV infrastructure technology unit costs should decrease, improving the business cases for various infrastructure investments.

Light-Duty PEV Charging Infrastructure

Both public funding and private funding have been essential to supporting infrastructure deployment. Of the nearly 80,000 operational PEV chargers in California, fewer than half received funding from the state, electric utilities, and settlement agreements.[9] The CEC's Clean Transportation Program, Caltrans, and DGS combined have funded nearly 10 percent of the operational public and shared private chargers. The electric utilities funded 29 percent and

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6 CEC. GFO-21-601 – Charging Access for Reliable On-Demand Transportation Services (CARTS). https://www.energy.ca.gov/solicitations/2021-08/gfo-21-601-charging-access-reliable-demand-transportation-services-carts.

7 CEC. GFO-21-603 – Reliable, Equitable, and Accessible Charging for multi-family Housing (REACH). https://www.energy.ca.gov/solicitations/2021-11/gfo-21-603-reliable-equitable-and-accessible-charging-multi-family-housing.

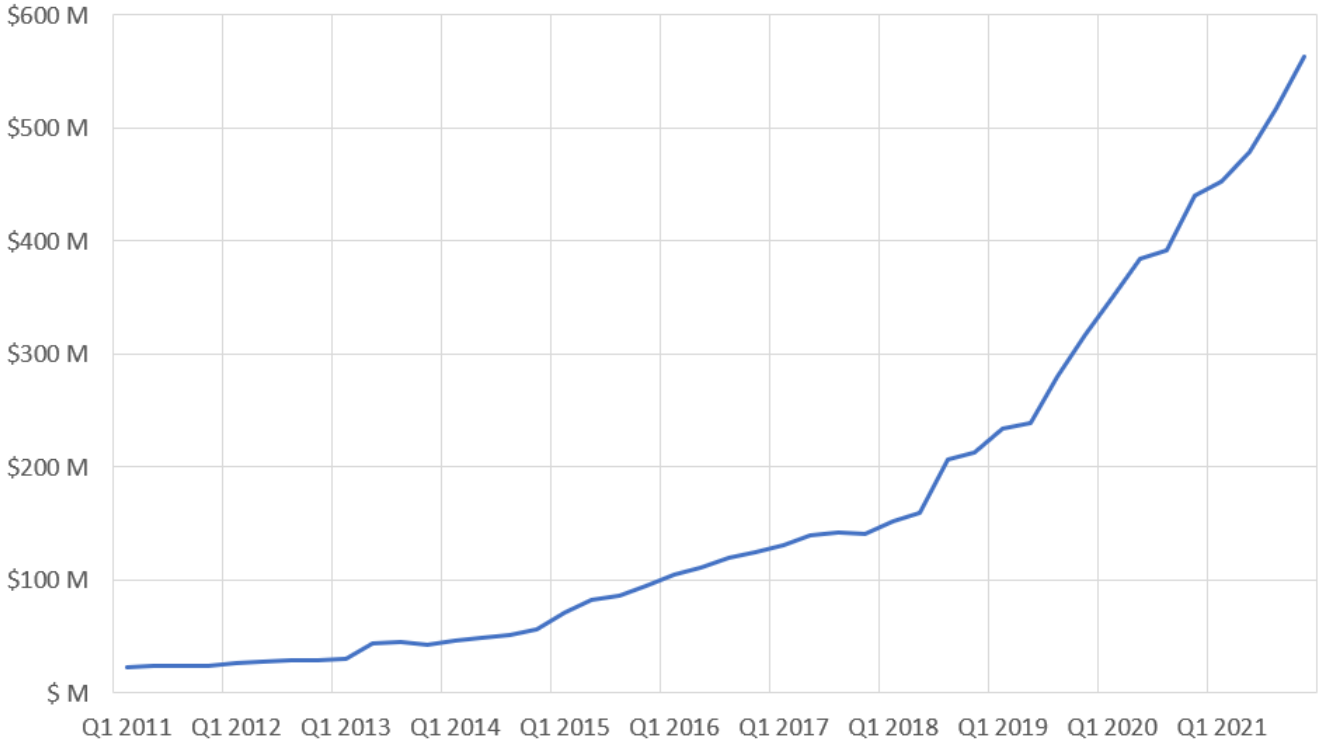
8 CEC. GFO-21-604 – Clean Transportation Program Rural Electric Vehicle (REV) Charging. https://www.energy.ca.gov/solicitations/2021-12/gfo-21-604-clean-transportation-program-rural-electric-vehicle-rev-charging.

9 In 2012 and 2015, California negotiated legal agreements with NRG and Volkswagen to install charging infrastructure to settle harms resulting from the 2001 electricity crisis and excessive diesel combustion emissions from Volkswagen vehicles, respectively.

settlements funded nearly 5 percent of operational PEV chargers in California.[10] Public and utility investments can continue to be targeted at the hardest-to-reach segments to ensure equitable access.

GO-Biz developed an EV Infrastructure Investment Model to look at the roles the private market, state programs, settlement agreements, and the investor-owned utility (IOU) investments played in funding publicly available chargers. **Figure 1** shows private investment is accelerating over time, demonstrating the critical role private investments has played and will continue to play in deploying PEV charging infrastructure.

Figure 1: Cumulative Private Investment in Light-Duty PEV Charging (2011–2021)



Source: GO-Biz EV Infrastructure Investment Model and CEC staff analysis

The model calculated the total costs of all public chargers at a given date and then subtracted identified investments by major public, semipublic, and large funding actors such as the CEC, settlement agreements, and IOUs.[11]

Legal settlements have also been a source of private investment in fast charging infrastructure. In 2020, EVgo completed the installation of 218 direct current fast charging (DCFC) Freedom stations as part of a settlement agreement between NRG Energy and the

10 Excludes make-ready stubs (mounting fixture and electrical infrastructure for electric vehicle chargers, but not the actual chargers) deployed by settlement funding.

11 Nicholas, Michael. August 2019. "Estimating Electric Vehicle Charging Infrastructure Costs Across Major U.S. Metropolitan Areas." August 2019. https://theicct.org/sites/default/files/publications/ICCT_EV_Charging_Cost_20190813.pdf.

CPUC.[12] Twenty-two high-powered charging plazas (more than 100 DCFCs total) were also constructed as part of the settlement. Electrify America, under Volkswagen's ZEV Investment Commitment has dedicated at least $100 million toward DCFC deployment for highway and regional routes. As of the end of 2021, Electrify America had opened more than 200 DCFC stations (more than 800 DCFCs) in California.[13]

Households have installed hundreds of thousands of chargers to take advantage of the convenience and low charging costs home charging offers. The state expects home charging to continue to be a popular choice and to be funded primarily by private individuals, with a proposed role for public funding to support installation in low-income households and multifamily housing.

As the market for ZEVs matures, private investment becomes more viable across market segments. Revenue from electricity sales alone is often not enough today for chargers to be profitable, especially for stations with lower utilization. Many actors from the private and public sectors are working on strategies to spur the growth of private sector funding and ongoing viability, including:

1) Reducing operating costs such as demand charges through rate design, distributed energy resources, smart charging, load management, and other managed charging strategies that can help mitigate costly grid upgrades and minimize charging expenses. The CEC is funding research and demonstration projects in these areas through solicitations under the Electric Program Investment Charge (EPIC) and the Clean Transportation Program.
2) The offering by some companies, such as Powertree Services, of innovative models such as monthly subscriptions with a scheduling and access control system for chargers. This offering can enable more drivers to share chargers, reducing the capital cost to serve the same amount of demand.
3) Credits earned through CARB's Low Carbon Fuel Standard (LCFS) that can provide additional revenue.
4) The incorporation by some companies of other revenue streams such as advertising (Volta) and bundling charging-as-a-service (Highland Transportation) with elements such as vehicles and maintenance.
5) Vehicle-grid integration (VGI), which may provide additional revenue opportunities.
6) The offering of PEV charging as part of a package of services to attract drivers. Examples of amenities packages include workplace charging, offered as a perk to employees; charging as an option at commercial parking garages; charging at multifamily housing for renters or owners; and charging funded by auto manufacturers

12 CPUC. CPUC/NRG Settlement Agreement. https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/infrastructure/transportation-electrification/nrg-settlement.

13 CARB. Volkswagen Zero-Emission Vehicle (ZEV) Investment Commitment. https://ww2.arb.ca.gov/our-work/programs/volkswagen-zero-emission-vehicle-zev-investment-commitment.

to stimulate sales of EVs. As an analogy, many gas stations today rely on on-site services and sales as a revenue stream.

Hydrogen Fueling Infrastructure and Supply

To reach 177 stations, the state will have provided about $279 million, and the private sector will have contributed about $190 million in match funds under CEC agreements. At least 13 of the 177 stations plan to be capable of fueling light-, medium-, and heavy-duty vehicles. The private sector is also developing 23 of the 177 planned stations without any public funding. Iwatani Corporation of America is developing 7 hydrogen stations outside a CEC agreement, and FirstElement Fuel is planning 16 privately funded stations within a CEC agreement. Chevron and Iwatani recently announced an agreement to fund and develop 30 hydrogen fueling stations in California by 2026, some of which may be in addition to the 177 stations above.[14]

The expected business model that would result in scaled deployment of hydrogen fueling infrastructure is similar to that for gas stations today. The short fueling times and potential for longer range for hydrogen vehicles may attract customers, including long-haul trucking fleets, drivers such as those for on-demand transportation services where fueling time means foregone revenue, or those who may be unable to charge at home. Potential revenue from fuel sales, convenience store sales, and other streams can be supplemented by Hydrogen Fueling Infrastructure credits under the Low Carbon Fuel Standard. CARB published a study showing that under certain assumptions and several scenarios the hydrogen network could reach a state of "self-sufficiency within the decade."[15] To achieve self-sufficiency, there must be sufficient driver usage of the stations and daily fuel throughput to create revenue. In 2027, the fueling network will have enough fueling capacity to support four times the number of FCEVs projected.

Reliable hydrogen supply, distribution, and dispensing have been a barrier to FCEV adoption, with major disruptions each of the last three years. Recent private sector investment in hydrogen production is worth noting and will help with supply. Linde is upgrading its plant in California to produce renewable hydrogen for the transportation sector.[16] Air Liquide is building a 30-tonnes-per-day liquid hydrogen plant in North Las Vegas, Nevada, and hydrogen from this plant will be available to various industries on the West Coast. Air Products is adding a new 30-tonnes-per-day liquid hydrogen plant in LaPorte, Texas, and investing in a joint project to produce 650 tonnes of hydrogen using wind and solar in the Middle East. Hydrogen from this project will be available anywhere there is demand is as long as it allows for economies of scale. An 11-tonnes-per-day plant is in development in Lancaster (Los Angeles

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14 "Chevron, Iwatani Announce Agreement to Build 30 Hydrogen Fueling Stations in California." https://www.chevron.com/stories/chevron-iwatani-announce-agreement-to-build-30-hydrogen-fueling-stations-in-california; Some stations may be developed as part of a CEC agreement with Iwatani.

15 CARB. 2021. *Hydrogen Station Network Self-Sufficiency Analysis per Assembly Bill 8.* https://ww2.arb.ca.gov/sites/default/files/2021-10/hydrogen_self_sufficiency_report.pdf.

16 Linde. November 2020. "Linde to Produce Green Hydrogen for Mobility Market in California." https://www.linde.com/news-media/press-releases/2020/linde-to-produce-green-hydrogen-for-mobility-market-in-california.

County) by SGH2 Energy to produce hydrogen from recycled wastepaper and recycled water. Plug Power is building a renewable hydrogen production plant in Mendota (Fresno County) that will produce 30 tonnes of liquid renewable hydrogen per day. FirstElement Fuel recently opened a 1,500 kg/day fueling hub in Livermore (Alameda County) supplied by Linde's Ontario (San Bernardino County) hydrogen production plant and a supply agreement with Air Liquide, which will serve liquid and gaseous hydrogen stations in Northern California. Federal hydrogen hubs may also expand hydrogen availability.

Public and Utility Funding for ZEV Infrastructure

Clean Transportation Program

The Clean Transportation Program, administered by the CEC and in its thirteenth year, has provided more than $1 billion to projects across the state covering a broad spectrum of alternative fuels and technologies. The *2021–2023 Clean Transportation Program Investment Plan Update* increased the budget of the program by six times, including $1.1 billion from a one-time appropriation from the general fund in the 2021–2022 state budget in addition to the remaining $238 million in program funds.[17] The Clean Transportation Program plans to invest more than 50 percent of funding to support projects benefitting low-income and disadvantaged communities. The Clean Transportation Program Investment Plan is guided by input from members of the Clean Transportation Program Advisory Committee, the Disadvantaged Communities Advisory Group, state transportation and environmental agencies, and a broad range of stakeholders.

The most recent Clean Transportation Program Investment Plan Update focuses on ZEV infrastructure build-out, with nearly 80 percent of available funding going to charging stations or hydrogen fueling, and prioritizes MDHD infrastructure. MDHD investments are allocated early in market development to help ensure public adoption of ZEVs is not stymied by lack of infrastructure. The funds will become available over the next two years and distributed to projects through competitive funding solicitations. The CEC will also continue to use block grants and other mechanisms to rapidly roll out funding for ZEV infrastructure and use targeted solicitations to encourage through incentives and investigate solutions for specific market segments.

Utility Investments in ZEV Infrastructure

Electric utilities have made important investments in charging infrastructure. As of October 2021, CPUC has authorized about $1.85 billion in ratepayer funding on transportation electrification (TE) programs for the six IOUs under the CPUC's jurisdiction.[18] The authorized

17 Brecht, Patrick. 2021. *2021-2023 Investment Plan Update for the Clean Transportation Program*. California Energy Commission. Publication Number: CEC-600-2021-038-CMF. Available at: https://www.energy.ca.gov/publications/2021/2021-2023-investment-plan-update-clean-transportation-program

18 Excludes costs for EV Infrastructure Rules enacted by AB 841 and LCFS Holdback Funds Programs.

funding will support nearly 61,500 Level 2 chargers, 521 DCFCs, and at least 2,600 MDHD on- and off-road chargers.[19]

Assembly Bill 841 (Ting, Chapter 372, Statutes of 2020) mandates the utilities create new electric rules to design and deploy infrastructure on the utility side of the meter for customers installing PEV charging. On October 7, 2021, the CPUC adopted resolutions approving the utilities' Electric Vehicle Infrastructure Rules.[20] These rules provide an option for customers installing separately metered TE charging, regardless of whether a customer participates in an IOU program for behind-the-meter infrastructure to not bear the costs of in-front-of-the-meter infrastructure upgrades. These upgrades include improvements to the distribution system needed to serve higher electric load created by electric vehicle charging. Customers will benefit from lower costs of electrification and certainty of in-front-of-the-meter costs. Customers installing separately metered TE infrastructure outside an IOU TE program are also allowed to take service through the Electric Vehicle Infrastructure Rules.

In February 2020, the CPUC published the Transportation Electrification Framework (TEF) that contains proposals on determining the appropriate role of utilities in TE, goals and metrics by which TE programs should be judged, and a process to streamline approval of utility programs.[21] Based on stakeholder comments and changes in the market, in February 2022, the CPUC issued a ruling with proposed modifications to the original TEF, including the establishment of funding cycles and a proposal for $1 billion over five years starting in 2025 to fund behind-the-meter infrastructure; marketing, education, and outreach; and technical assistance.[22] The program focuses solely on behind-the-meter needs as the Electric Vehicle Infrastructure Rules already cover all necessary investments on the utility side. The CPUC expects to issue a decision on TEF issues in 2022.

Publicly owned utilities are also investing in PEV charging infrastructure. Most notably, Los Angeles Department of Water and Power will spend up to $40 million per fiscal year from 2019 to 2029 to reach 10,000 chargers by 2022, 25,000 by 2025, and 28,000 by 2028.

Other ZEV Infrastructure Funding Efforts

California received about $423 million from the Volkswagen Environmental Mitigation Trust, which includes $10 million for light-duty ZEV infrastructure, administered by the Bay Area Air Quality Management District. Of this, half went to the CEC's latest hydrogen grant funding opportunity,[23] and half will fund light-duty chargers across the state.

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19 An additional 14,900 L2 ports and 1,100 DCFC are currently under consideration through Pacific Gas & Electric's Electric Vehicle Charge 2 application (A.21-10-010). The CPUC is expected to issue a Decision on this proposal no earlier than Q4 2022.

20 CPUC Resolutions E-5167 and E-5168.

21 CPUC. Transportation Electrification Framework.
https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M326/K281/326281940.PDF.

22 https://docs.cpuc.ca.gov/SearchRes.aspx?docformat=ALL&docid=453953154.

23 CARB. Appendix D of the Consent Decree.
https://ww2.arb.ca.gov/resources/documents/californias-beneficiary-mitigation-plan.

Volkswagen, through its subsidiary Electrify America, will also invest $800 million over 10 years for ZEV infrastructure, education, and access in California.[24] Electrify America will submit four ZEV investment plans, with each covering 30 months and $200 million, for CARB approval. The first ZEV investment plan was approved in July 2017, the second ZEV investment plan was approved in December 2018, and the third ZEV investment plan was approved in June 2021.

California Transportation Commission and Caltrans

The California Transportation Commission's Trade Corridor Enhancement Program (TCEP) supports the goals of the National Highway Freight Program[25] and the California Freight Mobility Plan[26], and the guiding principles in the California Sustainable Freight Action Plan.[27]

TCEP funds projects designed to move freight more efficiently on corridors with high volumes of freight. Eligible projects from the Trade Corridors Enhancement Account include highway improvement projects needed to accommodate ZEV charging and fueling infrastructure.

Caltrans administers the Transit and Intercity Rail Capital Program[28] and the Low Carbon Transit Operations Program,[29] which fund capital improvements to modernize and reduce emissions from California's intercity commuter and urban rail systems, buses (including feeder buses to intercity rail services, as well as vanpool and microtransit services), and ferry transit systems. ZEV infrastructure is eligible for these programs.

Future State and Federal Funding

To strengthen California's commitment to a clean transportation future, create jobs, and improve public health, California's 2021–22 budget (Senate Bill 129, Skinner, Chapter 69, Budget Act of 2021) included a three-year, $3.9 billion budget for ZEV-related investments by CEC, CARB, and GO-Biz. The budget prioritizes diesel emission reduction by earmarking funding to replace 1,125 drayage trucks, 1,000 school buses, and 1,000 transit buses with zero-emission alternatives and fueling infrastructure. The CEC funding is for infrastructure deployment to accelerate charging and hydrogen fueling station deployment and grants to promote in-state ZEV and ZEV-related manufacturing, such as infrastructure equipment and ZEV components.

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24 CARB. Appendix C ZEV Investment Commitment, "VW Settlement Consent Decrees." https://ww2.arb.ca.gov/resources/documents/vw-settlement-consent-decrees.

25 United States Department of Transportation, Federal Highway Administration. Fixing America's Surface Transportation Act or "FAST Act": National Highway Freight Program. https://www.fhwa.dot.gov/fastact/factsheets/nhfpfs.cfm.

26 Caltrans. California Freight Mobility Plan 2020. https://dot.ca.gov/programs/transportation-planning/division-of-transportation-planning/sustainable-freight-planning/cfmp-2020.

27 CARB. The California Sustainable Freight Action Plan. https://ww2.arb.ca.gov/our-work/programs/california-sustainable-freight-action-plan.

28 CalSTA. Transit and Intercity Rail Capital Program. https://calsta.ca.gov/subject-areas/transit-intercity-rail-capital-prog.

29 Caltrans. Low Carbon Transit Operations Program (LCTOP). https://dot.ca.gov/programs/rail-and-mass-transportation/low-carbon-transit-operations-program-lctop.

The Governor's proposed 2022–23 budget includes $6.1 billion to support ZEVs and fueling infrastructure. If this funding is appropriated by the Legislature, roughly $2 billion will be directed to ZEV infrastructure, including $600 million for DCFC to serve light-duty PEVs, $300 million for equitable at-home charging, and more than $1 billion for MD/HD ZEV infrastructure, including drayage trucks, transit buses, and off-road and port equipment. Combined with the $3.9 billion California invested last year, this amount represents potentially $10 billion for ZEV-related investments to help support in California's transition to ZEV over five years. The ZIP will help inform how those investments will be targeted.

Signed in November 2021, the federal Infrastructure Investment and Jobs Act of 2021 (IIJA)[30] provides $384 million in direct funding to California over five years to support the expansion of the PEV charging network. California will also have the opportunity to apply for $2.5 billion in grant funding for charging and hydrogen fueling infrastructure. The infrastructure is to be installed to fill gaps along designated Alternative Fuel Corridors.[31] An additional $9.5 billion for clean hydrogen hubs, electrolysis, and clean hydrogen manufacturing and recycling initiatives will also be available nationwide under IIJA.

To receive the National Electric Vehicle Infrastructure (NEVI) Formula Program funds made available by IIJA, each state will be required to develop a comprehensive PEV Infrastructure Deployment Plan by August 1, 2022.[32] The plan must include an analysis of existing and future conditions of the PEV market and emphasize public participation as well as equity, rural, and disadvantaged communities. States must also provide 20 percent match through public and private funds of the total award. CalSTA, Caltrans, and the CEC are collaborating to coordinate how the funding will be spent.[33]

30 "H.R.3684 - 117th Congress (2021-2022): Infrastructure Investment and Jobs Act." Congress.gov, Library of Congress. 15 November 2021. https://www.congress.gov/bill/117th-congress/house-bill/3684.

31 United States Department of Transportation, Federal Highway Administration. Alternative Fuel Corridors. https://www.fhwa.dot.gov/environment/alternative_fuel_corridors/.

32 United States Department of Transportation, Federal Highway Administration. Bipartisan Infrastructure Law: National Electric Vehicle Infrastructure Formula Program. https://www.fhwa.dot.gov/bipartisan-infrastructure-law/nevi_formula_program.cfm#:~:text=The%20BIL%20establishes%20a%20National,collection%2C%20access%2C%20and%20reliability.

33 CalSTA. November 19, 2021. IIJA 2021 Analysis. https://calsta.ca.gov/-/media/calsta-media/documents/calsta-high-level-iija-analysis-a11y.pdf.

CHAPTER 2:
California's Electric Grid Will Adapt to ZEV Load

The state's electric grid has expanded and evolved over time as consumer demand for electricity services has grown with the modern lifestyle. Electrification of California's transportation sector, particularly when combined with increased electrification of the state's buildings, will require careful grid planning and investments in transmission and local distribution systems. New electric load from PEVs has steadily increased in recent years and will grow rapidly over the coming decades.

The *2021 Integrated Energy Report (IEPR) Energy Demand Forecast* projected about 30,000 gigawatt-hours (GWh) in 2030 from charging battery-electric vehicles (including light-duty and MD/HD trucks, urban transit, and high-speed rail) in the "High" case.[34] Projections from the CEC's AB 2127 report,[35] which considered a larger PEV fleet, estimate that light-, medium-, and heavy-duty on-road vehicle charging will result in about 44,000 GWh by 2030.[36] These totals are estimated to increase annual statewide energy usage by 11–15.5 percent in 2030 compared to observed energy usage in 2020.[37] This analysis considers seasonal and weekday/weekend variation in energy usage, and charging is not expected to create a new systemwide peak. California's existing electric system planning process must and will keep pace and make investments to ready the grid for new PEV loads. With planning, foresight, and investments, the grid will be prepared for this new load.

State agencies collaborate to inform grid planning needs. In the case of transportation electrification, CARB regulations provide the foundation for understanding how ZEV populations will evolve. Approved regulations, along with other factors, inform the CEC's IEPR transportation energy demand forecast. This forecast considers many scenarios for ZEV adoption (Low, Mid, High, Aggressive, and Bookend), where all cases but the Low incorporate CARB's existing regulations. The IEPR Mid case is typically used by the CPUC in its Integrated Resource Plan (IRP) proceeding to develop 10-year plans among the IOUs. The CPUC used the High zero-emission vehicle forecast for the 2021 IRP Preferred System plan to reflect recent policy and market conditions. The IRPs ensure that system needs are met while enabling the electricity sector to contribute to California's GHG emission reduction and air quality goals. In parallel, the CPUC's Distribution Planning Process also leverages the IEPR forecasts to inform

34 Javanbakht, Heidi, Cary Garcia, Ingrid Neumann, Anitha Rednam, Stephanie Bailey, and Quentin Gee. 2022. *Final 2021 Integrated Energy Policy Report, Volume IV: California Energy Demand Forecast*. California Energy Commission. Publication Number: CEC-100- 2021-001-V4.

35 Alexander, Matt, Noel Crisostomo, Wendell Krell, Jeffrey Lu, and Raja Ramesh. July 2021. *Assembly Bill 2127 Electric Vehicle Charging Infrastructure Assessment: Analyzing Charging Needs to Support Zero-Emission Vehicles in 2030 – Commission Report*. California Energy Commission. Publication Number: CEC-600-2020-001-CMR.

36 Ibid.

37 Javanbakht, Heidi, Cary Garcia, Ingrid Neumann, Anitha Rednam, Stephanie Bailey, and Quentin Gee. 2022. *Final 2021 Integrated Energy Policy Report, Volume IV: California Energy Demand Forecast.* California Energy Commission. Publication Number: CEC-100- 2021-001-V4.

the utilities' Grid Needs Assessments and Distribution Deferral Opportunity Reports and support distribution system build-out to enable increased transportation electrification. In short, the state's electricity system planners are proactively working to ensure the grid will be capable of supporting increased transportation electrification.

Analysis of California's existing grid and approved investments occurring now at the bulk power level suggests the state will be able to handle millions of PEVs in the near term, and projections show the broader western grid can handle up to 24 million PEVs.[38] Other studies have found technical challenges can be overcome, and the grid can support increased transportation electrification, especially when considering historical growth rates in energy generation and generation capacity.[39] At the same time, these studies highlight the importance of thoughtful electrical distribution build-out and managed charging strategies, the latter of which have the potential to double the number of PEVs supported and substitute for additional generation and transmission requirements. The studies also speak to the importance of planning ahead, key parts of the CEC's forecasting, and the CPUC's resource planning efforts. In summary, while there are no fundamental obstacles to increased PEV adoption due to existing planning processes, there is work to be done, and the state's planners are working to ensure the grid will be capable of supporting increased transportation electrification.

The distribution system is more likely to require attention through the state's planning processes, though more research is needed to understand distribution impacts and needs.[40] On July 2, 2021, the CPUC opened a new proceeding (R.21-06-017) to modernize the electric grid for a high-distributed-energy-resources future.[41] One of the key goals of this proceeding is improving distribution planning, including charging infrastructure forecasting to support cost-effective and widespread transportation electrification. In parallel, CEC staff is developing the EVSE Deployment and Grid Evaluation (EDGE) tool, which uses the IOUs' Integration Capacity Analysis (ICA) map data to understand existing grid conditions and capacity. EDGE will help stakeholders identify suitable locations for charger deployments and act as an early warning system for utilities and grid planners to identify locations where grid upgrades may be required to support high charging demand. The ongoing development of EDGE has uncovered gaps in ICA maps that supported a ruling[42] by the CPUC in January 2021 establishing new

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38 Kintner-Meyer, Michael, et al. July 2020. *Electric Vehicles at Scale – Phase I Analysis: High EV Adoption Impacts on the Western U.S. Power Grid*. Pacific Northwest National Laboratory. https://www.pnnl.gov/sites/default/files/media/file/EV-AT-SCALE_1_IMPACTS_final.pdf.

39 Grid Integration Tech Team and Integrated Systems ANALYSIS Tech Team. 2019. *Summary Report on EVs at Scale and the U.S. Electric Power System*. https://www.energy.gov/sites/prod/files/2019/12/f69/GITT%20ISATT%20EVs%20at%20Scale%20Grid%20Summary%20Report%20FINAL%20Nov2019.pdf; Matteo Muratori et al. 2021. Prog. Energy 3 022002. Available at https://iopscience.iop.org/article/10.1088/2516-1083/abe0ad

40 Ibid.

41 California Public Utilities Commission. *Proposed Decision: Order Instituting Rulemaking to Modernize the Electric Grid for a High Distributed Energy Resources Future*. https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M382/K451/382451995.PDF.

42 California Public Utilities Commission. *Administrative Law Judge's Ruling on Joint Parties' Motion for an Order Requiring Refinements to the Integration Capacity Analysis*. https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M361/K810/361810169.PDF.

requirements to improve the accuracy and usefulness of the maps for grid planning moving forward. ICA data validation and mapping improvements are part of the CPUC's R.21-06-017 proceeding scope and a near-term priority following the scoping memo and ruling issued November 15, 2021.[43]

In the near term, local distribution system impacts from MD/HD charging loads will likely require circuit-level distribution upgrades in areas with low distribution system capacity. Forecasting the scope of upgrades needed with greater geographic specificity remains challenging and is the subject of the CPUC R.21-06-017 proceeding. While the EDGE tool also aims to address this challenge in part, state agencies and electric utilities have initiated efforts to plan for this new load. For example, several state agencies have created an Interagency MDHD Planning and Load Impact Working Group. The working group will plan for new load from MD/HD PEV charging as the sector converts to zero emission, a key public health and equity goal to ensure that the state converts diesel vehicles to zero emission as rapidly as possible. This type of interagency planning, along with CARB's vehicle regulation development, will continue to improve coordination with traditional statewide energy system planning processes, such as the CEC's IEPR forecasting, California ISO transmission planning, and CPUC generation, transmission, and distribution system resource planning. The working group also includes other agency efforts, such as the California Statewide Truck Parking Study, led by Caltrans, and an analysis of Clean Freight Corridors under Senate Bill 671 (Gonzalez, Chapter 769, Statutes of 2021), led by the California Transportation Commission. These tasks aim to understand where MD/HD vehicles park and prioritize freight corridors for ZEV charging and fueling infrastructure, respectively.

Hydrogen fueling stations are commercial utility customers and, in some cases, will face similar challenges as PEV infrastructure in ensuring that local grid capacity is adequate for new load. In the near term, the state forecasts fewer new hydrogen stations than new PEV charging infrastructure. While the planning described will be similar, the magnitude is expected to be smaller for hydrogen.

PEVs are a unique electric load and are potentially advantageous compared to other types of load. In most circumstances, PEVs are stationary longer than the time required to charge.[44] This provides some PEVs, most often light-duty vehicles, the flexibility to charge at times that are less impactful to the grid and at times when renewable generation is abundantly available. In fact, models suggest that PEV charging could reduce renewables curtailment anywhere from 25 to 90 percent.[45,46] PEVs are also able to take advantage of vehicle-grid integration

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43 California Public Utilities Commission. *Assigned Commissioner's Scoping Memo and Ruling*. https://docs.cpuc.ca.gov/SearchRes.aspx?DocFormat=ALL&DocID=422949772.

44 Wood, Eric, et al. February 2018. *Charging Electric Vehicles in Smart Cities: An EVI-Pro Analysis of Columbus, Ohio*. National Renewable Energy Laboratory. https://www.nrel.gov/docs/fy18osti/70367.pdf.

45 Kintner-Meyer, Michael, et al. July 2020. *Electric Vehicles at Scale – Phase I Analysis: High EV Adoption Impacts on the Western U.S. Power Grid*. Pacific Northwest National Laboratory. https://www.pnnl.gov/sites/default/files/media/file/EV-AT-SCALE_1_IMPACTS_final.pdf.

46 Jenn, A., and A. Brown. 2021. *Green Charging of Electric Vehicles Under a Net-Zero Emissions Policy Transition in California*. UC Office of the President: University of California Institute of Transportation Studies. http://dx.doi.org/10.7922/G28P5XTH Retrieved from https://escholarship.org/uc/item/2rv3h345.

strategies, such as electric rates that reflect real-time grid conditions, to encourage specific vehicle charging behaviors. Furthermore, software (that is, automated load management) and hardware solutions (that is, storage) can shift charging loads to hours that are less impactful to the grid, enable charging during periods of excess renewable generation, and manage peak loads.

Bidirectional charging, in which PEVs are capable of exporting stored battery energy, can enable emergency backup services in the event of grid shutoffs or general power failures, manage onsite load, and receive compensation for reducing system peaks. While flexibility and opportunities to take advantage of smart/managed or bidirectional charging are more common for light-duty PEVs, certain MDHD vehicles, such as school buses, and other use cases will also be able to leverage these benefits and should continue to be encouraged and explored. These are not technologies that are in the future. They are offered today, such as with the Ford F-150 Lightning.

In December 2020, the CPUC adopted a decision on VGI, which created metrics and strategies for advancing VGI and authorized almost $45 million for the utilities to spend piloting VGI technologies and programs.[47] In November 2021, the CPUC adopted a resolution creating a pathway for alternating current (AC) interconnection for vehicle-to-grid integration and allowing some PEVs to easily enable bidirectional mode.[48] The CPUC is considering streamlining procedures for PEV charging and bidirectional PEV interconnections.

The CEC has complemented these efforts by providing funding to support the development and commercialization of innovative technologies and charging solutions for smart/managed charging to address grid impacts. Recent examples of these solicitations include BESTFIT Innovative Charging Solutions,[49] Vehicle-to-Building Technologies for Resilient Backup Power,[50] and Research Hub for Electric Technologies in Truck Applications.[51] These projects will demonstrate solutions, such as charging deployments combined with on-site battery storage and advanced load-management software, completely off-grid charging solutions, and charging technologies integrated with existing utility assets to take advantage of available capacity.

At scale, hydrogen for transportation can be integrated into the electric grid in a variety of ways. Large-scale electrolysis of water to produce hydrogen could be a flexible electricity demand, potentially sited to take advantage of renewable electricity generation that would

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47 Decision (D.) 20-12-029 authorized the utilities to spend up to $35 million for VGI pilots, and $10 million for pilots, demonstrations, emerging technologies, and studies.

48 CPUC Resolution E-5165.

49 CEC. "GFO-20-605 – BESTFIT Innovative Charging Solutions." https://www.energy.ca.gov/solicitations/2020-08/gfo-20-605-bestfit-innovative-charging-solutions.

50 CEC. "GFO-21-303 – Vehicle-to-Building Technologies for Resilient Backup Power." https://www.energy.ca.gov/solicitations/2021-10/gfo-21-303-vehicle-building-technologies-resilient-backup-power.

51 CEC. "GFO-20-306 – Research Hub for Electric Technologies in Truck Applications (RHETTA)." https://www.energy.ca.gov/solicitations/2020-12/gfo-20-306-research-hub-electric-technologies-truck-applications-rhetta.

otherwise be curtailed because of transmission constraints. Hydrogen is also under consideration as an option for long-term storage of electricity, generated by electrolysis and stored in underground facilities like the ones now used to store natural gas. This hydrogen could then be used in fuel cells to generate electricity directly, or combusted in turbines, most likely in a mixture with natural gas. Hydrogen as a grid energy resource has the advantage of being able to be stored in large quantities for long periods without fading. Hydrogen storage may also open additional avenues for resilience in grid events, for example, with on-site zero-emission electricity generation. The production of hydrogen via electrolysis, compression, storage, and reconversion to electricity has inefficiencies that mean the full process would require two or more times the amount of electricity as charging a PEV.

California has consistently taken steps to reduce air pollution in local communities and combat climate change. The state has used data, analysis, planning, and innovation to adapt and evolve. The transition to ZEVs and grid readiness is no different. The state must continue to make smart investments and enact strong regulations. The actions being taken today will prepare the grid to integrate the new load.

CHAPTER 3: Assessment of Infrastructure Need and Challenges

Projections by CARB of vehicle populations in 2030 range from 5.5 million[52] to 8 million[53] light-duty ZEVs and 132,000[54] to 180,000[55] MD/HD ZEVs.[56] Under AB 2127,[57] the CEC projects that about 700,000 to 1.2 million public and shared-private chargers will be needed by 2030 to support 5 million to 8 million light-duty ZEVs, respectively, and about 157,000 chargers will be needed to support 180,000 MDHD vehicles.[58]

California's cumulative ZEV sales passed 1 million in 2021, supported by more than 79,000 light-duty public and shared-private PEV chargers, 61 light-duty and heavy-duty hydrogen stations operating in California,[59] 106 school bus chargers,60 MD/HD charging at ports, and estimated hundreds of thousands of home and private chargers. Charging and fueling access continues to increase.

The CEC and state agencies, in partnership with national labs and academia and informed by stakeholders, have strong modeling and analytical tools at their disposal. These tools and analyses help inform investment decisions and are the subject of reports to inform the public and decision makers.

Under SB 1000, the CEC assesses whether chargers are disproportionately deployed.[61] A staff report published in 2020 found that low-income communities have fewer public chargers per

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52 CARB. 2021. Public Workshop on Advanced Clean Cars II. https://ww2.arb.ca.gov/sites/default/files/2021-10/accII_october_2021_workshop_presentation_ac.pdf.

53 CARB. 2020 Mobile Source Strategy. https://ww2.arb.ca.gov/resources/documents/2020-mobile-source-strategy.

54 CARB. Advanced Clean Fleets. https://ww2.arb.ca.gov/our-work/programs/advanced-clean-fleets.

55 CARB. 2020. Draft 2020 Mobile Source Strategy. https://ww2.arb.ca.gov/resources/documents/2020-mobile-source-strategy.

56 CARB. 2022. Draft 2022 State Strategy for the State Implementation Plan. https://ww2.arb.ca.gov/sites/default/files/2022-01/Draft_2022_State_SIP_Strategy.pdf.

57 Assembly Bill 2127 (Ting, Chapter 365, Statutes of 2018). https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201720180AB2127.

58 Alexander, Matt, Noel Crisostomo, Wendell Krell, Jeffrey Lu, and Raja Ramesh. July 2021. *Assembly Bill 2127 Electric Vehicle Charging Infrastructure Assessment: Analyzing Charging Needs to Support Zero-Emission Vehicles in 2030 – Commission Report.* California Energy Commission. Publication Number: CEC-600-2021-001-CMR.

59 Fifty-four light-duty open retail and 7 heavy-duty operating hydrogen fueling stations.

60 California Energy Commission. 2021. "California Energy Commission Zero Emission Vehicle and Infrastructure Statistics." Data last updated: January 31, 2022. Retrieved from https://www.energy.ca.gov/zevstats.

61 Senate Bill 1000 (Lara, Chapter 368, Statues of 2018). https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201720180SB1000.

capita than middle- and high-income communities.[62] A second report, expected to be published in April 2022, shows that low-income and rural communities have some of the longest drive times to DCFC. These results will inform investments to ensure equitable access for EV drivers.

Executive Order B-48-18 set a goal of 200 hydrogen fueling stations by 2025. Assembly Bill 8 (Perea, Chapter 401, Statutes of 2013) requires CEC and CARB to jointly publish an annual report on the status of hydrogen fueling infrastructure and CARB to annually complete an analysis of the current progress and projected future development of California's hydrogen fueling station network and deploying FCEVs.[63] Automakers project 61,100 FCEVs on the road by the end of 2027, according to CARB's 2021 Annual Evaluation.

CEC and CARB evaluate fueling needs to analyze if the specific areas where vehicles are being sold and leased are adequality served by stations. The largest urban areas of the state will experience network capacity increases capable of supporting tens of thousands more FCEVs within the next two years. About 67 percent of California residents who live in disadvantaged communities are within a 15-minute drive time of an open retail or planned hydrogen station. When the 200-station goal is met, potentially more hydrogen installations will be near or in disadvantaged communities. The 200-stations are anticipated to support nearly 290,000 FCEVs, four times compared to automakers' projection of 61,000 FCEVs by the end of 2027.

SB 643 further requires the CEC, in consultation with the CARB and CPUC, to prepare a statewide assessment of FCEV fueling infrastructure and fuel production needs to support the adoption of zero-emission trucks, buses, and off-road vehicles to meet the goals and requirements of Executive Order N-79-20 and regulations.[64] The assessment will be completed by no later than December 31, 2023, and updated at least once every three years.

Caltrans' Zero Emission (ZE) Strategy for Intercity Passenger Rail is a framework for California to achieve zero-emission intercity rail mobility by 2035.[65] The ZE strategy promotes equity, improves the quality of life for Californians, particularly for disadvantaged communities adjacent to rail corridors, mitigates ongoing effects of climate change, and protects natural resources and ecosystems.

The ZE program consists of three strategic goals: decarbonizing the transportation system and improving air quality, increasing energy efficiency, and fostering leadership and facilitating collaboration in sustainable mobility.

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62 Hoang, Tiffany. 2020. *California Electric Vehicle Infrastructure Deployment Assessment: Senate Bill 1000 Report.* California Energy Commission. Publication Number: CEC-600-2020-009. Available at: https://www.energy.ca.gov/publications/2020/california-electric-vehicle-infrastructure-deployment-assessment-senate-bill.

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

64 Senate Bill 643 (Archuleta, Chapter 646, Statues of 2021) https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=202120220SB643.

65 Caltrans. CARB: ZE Seminar: Draft ZE Strategy for Intercity Fleet. https://ww2.arb.ca.gov/sites/default/files/2020-10/Day%201%20Ext%205%20Caltrans%2020201026.pdf.

SB 671 requires the California Transportation Commission, CARB, and CEC to develop a Clean Freight Corridor Efficiency Assessment that will identify freight corridors and the infrastructure needed to support zero-emission MD/HD vehicles by December 1, 2023.[66] The assessment will consider the potential for emissions reduction and the infrastructure needed for charging stations and alternative fueling infrastructure, such as hydrogen fuel.

Other Challenges and Responses

Improving Building Codes

The 2019 CALGreen, the state green building code (California Code of Regulations, Title 24, Part 11) requires new construction of single- and multifamily housing include raceway and panel capacity to support future installation of chargers.[67] The 2019 CALGreen is effective until December 31, 2022.

The 2022 CALGreen, effective January 1, 2023, will include new PEV charging provisions for newly constructed multifamily residential developments, hotels, and motels. These provisions include retention of the 2019 CALGreen provisions for PEV charging infrastructure (raceway and panel capacity) and new requirements for low-power Level 2 electric receptacles supplied by a minimum 208/240 Volt 20-ampere branch circuit for 25 percent of parking spaces. For projects with 20 or more units, sleeping units, or guest rooms, an additional requirement was added for installation of Level 2 (208/240 Volt 40-ampere branch circuit) PEV chargers for 5 percent of parking spaces. The 2022 CALGreen also provides for the use of automated load management systems when receptacles or chargers are installed in excess of the minimum required. The voluntary Tiers 1 and 2 of CALGreen for residential applications have been amended to require an increased percentage of receptacles and chargers.

Currently, the CALGreen Code requires new construction of nonresidential buildings (under CBSC authority) include raceway and panel capacity to support future installation of chargers for 10 percent of total parking spaces for light- and medium-duty vehicles.

Effective January 1, 2023, PEV infrastructure requirements for parking lots have increased to around 20 percent of total parking spaces to be PEV capable. About 25 percent of PEV capable spaces will require the installation of PEV chargers (Level 2 or DCFCs). Moreover, the use of an automatic load management system has been added as an alternate compliance pathway. For new warehouses, grocery stores, and retail buildings with off-street loading spaces, CBSC has adopted MD/HD ZEV infrastructure requirements that will support the future addition of chargers for MDHD vehicles.

The Division of the State Architect has co-adopted with CBSC PEV regulations for light-duty vehicles applicable for public schools and community colleges.

CBSC and HCD are considering additional measures for PEV charging in the next round of building code updates.

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66 Senate Bill 671 (Gonzalez, Chapter 769, Statutes of 2021) https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=202120220SB671.

67 California Building Standards Commission. CALGreen. https://www.dgs.ca.gov/BSC/CALGreen.

Building Reliability of Charging and Hydrogen Fueling Networks

California has the largest network of public chargers and hydrogen fueling stations in the nation. It is important to consider how well this charging and fueling network functions.

Reliability of the network overall, and of stations that drivers may rely on, has increased as a concern, especially as the vehicle market grows beyond early adopters to mainstream consumers. As the state invests in ZEV infrastructure, the state is investigating how to track and measure the reliability of those stations over time. The CEC held a public workshop March 11, 2022, to gather stakeholder input on how to define and measure reliability, publish reliability metrics for light-duty PEV chargers, and discuss how to incorporate reliability metrics in future CEC PEV charging infrastructure funding opportunities. The CEC will develop and publish reliability standards to increase uniformity and transparency. Consumer-facing apps and websites like PlugShare,[68] market surveys and studies,[69] and automakers' in-car navigation provide additional information. As the public network of charging for MD/HD vehicles grows, reliability of that network will also be important and should be monitored.

The CEC continues to monitor hydrogen fueling network reliability and resiliency. The CEC plans to release a survey to various stakeholders for feedback on how to better address FCEV adoption barriers, with a public workshop to follow.

Reliable hydrogen supply, distribution, and dispensing have been a barrier to FCEV adoption, with major disruptions each of the last three years. A robust hydrogen supply chain, including production, distribution, and dispensing, will be needed to help bolster consumer confidence and allow market expansion in light-duty and MD/HD FCEVs. To address the supply issue, the CEC's most recent grant funding opportunity for hydrogen stations required funded stations to have a second supply agreement as backup to ensure station operators do not rely on a single supply source.

The Clean Transportation Program is investing with a clean hydrogen future in mind and has funded the construction of two renewable hydrogen production plants expected to be open in 2023. These plants will produce 100 percent renewable hydrogen from in-state renewable resources. The CEC anticipates funding additional renewable hydrogen production plants through an existing funding opportunity.[70]

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68 PlugShare Website: https://www.plugshare.com/.

69 J.D. Power. August 18, 2021. "Public Charging Experience for Electric Vehicle Owners Can Get Much Better, J.D. Power Finds." https://www.jdpower.com/business/press-releases/2021-us-electric-vehicle-experience-evx-public-charging-study; Umlaut. January 31, 2022. "US EV Charging Infrastructure – How Fast and How Convenient?" https://www.umlaut.com/en/stories/us-ev-charging-infrastructure-how-fast-and-how-convenient.

70 GFO-20-609 Renewable Hydrogen Transportation Fuel Production, https://www.energy.ca.gov/solicitations/2021-04/gfo-20-609-renewable-hydrogen-transportation-fuel-production.

Streamlining Permitting

Streamlined permitting and approval processes will allow accelerated deployments of ZEV infrastructure. All cities and counties in California are required by law (Assembly Bill 1236, Chiu, Chapter 598, Statutes of 2015, and Assembly Bill 970, McCarty, Chapter 710, Statutes of 2021) to streamline permitting processes for PEV charging stations and limit project review to health and safety requirements in an expedited timeframe. While a growing number of California jurisdictions are streamlining their PEV charging station permitting processes, 252 of the 540 California cities and counties are not streamlined, and 137 are in progress. Direct outreach to local jurisdictions on best practices, coordinated by GO-Biz with several agencies (local and state agencies, utilities, and various stakeholders), is helping address this barrier to the expeditious deployment of PEV chargers that is needed to meet the state's goals. GO-Biz is updating the Electric Vehicle Charging Station Permitting Guidebook with a targeted completion of summer 2022.[71] GO-Biz also developed the "EV Charging Station Permit Streamlining Map" to track compliance with California laws.[72]

Permitting hydrogen stations in California can be complex and time-intensive but has been completed successfully for more than 50 stations in public, retail environments. To obtain approval and successfully construct a project, developers must ensure compliance with relevant regulations, codes, and standards, which often vary among local jurisdictions. In recent years, hydrogen station permitting and development timelines have decreased as station developers and permitting officials have become more familiar with hydrogen and FCEV technology. In addition, direct outreach to local jurisdictions, coordinated by GO-Biz and with several parties, has also helped identify and overcome specific barriers as well as opportunities to further streamline development. However, more work is needed to determine how hydrogen station permitting can be accelerated.

Improving Interconnection Times

Deployment of ZEV infrastructure has experienced slowdowns due to utility interconnection. Electrify America has identified utility interconnection costs and timelines as a barrier to DCFC deployment, stating that as of the end of the third quarter of 2021, the new service utility interconnections averaged nearly nine months in California. EVgo noted bottlenecks in interconnections have delayed projects from six months to a year. EVgo notes that Southern California Edison's interconnection procedures have evolved and include clear application requirements, predictable timelines, and access to the utility's authorities when clarifications are needed. In the resolutions approving the IOUs' Electric Vehicle Infrastructure Rules, the CPUC directed the IOUs to host a public workshop to discuss the barriers to timely PEV charging service energization. Following the workshop, the IOUs are to propose an average timeline for PEV charging interconnection of between 90 and 160 days.

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71 GO-Biz. 2019. *Electric Vehicle Charging Stations Permitting Guidebook.* https://static.business.ca.gov/wp-content/uploads/2019/12/GoBIZ-EVCharging-Guidebook.pdf.

72 GO-Biz. "Plug-In Electric Vehicle Charging Station Readiness." https://business.ca.gov/industries/zero-emission-vehicles/plug-in-readiness/.

For hydrogen station development, the COVID-19 pandemic caused delays in scheduling final inspections with utilities.

As station developers need to move quickly to deploy charging and fueling infrastructure, resolving the utility interconnection issue is critical to accelerating the market.[73]

Standardization of Charging and Fueling Infrastructure

There are three types of DCFC connectors for light-duty PEVs: CHAdeMO, Combined Charging Standard (CCS), and Tesla. Having multiple connectors can cause confusion for PEV drivers and has the potential to increase the number of DCFCs needed to meet California's ZEV infrastructure goals. The market is moving toward CCS, including a CARB proposal that light-duty vehicles with fast charging capability sold in California would have to be CCS-compatible beginning with Model Year 2026. The CEC's Clean Transportation Program block grants and funding opportunities have reduced, and in some cases eliminated, CHAdeMO requirements. The recently released NEVI Formula Program Guidance states funds are directed to designated Alternative Fuel Corridors. The latest requirement for the Alternative Fuel Corridors for PEV focuses on DCFCs with CCS connectors.[74]

Beyond connector standardization, the AB 2127 report identified the Open Charge Point Protocol (charger-network communication) and International Organization for Standardization (ISO) 15118 (charger-vehicle communication) as important communication protocols to support an easier-than-gas charging experience for drivers, interoperability, and grid-integration functions. Despite growing use of ISO 15118 among automakers, many chargers today are not equipped with the hardware to reciprocate ISO 15118 communication. CEC staff held a workshop in November 2021 discussing market implementation of ISO 15118 and efforts to support ISO 15118 standardization, and later published a recommendation that charging providers pursue widespread deployment of ISO 15118-ready charging equipment beginning in 2022.[75]

MD/HD charging infrastructure is in earlier stages of development and is less standardized than light-duty charging. For MDHD, some manufacturers use proprietary connectors that are incompatible with other vehicles from different manufacturers, and many others use the CCS connector (also used for light-duty fast charging). The different standards can cause confusion and frustration for MDHD fleet operators that operate several equipment types. CharIN, a nonprofit organization, assembled a task force of industry stakeholders to develop a connector capable of supporting megawatt-level charging power, called the Megawatt Charging System (MCS). CEC staff expects vehicles and chargers supporting the MCS connector to be deployed as soon as 2022–2023, with official standardization through standards development

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73 Trabish, Herman K. April 22, 2019 (Utility Dive). "Utilities, Charger Vendors Find Interconnection Best Practices To Propel EV Growth." Available at https://www.utilitydive.com/news/utilities-charger-vendors-find-interconnection-best-practices-to-propel-ev/549593/.

74 "Request for Nominations – Alternative Fuel Corridors Round 6." https://www.fhwa.dot.gov/environment/alternative_fuel_corridors/nominations/2022_request_for_nominations_r6.pdf.

75 CEC. February 2022. "Recommendation for Deployment of ISO 15118-Ready Chargers." https://efiling.energy.ca.gov/GetDocument.aspx?tn=241955.

organizations completing around 2024. In addition to CCS and MCS, other standardized charging interfaces for MD/HD vehicles in North America include the Society of Automotive Engineers (SAE) J3105 for automated pantograph charging and J3068 for AC charging.

For hydrogen fueling infrastructure, station developers are required to comply with international fueling standards to maintain reliable and safe fueling at stations. Hydrogen stations in California operate at two different pressures, 35 Megapascal (MPa) and 70 MPa; for safety reasons, vehicles with 35 MPa systems cannot be fueled by 70 MPa dispensers, though all modern stations and light-duty vehicles are built to the 70 MPa standard. While standards for HD fueling with 35 MPa systems, such as those used for transit buses, are well established, hydrogen standards for fueling MDHD vehicles with larger tank systems and with dispensers for 70 MPa systems have not yet been developed but will be critical to a scaled buildout of hydrogen vehicles.

For both electric charging and hydrogen fueling, further development on MD/HD standards and fueling protocols will be important. Interoperability, commonality in design, ability to work for on-road vehicles and off-road equipment, and functionality are all being discussed and analyzed by state agencies, national labs, and industry stakeholders to ensure that MD/HD vehicles and their drivers have consistent and familiar fueling experiences.

CHAPTER 4:
ZEV Infrastructure Categories

The ZIP divides ZEV infrastructure into five categories:

- Charging and Hydrogen Fueling for MDHD ZEVs
- Public Hydrogen Fueling for Light-Duty FCEVs
- Level 1 and Level 2 Charging for Light-Duty PEVs
- Fast Charging for Light-Duty PEVs
- Emerging Technologies

These categories target different use cases described below. For each category, this chapter will provide the current position, private sector actions, and actions the state is taking.

Charging and Hydrogen Fueling for MD/HD ZEVs

The Governor's executive orders and CARB's Advanced Clean Trucks Regulation and proposed Advanced Clean Fleets Regulation are placing more emphasis and focus on converting MD/HD fleets to ZEVs to improve public health and address the climate crisis. CARB's draft *2020 Mobile Source Strategy* recognizes this direction and calls for the deployment of about 1.4 million MDHD ZEVs in California by 2045. These policy directions and regulations are backed up by robust investments, including Clean Transportation Program and CPUC-authorized IOU funding and private funding.[76]

MD/HD fleets have a disproportionate impact on air quality as they tend to have higher air pollution emissions per mile, are driven more miles, and are concentrated in certain regions and along certain routes. MD/HD ZEVs represent a significant opportunity to reduce greenhouse gas emissions and criteria pollutant emissions. In the near term, the CEC and CPUC have prioritized investments toward MD/HD vehicles and infrastructure to meet the growing needs of charging and hydrogen fueling infrastructure for MD/HD ZEVs, as well as demonstrate the state's commitment to improving air quality, especially in low-income and disadvantaged communities. These investments leverage private funds to accelerate infrastructure deployment. Significant investments have been made and are being made in these sectors to ensure that infrastructure arrives ahead of vehicles.

The MD/HD segment includes a wide variety of vehicles, such as school and transit buses, first- and last-mile specialized delivery vans customized for a variety of services, and freight and long-haul goods movement vehicles including drayage trucks and regional-haul trucks.

76 For example, Daimler Truck North America, BlackRock Renewable Power and NextEra Energy Resources recently announced a $650 million joint venture to build charging infrastructure for electric and hydrogen fuel cell MDHD trucks. The first phase of construction is expected to begin in 2023 along critical freight routes along the East and West Coasts. https://www.freightwaves.com/news/daimler-truck-blackrock-and-nextera-energys-650m-bet-on-electric-infrastructure.

Because of the diversity of MD/HD vehicle applications in California and the specific needs of each, the state has taken several approaches to ZEV adoption. CARB has enacted regulations that are expected to promote the rapid electrification of the state's MD/HD vehicles and equipment in the next decade:

- The Innovative Clean Transit Regulation (2018) requires large transit agencies to have 25 percent of new bus acquisitions be zero-emission starting in 2023, with all transit agencies rising to 100 percent in 2029.
- The Zero-Emission Airport Shuttle Regulation (June 2019) requires airport shuttle operators to begin adding zero-emission shuttles to their fleets in 2027 and complete the transition to ZEVs by the end of 2035.[77]
- The Advanced Clean Truck Regulation (June 2020) requires truck manufacturers to sell an increasing proportion of zero-emission trucks in California.
- The 2022 Amendments to CARB's rule for transportation refrigeration units (TRU) requires all truck TRUs operating in California to be zero-emission by December 31, 2029.[78]

CARB is developing the Advanced Clean Fleets regulation that is a phased-in fleet transition to zero-emission trucks from 2024 through 2042 for certain fleets and would require all new vehicle sales to be ZEVs starting in 2040. This fleet-focused strategy ensures that fleets begin to purchase MD/HD ZEVs offered for sale by truck manufacturers and deploy them in market segments that are suitable for electrification. The goals of these regulations are to transition California's entire MDHD truck and bus fleet to zero emission by 2045.

ZEV charging and hydrogen fueling can be very different, depending on the duty cycle and use of the vehicle. Some MD/HD ZEVs can use the same charging technologies as light-duty electric vehicles (Level 2 and DCFC), while some may have a greater reliance on DCFC than light-duty EVs. While some MD/HD EVs can charge at centralized depots (home base charging), others may not have consistent access to home base or overnight charging and have to rely on on-route DCFC or public charging options to refuel enroute, also known as "opportunity charging." Certain MD/HD vehicles can also take advantage of other charging technologies such as overhead charging applications, overhead catenary, and wireless charging systems.

While cost is a barrier, vehicle costs, including battery costs, are decreasing. In the long term, total cost of ownership (TCO), which includes purchase costs, fuel costs, and maintenance costs, will be a critical metric for mass adoption of electrified commercial vehicles when looking at advantages of battery-electric or fuel cell electric commercial trucks over traditional diesel-fueled trucks. CARB's TCO Discussion Document for the ACT regulation found costs of batteries and fuel cell components are expected to decline substantially over the next decade and will bring down the incremental capital costs of zero-emission trucks and buses improving

77 CARB. 2019. "Zero-Emission Airport Shuttle Regulation Factsheet." https://ww2.arb.ca.gov/sites/default/files/2019-10/asb_reg_factsheet.pdf.

78 CARB. "Proposed Amendments to the TRU ATCM." https://ww2.arb.ca.gov/resources/fact-sheets/proposed-amendments-tru-atcm.

the associated TCO compared to the diesel equivalent.[79] Electricity costs depend on how, when, and where the vehicles are charged, with lower costs for charging overnight or morning during off-peak periods than fast charging during the day or peak periods. Even including energy costs, demand charges, and fixed fees, electricity costs are expected to be lower on a per-mile basis than diesel in most cases. In the long term, especially for larger fleets, the TCO will drive the change to zero emission. The transition may happen more rapidly than it will for light-duty vehicles as commercial fleet owners are better able to predict TCO, and potentially are more influenced by it in their vehicle choices, than most consumers. Business models such as mobility as a service for commercial fleets are also gaining prominence and may play a role in the ZEV transition.

Public and private funding will play an important role in the transition. The CEC has funded charging and hydrogen fueling infrastructure to support large-scale conversion of transit bus fleets, drayage trucks, and school buses to ZEVs. The CEC's recently funded EnergIIZE project will help with deployment of infrastructure throughout the state and is designed to support CARB's Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project to align infrastructure incentives with vehicle incentives. CEC and CARB have held ongoing infrastructure workshops through March 2022 to solicit feedback from fleets in preparation of the Advanced Clean Fleets regulation.

These dual funding sources will help ensure that the state can meet its goals by putting program funds and recent general fund dollars to work. The California Budget Act of 2021 allocated investments to support thousands of MD/HD vehicles and infrastructure. The Governor's proposed budget for Fiscal Year 2022–23 will provide infrastructure for thousands more. Public funding combined with IOU and private funding provides high level of funding to make the transition to MDHD ZEV adoption.

Hydrogen Fueling for Light-Duty FCEVs

This segment focuses on hydrogen infrastructure that primarily serves light-duty FCEVs. As of the end of 2021, nearly 12,000 FCEVs had been sold in California, with an on-road population of 7,129 as of the end of 2020. A network of 55 open-retail hydrogen fueling stations in California has the capability to serve around 40,000 light-duty FCEVs with 33 light-duty and 2 heavy-duty stations planned.[80]

California, as a state, including the most recent solicitation,[81] has made dedicated cofunding for more investments in hydrogen infrastructure than any country except Japan. California is cofunding 170 light-duty hydrogen fueling stations, with up 13 of those also incorporating fueling for medium-duty commercial vehicles. The *Clean Transportation Program 2021–2023 Investment Plan Update* also allocated up to $27 million to close the gap to 200 fueling

79 CARB. 2019. *Preliminary Draft TCO Discussion Document*. https://ww2.arb.ca.gov/sites/default/files/2020-06/190225tco_ADA.pdf.

80 California Energy Commission. 2022. "New ZEV Sales in California." Data last updated January 31, 2022. Retrieved February 18, 2022, from https://www.energy.ca.gov/zevstats.

81 "GFO-19-602 Hydrogen Refueling Infrastructure." https://www.energy.ca.gov/solicitations/2019-12/gfo-19-602-hydrogen-refueling-infrastructure.

stations.[82] The state plans to invest more than $300 million in light-duty hydrogen infrastructure and reach 200 stations. With 200 stations deployed, the CEC anticipates that nearly 290,000 FCEVs can be supported. Additional public funding for hydrogen fueling stations dedicated to light-duty passenger vehicles will be informed by consumer uptake, market conditions, and other factors in collaboration across state agencies. Hydrogen fueling infrastructure is not expected to be a barrier to light-duty FCEV adoption.

State and private actors should collaborate to address other challenges for light-duty FCEVs, such as areas where local fueling capacity may be a limitation, high prices at the pump for hydrogen, station reliability, and others.

Level 1 and Level 2 Charging for Light-Duty PEVs

Providing a convenient and reliable network of chargers in California remains a fundamental part of accelerating market growth and acceptance of PEVs. In addition to residential charging, publicly accessible and shared-private Level 2 charging plays an important role in extending the range of PEVs and improving convenience and access to charging. Today, most of the chargers deployed in California are Level 2 chargers. The state is on track meet its goal of 250,000 (of which 10,000 are DCFC) chargers by 2025; however, even more chargers may be needed by 2025 to meet updated PEV population projections.

Level 1 and Level 2 charging can be found in a variety of locations including home, workplace, fleet, and public sites. This category is further broken down into two subsegments, home charging and charging away from home.

Home Charging

Home charging for personal vehicles at single-family and multifamily housing usually has the longest dwell time, usually overnight. This is typically the least expensive and most convenient option and, in many circumstances, has the smallest impact on the electric grid. The same can be said for charging for light-duty fleets where fleet vehicles return to a home-based location to charge or for light-duty fleet vehicles that may be parked at a depot when not in use.

Level 1 or Level 2 chargers can be installed in the home. Level 1 charging can deliver between 3 to 5 miles of electric range per hour of charge, and a Level 2 charging typically provides 14 to 35 miles of electric range per hour of charge for vehicles available today.[83] As vehicle range and the power of onboard chargers increase, Level 2 chargers can provide more than 35 miles of electric range per hour in the future. Level 2 charging can provide many advantages over Level 1 charging, including a quicker charge and additional functionalities such as allowing a driver to manage their charge with remote start/stop and scheduling. Vehicle owners have typically been supplied with a Level 1 cord set from the vehicle manufacturer that can be plugged into a standard 120-volt outlet. Recently, many cord sets are Level 2 capable if plugged into a dryer outlet, and CARB has proposed to make dual voltage cord sets

82 Brecht, Patrick. 2021. *2021-2023 Investment Plan Update for the Clean Transportation Program*. California Energy Commission. Publication Number: CEC-600-2021-038-CMF.

83 Center for Sustainable Energy. "CALeVIP Electric Vehicle Charging 101." https://calevip.org/electric-vehicle-charging-101.

mandatory. The install costs for Level 2 chargers are higher than for Level 1 charging, especially at multifamily housing if electrical upgrades are required due to lack of electrical capacity at the site. At homes where the cost of upgrading electrical capacity is too high, especially in older buildings, Level 1 can be a second-best solution that provides access to vehicle charging. As vehicle battery capacities increase, Level 2 will be increasingly preferred by drivers.

A recently published CEC report showed that single-family homes have much greater access to driveways, personal garages, and free on-street parking compared to multifamily homes.[84] Multifamily homes are limited primarily to parking garages, parking lots, and on-street parking. Also, in general, households with higher incomes have greater access to preferred parking options. Home charging access is observed to be lower for multifamily residents, single-family renters, low-income residents, and residents of color. Three key barriers that could hinder PEV adoption and home charging access include education and awareness of PEVs, electrical installation costs, and parking behavior.

Increasing access to home charging is an important step in planning for a zero-emission future. Actions are being taken to address new home construction and the existing stock. See Chapter 2 on improving building codes.

The CEC's Clean Transportation Program funded the installation of nearly 4,000 chargers for private home charging use early in the program and is increasingly focus on investments in multiunit dwellings such as apartments. Many publicly owned utilities continue to offer rebates for residents to install home charging.[85] As costs have come down for home charging equipment and home chargers can be purchased off the shelf by the consumer, the state expects home charging to continue to be a popular choice and primarily funded by individuals. However, not all residents have the ability to pay for necessary electrical upgrades and other requirements for home charging. Residents of multifamily homes, as well as renters, may not have access or the ability to install chargers near where their vehicles are parked. It would not be meeting the state's equity goals if only those with the greatest ability to pay had access to the least expensive and most convenient charging option.

Stronger EV-ready building codes, incentives for low-income home and multiunit dwelling chargers, and strategic and targeted deployment of curbside chargers in residential areas can facilitate adequate and equitable home charging access.

Charging Away From Home

Level 1 and Level 2 charging away from home will play an important role. It can provide access to potentially low-cost charging to extend range and for those without access to charging at home. These chargers can also serve as overnight charging for vehicles serving fleets and transportation network companies. Prime examples include workplace charging or

84 Alexander, Matt. 2022. *Home Charging Access in California*. California Energy Commission. Publication Number: CEC-600-2022-021. Available at https://www.energy.ca.gov/sites/default/files/2022-01/CEC-600-2022-021.pdf.

85 CARB. "California Clean Fuel Reward: Participating Electric Utilities." https://cleanfuelreward.com/california-ev-rebate-program/electric-utilities-discounts.

public charging in parking garages and lots. Though some charging would occur when electricity demand is higher, smart charging can maximize use of solar energy and reduce impacts to the electric grid.

These chargers include both public and shared-private access.[86] Chargers can be at workplaces, parking garages, retail centers, universities, and other locations where drivers are likely to park for several hours. These locations also include near-home overnight public charging (that is, curbside, parking garages within walking distance). Charging away from home can be a good alternative to residents at multifamily housing that are unable to charge at home, providing a reliable site to charge, such as at work. These charging options can provide primary access for some drivers and can also help PEV drivers extend their range as a secondary charging location. Near-home overnight public charging may also serve as a good alternative for fleets and transportation network companies that don't have home-based overnight charging.

Public charging is an important part of the network but often faces high upfront costs for equipment and installation, paired with uncertain usage of charging services and consumers' willingness to pay for public charging. Site hosts/charger operators may have a tougher time recovering capital and operational costs with this use case. In the near term, it is unclear that many Level 1 or Level 2 chargers will be profitable based on electricity sales alone. Mechanisms such as credits generated under the Low Carbon Fuel Standard aid the business case. But, in most cases, charging will be bundled with other amenities. For example, employers who now offer parking as a perk to employees may add charging; parking garages may attract customers by offering packages of parking and charging; retail establishments and hotels may offer charging, free or paid, to distinguish themselves from competitors.

The utility of Level 1 and Level 2 charging depends on the expected duration a driver will use it and the rate of power transfer. Due to the relatively low charging rate compared to high-powered fast chargers, charging for short visits (short "dwell times") may not be of much benefit, especially if plugging in and initiating charging is not convenient. Level 1 and Level 2 charging are likely to have the highest value to consumers when their cars will be stationary for long periods — a few hours or more (long "dwell times"). Level 1 and Level 2 charging for light-duty passenger vehicles can provide access and have a lower impact on the grid.

Fast Charging for Light-Duty PEVs

DCFCs can refuel PEVs quicker than Level 1 and Level 2, with rates ranging from 50 to 350 kilowatts (kW). When DCFCs are located along major highway corridors, these chargers can enable long-distance travel by PEVs. DCFC also have a key role in serving the needs of drivers without access to home charging, such as those living in multifamily housing, and for community charging needs with drivers who need additional miles quickly. DCFC in shopping centers, grocery stores, and within communities help create a broad network and equitable access.

86 "Shared-private" charging is not open to the public but also not assigned to an individual. This can include workplace charging and multifamily charging where several employees or residents, respectively, have access to the charger.

DCFC is typically more expensive than Level 1 and Level 2 charging[87] and can create more strain on the electricity grid, both because of the higher power demanded and because it is less flexible than long-dwell time Level 1 and Level 2 charging.

DCFC technology continues to evolve as higher-powered chargers come to market with uncertain long-term payoffs and risks. State funding may continue to be essential to encouraging private investment and demonstrating the various charging business models for DCFC operations. DCFC owners can use LCFS capacity credits to provide a revenue stream for charging stations. In addition to revenue from use of the DCFC, siting a DCFC near amenities such as retail shopping and restaurants can draw consumers. The state continues to see a high demand for state subsidization for DCFC. For example, CALeVIP continues to see high oversubscription for DCFC rebates. CALeVIP is oversubscribed by nearly $200 million in incentive demand.

A robust DCFC network can create the backbone for mass EV adoption within California. California is on track to meet its goal of 10,000 DCFC by 2025, but further investments will help accelerate the transition. State, federal, and private investments are expected to continue and will support equity, access, and scale.

Emerging Technologies

Battery swapping, wireless charging, and mobile charging are three emerging technologies that may play a larger role in the future of PEVs.

Battery swap technology may become a good solution for those without access to home charging or long-distance travelers that need a quick recharge. Battery swap technology is being tested by California companies Ample and Uber[88] and is in broader use in China. The Chinese Ministry of Industry and Information Technology announced a pilot project in October 2021 to deploy more than 1,000 battery swap stations and 100,000 battery-swap vehicles, including trucks.[89] Battery-swappable heavy-duty trucks made up 30.7 percent of ZEV heavy-duty truck sales in 2021 in China.[90] Chinese automaker NIO has more than 500 battery-swap stations[91] and is demonstrating a battery-as-a-service subscription model, with a pilot program in Norway.[92] It takes an average of three to five minutes to swap a battery at one of NIO's

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87 *Going from Pump to Plug: Adding Up the Savings From Electric Vehicles*. November 2017. Union of Concerned Scientists. https://www.ucsusa.org/sites/default/files/attach/2017/11/cv-report-ev-savings.pdf.

88 Kolodny, Lora. March 2021. *Ample is Trying to Make Battery Swapping for EVs a Reality, Starting with Uber Drivers in the Bay Area*. CNBC. https://www.cnbc.com/2021/03/03/ample-opens-5-ev-battery-swapping-stations-for-bay-area-uber-drivers.html.

89 Zhang, Phate. October 2021. *China Launches Pilot Program in 11 Cities to Promote Battery Swap Model*. CnEVPost. https://cnevpost.com/2021/10/28/china-launches-pilot-program-in-13-cities-to-promote-battery-swap-model/.

90 Wang, Yunshi. 2021. *A Glance at the Chinese NEV Deployment in 2021*. UC Davis. https://its.ucdavis.edu/wp-content/uploads/brief-on-2021-zev-development-in-china.pdf.

91 *The Current State of EV Battery Swapping*. October 2021. NIO. https://www.nio.com/blog/current-state-ev-battery-swapping.

92 Parikh, Sagar. September 2021. *Nio is Launching in Norway on September 30*. ElectricVehicleWeb. https://electricvehicleweb.com/nio-norway-export-report/.

more than 500 Power Swap stations, offering a similar fueling experience to the gas station experience. Contemporary Amperex Energy Service Technology (subsidiary of Chinese battery manufacturer CATL) offers a battery replacement solution that is compatible with cars from different automakers.[93] In India, battery-swapping policies are being developed to address the space constraints in installing charging infrastructure in urban areas.[94]

Battery swapping has the potential to be grid-friendly and allows rapid and convenient charging for the consumer. However, vehicles compatible with battery swapping are not yet available for sale in California, and there have been no announcements that auto manufacturers intend to produce them in significant quantities.

Wireless charging can offer convenience to consumers by providing a "touchless" charging experience and potentially charging many different types of vehicles and equipment. However, like battery swapping, it would require deployment of new infrastructure and standards. There are few wireless options, and vehicle manufacturers have not announced widespread inclusion of wireless charging capabilities with their vehicles. Monterey Salinas Transit has an electric bus that uses wireless charging, and the CEC recently awarded a project to demonstrate wireless charging for transit buses with the Solano Transit Authority.[95]

Mobile charging solutions can be deployed in locations where electrical upgrades would be cost-prohibitive in deploying grid-tied pedestal chargers. This technology can provide resiliency and lower costs to deploy charging.

93 Electrive.com. *CATL Subsidiary Demonstrates Battery Swapping System*. https://www.electrive.com/2022/01/18/catl-subsidiary-demonstrates-battery-swapping-system/.

94 Shah Aditi. February 2022. *India to Introduce New Battery Swapping Policy in EV Push*. Reuters. https://www.reuters.com/technology/india-introduce-new-battery-swapping-policy-ev-push-2022-02-01/.

95 *Momentum Dynamics and Solano Transportation Authority Build Interagency Wireless Bus Charger Network in Northern California*. Cision PR Newsire. 2021. https://www.prnewswire.com/news-releases/momentum-dynamics-and-solano-transportation-authority-build-interagency-wireless-bus-charger-network-in-northern-california-301399805.html.

CHAPTER 5:
Infrastructure Deployment Plan

For each of the five market segments, this section outlines state actions and plans for each of the five categories identified in Chapter 4. More information on existing projects and ways that the public may participate in future project development is available in the resources cited below. Many considerations will help inform project design, including specific equity strategies, technologies, vehicle choices, and market conditions. However, the ZIP, as a strategy document, does not go to the level of detail of project design. Those decisions will be made for future projects through agency processes and public consultation.

Charging and Hydrogen Fueling for MDHD ZEVs

Near-Term Actions

Continue to Deploy Appropriated Funding for MDHD ZEV Infrastructure

Through fiscal year 2020-2022, the CEC's Clean Transportation Program has dedicated nearly $194 million in MDHD ZEV infrastructure. In addition, SB 110 (2017) provided one-time funding of $75 million to the CEC to fund electric school buses and infrastructure to replace the oldest and most polluting diesel school buses in California with a focus on replacing school buses operating in disadvantaged and low-income communities.[96]

The Budget Act of 2021 included a ZEV Package to fund vehicles and infrastructure. It includes, over three years:

- $250 million for infrastructure for 1,125 drayage trucks
- $25 million for drayage and infrastructure pilot
- $90 million for infrastructure for 1,000 transit buses
- $50 million for infrastructure for 1,000 school buses
- $208 million for other MDHD infrastructure

These funding allocations have resulting in projects including:

- $36.2 million to fund EV charging or hydrogen fueling infrastructure to support large-scale conversion of transit bus fleets to ZEVs.
- $44.3 million (joint solicitation with CARB) to fund zero-emission (battery-electric and hydrogen fuel cell) drayage truck infrastructure and installation.

96 Senate Bill 110 (Committee on Budget and Fiscal Review, Chapter 55, Statutes of 2017). https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201720180SB110.

- $4 million to fund the design, integration, and demonstration of hydrogen fuel cell systems and hydrogen fueling infrastructure for locomotives and commercial harbor craft applications at California ports.
- $14 million to provide charging infrastructure for electric school buses.

The CEC is working to rapidly and effectively to deploy the remainder of the allocated funding. Among other efforts, the CEC launched the EnergIIZE (Energy Infrastructure Incentives for Zero-Emission) Commercial Vehicles project to implement MDHD ZEV refueling infrastructure incentive projects. EnergIIZE has been allocated $50 million and is authorized for up to $276 million. The project supports both electric vehicles and hydrogen fuel cell vehicles. The project will support a wide range of infrastructure including both dedicated to a specific fleet and public charging/fueling. This will allow the state to support large and small public and private fleets, including regional- and long-haul, independent owner/operators, and rural. The EnergIIZE website (https://www.energiize.org/) is accepting EV Fast Track applications. The CEC held a workshop February 28, 2022, to gather stakeholder feedback on potential MDHD ZEV infrastructure projects. Presentations included funding projects that will increase the charging and fueling infrastructure needed to support the deployment of ZEV technologies within the California freight system, transit bus fleets, school bus fleets, and other transportation sectors.

The CPUC has authorized $864 million to deploy at least 2,600 chargers to support 11,500 MDHD vehicles. IOUs will continue to deploy this funding over the next few years. The CPUC will monitor the energization of MDHD chargers under their authorized programs. To date, 388 of the 2,600 chargers have been energized.

Continue Grid Planning and Developing Blueprints

The CEC recently provided funding for "Blueprints for Medium- and Heavy-Duty Zero-Emission Vehicle Infrastructure." These planning "blueprints" will identify actions and milestones needed for the implementation of MDHD ZEVs and the related electric charging or hydrogen fueling infrastructure or both.

Concurrent to individual fleet planning, CEC with CPUC and CARB, is planning for the state's EV load impacts. The CEC's HEVI-Load model analyzes truck travel patterns, load curve scenarios, and charging demand to inform where loads could exist and behave through time. In tandem, the CEC's EVSE Deployment and Grid Evaluation tool (or EDGE) seeks to integrate those results with utility grid capacity data to inform users about how load could impact certain regions.[97] Proceedings at the CPUC including transportation electrification, infrastructure planning, rates, and load management are investigating opportunities to enable and ease transportation electrification, including preparing the electric grid for a high number of distributed energy resources. Other parties, such as the U.S. Department of Energy (DOE) national labs, are also looking into the impacts of MDHD charging. It is anticipated that grid infrastructure upgrades will eventually be needed, so it will be important to identify where load will grow. State agencies will continue to work with utilities to prepare the grid for the

97 CEC. 2020. EVSE Deployment and Grid Evaluation (EDGE) Tool. https://efiling.energy.ca.gov/getdocument.aspx?tn=234175.

increased load. The CEC has invested in projects demonstrating technology to reduce impacts on the grid.[98]

Beginning in 2023, CALGreen will require capacity to support charging of MDHD vehicles in new warehouses, grocery stores, and retail buildings with off-street loading spaces.

State, utility, and private sector actors have committed to and proposed significant investments over the next few years to dramatically accelerate market development and increase private investment. The state will continue to use block grants and other mechanisms to rapidly roll out funding for MDHD ZEV infrastructure, and to use targeted solicitations to incentivize and investigate solutions to the most challenging use cases, such as small owner-operator fleets of one or a few trucks.

Collect Project Data to Inform Future Incentive Structures and Levels

In the near term, the CEC has structured MDHD infrastructure incentives to balance both BEV and FCEV technology, providing fleets with the option to choose technology based on duty cycles and other attributes. As the market evolves and projects begin construction and operation, the CEC will assess vehicle populations and costs, infrastructure utilization and costs, fleet and manufacturer announcements, and other data, and seek input on equity considerations, to inform decisions on future incentive structures and levels.

Meet Needs of Independent Owner-Operator Fleets and Fleets Located in Rural Areas

As large companies begin adopting ZEVs at a faster rate, there will continue to be market segments that need government assistance to convert to new technologies. Independent owner-operator fleets and fleets located in rural areas are two areas of focus and priority for the state. Barriers to MDHD deployment for these segments may include high initial vehicle cost and lack of publicly available MDHD charging and fueling infrastructure. Broad infrastructure deployment is needed with an increased focus on incentive funding fueling for vehicle segments that continue to face barriers to the deployment of MDHD ZEV infrastructure.

Longer-Term Actions and Decisions

Distribute Additional State Funding for MDHD ZEV Infrastructure

The Governor's budget for fiscal year 2022-23 included a second ZEV Package that proposes funding for MDHD infrastructure that is incremental to the first ZEV package:

- $250 million for drayage truck infrastructure
- $140 million for transit bus infrastructure
- $500 million for clean trucks, buses, and off-road equipment
- $150 million for ZEV infrastructure at ports

The proposed budget also included funding for vehicle incentives and other projects, including $1.5 billion to go to school districts for school buses and infrastructure. Altogether, if fully

98 CEC. Agreement with WattEV, Inc (EPC-21-006). https://www.energy.ca.gov/filebrowser/download/3679.

appropriated, the two packages would total a historic $10 billion over five years to accelerate ZEV deployment; of this, about $3 billion would go to infrastructure investments.

California's clear policy direction has primed the MDHD market to move in the direction of zero-emission. Regulations, in partnership with incentive funding, have resulted in MDHD ZEV commitments from large companies, such as Amazon, UPS, Ikea, FedEx, PepsiCo, and Walmart, to name a few. Additionally, increasing numbers of vehicles are becoming available in every weight class, with multiple configurations making ZEV adoption easier for all MDHD segments. State, national, and global policy direction and regulations have encouraged private investments and is expected to continue as the business case for ZEVs gets stronger and stronger compared to combustion vehicle alternatives.

Public Hydrogen Fueling Stations for Light-Duty FCEVs

Near-term Actions

Continue to Deploy Appropriated Funding for Hydrogen Fueling Infrastructure

The Clean Transportation Program has invested nearly $166 million in light-duty hydrogen fueling stations and plans to invest a total of $279 million in light-duty hydrogen infrastructure. California is on track to reach 100 hydrogen fueling stations by the end of 2023 and on its way to 200 stations.

Longer-Term Actions and Decisions

Close the Gap to the 200-Station Goal

CEC will deploy $27 million appropriated for ZEV infrastructure from the General Fund in the California Budget Act of 2021 to support additional light-duty hydrogen stations, with the potential to also serve MDHD FCEVs, to help close the gap to the 200-station goal.[99]

The planned stations are expected to have the theoretical capacity to support about 240,000 FCEVs by 2027, which is nearly four times the amount of capacity needed to supply the projected 61,100 FCEVs reported in CARB's 2021 Annual Evaluation, based on the latest auto manufacturer survey responses. Further, public funding to expand the network beyond 200 stations for light-duty passenger vehicles will consider factors such as market conditions, vehicle offerings, consumer demand, and consumer uptake.

Address Barriers to FCEV Adoption

While it seems unlikely that overall network dispensing capacity will be a bottleneck, CEC and CARB will continue to monitor the market. More immediately, in the near-term, State and private actors will need to address other challenges for light-duty FCEVs. Funding from the Budget Act of 2021 as allocated within the Clean Transportation Program could potentially address areas where local capacity, rather than network capacity, may be a limitation. Other barriers to FCEV adoption include high prices at the pump for hydrogen, hydrogen station

99 California Budget Act of 2021 per Senate Bill 170 (Skinner, Chapter 240, Statues of 2021) https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=202120220SB170.

downtime due to equipment failures and other factors, high FCEV purchase and lease prices, lack of FCEV model availability, and lack of consumer awareness about FCEVs. CEC staff continues to monitor hydrogen fueling network reliability and resiliency. Staff plans to release a survey to ask how the CEC can better address FCEV adoption barriers with a public workshop to follow.

Monitor FCEV Market

The state will continue to monitor FCEV populations, FCEV projections, station capacity projections, station utilization and reliability, private investment in fueling stations, and hydrogen supply to inform future decisions on hydrogen stations to serve light-duty FCEVs.

Level 1 and Level 2 Charging for Light-Duty PEVs

Near-Term Actions

Maximize Home Charging

Home charging is typically the least expensive and most convenient option, and in many circumstances has the smallest impact on the electric grid. State policies should encourage private and public investment in home charging at single-family and multifamily housing.

Beginning in 2023, CALGreen will require that existing multifamily dwellings, hotels, and motels undergoing certain retrofit activities have capacity to support EV charging. Adoption of building code requirements that address existing buildings, in addition to new construction, can help provide broader access and equity particularly to low-income residents that live in older buildings.

Continue to Deploy Appropriated Funding for Charging Infrastructure

The CEC's Clean Transportation Program has supported the rollout of light-duty electric vehicles by awarding more than $109 million for Level 1 and Level 2 electric vehicle charging infrastructure including both Level 2 and DCFC. These investments so far have resulted in nearly 4,000 Level 2 chargers for private single family/multifamily use and over 9,600 Level 1 and Level 2 chargers for shared-private and public use.

The CEC is implementing three block grants for rapid deployment of light-duty PEV infrastructure. The California Electric Vehicle Infrastructure Project (CALeVIP) is funded with up to $200 million in Clean Transportation Program funding and has attracted about $40 million in additional funding from local partners. It has also leveraged additional private funding: rebates are funding less than half the reported project costs for Level 2 chargers and about two-thirds of costs for DCFC.[100] CALeVIP will continue to take applications and issue rebates for charger deployment. The CEC recently approved two additional block grants of up to $250 million each.[101] Incentive projects under these will be designed in the spring of 2022

100 CEC. California Electric Vehicle Infrastructure Project (CALeVIP) Cost Data. https://www.energy.ca.gov/programs-and-topics/programs/clean-transportation-program/california-electric-vehicle.

101 Funding may be for Level 1, Level 2, and DCFC. Funding amounts and project types are still in design phase.

to further the goals of the ZIP, including the specifics of equity strategies and project eligibility.

The CEC has allocated about $270 million in Clean Transportation Program and General Fund funding for fiscal year 2021-2022 dedicated to light-duty electric vehicle charging. Up to $150 million will be used for the two new block grants described above.

The CPUC has authorized $1.16 billion for light-duty Level 2. To date 13,300 of the 61,500 authorized chargers have been energized. The CPUC is reviewing PG&E's application for EV Charge 2, which proposes a budget of $224.4 million over 5 years for 14,900 Level 2 and 1,100 DCFC. Utility investments will continue to support charger deployment. About 80 percent of authorized CPUC funding for light-duty Level 1 and Level 2 is available and is expected to be expended through 2024 and potentially beyond, which will further increase the network.

Deploy Infrastructure to Provide Greater Charging Access by Priority Populations

The state will deploy infrastructure to provide greater access by priority populations including low-income and disadvantaged communities. Infrastructure deployments are targeted at meeting the needs of low income and disadvantaged communities who may have less access to or less ability to afford at-home charging. Strategies to address this gap include financial assistance to install at-home charging in single-family and multifamily housing, increased focus on overnight public charging near residences in densely populated areas, DC fast charging to provide basic universal access, increased public charging at retail and work locations, and electrifying alternatives to car ownership such as on-demand transportation services. The CEC recently released grant funding opportunities for charging to support on-demand transportation services, multifamily housing residents, and rural drivers.

The CPUC's Transportation Electrification programs require multifamily deployments to increase charging access for low- and middle-income customers.

Continue to Deploy and Plan Charging at State Facilities

Caltrans's Workplace and Fleet EV Charging Implementation Plan identifies priority locations to install workplace and fleet chargers. The plan aims to install 1,000 Level 2 chargers at Caltrans facilities across the state by July 2022.[102] DGS's Office of Sustainability's Transportation Unit is implementing a Five-Year Infrastructure Investment Plan to guide the installation of chargers at state-owned and long-term leased facilities to support state fleet and state employee charging needs. To date, 2,251 Level 2 charging ports have been installed. DGS is developing a new Five-Year Infrastructure Plan to continue meeting the state's EV charging infrastructure needs. While these efforts focus on providing charging at state facilities for fleets and employees, there is potential to evaluate existing state facilities to offer public charging, especially those that offer services to the public.

102 Caltrans. 2021. Caltrans Zero-Emission Vehicle Action Plan 2.0. Available at https://static.business.ca.gov/wp-content/uploads/2021/03/Caltrans_ZEV-Action-Plan_Web_v2.pdf.

Encourage Private Buildout of Charging Away from Home

A significant amount of charging away from home—probably the majority—has been installed without public or utility support. The state recognizes the success of the private market in this area and should target public investments to maximize their value while encouraging private buildout of daytime charging.

Fund Business Cases to Maximize Benefits from Public Support

The business case and driver value appear to be stronger for long-dwell time charging, such as EV charging offered as part of a package of services to attract drivers, than for short-dwell time charging. Therefore, to accelerate the market, public support may best be targeted to long-dwell time charging to grow the business case that best leverages private funding. The CEC will request public input on whether emphasizing long-dwell time charging has any equity implications.

The state should also consider the equity implications of various implementations of away from home charging. Considerations include whether workplace charging to date has been offered equitably or whether it is more available to high-income office workers than to low-income workers. The state should also examine how it can accelerate equitable workplace charging so that a wide range of employees at a wide range of job types are able to have convenient charging away from home. Long-duration nighttime public charging locations near residential locations including at curbside, parking garages or nearby businesses present potential opportunities to increase equitable access to electrification.

Longer-Term Actions and Decisions

Deploy Additional Funding, If Appropriated

The Governor's budget proposal for fiscal year 2022-23 includes $300 million over four years in additional funding for home charging for multifamily homes and for low-income and disadvantaged community single-family homes. This investment would help implement the policy to maximize home charging.

Maximize Grid Benefits of Charging Away from Home

PEVs with demand-side management can increase charging during times of excess electricity and decrease use during peak times. As more intermittent renewable energy is available to the electricity grid, such as solar and wind, daytime charging with vehicle-grid integration can maximize the use of this renewable energy and minimize grid impacts. These strategies are being piloted today and will help mitigate grid upgrades.

Fast Charging for Light-Duty PEVs

Continued investment in DCFC deployment will be crucial to support long-distance travel, providing quick opportunity charging, and serving drivers who do not have access to charging at home. Nearly every driver will need DCFC sometimes, and it is a critical part of the ecosystem.

Near-term Actions

Continue to Deploy Appropriated Funding for Charging Infrastructure

The CEC's Clean Transportation Program has invested $151 million to fund the installation of DCFC (nearly 500 installed and more than 1,000 planned) along highway corridors and DCFC across the state through targeted solicitations and rebate incentives through the California Electric Vehicle Infrastructure Project (CALeVIP). The Clean Transportation Program will continue to deploy DCFC through CALeVIP, block grants, and other targeted solicitations.

Of the $55 million authorized for DCFC by the CPUC to date, $6.5 million has been spent. The remaining 88 percent of available funding is anticipated to be spent through 2024.

Caltrans has installed over 60 publicly accessible DCFCs on Caltrans properties to fill gaps within California's DCFC network along key highway corridors.

Longer-Term Actions and Decisions

Deploy Additional Funding, If Appropriated

The Infrastructure Investment and Jobs Act of 2021 provides $384 million in federal funding over five years to support the expansion of the electric vehicle charging network along designated corridors. CalSTA, Caltrans, and the CEC will work together to coordinate how the funding will be spent and to ensure that it is complementary to other investments.[103]
The Governor's budget proposal for fiscal year 2022-23 includes $600 million over four years in additional funding for grid friendly DCFC. This investment, complementing the federal investment in corridor charging, will deploy approximately 5,000 publicly accessible DCFCs and grid integration such as co-sited energy storage. This funding would make a significant impact on meeting the 15,000 DCFCs needed by 2025 and 40,000 DCFC by 2030 according to AB 2127 analysis, and State deployment would include equity in every decision.

Phase Out CHAdeMO Support

The population of vehicles in California capable of using CHAdeMO chargers is declining, while the number of CHAdeMO chargers has continued to rise. The ratio of chargers to vehicles is higher for CHAdeMO than for CCS and Tesla. There may be specific cases where CHAdeMO-equipped vehicles in the used vehicle market require public support for additional CHAdeMO chargers, but the vehicle market is clearly moving away from this standard. Nissan, which has produced the most CHAdeMO-equipped vehicles (the LEAF), has announced its latest electric crossover will be equipped with a CCS inlet.[104] CARB staff has proposed to require light-duty vehicles with fast charging capability sold in California to be compatible with the CCS connector, beginning with model year 2026.

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103 CalSTA. IIJA 2021 Analysis. 19 November 2021. https://calsta.ca.gov/-/media/calsta-media/documents/calsta-high-level-iija-analysis-a11y.pdf.

104 Goodwin, A. July 15, 2020. "Nissan Adopts CCS Fast-Charging With New Ariya Electric SUV." Road Show by C|Net. https://www.cnet.com/roadshow/news/nissan-ariya-electric-suv-adopts-ccs-fast-charging/.

Understand and Improve Consumer Benefits

There is a push to provide higher-powered charging (150 kW–350 kW) to serve the current vehicle market and future-proof investments. However, DCFC deployment costs are still high, and power levels pose challenges for the grid if not integrated appropriately. There are cases where higher-powered charging isn't necessary. For example, where DCFCs are provided as a charging amenity where a driver may dwell for 30 minutes or more, a 50 kW DCFC may be sufficient for the site. However, higher-powered DCFC will be needed for long distance travelers or serving multifamily residents that rely on the DCFC for a quick refuel. A recent study by Atlas Public Policy finds that installing 150 kW fast chargers rather than 350 kW chargers would increase the needed national investment in public infrastructure from $39 billion to $52 billion.[105] The capital cost to deploy a higher-powered charging site may be higher up front, but the higher throughput and utilization may be more cost effective.

Strategies such as power sharing among chargers and onsite batteries may allow individual chargers to be higher power, while minimizing overall site installation and operation cost as well as reducing the grid impact. Publicly funded projects will be designed to take advantage of advanced technologies and minimize costs to consumers, as well as to accelerate and leverage private funding.

Emerging Technologies

Near-term Actions

New business models and strategies are being developed as charging technology continues to advance. The CEC recently funded advanced technology demonstrations, for example, through the BESTFIT solicitation that funded 15 projects in light-, MDHD charging technologies.[106]State funding and CPUC-authorized investments will continue to consider technological readiness and market developments to understand opportunities to advance promising emerging technologies.

Longer-Term Actions and Decisions

The state will continue to monitor the demonstration of these technologies and automaker announcements for plans to incorporate them in significant numbers of vehicles.

Conclusion

ZEV infrastructure plays an important role in transitioning California to clean transportation, reducing GHG emissions, improving air quality, reducing pollution, and creating high-quality in-

105 Atlas Public Policy. How Much Should The US Invest In Public EV Charging? https://atlaspolicy.com/wp-content/uploads/2021/04/US_Electrification_Infrastructure_Assessment_Exec-Summary.pdf.

106 GFO-20-605 BESTFIT Innovative Charging Solutions. https://www.energy.ca.gov/solicitations/2020-08/gfo-20-605-bestfit-innovative-charging-solutions; Noticed of Proposed Awards for GFO-20-605. https://www.energy.ca.gov/sites/default/files/2021-10/GFO-20-605_Revised_NOPA_Cover_Letter_09-09-2021_ADA.pdf.

state jobs. Sales of light-duty ZEVs surpassed one million vehicles in 2021 and the state is placing more emphasis and focus on converting MDHD fleets to ZEVs. Proposed regulations to increase ZEV adoption will require infrastructure, both at the site level and grid level, to charge and fuel those vehicles. Extensive planning efforts have been conducted to determine ZEV infrastructure needs and where more work needs to be done to ensure all Californians have access to ZEV infrastructure.

The ZIP presents a pathway to success including increasing strategic investments from the private sector, utilities, and the public sector. The state recognizes the significant private investment that has deployed most ZEV infrastructure in the state, and this will continue to be the case. However, there is a significant and ongoing role for public and utility funding in accelerating deployment and ensuring equitable outcomes. Continued public funding support for ZEV infrastructure and strategies discussed in this ZIP is critical to promoting private investment and a sustainable industry.

The state is committed to doing its part through regulation, targeted investment, and continued coordination across state agencies, utilities, and the private market. Strong and clear regulations have helped provide direction to private actors and created the market conditions necessary to support the path to a zero-emission transportation future. California must continue to set strong regulations to provide certainty and must also provide funding for vehicles and infrastructure to support the transition in the near- and mid-term. This will allow for a handoff to the private market in the longer-term. Action underway and planned by stakeholders, both public and private, will ensure the state meets its ZEV goals. This includes robust data-driven grid planning and on-site infrastructure deployment.

GLOSSARY

AIR POLLUTANT – Amounts of foreign or natural substances occurring in the atmosphere that may result in adverse effects to humans, animals, vegetations, or materials or any combination thereof.

AMPERE (Amp) – The unit of measure that tells how much electricity flows through a conductor. It is like using cubic feet per second to measure the flow of water. For example, a 1,200 watt, 120-volt hair dryer pulls 10 amperes of electric current (watts divided by volts).

ASSEMBLY BILL (AB) – A proposed law, introduced during a session for consideration by the Legislature, and identified numerically in order of presentation; also, a reference that may include joint and concurrent resolutions and constitutional amendments, by Assembly, the house of the California Legislature consisting of 80 members, elected from districts determined on the basis of population. Two Assembly districts are situated within each Senate district.

BATTERY ELECTRIC VEHICLE (BEV) – Also known as an "All-electric" vehicle (AEV), BEVs utilize energy that is stored in rechargeable battery packs. BEVs sustain their power through the batteries and therefore must be plugged into an external electricity source in order to recharge.

BAY AREA AIR QUALITY MANAGEMENT DISTRICT (BAAQMD) – Tasked with regulating stationary sources of air pollution in the nine counties that surround San Francisco Bay: Alameda, Contra Costa, Marin, Napa, San Francisco, San Mateo, Santa Clara, southwestern Solano, and southern Sonoma counties. It is governed by a 24-member Board of Directors composed of locally elected officials from each of the nine Bay Area counties, with the number of board members from each county being proportionate to its population.

BEHIND-THE-METER (BTM) – Energy production and storage systems that directly supply homes and buildings with electricity. Energy that is produced and/or stored by these systems is separate from the grid and does not need to be counted by a meter before being used, so they are positioned behind the meter. Examples include on-site generation, on-site energy storage, and microgrids.

CALIFORNIA AIR RESOURCES BOARD (ARB) – The "clean air agency" in the government of California, whose main goals include attaining and maintaining healthy air quality; protecting the public from exposure to toxic air contaminants; and providing innovative approaches for complying with air pollution rules and regulations.

CALIFORNIA DEPARTMENT OF GENERAL SERVICES (DGS)—Serves as business manager for the state of California. DGS serves the public by providing a variety of services to state agencies through procurement and acquisition solutions; real estate management and design; environmentally friendly transportation; professional printing, design and web services; administrative hearings; legal services; building standards; oversight of structural safety, fire/life safety and accessibility for the design and construction of K-12 public schools and community colleges; funding for school construction; and disability access

CALIFORNIA DEPARTMENT OF TRANSPORTATION (Caltrans) – is responsible for the design, construction, maintenance, and operation of the California State Highway System, as well as that portion of the Interstate Highway System within the state's boundaries.

CALIFORNIA DIVISION OF MEASUREMENT STANDARDS (DMS) – Enforcement of California weights and measures laws and regulations is the responsibility of the Division of Measurement Standards. The Division works closely with county sealers of weights and measures who, under the supervision and direction of the Secretary of Food and Agriculture, carry out the vast majority of weights and measures enforcement activities at the local level. Ensuring fair competition for industry and accurate value comparison for consumers are the primary functions of the county/state programs.

CALIFORNIA ELECTRIC VEHICLE INFRASTRUCTURE PROJECT (CALeVIP) – Project funded by the California Energy Commission and implemented by Center for Sustainable Energy to provide regional rebate incentives for the installation of electric vehicle chargers.

CALIFORNIA ENERGY COMMISSION (CEC) – The state agency established by the Warren-Alquist State Energy Resources Conservation and Development Act in 1974 (Public Resources Code, Sections 25000 et seq.) responsible for energy policy. The Energy Commission's five major areas of responsibilities are:

1 Forecasting future statewide energy needs
2 Licensing power plants sufficient to meet those needs
3 Promoting energy conservation and efficiency measures
4 Developing renewable and alternative energy resources, including providing assistance to develop clean transportation fuels
5 Planning for and directing state response to energy emergencies

Funding for the Commission's activities comes from the Energy Resources Program Account, Federal Petroleum Violation Escrow Account and other sources.

CALIFORNIA PUBLIC UTILITIES COMMISSION (CPUC) – A state agency created by constitutional amendment in 1911 to regulate the rates and services of more than 1,500 privately owned utilities and 20,000 transportation companies. The CPUC is an administrative agency that exercises both legislative and judicial powers; its decisions and orders may be appealed only to the California Supreme Court. The major duties of the CPUC are to regulate privately owned utilities, securing adequate service to the public at rates that are just and reasonable both to customers and shareholders of the utilities, including rates, electricity transmission lines and natural gas pipelines. The CPUC also provides electricity and natural gas forecasting, and analysis and planning of energy supply and resources. Its main headquarters are in San Francisco.

CHAdeMO – A connector standard for fast charging of electric vehicles that can provide up to 62.5 kilowatts of power.

CLEAN MOBILITY OPTIONS PROGRAM (CMO) – Program administered by CALSTART and Shared-Use Mobility center in partnership the Local Government Commission. The program aims to improve underserved communities' access to clean mobility options that are safe, reliable, convenient, and affordable, by creating a streamlined application process for

communities to apply for funding. The program also seeks to further mobility equity, improve local air quality, increase zero-emission vehicle adoption, reduce vehicle miles traveled, and advance workforce development in clean transportation.

CLEAN TRANSPORTATION PROGRAM (Formerly the Alternative and Renewable Fuels and Vehicle Technology Program) – Created by Assembly Bill 118 (Nunez, Chapter 750, Statutes of 2007), the program with an annual budget of about $100 million supports projects that develop and improve alternative and renewable low-carbon fuels, improve alternative and renewable fuels for existing and developing engine technologies, expand transit and transportation infrastructures, and establishing workforce training programs, conduct public education and promotion, and create technology centers, among other tasks.

CLIMATE CHANGE – Also referred to as 'global climate change'. The term 'climate change' is sometimes used to refer to all forms of climatic inconsistency, but because the Earth's climate is never static, the term is more properly used to imply a significant change from one climatic condition to another. In some cases, 'climate change' has been used synonymously with the term, 'global warming'; scientists, however, tend to use the term in the wider sense to also include natural changes in climate.

COMBINED CHARGING SYSTEM (CCS) – A connector standard for fast charging of electric vehicles that provide up to 350 kilowatts of power.

CRITERIA AIR POLLUTANT – An air pollutant for which acceptable levels of exposure can be determined and for which an ambient air quality standard has been set. Examples include ozone, carbon monoxide, nitrogen dioxide, sulfur dioxide, PM10, and PM2.5. The term "criteria air pollutants" derives from the requirement that the U.S. EPA must describe the characteristics and potential health and welfare effects of these pollutants. The U.S. EPA and ARB periodically review new scientific data and may propose revisions to the standards as a result.

DEMAND CHARGE – The sum to be paid by a large electricity consumer for its peak usage level.

DEMAND RESPONSE – Providing wholesale and retail electricity customers with the ability to choose to respond to time-based prices and other incentives by reducing or shifting electricity use, particularly during peak demand periods, so that changes in customer demand become a viable option for addressing pricing, system operations and reliability, infrastructure planning, operation and deferral, and other issues. (Source: Dan Delurey, U.S. Demand Response Coordinating Committee).

DIRECT CURRENT (DC) – Electricity that flows continuously in the same direction.

DISTRIBUTION – The delivery of electricity to the retail customer's home or business through low voltage distribution lines.

DISTRIBUTED ENERGY RESOURCES – Small-scale power generation technologies (typically in the range of 3 to 10,000 kilowatts) located close to where electricity is used (for example, a home or business) to provide an alternative to or an enhancement of the traditional electric power system.

DISTRIBUTED GENERATION – A distributed generation system involves small amounts of generation located on a utility's distribution system for the purpose of meeting local (substation level) peak loads and/or displacing the need to build additional (or upgrade) local distribution lines.

ELECTRIC PROGRAM INVESTMENT CHARGE (EPIC) – Program established by the California Public Utilities Commission in 2011 to fund research leading to technological advancements and scientific breakthroughs supporting California's clean energy goals, with a focus on providing ratepayer benefits, including reliability, lower costs, and safety. EPIC investments advance precommercial clean energy technologies and approaches for the benefit of electricity ratepayers of California's three largest electric investor-owned utilities.

ELECTRIC UTILITY – Any person or state agency with a monopoly franchise (including any municipality), which sells electric energy to end-use customers; this term includes the Tennessee Valley Authority but does not include other Federal power marketing agency (from EPAct).

ELECTRIC VEHICLE CHARGING STATION — An electric vehicle charging station, also called EV charging station, electric recharging point, charging point, charge point, electronic charging station (ECS), and electric vehicle supply equipment (EVSE), is an element in an infrastructure that supplies electric energy for the recharging of plug-in electric vehicles—including electric cars, neighborhood electric vehicles and plug-in hybrids.

ELECTRIC VEHICLE CHARGING STATION (EVSE) – Infrastructure designed to supply power to electric vehicles. EVSE can charge a wide variety of electric vehicles including battery electric vehicles and plug-in hybrid electric vehicles.

ELECTRIC VEHICLE INFRASTRUCTURE RULES – CPUC Resolutions E-5167 and E-5168 established new rules in response to AB 841 to account for utility-side distribution costs associated with electric vehicle charging deployment.

ELECTRIC VEHICLES (EV) – A broad category that includes all vehicles that are fully powered by electricity or an electric motor.

ELECTRICITY – A property of the basic particles of matter. A form of energy having magnetic, radiant and chemical effects. Electric current is created by a flow of charged particles (electrons).

ELECTRIFY AMERICA (EA) – A Volkswagen Group of America subsidiary created to fulfill the Volkswagen Zero Emission Vehicle Investment Commitment to address the adverse impacts to California's Zero Emission Vehicle program resulting from the sale of Volkswagen diesel vehicles equipped with emissions defeat devices to consumers who believed they were purchasing clean vehicles.

ELECTROLYSIS – Breaking a chemical compound down into its elements by passing a direct current through it. Electrolysis of water, for example, produces hydrogen and oxygen.

ENERGY INFRASTRUCTURE INCENTIVES FOR ZERO-EMISSON COMMERCIAL VEHICLES (EnergIIZE) – Project funded by the California Energy Commission and implemented by

CALSTART. The Project will use a concierge-like model working directly with eligible applicants to help plan and fund the purchase of charging and hydrogen fueling infrastructure.

EVgo Services LLC (EVgo) – A LS Power subsidiary that owns and operates public fast chargers for electric vehicles.

EVSE DEPLOYMENT AND GRID EVALUATION (EDGE) Tool – A modeling tool to help users strategically target EVSE deployment and plan future infrastructure investments in order to minimize/mitigate gride impact, achieve air quality improvement targets, meet electric vehicle travel demand in California, and ensure equitable deployment.

FUEL CELL – A device or an electrochemical engine with no moving parts that converts the chemical energy of a fuel, such as hydrogen, and an oxidant, such as oxygen, directly into electricity. The principal components of a fuel cell are catalytically activated electrodes for the fuel (anode) and the oxidant (cathode) and an electrolyte to conduct ions between the two electrodes, thus producing electricity.

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.

GOVERNOR'S OFFICE OF BUSINESS AND ECONOMIC DEVELOPMENT (GO-Biz) – The Governor's Office of Business and Economic Development (GO-Biz) serves as the State of California's leader for job growth and economic development efforts. They offer a range of services to business owners including attraction, retention and expansion services, site selection, permit assistance, regulatory guidance, small business assistance, international trade development, and assistance with state government.

GREENHOUSE GAS – Any gas that absorbs infra-red radiation in the atmosphere. Greenhouse gases include water vapor, carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), halogenated fluorocarbons (HCFCs), ozone (O3), perfluorinated carbons (PFCs), and hydrofluorocarbons (HFCs).

GRID – The electric utility companies' transmission and distribution system that links power plants to customers through high power transmission line service (110 kilovolt [kv] to 765 kv); high voltage primary service for industrial applications and street rail and bus systems (23 kv-138 kv); medium voltage primary service for commercial and industrial applications (4 kv to 35); and secondary service for commercial and residential customers (120 v to 480 v). Grid can also refer to the layout of a gas distribution system of a city or town in which pipes are laid in both directions in the streets and connected at intersections.

HYDROGEN (H2) – A colorless, odorless, highly flammable gas, the chemical element of atomic number 1.

IN-FRONT-OF-THE-METER – Systems where electricity must pass through an electric meter before it can be used. Example includes energy generation and storage systems that feed the grid and transmission and distribution lines.

INFRASTRUCTURE – generally refers to the recharging and refueling network necessary to successful development, production, commercialization, and operation of alternative fuel vehicles, including fuel supply, public and private recharging and refueling facilities, standard

specifications for refueling outlets, customer service, education and training, and building code regulations.

INTEGRATION CAPACITY ANALYSIS (ICA) – Quantifies the maximum amount of power that can be injected to, drawn from the distribution system requiring minimal to no distribution upgrades or operational restrictions.

INVESTOR-OWNED UTILITIES – A private company that provides a utility, such as water, natural gas or electricity, to a specific service area. The investor-owned utility is regulated by the California Public Utilities Commission.

INTEGRATED RESOURCE PLANNING (IRP) – A public planning process and framework within which the costs and benefits of both demand- and supply-side resources are evaluated to develop the least-total-cost mix of utility resource options. In many states, IRP includes a means for considering environmental damages caused by electricity supply/transmission and identifying cost-effective energy efficiency and renewable energy alternatives. IRP has become a formal process prescribed by law in some states and under some provisions of the Clean Air Act amendments of 1992.

KILOWATT (kW) – One thousand (1,000) watts. A unit of measure of the amount of electricity needed to operate given equipment. On a hot summer afternoon, a typical home, with central air conditioning and other equipment in use, might have a demand of four kW each hour.

KILOWATT-HOUR (kWh) – The most commonly-used unit of measure telling the amount of electricity consumed over time. It means one kilowatt of electricity supplied for one hour. In 1989, a typical California household consumes 534 kWh in an average month.

LEVEL 1 CHARGING – Electric vehicle charging at 120 volts.

LEVEL 2 CHARGING – Electric vehicle charging at 240 volts.

LIGHT-DUTY VEHICLE (LDV) – Any motor vehicle with a gross vehicle weight of 6,000 pounds or less.

LOW CARBON FUEL STANDARD (LCFS) – A set of standards designed to encourage the use of cleaner low-carbon fuels in California, encourage the production of those fuels, and therefore, reduce greenhouse gas (GHG) emissions. The LCFS standards are expressed in terms of the "carbon intensity" (CI) of gasoline and diesel fuel and their respective substitutes. The LCFS is a key part of a comprehensive set of programs in California to cut greenhouse gas emission and other smog-forming and toxic air pollutants by improving vehicle technology, reducing fuel consumption, and increasing transportation mobility options.

MEGAWATT (MW) – One-thousand kilowatts (1,000 kW) or one million (1,000,000) watts. One megawatt is enough electrical capacity to power 1,000 average California homes. (Assuming a loading factor of 0.5 and an average California home having a 2-kilowatt peak capacity.)

MEGAWATT HOUR (MWh) – One-thousand kilowatt-hours, or an amount of electrical energy that would supply 1,370 typical homes in the Western U.S. for one month. (This is a rounding up to 8,760 kWh/year per home based on an average of 8,549 kWh used per household per year [U.S. DOE EIA, 1997 annual per capita electricity consumption figures]).

OFF-ROAD – Any non-stationary device, powered by an internal combustion engine or motor, used primarily off the highways to propel, move, or draw persons or property, and used in any of the following applications: marine vessels, construction/farm equipment, locomotives, utility and lawn and garden equipment, off-road motorcycles, and off-highway vehicles.

ON-ROAD, ON-ROAD VEHICLE – Vehicles that are intended by their manufacturer for use on public highways. On-road vehicles must be certified by their manufacturer with the U.S. Department of Transportation (DOT), National Highway Traffic Administration (NHTSA), as compliant with on-highway safety standards as well as certified to all applicable ARB and U.S. EPA on-road emission standards. Compliance with these standards is indicated by separate safety and emissions labels on the vehicle.

PERMIT – Written authorization from a government agency (e.g., an air quality management district) that allows for the construction and/or operation of an emissions generating facility or its equipment within certain specified limits.

PLUG-IN ELECTRIC VEHICLE (PEV) – is a general term for any car that runs at least partially on battery power and is recharged from the electricity grid. There are two different types of PEVs to choose from – pure battery electric and plug-in hybrid vehicles.

PLUG-IN HYBRID ELECTRIC VEHICLE (PHEV) – PHEVs are powered by an internal combustion engine and an electric motor that uses energy stored in a battery. The vehicle can be plugged in to an electric power source to charge the battery. Some can travel nearly 100 miles on electricity alone, and all can operate solely on gasoline (similar to a conventional hybrid).

PUBLIC OWNED UTILITIES (POUS) – Non-profit utility providers owned by a community and operated by municipalities, counties, states, public power districts, or other public organizations. Within POUs, residents have a say in decisions and policies about rates, services, generating fuels and the environment.

PUBLIC WORKSHOP – A workshop held by a public agency for the purpose of informing the public and obtaining its input on the development of a regulatory action or control measure by that agency.

SOCIETY OF AUTOMOTIVE ENGINEERS (SAE) – SAE International, formerly the Society of Automotive Engineers, is a U.S.-based, globally active professional association and standards organization for engineering professionals in various industries.

TIME-OF-USE RATES (TOU) – Electricity prices that vary depending on the time periods in which the energy is consumed. In a time-of-use rate structure, higher prices are charged during utility peak-load times. Such rates can provide an incentive for consumers to curb power use during peak times.

TRANSPORTATION ELECTRIFICATION – The use of electricity from external sources of electrical power, including the electrical grid, for providing all or part of the power for vehicles, vessels, trains, boats, or other equipment that are mobile sources of air pollution and greenhouse gas emissions, and related programs and charging and propulsion infrastructure investments to enable and encourage this use of electricity.

TRANSPORTATION NETWORK COMPANY (TNC) – A ride sourcing company that provides prearranged transportation services for compensation using an online-enabled application or platform (such as smart phone apps) to connect drivers using their personal vehicles with passengers.

UNITED STATES DEPARTMENT OF ENERGY (U.S. DOE) – The federal department established by the Department of Energy Organization Act to consolidate the major federal energy functions into one cabinet-level department that would formulate a comprehensive, balanced national energy policy. DOE's main headquarters are in Washington, D.C.

VEHICLE-GRID INTEGRATION (VGI) – Methods to align electric vehicle charging with the needs of the electric grid. To do this, electric vehicles must have capabilities to manage charging or support two-way communication between vehicles and the grid.

VOLKSWAGEN ENVIRONMENTAL MITIGATION TRUST FOR CALIFORNIA – Provides about $423 million for California to mitigate the excess nitrogen oxide emissions caused by Volkswagen's use of illegal emissions testing defeat devices in certain Volkswagen diesel vehicles.

VOLT (V) – A unit of electromotive force. It is the amount of force required to drive a steady current of one ampere through a resistance of one ohm. Electrical systems of most homes and office have 120 volts.

WATT – A unit of measure of electric power at a point in time, as capacity or demand. One watt of power maintained over time is equal to one joule per second. Some Christmas tree lights use one watt. The Watt is named after Scottish inventor James Watt and is capitalized when shortened to w and used with other abbreviations, as in kWh.

WATT-HOUR – One watt of power expended for one hour. One thousandth of a kilowatt-hour.

ZERO EMISSION (ZE) – An engine, motor, process, or other energy source, that emits no waste products that pollute the environment or disrupt the climate.

ZERO-EMISSION VEHICLE (ZEV) – Vehicles which produce no emissions from the on-board source of power (e.g., an electric vehicle).

APPENDIX A:
LIST OF ACRONYMS

AB	Assembly Bill
AC	Alternating Current
CALeVIP	California Electric Vehicle Infrastructure Project
CalSTA	California State Transportation Agency
Caltrans	California Department of Transportation
CARB	California Air Resources Board
CBSC	California Building Standards Commission
CCS	Combined Charging Standard
CEC	California Energy Commission
CPUC	California Public Utilities Commission
DCFC	Direct Current Fast Charger
DGS	Department of General Services
DOE	Department of Energy
EDGE	EVSE Deployment and Grid Evaluation
EnergIIZE	Energy Infrastructure Incentives for Zero-Emission
EPIC	Electric Program Investment Charge
FCEV	Fuel Cell Electric Vehicle
GHG	Greenhouse Gas
GO-Biz	Governor's Office of Business and Economic Development
HCD	Housing Community Development
ICA	Integration Capacity Analysis
IEPR	Integrated Energy Policy Report
IIJA	Infrastructure and Investment Jobs Act
IOU	Investor-Owned Utility
IRP	Integrated Resource Plan
ISO	International Organization for Standardization
kW	Kilowatt
LCFS	Low Carbon Fuel Standard
MCS	Megawatt Charging System
MDHD	Medium- and Heavy-Duty
MPa	Megapascal
NEVI	National Electric Vehicle Infrastructure
PEV	Plug-in Electric Vehicle
SAE	Society of Automotive Engineers
SB	Senate Bill
TCEP	Trade Corridor Enhancement Program

TCO	Total Cost of Ownership
TE	Transportation Electrification
TEF	Transportation Electrification Framework
TRU	Transportation Refrigeration Unit
VGI	Vehicle Grid Integration
ZEV	Zero-Emission Vehicle
ZIP	Zero-Emission Vehicle Infrastructure Plan