PLUGGING AWAY

How to Boost Electric Vehicle Charging Infrastructure

June 2017

Bank of America

Berkeley Law
UNIVERSITY OF CALIFORNIA
Center for Law, Energy & the Environment

THE EMMETT INSTITUTE
ON CLIMATE CHANGE AND THE ENVIRONMENT
UCLA | SCHOOL OF LAW

About this Report

This policy report is the eighteenth in a series on how climate change will create opportunities for specific sectors of the business community and how policy makers can facilitate those opportunities. Each report results from workshop convenings that include representatives from key business, academic, and policy sectors of the targeted industries. The convenings and resulting policy reports are sponsored by Bank of America and produced by a partnership of the UC Berkeley School of Law's Center for Law, Energy & the Environment and UCLA School of Law's Emmett Institute on Climate Change and the Environment.

Authorship

The author of this policy paper is Ethan N. Elkind, Director of the Climate Change and Business Program at UC Berkeley School of Law's Center for Law, Energy & the Environment (CLEE) and UCLA School of Law's Emmett Institute on Climate Change and the Environment. Additional contributions to the report were made by Jordan Diamond of the UC Berkeley School of Law and Sean Hecht and Cara Horowitz of the UCLA School of Law.

This report and its recommendations are solely a product of the UC Berkeley and UCLA Schools of Law and do not necessarily reflect the views of all individual convening participants, reviewers, or Bank of America.

Acknowledgments

The author and organizers are grateful to Bank of America for its generous sponsorship of the Climate Change and Business Research Initiative. We would specifically like to thank Anne Finucane, Vice Chair at Bank of America, for her commitment to this work.

In addition, we are grateful to Marilee Hanson and Dániel Gergely Szabó for research and drafting support, Claire Hermann and Emily Van Camp for designing this policy report, and Summer Rose of UCLA Law and Luke Sherman of UC Berkeley Law for coordinating the convenings.

Finally, the UC organizers gratefully acknowledge Max Baumhefner, Josh Boone, Frank Breust, Jana Corey, Wade Crowfoot, Joshua Cunningham, Mark Duvall, Tyson Eckerle, Jamie Hall, Andrew Hoskinson, Joel Levin, Tony Markel, Fred Minassian, Patti Monahan, Marvin Moon, Colleen Quinn, Cliff Rechtschaffen, Stacey Reineccius, Nancy Ryan, Janea Scott, Mark Triplett, and Eileen Wenger Tutt for their insight and commentary at the June 15, 2016 convening that informed this analysis.

We also acknowledge (with some repetition of names for those who attended both convenings) Tom Ashley, Alberto Ayala, Marcus Alexander, James Avery, Max Baumhefner, Josh Boone, Eric Borden, Bill Boyce, Jana Corey, Tyson Eckerle, Jamie Hall, Stephen Jones, Marvin Moon, Terry O'Day, Tim Olson, David Peterson, Stacey Reineccius, Laura Renger, Nancy Ryan, Katherine Stainken, John Tillman, Mark Triplett, Sarah Van Cleve, and Eileen Wenger Tutt for their insight and commentary at the November 7, 2016 convening that also informed this analysis.

Photos for the report are courtesy of Flickr's Kārlis Dambrāns (cover and p. 31), Flickr's Birmingham News Room (p. 1), Flickr's Vattenfall (p. 4), Flickr's Myrtle Beach TheDigitel (p. 5 and 26), Flickr's Portland General Electric (p. 7), Flickr's Isaac Bowen (p. 9), Flickr's Richard Kelly (p. 9), Flickr's Washington State Department of Transportation, (p.9), EVGo (p. 13, 15, 17), Flickr's Paul Krueger (p. 14), Powertree Services Inc. (www.electrictrees.com) (c) 2017 (p. 16 and 23), Flickr's Tony Webster (p. 23), Flickr's RedBoy [Matt] (p. 26) and Oregon Department of Transportation (p. 28).

For more information, contact Ethan Elkind at Eelkind@law.berkeley.edu and Elkind@law.ucla.edu.

Bank of America

BerkeleyLaw
UNIVERSITY OF CALIFORNIA
Center for Law, Energy & the Environment

THE EMMETT INSTITUTE
ON CLIMATE CHANGE AND THE ENVIRONMENT
UCLA | SCHOOL OF LAW

Glossary of Terms

California Air Resources Board (CARB): An organization within the California Environmental Protection Agency responsible for providing and maintaining clean air, including enforcement of the state's greenhouse gas reduction laws (AB 32 and SB 32).

California Energy Commission (CEC): The state's primary energy policy and planning agency, which includes supporting energy research, developing renewable energy resources, and advancing alternative and renewable transportation fuels and technologies.

California Global Warming Solutions Act of 2006 (AB 32): California state law which sets out the greenhouse gas emissions reduction goal to be achieved by 2020.

California Public Utilities Commission (CPUC): California's agency in charge of regulating investor-owned utilities.

E-Gallon Equivalent (EGE): The cost of driving a plug-in electric vehicle the same distance a gasoline-powered vehicle could travel on one gallon of gasoline.

Electric Vehicle Supply Equipment (EVSE): also called an electric vehicle charging station, it delivers electrical energy from an electricity source to charge the batteries of electric vehicles.

- **Level 1 charging:** uses a 120-volt alternating current (AC) plug that is found in most standard household outlets.
- **Level 2 charging:** uses a 240-volt AC plug that requires installation of additional charging equipment.
- **DC fast charging:** uses a 480-volt direct current (DC) plug that enables rapid charging along heavy traffic routes. Planned charging stations at up to 350 kilowatts will far exceed current 50 kilowatt CHAdeMO and SAE Combo public chargers or Tesla 120 kilowatt Superchargers.

Investor-Owned Utilities (IOU): A privately-owned electric company that in California is regulated by the California Public Utilities Commission.

Low Carbon Fuel Standard (LCFS): a state program, pursuant to AB 32, that created a performance-based market and mandate for transportation fuels with reduced carbon intensity.

Make-Ready: A parking space wired with all the electrical infrastructure necessary to support the installation of a customer-purchased charger.

Multi-Unit Dwellings (MUDs): apartments, townhouses and condominiums.

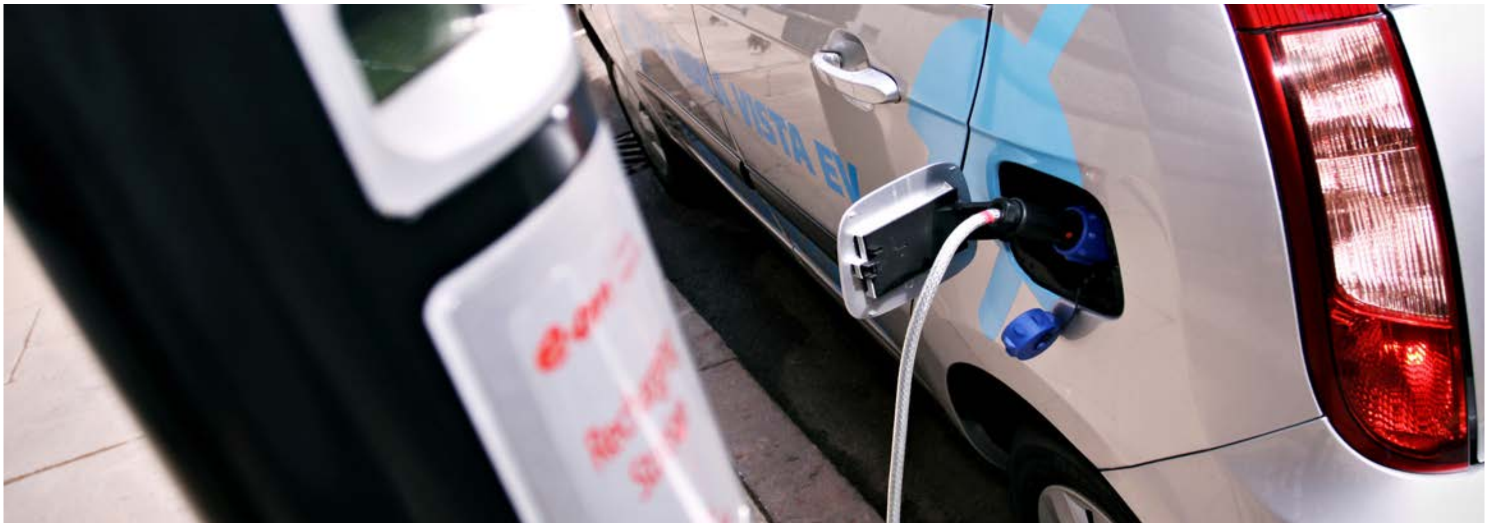
Senate Bill 350 (de León, 2015) or Clean Energy and Pollution Reduction Act of 2015: California climate and clean energy legislation that encourages electric vehicle charging station deployment in part through more investor-owned utility investment.

Senate Bill 32 (Pavley, 2016): A California law requiring statewide greenhouse gas emissions to be reduced 40% below 1990 levels by 2030.

Vehicle-Grid Integration (VGI): rates, programs and technologies that allow electric vehicles to provide grid services. Examples include "real-time" or "day-ahead real-time pricing," "demand response" and "vehicle-to-grid" that encourage drivers to charge during hours when the electricity grid has spare capacity, rather than exacerbating the system-wide peak demand, and on-board technology that allows for varied charging or bidirectional flow.

Vehicles:

- **Battery Electric Vehicles (BEVs)** use a battery to store the electric energy that powers the motor. BEV batteries are charged by plugging the vehicle into an electric power source. BEVs are sometimes referred to simply as electric vehicles (EVs).
- **Hybrid Electric Vehicles (HEVs)** are primarily powered by an internal combustion engine that runs on conventional or alternative fuel and an electric motor that uses energy stored in a battery. The battery is charged through regenerative braking and by the internal combustion engine and is not plugged in to charge.
- **Plug-in Electric Vehicle (PEV)** is any vehicle that runs at least partially on battery power and the battery of which can be recharged from the electricity grid. In California, the term PEVs includes both BEVs and PHEVs.
- **Plug-In Hybrid Electric Vehicles (PHEVs)** are motor vehicles powered by a battery that can be recharged by plugging it into an external source of electricity but which also incorporate the use of a combustion engine when the battery is depleted to power the vehicle.
- **Zero Emission Vehicles (ZEVs)** are vehicles that are capable of travelling certain distances without emitting tailpipe pollutants from their onboard power sources.



Summary and Introduction

California will need widespread consumer adoption of electric vehicles in order to achieve the state's environmental and energy goals. Governor Brown set a goal of reaching 1.5 million zero emission vehicles (ZEVs) on California's roadways by 2025, and as of June 2017, Californians were driving almost 300,000 electric vehicles.

Achieving the state's electric vehicle goals will require a significant boost to charging infrastructure. This need is particularly acute for residents who do not live in single-family detached homes, where more than 80 percent of current electric vehicle owners reside. Overall, approximately 40 percent of Californians live in multi-unit dwellings (with even higher percentages in the state's urban areas), such as apartments, townhouses, and condominiums, with impeded or no access to charging.

Ultimately, some analysts estimate that the state will need private and public sources to provide 125,000 to 220,000 publicly accessible charging ports by 2020, well beyond the roughly 12,000 available in the state today. Additionally, hundreds of thousands of other charging stations will be necessary at multi-unit dwellings.

Analysts estimate that the state will need private and public sources to provide 125,000 to 220,000 publicly accessible charging ports by 2020, well beyond the roughly 12,000 available in the state today. Additionally, hundreds of thousands of other charging stations will be necessary at multi-unit dwellings.

This infrastructure deployment is unlikely to occur without policy action. Charging stations and installation and maintenance typically entail high costs, with often uncertain revenues from various potential sources, which deters investment. For example, a recent California Energy Commission charging program found that a dual standard fast charger, coupled with a single "Level 2" (240 volt) charger and additional stub, averaged $135,000 in equipment costs. Even the total costs of installing "make-ready" infrastructure, which covers all the electrical wiring needed to support a customer-purchased charger, for Level 2 charging (including customer rebates for the charging stations) were at $13,734 per port and $219,424 per site with 16 ports on average, as Southern California Edison recently found.

Charging site owners can also incur significant expenses from commercial electricity rates that were not always designed with electric vehicle charging in mind. Commercial charging generally involves payment by time of use. These rates therefore reward electric vehicle owners or site hosts who charge during hours when the cost of energy is lowest but punish those who are unable to moderate demand successfully. In addition, some large commercial and industrial rates have “demand charges” that entail additional costs on the maximum load drawn by a customer during the billing period. Many electric vehicle charging sites that have high but infrequent demand and inconsistent low-energy utilization (particularly for fast charging) face high exposure to demand charges as a result, sometimes severely undercutting the economics of infrastructure deployment and operation.

To address these costs and spur the needed investment in electric vehicle charging infrastructure, UC Berkeley and UCLA Schools of Law convened experts from the private and public sectors for two separate discussions in June 2016 at UCLA Law and November 2016 at Berkeley Law (all participants are listed in the appendix). The first convening focused on general barriers and solutions to increasing charging deployment, while the second covered the specific topic of reforming commercial electricity rates to boost the infrastructure. This report is informed by both discussions, offering a vision for deployment and commercial electricity rate reform and identifying the top barriers and solutions to electric vehicle charging in California.

Key Barriers & Solutions for Boosting Electric Vehicle Charging Deployment

Barrier #1: Unclear or inconsistent business case for installing charging in workplaces, multi-unit dwellings, and direct current fast-charge locations

▶WORKPLACE CHARGING – IMPROVING THE BUSINESS CASE

CHALLENGES: Site host and service provider reluctance to invest in charging equipment due to high costs of operation, maintenance, and administration

SOLUTION: More incentives, including strategic utility investments in infrastructure, to encourage service providers and workplace site hosts to install charging infrastructure

Utilities could invest in workplace charging infrastructure (at least “make-readies,” with all the electrical infrastructure needed to support installation) and provide more flexible electric service and rate options for workplace service providers, such as “network” rates that apply across multiple workplaces that are within the same network.

State and local government leaders could offer incentives for workplaces to install charging equipment, such as rebates or tax credits.

Air districts and other local agencies could develop new rules to encourage workplace charging, such as a South Coast Air Quality Management District rule that provides economic incentives for employers to encourage charging, similar to existing carpooling incentives for businesses.

State and local policy makers could consider offering economic incentives or reducing costs for service providers to encourage workplace site hosts to hire them for “full service” charging, such as faster permitting or reduced taxes.

The California Energy Commission could consider reforming the green building code to require developers to install not only the conduit but charging equipment in new workplace buildings and to require that any reconstruction of parking lots includes charging infrastructure.

Industry and policy makers could educate site owners on the potential economic value of low carbon fuel standard credits, which may be currently underutilized as a source of revenue to offset infrastructure and operation costs, potentially involving third parties to help aggregate and monetize the credits for users, including some public agencies.

Utility and charging industry leaders could compile and promote best practices on workplace charging to potential site hosts by accumulating, analyzing, and sharing existing data on these sites, including on pricing.

State leaders and utilities could reform utility rates that discourage installation to avoid risks from demand charges and other escalating rates (discussed in more detail below).

▶MULTI-UNIT DWELLINGS – IMPROVING THE BUSINESS CASE

CHALLENGE: Difficult access to charging for multi-unit dwelling residents

SOLUTION: Lower the installation costs for charging in multi-unit dwellings through incentives, installation streamlining, and strategic utility investment

State leaders could assist the private sector, including utilities, in identifying and lowering infrastructure installation costs in critical multi-unit dwellings and areas by determining how to prioritize multi-unit dwellings and regions for investment and then facilitating outreach to property owners.

Utilities could provide consistent treatment of charger installations to increase predictability and lower the costs of installation, by expediting the interconnection process and making fees for this equipment consistent and predictable.

State leaders could encourage high-concentration building owners like real estate investment trusts (REITs) to install charging by reforming existing regulations or development of other incentives, such as tax credits.

State and local leaders could encourage more curbside charging for multi-unit dwelling residents who lack dedicated on-site, off-street parking by coordinating permitting and planning processes, as well as possible state legislation to facilitate municipal enforcement of street regulations to implement curbside charging.

Utilities and state policy makers could improve upfront data access for charging service providers, with building owner consent, such as the size of the existing service panel, current usage and peak demand, and how much capacity is available on site for the chargers.

The California Public Utilities Commission and electric utilities could encourage integration of energy storage with charging infrastructure to provide additional revenue and savings from multi-unit dwelling installations and ensure that energy storage is not treated as a "new load" that entails additional costs.

The California Public Utilities Commission could expand Rules 15 and 16 exceptions for energy storage interconnection to multi-family dwellings when these technologies support electric vehicle charging.

The California Energy Commission could strengthen the green building code to encourage new charging infrastructure when multi-unit dwellings undergo retrofits and develop a model ordinance for cities to require such infrastructure through their local codes.

State leaders could encourage the establishment of more fast-charging "plazas" in urban areas for multi-unit dwellers who lack access to dedicated on-site charging (discussed below).

▶DC FAST CHARGERS – IMPROVING THE BUSINESS CASE

CHALLENGE: High costs and relatively low revenue

SOLUTION: Explore alternative business models and reduce costs for installation and operation

State policy makers and industry leaders could examine and consider authorizing multiple ownership arrangements to ensure deployment, based on the following inclusive list of business model/ownership options:

- Utility-owned (at least "make-readies") and operated network of direct current fast chargers
- An automaker-owned network (like Tesla) or collaboration between automaker and electric vehicle service provider
- Public-private partnership
- Dual-site usage model (co-location of charging with other economic activities like retail)
- Automaker/dealer owned (like Tesla)

Utilities and state regulators could set policy and establish incentives to guarantee some part of the development costs associated with identifying and preparing sites for deployment, such as through allowances to cover line extensions (with publicly owned utilities recovering costs through full rate recovery mechanisms).

State leaders could consider investigating optimal locations for fast-chargers, from urban spaces to interstate corridors, such as at existing gas stations, and applying incentives for installation in these locations.

Cities and other local governments could provide funding for fast charging from grant programs, possibly based on future increases in sales tax revenue increments, if charging generates new sales.

Federal leaders could reform Section 1603 U.S. Treasury grants (payments for electric vehicle charging equipment in lieu of tax credits) to provide direct cash incentives immediately with no wait lists.

Barrier #2: Commercial rate design that may inadvertently add excessive costs to charging infrastructure

CHALLENGE: Most commercial electricity rates do not contemplate electric vehicle charging or encourage optimal deployment of infrastructure

SOLUTION: Design new rates and encourage experimentation to optimize charging in the right places and times that best meet grid needs

The California Public Utilities Commission could encourage utilities to design vehicle-grid integration (VGI) rates with "real-time" or "day-ahead real-time pricing," "demand response," and possibly "vehicle-to-grid" or managed charging to encourage drivers to charge during hours when the electricity grid has spare capacity or to alleviate local distribution-level constraints, rather than exacerbating the system-wide peak demand (particularly in jurisdictions with supply constraints).

The California Public Utilities Commission could adopt incentives for investor-owned utilities to improve the overall utility load factor (the ratio of average electricity demand to peak electricity demand to measure asset utilization) to encourage utilities to utilize their assets better through performance-based ratemaking, which could encourage utilities to adopt incentive programs to encourage optimal charging at all sites in their service territory, potentially without the need for charging-specific rates.

California policy makers at various energy agencies, as well as industry leaders, could work together to fill knowledge gaps regarding the best rate design and investment and charging needs for the grid and ratepayers, through demonstration rate programs and extensive data collection on the most optimal rates for charging.

The California Public Utilities Commission could allow demonstration or pilot rates for investor-owned utilities to gather data on what rates and degrees of utility investment might best encourage optimal infrastructure deployment, as well as data on utilization, maintenance, and reliability of the charging station.

Utilities and the California Independent System Operator could enable charging sites to take advantage of demand response, frequency regulation, and vehicle grid integration programs, with revenue from this infrastructure stemming from rate design by California utilities and regulators that encourages optimal usage.

State agencies, such as the California Energy Commission, could assist load-serving entities in commercializing vehicle-grid integration technologies through qualifying as "revenue grade" on-board car and charger technologies and software that can improve response to dynamic rates and help implement smart charging.

State regulators and utilities could ensure that workplace charging encourages optimal charging patterns to match grid needs through improved rate design, which could involve employees charging at home at night rather than during the day when the grid may be more constrained (or during the day when surplus solar energy is available), workplace charging rates for Level 2 to encourage more employee turnover, and more all-day "slow" charging.

The California Public Utilities Commission could ensure that rates are flexible and tailored for different solutions and use cases, such as for fleets of electric vehicles or public transit agencies, in order to reflect their different charging needs and resources compared to single-vehicle owners.

California policy makers could consider other incentives beyond rates to influence charging behavior to optimize the grid, such as using low carbon fuel standard (LCFS) credits or greenhouse gas reduction funds under the cap-and-trade program to give commercial customers a rebate when they charge during times that could benefit the grid, assuming usage times can be verified easily.

The California Air Resources Board could maintain and strengthen the low carbon fuel standard (LCFS) program to ensure continued credits are available for charging, so that the program continues to provide credits for charging and can encourage optimal charging.

CHALLENGE: High demand charges can discourage deployment of electric vehicle charging infrastructure in certain locations or scenarios

SOLUTION: Explore options to minimize or replace demand charges with more grid-efficient rates that recover costs from charging more effectively

The California Public Utilities Commission could direct utilities to develop new electric vehicle charging rates that institute alternatives for demand charges with proper cost recovery and strong price signals on timing, such as enhanced time-of-use, demand response, or vehicle-grid integration rates.

The California Public Utilities Commission and utilities could adopt "conjunctive" or network billing for electric vehicle charging service providers to allow them to pay one electricity bill for all their various charging sites, with the utility billing for these various metered sites as if they were together at one physical entity, in order to avoid high demand charges.

Utilities and electric vehicle service providers, with state policy makers' encouragement, could educate site hosts and operators on technology solutions to avoid high demand charges, such as through energy storage solutions and facility energy management systems, as well as pricing that encourages charging at optimal times.

The California Public Utilities Commission and Energy Commission could encourage the inclusion of energy storage assets, particularly for fast-charging sites, in order to reduce the costs and need for capacity upgrades and encourage the use of vehicle-grid integration and battery "second-life" applications.

State policy makers and/or industry leaders could develop an easily understandable metric like "e-gallon equivalent" (EGE) and post it widely on all charging infrastructure, as well as consider mandating transparent pricing at all charging locations.

Industry leaders and state policy makers could educate consumers and dealers on attractive rate options and develop creative opt-ins, such as encouraging electric vehicle dealers to educate new buyers about rates, through using the Clean Vehicle Rebate Project list of new electric vehicle buyers and leases.

This report explores these solutions in more detail below and provides an overview of current electric vehicle technologies and trends, as well as relevant policies at the federal and state level.

Introduction: Electric Vehicle Deployment is Central to California's Environmental and Energy Goals but Requires More Charging Infrastructure

California will need widespread consumer adoption of electric vehicles in order to achieve the state's environmental and energy goals. The state seeks to reduce emissions to 1990 levels by 2020, per California's Global Warming Solutions Act of 2006 (Assembly Bill 32, Nuñez, 2006).[1] Senate Bill 32 (Pavley, 2016) sets further targets of 40 percent reductions below 1990 levels by 2030. Executive orders issued by Governor Schwarzenegger in 2005 (Executive Order S-3-05) and Governor Brown in 2015 (Executive Order B-30-15) both set the state's long-term goal of an 80 percent reduction below 1990 levels by 2050.[2] Meanwhile, Senate Bill 350 (de León, 2015) set goals for accelerating widespread transportation electrification.[3]

Meeting these goals will only occur with emissions reductions from the state's transportation sector, which accounts for approximately 37% of greenhouse gas emissions.[4] Vehicles will need to switch from petroleum to cleaner transport fuels. Electric vehicle technology reduces pollution from petroleum transportation fuels and can also help clean the electricity grid by using battery charging as a flexible resource. It can moderate demand depending on supply availability and soak up surplus renewables when prices are inexpensive.

"We are all focused on 2025. But our initial calculations for 2030 show we need 4 million zero-emission vehicles. The barriers and challenges will be amplified."

- Alberto Ayala
California Air Resources Board

As a result of the environmental benefits, Governor Brown issued Executive Order B-16-2012 on March 23, 2012 to encourage electric vehicle adoption in California. He set a long-term goal of reaching 1.5 million zero emission vehicles (ZEVs) by 2025. The order included an interim goal of sufficient infrastructure to support 1 million zero emission vehicles on the road by 2020.[5] Similarly, Senate Bill 1275 (De León) created the Charge Ahead California Initiative, which seeks to deploy one million zero- and near-zero-emission vehicles by 2023 and improve access to such vehicles in disadvantaged communities.[6] As of June 2017, Californians were driving almost 300,000 electric vehicles.[7]

Federal and state laws boost electric vehicle deployment

To support electric vehicle deployment, federal and state policy makers have enacted laws and incentive programs. Most prominently, California's Zero Emission Vehicle Program requires vehicle manufacturers selling in the California market to ensure that an increasing proportion are ZEVs. Vehicle manufacturers can generate and bank ZEV credits for compliance.[8] The first phase of the program lasted until 2008, the second phase will end in 2017, and the third phase begins in 2018.[9]

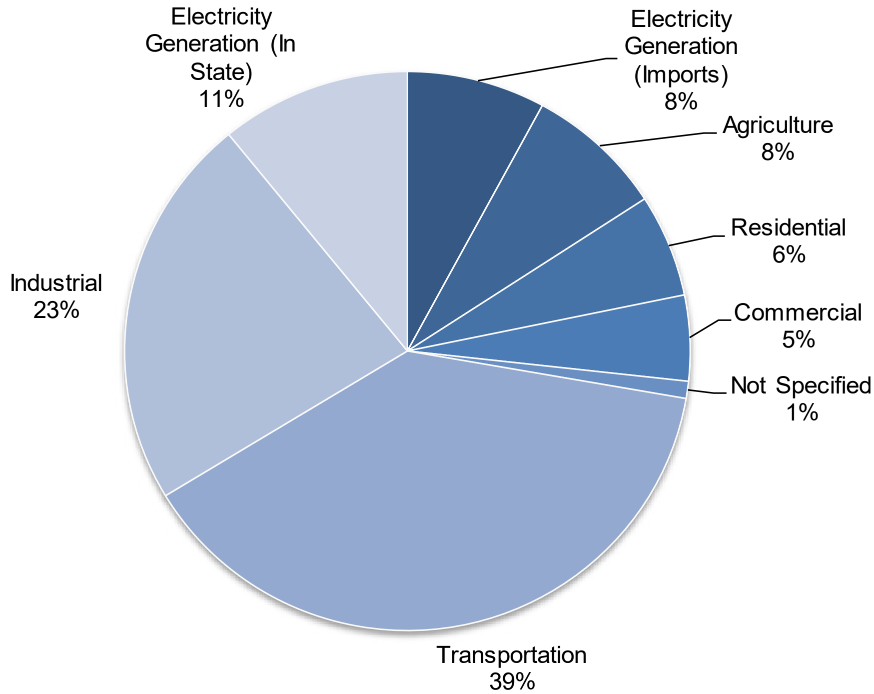
What are electric vehicles?

Hybrid and plug-in electric vehicles fall into one of three categories:

1) Battery Electric Vehicles (BEVs)
2) Plug-In Hybrid Electric Vehicles (PHEVs)
3) Hybrid Electric Vehicles (HEVs) (not the subject of this report)[10]

Both PHEVs and BEVs contain batteries that are recharged by plugging in the vehicle into a charger.

PHEVs, some of which are also called Extended Range Electric Vehicles (EREVs), are powered by a battery that can be recharged by plugging into an external source of electricity but which also incorporate the use of a combustion engine when the battery is depleted.[11] Ubiquitous and reliable access to charging infrastructure would help ensure that PHEVs drive more miles using electricity rather than gasoline or diesel. BEVs operate on electricity only and may only be charged by plugging the vehicle into a charger. They therefore are the most dependent on ubiquitous and reliable charging infrastructure.



2015 Total CA Emissions: 440.4 MMTCO2e

Figure 1. California's Greenhouse Gas Emissions by Sector (2015)
Source: California Air Resources Board

Electric vehicle drivers also qualify for financial credits, rebates, and other incentives, albeit inconsistent ones. California offers cash rebates for the purchase or lease of electric vehicles in amounts between $1,500 and $2,500, depending on the type of vehicle listed on the rebate program's webpage.[12] As of December 2016, more than 170,000 electric vehicle owners received such tax rebates, totaling nearly $370 million.[13] Meanwhile, the federal government offers a "Qualified Plug-In Electric Drive Motor Vehicle Tax Credit" upon purchase of a new qualified electric vehicle.[14] The amount of the credit ranges between $2,500 and $7,500, depending on battery capacity and vehicle weight. However, the credit will be phased out for each manufacturer, once they sell 200,000 qualified electric vehicles in the U.S. In addition, California exempts electric vehicles from the High Occupancy Vehicle (HOV) lane requirements, issuing white and green clean air vehicle decals for access to the lanes.[15] The decals will be effective through January 1, 2019.

California needs more electric vehicle charging infrastructure to meet projected demand

California currently has roughly 12,000 publicly accessible charging ports.[16] Yet the state will need significantly more electric vehicle charging infrastructure to meet its goal of 1.5 million electric vehicles on the road by 2025. Estimates of the deployment needed vary. According to the National Renewable Energy Laboratory, to reach the 2020 goal of charging infrastructure to support one million electric vehicles, the state will need a roughly similar number of charging points, most of which would be home charging stations.[17] The report described substantial variability among different scenarios in terms of the charging types and locations and predicted the need for approximately 100-170,000 workplace charging points and 20-50,000 public charging points.[18]

Types of electric vehicle charging

Electric vehicle owners have four options for charging their batteries, involving increasing levels of power and quickness:

Level 1 charging denotes 110 to 120 volt alternating current power found in most household outlets, which can power most electric vehicles overnight.[19] Many electric vehicle owners use Level 1 charging today at home because the technology does not require installing new infrastructure. Level 1 also has less impact on the grid than more intensive charging processes due to the typically off-peak nature of its use and its reduced intensity of power demand that drives peak load on the distribution system.

Level 2 charging entails 220 to 240 volt alternating current that can fully recharge a battery overnight at as little as 1/3 the charging time as Level 1. Level 2 charging can replenish 10 to 25 miles of range per hour.[20] Many homes and businesses may require new wiring to enable Level 2 charging.

Direct Current (DC) Fast Charging with today's technology involves 208 to 480 volts charging a typical battery to 80 percent capacity in 30 minutes or less, although it varies depending on multiple factors. The technology requires dedicated charging infrastructure, typically located in public access areas for drivers on extended trips. While Level 1 and Level 2 charging requires a standard J1772 plug, with a standardized charging protocol, DC fast charging has multiple standards. The typical DC fast charging plugs used in the U.S. include:

- The J1772 combo or **Combo Charging System** (CCS) plug, supported by automakers such as Audi, BMW, Daimler, Ford, General Motors, Honda, Hyundai Porsche, Volvo and Volkswagen;
- The **CHAdeMO** plug, supported in the U.S. market by automakers such as Renault-Nissan, Kia, and Mitsubishi; and
- The **Tesla** combo plug, supported solely by Tesla.

These technologies have their own charging protocols, resulting in limited interoperability. While Tesla recently joined the CCS consortium,[21] Nissan and BMW announced the expansion of the EVgo fast charging network in the U.S., which supports both the CHAdeMO and the CCS standards.[22]

Technologies in development

Multiple charging technologies in development may leapfrog the current charging infrastructure landscape. Supporters of all three DC fast charging standards have announced plans to improve the charging power and speed possible using their charging solutions. The CHAdeMO coalition recently announced that they are planning to introduce a 150 kilowatt (kW) charging protocol in 2017 (three times faster than the current 50 kW version or Tesla 120 kW "Supercharger").[23] Ford, BMW, Mercedes, and Volkswagen also signed a memorandum of understanding to introduce a 350 kW charging standard and deploy a large number of such charging stations in Europe, primarily in Germany.[24] Finally, Tesla may soon introduce its V3 Supercharger capable of 350 kW fast charging.[25]

Two additional technologies could alter electric vehicle charging in the future: inductive charging and battery swapping technology. Inductive charging transfers electricity to electric vehicles using an electromagnetic field, eliminating the need for plugging in.[37] Battery switching involves electric vehicle owners swapping depleted batteries for fully charged ones at designated locations.[38] However, despite early investment, most battery swapping pilots have been halted.[39]

"1.5 million electric vehicles by 2025 means we need 300,000 workplace chargers at $5,000 per charging point, or $1.5 billion on infrastructure. Plus 5,000 DC fast chargers, at $50,000 each, is another $250 million."

- *Dan Lashof*
  NextGen Climate America

The infrastructure need is particularly acute for residents who do not live in single-family detached homes, where more than 80 percent of current electric vehicle owners live. The lack of available charging for these residents (approximately 40% of Californians) represents a major barrier to their adoption of electric vehicles.[40] Ultimately, some analysts estimate that the state will need 125,000 to 220,000 publicly accessible charging ports by 2020, well beyond the 12,000 available today.[41] Additionally, hundreds of thousands of other charging stations will be necessary at multi-unit (or multifamily) dwellings (MUDs), such as apartments, townhouses and condominiums, to meet future demand from residents of these buildings.[42] Because multi-unit dwellings are expected to constitute an increasing share of California's future housing supply, their proliferation will add to the demand for charging stations at housing types beyond single-family detached homes.

"State and utility incentives should be made in a way that accelerates the market for electric vehicles and consumer investment."

- *Eileen Wenger Tutt California Electric Transportation Coalition*

Current state of electric vehicle deployment in California and the United States

By June 2017, Californians were driving almost 300,000 electric vehicles, most of which were plug-in electric vehicles.[43] Through May 2017, more than 185,000 electric vehicle owners received tax rebates.[44] To meet the 1.5 million electric vehicle target by 2025, the state will need to see an exponential growth in electric vehicle sales. Meanwhile, U.S. electric vehicle sales amounted to nearly 160,000 vehicles in 2016, close to 40% growth compared to the previous year.[45]

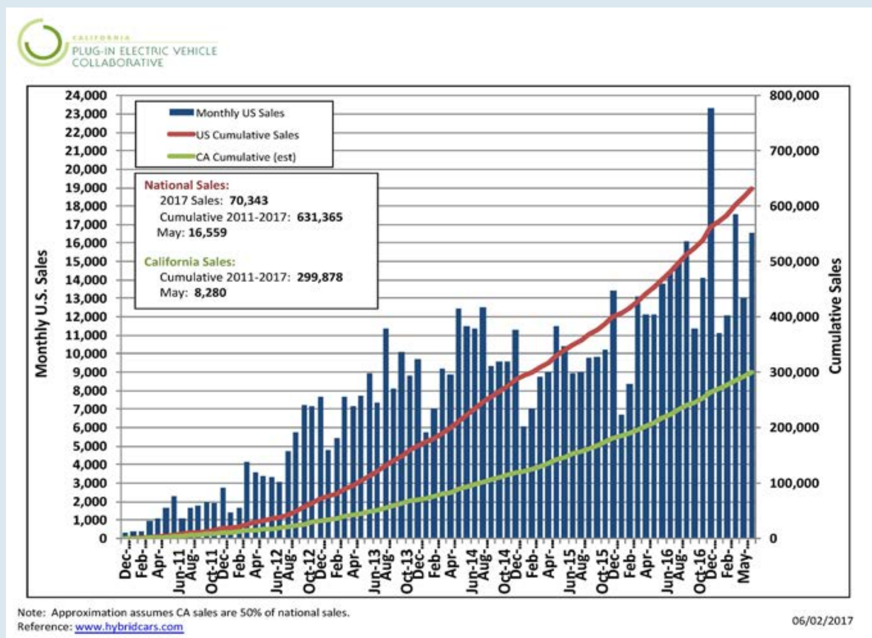


Figure 2. Electric Vehicle Monthly Sales Chart, Nationwide and California, 2011-2017

Source: Plug-In Electric Vehicle Collaborative

Current state of charging infrastructure deployment in California

By the end of 2016, California had nearly 12,000 public electric vehicle charging points at more than 3,600 charging stations,[46] a 50 percent increase from 2015.[47] The charging stations are typically located along interregional corridors or in high vehicle-density areas.[48] No information is available on the number of home chargers and workplace chargers deployed in the state.

Current state and utility incentives and programs encourage charging infrastructure

California encourages the development of electric vehicle charging infrastructure through multiple incentives. The Alternative and Renewable Fuel and Vehicle Technology Program (ARFVTP), established by Assembly Bill 118 (Núñez, 2007) and extended by Assembly Bill 8 (Perea, 2013), authorized the California Energy Commission to develop and deploy advanced transportation technologies in support of the state's climate change policies.[49] Through this program, the energy commission invests up to $100 million each year in alternative fuels, advanced technology vehicles and manufacturing, and fueling infrastructure. In 2016, for example, the commission allocated close to $9 million for DC fast charging deployment in California's north-south corridors.[50] The California Capital Access Program's (CalCAP) Electric Vehicle Charging Station (EVCS) Financing Program, which went online in 2015, supports small businesses and landlords in deploying workplace or home charging stations by providing a maximum loan amount of $500,000 per eligible borrower.[51] Additional state incentives focus on certain regions of California, such as the Electric Vehicle Supply Equipment (EVSE) Incentives - San Joaquin Valley and the Technology Advancement Funding - South Coast.[52] In addition, the California Air Resources Board reached a settlement with Volkswagen to invest $800 million in electric vehicle charging infrastructure over the next 10 years, as part of the compensation from the automakers' illegal "defeat devices" to avoid emissions standards testing.[53]

Investor-owned utilities in California support electric vehicle adoption by providing charging infrastructure, rebates, rates, and vehicle-grid integration. Following Decision 14-12-079 of the California Public Utilities Commission, which promoted a case-specific approach to utility involvement in charging infrastructure development, the state's three largest investor-owned utilities (Southern California Edison, San Diego Gas & Electric Company, and Pacific Gas & Electric Company) submitted their first round of applications to install light-duty electric vehicle charging infrastructure to the California Public Utilities Commission. In January 2016, the commission approved a $45 million pilot program for San Diego Gas & Electric Company to install 3,500 charging stations at multi-unit dwellings and workplaces and a $22 million pilot for Southern California Edison to install 1,500 charging stations at multi-unit dwellings, workplaces, and public places.[54] In December 2016, the commission then approved Pacific Gas & Electric Company's proposal to provide another 7,500 chargers at nearly 750 multi-unit dwellings and workplaces.[55] The goal was to make charging equipment and associated electrical infrastructure less expensive for site owners, in order to overcome identified business model challenges (discussed below).

With the passage of SB 350 in 2015, the California Public Utilities Commission directed investor-owned utilities to propose additional investments in transportation electrification.[56] In January 2017, the three largest utilities proposed a portfolio of programs and investments in transportation electrification, including technology demonstration pilots, charging infrastructure installation, and rates, which is currently undergoing commission review.[57]

High costs thwart charging infrastructure deployment

High installation costs can deter the infrastructure deployment needed to meet demand from electric vehicle drivers. Charging stations entail certain common expenses, particularly in settings such as multi-unit dwellings and commercial venues. These include costs for securing property, architectural and/or electrical design, permitting, equipment acquisition, operation and maintenance, construction costs like trenching, and electricity. Costs at non-residential sites (and some residential ones) are also influenced by the opportunity costs of parking, government subsidies such as tax credits, and equity.[58]

Electric Vehicle Models

A high number of PHEVs and BEVs are for sale worldwide, and this report only takes into account the models available in the U.S. through January 2017.[26] Notably, sales figures of some vehicles have been significant in other regions and could influence the U.S. market eventually, once consumers can access them. The BYD Tang, for example, was the best-selling plug-in electric vehicle in China and the third-best-selling plug-in vehicle in the world in the first half of 2016.[27] The Renault Zoe and the Mitsubishi Outlander PHEV have also been the best-selling BEV and PHEV, respectively, in Europe during the first three quarters of 2016[28] and the fourth- and fifth-best-selling plug-in vehicles in the world during the first half of 2016.[29] BEVs and PHEVs (not including fuel cell electric vehicles) available on the U.S. market include:

- Audi A3 Sportback e-tron
- BMW 330e, 740e, i3, i8, and X5 xDrive40e
- Chevrolet Bolt EV and Volt
- Chrysler Pacifica Hybrid
- Fiat 500e
- Ford Focus Electric, C-Max Energi, and Fusion Energi
- Hyundai Sonata PHEV
- Kia Soul EV
- Mercedes-Benz B-Class Electric Drive, GLE 550e, and S550 Plug-in Hybrid
- Mitsubishi iMiEV
- Nissan LEAF
- Porsche Cayenne S-E Hybrid and Panamera S-E Hybrid
- Tesla Model S and Model X
- Smart Fortwo Electric Drive
- Toyota Prius Prime
- Volkswagen e-Golf
- Volvo XC90 T8 PHEV[30]

Automakers have announced additional models for the coming months and years, many of which may be available on the U.S. market. For example, the Mitsubishi Outlander Plug-in Hybrid is expected to debut in the U.S. in 2017.[31] Established manufacturers are planning to launch several BEVs in the coming years, such as Hyundai's Ioniq EV[32] and the second generation of Nissan's pioneering LEAF.[33] Hybrid vehicle pioneer Toyota intends to develop a BEV by 2020.[34] Tesla's Model 3 is also expected to launch in late 2017.[35] Finally, new entrants promise BEVs and PHEVs in the near future, such as Farraday Future and Lucid Motors.[36]

The cost and time of installation varies greatly depending on the electrical requirements at the site, as well as factors such as permit and inspection fees. A U.S. Department of Energy study from February 2016, conducted by Idaho National Laboratory, examined charging installations around the United States and found significant variability. For example, the installation of DC fast chargers were by far the most expensive, with costs ranging from $8,500 to $50,000 per installation (the DC fast chargers studied had dual ports as opposed to the single ports common in Level 2 – or 240-volt – charging stations).[59] These costs typically reflect the installation of the hardware only and do not include the cost of the DC fast charger equipment (typically in the $30,000 range), the upfront architectural and electrical design work ($25,000), the utility service drop (running the overhead electrical line from a utility pole to a customer's building or other premises, at an estimated cost of $30,000), or the permitting. Meanwhile, the cost for installing public Level 2 chargers ranged from $600 to as high as $12,660.[60]

Type of Charging Station	Minimum	Maximum	Mean
Workplace Level 2	$624	$5,960	$2,223
Public Level 2	$600	$12,660	$3,108
Blink DC Fast Charger	$8,500	$50,000	$22,626

Installation Costs of Electric Vehicle Charging Stations

Source: Idaho National Laboratory Study, U.S. Dept of Energy

"The biggest challenge is the uncertainty of cost and location. We spend most on figuring this out. Then once it's built, there are ongoing operational costs. These are costs that need to be looked at."

- Stacey Reineccius Powertree Services

State-level data in California indicate that total costs in the state may actually be significantly higher than the national studies have found, particularly for DC fast chargers. Los Angeles Department of Water and Power, for example, recently installed 16 DC fast chargers that had typical installation costs (equipment and labor) ranging from $55,000 to $100,000, with an average of $85,000 each. The dual standard DC fast charger equipment alone cost the utility $32,000.[61] Meanwhile, preliminary reports from Southern California Edison's Charge Ready program show the total cost of installing make-ready infrastructure for Level 2 charging (including customer rebates for the charging stations) at $13,734 per port and $219,424 per site, with 16 ports on average.[62]

The cost and time of installation varies greatly depending on the electrical requirements at the site, as well as factors such as permit and inspection fees. In advance of the most recent DC fast charge corridor grant funding opportunity, the California Energy Commission commissioned a study to help establish funding levels and priorities. This study recommended planning for each DC fast charger site to cost $140,000 to install one single port CHAdeMO fast charger, one dual standard fast charger, and one single port Level 2 charger. The study also estimated $215,000 for two single-port CHAdeMO fast chargers, two dual standard fast chargers, and one dual port Level 2 charger.[63] The actual results had greater variability, via installation site cost averages from the agency's grant-funded GFO-15-601 and GFO-15-603 (with recipient administration costs removed):

Equipment	Average Cost
1 Dual Standard DC Fast Charger, 1 Level 2, and 1 Stub-out	**$135,000**
2 Dual Standard DC Fast Chargers, 1 Level 2, and 1 Stub-out	**$160,000**
4 Dual Standard DC Fast Chargers, 1 Level 2, and 1 Stub-out	**$220,000**

Average Site Cost by Equipment at California DC Fast Charge Corridor Site

Source: California Energy Commission

Notably, the average site costs along the California DC Fast Charge Corridor did not include signage, permits, networking, customer service, maintenance, warranties, or site host negotiation costs. Some of these additional costs are as follows, per site:

Non-Equipment Installation Needs	Average Cost
Signage	**$1,150**
Permits	**$1,900**
Network/customer service	**$5,200**
Five-year maintenance plan or warranty	**$47,500 or $9,500/year**

Additional Costs for Electric Vehicle Charging Stations

Source: California Energy Commission[64]

Due to the high costs, a 2012 UCLA Luskin School for Innovation study of non-residential charging stations in the Los Angeles area found significant business model challenges. The study identified common factors that influence the net present value (NPV) of a charging station, including costs related to equipment, installation, maintenance, marginal electricity use, depreciation, subsidies/tax credits, equity, and revenue sharing (site owner sharing with the charging network operator).[65] The study found that the costs of non-residential electric vehicle charging stations frequently exceeded the revenues.[66] For grocery stores and shopping malls, the factors that impacted net present value the most included higher fixed fees, the number of charge events, and the level of fixed fees. For workplace locations, electricity cost was the most influential factor.[67]

Current commercial electricity rates can hinder electric vehicle charging deployment

Commercial electricity rates can also present a challenge for the charging station business model. Commercial charging typically occurs in four settings: DC fast charging locations, workplaces, retailers/malls, and multi-unit dwellings (with common meters). Commercial rates in California that affect these settings are generally based on time of use, with and without demand charges, which means the amount the utility charges per kilowatt hour depends on when the customer uses the electricity and the largest load incurred during the billing period. Under time-of-use rates, the utility rewards electric vehicle owners or site hosts who charge during hours when the cost of energy is lowest.

At one DC fast charger in San Diego County, demand charges were responsible for over 90% of electricity costs, at $1.96 per kilowatt hour during summer months (compared to the gasoline equivalent cost of $0.29 per kilowatt hour).

Some large commercial and industrial rates also have “demand charges” that entail additional costs on the maximum load drawn by a customer during the billing period. Utilities institute these demand charges to cover the wear-and-tear on the distribution system components (i.e., transformers, substations, and primary conductors) and some portion of the transmission system, if the load is large enough. They are meant to cover the maximum capacity needed to satisfy all their customers’ peak energy needs and are usually based on the highest 15-minute average usage within a billing period (called “coincident” if the demand charges are tied to a specific time period and “non-coincident” if the time period is not a factor). Facilities that use a significant amount of power in short bursts, as opposed to more consistent usage throughout the billing period, are more affected by demand charges, since they have less electricity throughput to spread the cost.

Demand charges also function to encourage high-demand customers to reduce peak power usages, if possible, to reduce the amount of electrical infrastructure needed to serve them. Many electric vehicle charging sites that have high but infrequent demand and inconsistent low-energy utilization (particularly for fast charging) face high exposure to demand charges as a result, undercutting the economics of infrastructure deployment and operation. This dynamic is particularly acute at commercial sites that otherwise do not have high electricity demand or have consistent high utilization that would absorb or mask spikes in usage from fast-chargers or spread the associated demand charges over many kilowatt-hours. For example, at one DC fast charger in San Diego County, demand charges were responsible for over 90% of electricity costs, at $1.96 per kilowatt hour during summer months (compared to the gasoline equivalent cost of $0.29 per kilowatt hour).[68]

Existing commercial rates were developed over decades for normal commercial buildings that had primarily steady loads and high energy usage. They were not intended for high-load, low-energy applications such as DC fast charging. As a result, DC fast charging site hosts often are exposed to crippling demand charges, depending on the overall usage on the site. Workplaces and retail sites with otherwise low on-site usage can also incur high demand charges once employees or visitors begin charging, while time-of-use charges can discourage shared use of electric vehicle chargers in multifamily sites.

Top Barriers and Opportunities for EV Charging Infrastructure Deployment

At the June 15, 2016 convening of electric vehicle charging experts at UCLA Law, participants described a vision for ideal electric vehicle charging infrastructure deployment. They discussed the barriers preventing the vision from becoming a reality and the potential solutions to overcome them. The following section is informed by that discussion and details those barriers, covering the lack of a clear business model for charging in workplaces, multi-unit dwellings, and DC fast charge "plazas."

This section then later encapsulates a subsequent discussion at a November 7, 2016 convening of electric vehicle charging experts at UC Berkeley Law, in which participants focused on the specific barrier of commercial electricity rates that can hinder deployment. As part of that second convening, participants described a vision for ideal commercial electricity rate design, as well as the barriers preventing the vision from becoming a reality and the potential solutions to overcome those barriers.

"There is not an unlimited appetite to spend public money on EV charging. We don't have enough public dollars to do all the types of charging we may want."

- Cliff Rechtschaffen
California Governor's Office (now Public Utilities Commission)

Key principles for electric vehicle infrastructure deployment

Alignment with Environmental and Energy Goals:
Ubiquitous and reliable charging infrastructure that furthers California's ability to achieve its environmental and energy goals through decarbonized transportation and a renewable, low-carbon grid

Encourages and leverages multi-state and national action on electric vehicle infrastructure deployment; and aligns with a national vision for charging infrastructure.

Equity:
Charging infrastructure that furthers economic development goals across the state for residents of all income levels and in all geographic regions and that provides easy access to charging for all Californians.

Consumer-Orientation:
Convenient and seamlessly interoperable charging infrastructure that provides economical options in the form of plentiful, highly visible, easy-to-locate, and reliable charging stations that utilize a transparent pricing arrangement.

"We need to have a national vision on promoting EV infrastructure"

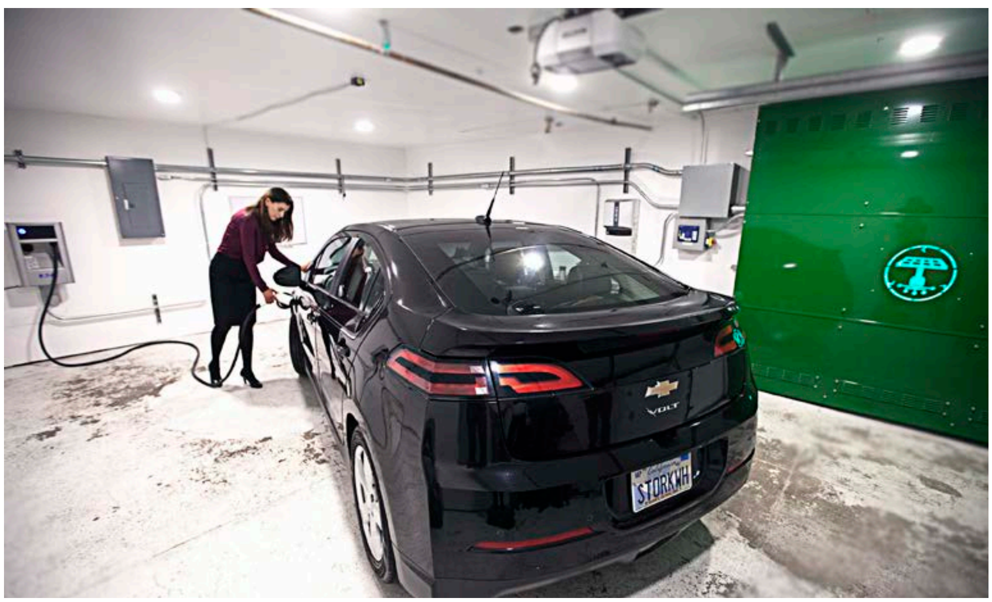
- *Colleen Quinn ChargePoint*

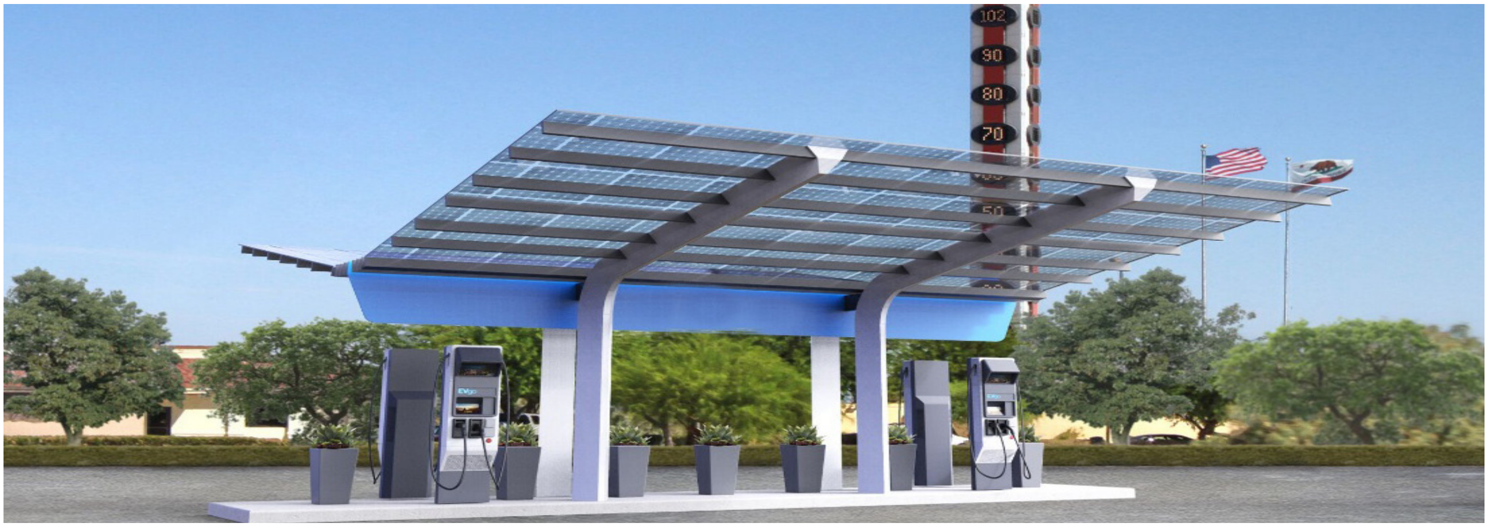
Timeliness:
Charging infrastructure that can be deployed quickly to meet anticipated demand and achieve the state's near- and long-term environmental and energy goals, without becoming prematurely obsolete.

Location:
Ubiquitous charging in workplaces, multi-unit developments, and interstate and urban fast-charging locations, along with standard availability of charging in new buildings, which supports (when optimal) infrastructure for electrified medium- and heavy-duty trucks/goods movement and is flexible to adapt to changing market conditions and technologies, per the latest available data.

Technology:
"Right-sized" level charging for the location context, such as encouraging inexpensive options before more expensive technologies, and highest-speed fast-chargers in appropriate locations based on the latest available data, with flexibility to adapt to changing market conditions and technologies.

Financing and revenue:
A sustainable charging market that does not require taxpayer dollars (other than in the near-term to maximize private investment in the most promising, low-cost infrastructure and locations) and relies on multiple financing sources that leverage the full range of benefits the charging infrastructure can provide, with competition and innovation to improve consumer choice and affordability.





Barrier 1: Unclear or Inconsistent Case for Installing Charging in Workplaces, Multi-Unit Dwellings and Direct Current Fast-Charge Locations

Given the high costs of installation and operation, coupled with uncertain revenue, electric vehicle charging in the key settings of workplaces, multi-unit dwellings, and fast charge locations suffers from the lack of a strong business model. Policy makers and industry leaders need to improve the general business case for electric vehicle charging in these areas, or else they will not be successful in encouraging optimal deployment and may run counter to the directives in SB 350. An improved business case will require revenue certainty in order to stimulate major capital investment. Policy makers will need to determine the total cost of charging infrastructure that rates can cover, over different time scales and locations. Market participants will then need to determine which specific elements of project delivery costs they can fund.

SOLUTION: Reduced costs and improved revenues

"There must be a profit. No one will invest if they can't make money."

- John Tillman
Nissan Motor Company

▶WORKPLACE CHARGING – IMPROVING THE BUSINESS CASE

CHALLENGE: Site host and service provider reluctance to install and operate the charging equipment

Potential site owners in workforce areas lack motivation to host charging infrastructure, in part because the costs of installation and maintenance may be too high. In addition, charging can negatively impact or limit parking lot spaces on-site or other physical assets on the property. Many service providers also may be reluctant to work with workplace charging sites due to the high costs of operation and maintenance, as well as administrative costs related to securing site approval and then operating the infrastructure.

SOLUTION: More incentives and programs to encourage workplace site hosts and service providers to install and operate charging

Utilities could invest in workplace charging infrastructure (at least "make-readies") and provide more flexible electric service and rate options for workplace service providers. For example, charging providers might qualify for "network" rates that apply across multiple workplaces that are within the same network to

level the overall demand for electricity across the workplace, thereby reducing customer costs. Utilities could also offer separate electric service planning options for building owners and parking lots that could allow separate rate treatments for charging and potentially avoid the need for trenching from existing service, if the parking area is near utility infrastructure (like distribution poles).

State and local government leaders could consider offering incentives for workplaces to install charging equipment. Examples could include rebates that help lower the costs of installation. State or local government leaders could also offer economic incentives such as tax credits to discourage site hosts from making employees pay excessively for charging at work. In addition, state policy makers could consider offering utilities greenhouse gas allowances under the state's cap-and-trade program for investments in electric vehicle infrastructure that shift workplace vehicle fuel usage from petroleum to electricity.

Air districts and other local agencies could develop new rules to encourage workplace charging. As an example, the South Coast Air Quality Management District amended a rule (Rideshare Rule 2202) that provides compliance incentives for employers to encourage electric vehicle charging, similar to existing carpooling incentives they offer to businesses.[69]

State and local policy makers could consider offering economic incentives or reducing costs for service providers to encourage workplace site hosts to hire them for "full service" charging. These incentives could address costs from installation to management and could include faster permitting or reduced taxes for service providers engaged in this work.

The California Energy Commission could consider reforming the green building code to require developers to install not only the conduit but also the charging equipment in new workplace buildings. The California Green Building Standards Code (CALGreen Code) represents the first statewide "green" building code in the country and already requires Level 2-type infrastructure in certain new commercial buildings. It could also require that any reconstruction of parking lots must include charging infrastructure.

Industry and policy makers could educate site owners on the potential economic value of low carbon fuel standard credits, which may be currently underutilized as a source of revenue to offset infrastructure and operation costs. The credits come from a state program that created a performance-based market and mandate for transportation fuels that have reduced carbon intensity, such as electricity. The effort could potentially involve third parties to help aggregate and monetize the credits for users, including public agencies like school districts that may own an electric vehicle bus or delivery truck. Industry leaders and state policy makers could also educate charging station operators about how to manage usage to avoid high demand charges. They could also educate operators on the value of low carbon fuel standard credit options to partially offset high demand charge costs and reduce the cost of electricity as a fuel overall. These credits may currently be widely under-utilized by site hosts.[70]

Utility and charging industry leaders could compile and promote best practices on workplace charging to potential site hosts. Policy makers, industry leaders, academics, and nonprofits could accumulate, analyze, and share existing data on workplace charging to inform these practices, including for pricing.

State leaders and utilities could reform utility rate rates that discourage installation. Site hosts at workplaces typically face risks from demand charges and other escalating rates. To offset these risks, utilities could consider allowing site owners to receive some additional revenue from charging infrastructure from vehicle grid integration services (see discussion below).

▶MULTI-UNIT DWELLINGS – IMPROVING THE BUSINESS CASE

CHALLENGE: Difficult access to charging for multi-unit dwelling residents

Approximately 40 percent of Californians live in multi-unit dwellings (MUDs), with impeded or no access to charging. The percentages are higher in the state's urban areas, with 56 percent in Los Angeles and 67 percent in San Francisco. Property owners need to be convinced of the value (i.e. the ability to increase rent or receive revenue at a suitable rate to gain return on investment) in order to provide tenants access to tenants.

SOLUTION: Lower the installation costs for charging in multi-unit dwellings

State leaders could assist the private sector, including utilities, in identifying and lowering infrastructure installation costs in critical multi-unit dwellings and areas. According to participants, private installers may spend as much as $11,000 to do site surveys, interconnection applications, engineering plans, and basic communication with property owners. The state could lower these costs by determining how to prioritize multi-unit dwellings and regions for investment (including by utilities, at least for "make-readies") and then facilitating education and outreach to property owners. The state could also help offset the cost of acquiring data and information from these buildings, as well as explore other ways to reduce costs. As one possible threshold, the state could focus on buildings with tenant density of at least 40 units, while generally focusing on larger buildings with the greatest potential impact.

"We need a 'no regrets' strategy. What are the 'low hanging fruit' for vehicle charging? What can we put in place right now?"

- Janea Scott
California Energy Commission

Utilities could provide consistent treatment of charger installations to increase predictability and lower the costs of installation. For example, the interconnection process and fees for this equipment should be as consistent and predictable as possible, across both investor-owned and municipal utilities, in order to encourage investment in multi-unit dwelling charging installations. As discussed above, utilities could also offer separate electric service planning options for building owners to facilitate separate rate treatments for charging.

State leaders could encourage high-concentration building owners like real estate investment trusts (REITs) to install charging. Such an effort may require reform to existing regulations or development of other incentives, such as tax credits for participating REITs.

State and local leaders could encourage more curbside charging for multi-unit dwelling residents who lack dedicated on-site, off-street parking. State agencies, in cooperation with local governments, may need to coordinate their permitting and planning processes to enable this deployment. As an example, cities like Burbank and Los Angeles have installed a significant amount of curbside charging (Los Angeles has 32 curbside street light chargers, 2 wood power pole curbside chargers, and 1 curbside DC Fast Charger), while Berkeley and San Francisco have not yet installed significant amounts. State legislation like Assembly Bill 1452 (Muratsuchi), which would allow municipal governments to designate stalls or spaces on public streets for electric vehicle charging and enforce those designations, could help implement more curbside charging.[71]

Utilities and state policy makers could improve upfront data access for charging service providers, with building owner consent, to lower installation "soft costs." Service providers and other third-party installers need to access data regarding the building service panel and current energy use in order to know what kind of equipment to install. They need to know the size of the existing service panel (which can range from 200 to 1200 amps), current usage and peak demand, and how much capacity is available on site for the chargers.

The California Public Utilities Commission and utilities could encourage integration of energy storage with charging infrastructure if it would entail additional offsetting revenues and savings from multi-unit dwelling installations. Some installers noted that utilities often see energy storage as a "new load" that requires them to cover additional costs. Electricity demand from these integrated solutions should instead equal the greater of the two loads, between the vehicle charging and charging the storage asset, and not the sum of the two.

The California Public Utilities Commission could expand Rules 15 and 16 exceptions for energy storage interconnection to multi-family dwellings when these technologies support electric vehicle charging. Rules 15 and 16 cover the process and cost allocations for distribution grid upgrades required when a facility significantly increases its on-site electricity demand. Rather than allow electric vehicle charging infrastructure to trigger this additional process and cost, the California Public Utilities Commission decided in D.11-07-029 and D.13-06-014 to treat electric vehicle-related distribution costs in excess of the Rules 15 and 16 allowances as "common facility" costs not requiring compliance with the rules. Expanding this exception further to energy storage equipment associated with electric vehicle infrastructure could help expedite the interconnection of these assets and therefore decrease the costs of installation, leading to savings through improved on-site load management for the charging facility owner.[72]

"You may not need that many home and workplace charging – at least in the future. In time, DC fast charging will take over and meet many of these needs."

- Frank Breust BMW

The California Energy Commission could strengthen the green building code to encourage new charging infrastructure when multi-unit dwellings undergo retrofits. The agency could also develop new regulations or a model ordinance for cities to require such infrastructure through their local codes.

State leaders could encourage the establishment of more fast-charging "plazas" in urban areas for multi-unit dwellers. These residents could then fast-charge a vehicle battery from time-to-time at public sites if they lack access to dedicated on-site charging (discussed in more depth below).

▶DC FAST CHARGERS – IMPROVING THE BUSINESS CASE

CHALLENGE: High costs and relatively low revenue

Fast chargers are needed to encourage more adoption of electric vehicles in general, in order to enable long-distance driving, expand the electric range of plug-in vehicles on battery power, and allow more multi-unit dwelling residents access to electric vehicle ownership (discussed above). Utilities need to be prepared for this deployment, given the high energy demand these stations create, while the state may need to help offset the upfront costs of these installations until demand grows. Ideally, increased demand will repay those costs over time.

Additional challenges to fast-charger deployment include split incentives, particularly with commercial properties where the tenant does not own the land but may want a charger. High demand charges can also negatively impact site owners, due to the high electricity usage even from single-charge sessions. Finally, as automakers seek to install 350 kW chargers for faster charging, the result will be even more expensive installations with more front-loaded costs.

Policy makers also need to consider how to maintain a fast-charging network among diverse companies as a singular, integrated system for ultimate consumer convenience.

Current fast-charging technology is not interoperable among the various formats.

SOLUTION: Explore alternative business models and reduced costs for installation and operation

State policy makers and industry leaders could examine and consider authorizing multiple ownership arrangements to ensure deployment. Participants at the convening identified the following business model/ownership options (without necessarily endorsing any particular option):

- **Utility-owned (at least "make-readies") and operated DC fast chargers.** This investment could socialize some or all of the costs that are not covered by direct revenues or be partially owned through the "make ready" model.

- **Automaker-owned DC fast chargers (like Tesla) or collaboration between automaker and electric vehicle service provider.** This arrangement would be paid for by a subscription and could be bundled with the purchase price of the automobile. An example would be EVgo's "no charge to charge" program with new Nissan LEAF customers receiving two years of complimentary charging, assuming this model is scalable.[73]

- **Public-private partnership.** The state could provide more grants for corridors with fast-charging and provide "plazas" for this infrastructure. The state would have to provide detailed specifications, such as the location, number of chargers, and capacity needed. It would have to future-proof the technology to ensure the highest-level charging rate is possible, such as having the utility cover the "basic" fast charge costs and then have the automaker or service provider pay for extra functionality for "premium" service. The state would also need to determine the needs for restrooms and other amenities and assess the scalability potential to maximize the return on its investment. This solution could potentially involve the utilities, because the 350 kW DC fast chargers that automakers want for super-fast charging could trigger the need for demand charge reform or mitigation. If the state helps fund the charging infrastructure deployment through bids from private operators, it could require the winning bidder to secure site host approval first in order to be eligible.

- **Dual-use model (co-location of charging with other economic activities).** This model would work like a gas station, where retail or other economic activity can provide the revenue to offset the high costs of charging.

- **Automaker/dealer.** The two entities can partner on providing the infrastructure, with the costs bundled into the purchase price (although this bundling could potentially raise vehicle prices and therefore discourage adoption), as with Tesla's network of automaker-owned charging stations.

"There is value in purchasers understanding there is charging available for longer distances when they need it."

*- Sarah Van Cleve
Tesla*

Business model: costs vs. revenues

The following charts describe the various cost components and potential revenue streams that could be managed to improve the business model, along with recommendations to improve each factor (many of which are discussed elsewhere in this report).

Costs	Who can help ease?
Service electricity to the electric vehicle service provider or the site-host	**California Public Utilities Commission can encourage utilities to develop an improved rate** to reduce costs. Examples (as discussed below) could be rates that encourage grid services from rates/programs such as demand response, frequency regulation, and vehicle grid integration. California utilities and regulators could design these rates and programs to encourage optimal usage and then pass along the grid savings to the operator through reduced charges.
Infrastructure (plus service to the electric vehicle supply equipment stub-out)	**Utilities and state regulators could set policy and establish incentives to guarantee or pay for some part of the development costs** associated with identifying and preparing sites for deployment, such as through allowances to cover line extensions (with publicly owned utilities recovering costs through full rate recovery mechanisms) and "make-ready" investments. **In addition, Section 1603 U.S. Treasury grants (payments for electric vehicle charging equipment in lieu of tax credits) could provide direct cash incentives immediately** with no wait lists.
Integrating charging systems into the grid via interconnection (relying on Rule 21 or Rules 15/16, a California Public Utilities Commission-approved set of interconnection requirements for electric vehicle charging)	**Utilities could determine ways to expedite interconnect queues** for optimal charging installations. As discussed previously, the **California Public Utilities Commission could expand Rules 15 and 16 exceptions** for energy storage interconnection to multi-unit dwellers when it supports electric vehicle charging.
Electric vehicle supply equipment (the charger itself)	**California Energy Commission could adopt appliance standards for chargers** that might reduce the costs of the equipment. **Cities and other local governments could provide funding** from grant programs, possibly based on future increases in sales tax revenue collection from new retail sales on site.
Lack of standardization for installing electric vehicle charging equipment in buildings	**Charging equipment manufacturers, with state and federal support, could adopt an energy star goal for buildings** that could encourage building owners to standardize their infrastructure for charging in order to achieve the rating, which could then reduce on-site installation costs. **State regulators and local building departments could institute codes and standards** for new buildings to require them to install chargers or "make-ready" wiring. **State regulators could reform the green building code** to require developers to install not only the conduit but charging equipment in new workplace buildings, as discussed previously. The code could also require that any reconstruction of parking lots must include charging infrastructure.

In order to attract private investors, potential site hosts and equipment purveyors need to have predictable revenue streams. Revenue streams can vary by use case and geography and territory involved. These installations are generally considered long-term investments and must be at a significant scale in order to attract tax credits and investors.

Potential Revenues	Who can help improve?
Payments for charging	**Electric vehicle service provider and automakers (when they own or operate charging) can adopt sustainable pricing** to encourage both optimal usage and vehicle adoption.
Low carbon fuel standard and renewable fuel standard credit sales, cap-and-trade proceeds	**California Air Resources Board has regulatory authority, as well as California Legislature and U.S. Congress, to encourage use of the credits** and funds for optimal charging sites.
Grid services payments (such as from demand response, frequency regulation, and vehicle grid integration rates/ programs)	**Utilities and the California Independent System Operator (CAISO, which has jurisdiction over wholesale energy market participation) could enable charging sites to take advantage of these programs** to some extent. This revenue from infrastructure could be enhanced with proper rate design by California utilities and regulators to encourage optimal usage and savings as a result.
Vehicle sales/marketing	**Automakers and dealers could consider subsidizing more charging installations since they may encourage more purchases** (the Tesla model). DC fast charging in particular may be a useful way to market the vehicles. However, automaker expenses on these installations could increase the vehicle costs, leading to higher prices and diminished purchases.
Increased sales of goods and services at retail host sites	**Local governments could explore funding** these installations based on potential increases in sales tax revenue from additional retail activity. **State energy agencies and researchers can also help determine the economic value of the "gas station model,"** with customers staying to shop while charging.

State leaders, with utilities, could consider investigating optimal locations for fast-chargers, from urban spaces to interstate corridors. One possibility is to locate the infrastructure at existing gas stations, which would need to be wired for the technology. However, because gas stations are usually privately owned, developers would have to approach them individually, as owners on average have one-to-three stations with average profits of possibly $40,000 per station per year (according to some participants). As a result, these sites may present logistical and financial challenges for installation. Yet given the ongoing decline in gas station businesses, fast-charging plazas may provide them an economic lifeline.

Barrier 2: Lack of Commercial Rate Design to Encourage EV Infrastructure

"It takes the California Public Utilities Commission a really long time to design and implement new tariffs. They therefore need to have flexibility built into the rates."

- Dr. Nancy E. Ryan Energy and Environmental Economics (E3)

Current commercial electricity rates are often higher than the equivalent cost of gasoline, creating a barrier to electric vehicle adoption. As a result, these rates may fail to support state goals for ambitious zero-emission vehicle deployment. Specifically, SB 350 declared that electric vehicles should "assist in grid management, integrating generation from eligible renewable energy resources, and reducing fuel costs for vehicle drivers who charge in a manner consistent with electrical grid conditions."[74] The price of 'e-fill' is also largely incomprehensible to the public, and they are unaware of rate options to lower costs.

High commercial rates can impede electric vehicle deployment and grid optimization. They can discourage deployment of charging infrastructure, particularly low-utilization but high-powered charging, by placing significant operating costs on infrastructure installations. The costs also do not reflect the benefits that charging can bring to the grid and the environment. Furthermore, commercial rates do not automatically encourage optimal utilization of charging as a way to provide important grid services (such as balancing intermittent renewable energy), which can reduce overall ratepayer costs and help the state meet its low-carbon grid goals.

SOLUTION: Rates that encourage charging as a grid service and that more fairly reflect the costs

CHALLENGE: Most commercial electricity rates do not contemplate electric vehicle charging or encourage optimal deployment of infrastructure

Most utilities did not design electricity rates with electric vehicle charging in mind. As a result, existing rates may inefficiently allocate costs on certain charging stations that exceed the real costs of those stations' operation on the grid. This dynamic serves to raise charging costs and depress the market for charging installations. At the same time, the rates miss opportunities to secure grid benefits from electric vehicle charging. For example, new rate design could encourage charging at optimal places and times to better balance grid needs and potentially lower costs for ratepayers.

Ultimately, new rates should have flexibility as the market changes and would work with revenue streams from charging, such as from the value of communications and data on charging and serving as an additional grid resource as flexible demand (vehicle-grid integration) or bi-directional energy flow (vehicle-to-grid or battery second-life). Generally, the cost to serve these sites should reflect the price of grid services at the location, with vehicle-grid integration as potentially an accurate reflection of costs.

Key principles for commercial electricity rates for EV charging

Environmental Benefits

Improve air quality and the environment: promote a charging network that furthers California's ability to achieve its environmental and energy goals through decarbonized transportation and a renewable, low-carbon grid.

Timeliness and flexibility of implementation: prioritize fast deployment of infrastructure to meet anticipated demand and to achieve the state's near- and long-term environmental and energy goals, without becoming prematurely obsolete.

Grid Benefits

Tailored to locations and type of charging: encourage improved reliability of the chargers and provide consumer choice, with "right-sized" level charging for the location context, such as encouraging inexpensive options before more expensive technologies, as well as placement in the optimal locations based on the latest available data on travel patterns, battery and distribution grid capacity, and existing charging station locations.

Improved grid reliability and reduced costs for the delivery of energy supply: encourage charging at sites that have available grid capacity and that allow for vehicle-grid integration (VGI) or possibly dispatch from the vehicle battery to the grid; rates should also encourage charging during times that match grid needs.

Allow for utility cost recovery with fair allocation of costs: ensure that utilities can recover costs based on actual grid needs and cost of service without shifting costs to other ratepayers.

User Benefits

Complete coverage that provides multiple user options: encourage ubiquitous, convenient, reliable, and seamlessly interoperable charging stations that provide economical options in workplaces, public locations, and multi-family dwellings to extend the electric range of plug-in vehicles and provide access to charging for drivers who do not otherwise have access at home.

Be cyber-secure: promote charging infrastructure that is cyber-secure and will not compromise user identity and personal information.

Encourage efficient use of chargers through transparent and fair pricing: utilize a transparent pricing arrangement, with prices that reflect the actual costs of delivering electricity and providing the service and that help consumers understand the financial benefit of driving on electricity instead of petroleum.

"Electric vehicle charging represents a great opportunity to fix our air, energy, and other environmental needs. But pricing is built on a model that's 80 years old, as if the utility is providing all energy. In fact, the energy is coming from lots of sources."

- James P. Avery San Diego Gas & Electric (retired)

SOLUTION: Design new rates and encourage experimentation to optimize charging to meet grid needs (charging at the optimal place and time)

The California Public Utilities Commission could encourage utilities to design vehicle-grid integration (VGI) rates. Vehicle-grid integration refers to the ways that electric vehicles can provide grid services, through vehicles with capabilities to manage charging or support two-way interaction with the grid.[75] The rates that can encourage this integration include programs such as "real-time" or "day-ahead real-time pricing," "demand response," and possibly "vehicle-to-grid." They represent an important

tool to encourage drivers to charge during hours when the electricity grid has spare capacity or to alleviate local distribution-level constraints, rather than exacerbating the system-wide peak demand (particularly in jurisdictions with supply constraints to meet peak demand).[76] Real-time pricing programs encourage vehicle owners through price signals and potentially software that accesses the on-board charging technology to avoid charging when demand for electricity peaks and grid resources are constrained, while encouraging charging when electricity is cheaper, such as during a time of surplus solar or wind energy. Real-time pricing is based on the marginal price of supplying electricity at that moment. "Traditional" demand response involves software that only turns the charging off, while more advanced "smart charging" can turn charging both off and on and adjust the rate of charging. Vehicle-to-grid programs additionally enable electric vehicles to sell electricity back to the grid by discharging from the battery when demand peaks.[77] These various rate options and programs could encourage charging that enables electric vehicles to reduce stress on the grid. Notably, a vehicle-grid integration rate could apply to uses beyond electric vehicle charging, such as appliances that can moderate their usage in a manner similar to vehicle charging.

A vehicle-grid integration rate could apply to uses beyond electric vehicle charging, such as appliances that can moderate their usage in a manner similar to vehicle charging.

New investor-owned utility vehicle-grid integration rates could serve as models for municipal (publicly owned) utilities, which are not regulated by the California Public Utilities Commission. As some participants noted, during times of surplus solar power (currently approximately two months of the year), all consumers and drivers could see low rates as a result. Ultimately, regulators should seek system cost minimization as the goal and leverage the "smarts" inherent in charging stations and in the vehicles themselves.

Utilities are already moving toward commercial rate reform to improve the grid services provided by charging stations. In 2015, the Sacramento Municipal Utility District developed a new pilot electricity rate for vehicle charging that has a flat energy rate without a demand charge to support DC fast charging-type operations. Then on January 20, 2017, as referenced previously, San Diego Gas & Electric Company,[78] Southern California Edison Company, and Pacific Gas & Electric Company[79] filed applications with the California Public Utilities Commission, per Senate Bill 350. Southern California Edison and San Diego Gas & Electric proposed some new electric vehicle commercial rates. While the utilities proposals differed, they all included more defined and granular price signals to encourage optimal charging times. Southern California Edison specifically proposed a five-year introductory period that would suspend demand charges in favor of volumetric energy charges (i.e., higher rates when customers use more electricity).[80]

"We have so many electricity rates, it would be helpful to reduce the number of rates."

- Jana Corey
Pacific Gas & Electric Company

The California Public Utilities Commission could adopt incentives for investor-owned utilities to improve the overall utility load factor, which is the ratio of average electricity demand to peak electricity demand to measure asset utilization, with a higher ratio better than a lower one. If regulators encouraged utilities to utilize their assets better through performance-based ratemaking and not leave as many idle over time simply to meet peak demand, the utilities could adopt their own incentive programs to encourage optimal charging at all sites in their service territory, potentially without the need for charging-specific rates. Ratepayers could potentially benefit through reduced costs. Utilities could also then take advantage of increasing capacity from distributed and other renewable energy resources. The state already has technology and energy storage policies to implement these approaches. For example, new technology on the market can control charging at a site to flatten the load or reduce overall charging loads to avoid unplanned demand charge events. Similarly, site owners are using energy storage to reduce peak charging loads to avoid either time of use rates or demand charges.

California policy makers at various energy agencies, as well as industry leaders, could work together to fill knowledge gaps regarding the best rate design and investment and charging needs for the grid and ratepayers, through demonstration rate programs. Regulators will need extensive data to help design the most optimal rates for charging, based on existing experience. Utilities could

determine how their existing charging infrastructure investments have benefitted drivers, the environment, and the ratepayers who have supported programs that subsidize electric vehicles. They could collect and share data on the benefits or disadvantages of scenarios, such as more workplace versus home charging or workplace versus public charging elsewhere, particularly in terms of furthering state goals related to electrifying transportation.

In addition, utility leaders could determine how much they should invest in charging infrastructure to achieve specific energy usage or vehicle adoption in support of state policy goals. The data could help inform electricity rate design and vehicle adoption goals. Utilities, electric vehicle service providers, fleet operators, ratepayer advocates, and other stakeholders could also collaborate on this effort as a coalition at the California Public Utilities Commission, along with publicly owned utilities. They could focus on user-specific situations, such as helping a public transit agency customer determine the benefits of charging off-peak versus during daytime hours.

"We would find a transitional rate today on DC fast charging demand charges helpful as we move into the future."

- Claire Dooley EVgo

The California Public Utilities Commission could allow demonstration or pilot rates for investor-owned utilities to gather data on what rates might best encourage optimal infrastructure deployment. The commission could also encourage data collection on utilization, maintenance and reliability of the charging station, and different models of utility investment (such as utility-owned versus make-ready). Municipal utilities could follow suit. These pilot rates could involve rigorous experimental designs and follow-up evaluation. SB 350 could provide a statutory basis to give utilities direction in designing them. Analysts would then need to test the results thoroughly, and the data from these pilots could be used to inform new commercial rates statewide for investor-owned utilities.

State agencies, such as the California Energy Commission, could assist load-serving entities in commercializing vehicle-grid integration technologies to take advantage of new vehicle-grid integration rates. These on-board car and charger technologies and software can improve response to dynamic rates and help implement smart charging. As the charging software technology within electric vehicles improves and becomes more sophisticated, policy makers could potentially save costs by avoiding duplication of that intelligence in the chargers or other "smart" grid technologies at the site. As a possible step, industry leaders and policy makers at the California Energy

> *"We do not want to foreclose opportunities. We have to ensure the technologies can handle what we want to do in the future and not have to rip them out."*
>
> - *Noel Crisosotomo California Energy Commission*

Commission could consider having vehicles' on-board diagnostics (which monitor battery performance and charging in electric vehicles) qualified as "revenue grade" after testing and certification for accuracy. This qualification would enable customers and owners to be eligible for the performance-based incentives from vehicle-grid integration rates. Similarly for smart chargers, revenue-grade metrology is needed to support the smart charger concept as well.

State regulators and utilities could ensure that workplace charging encourages optimal charging patterns to match grid needs through improved rate design. This design could have outcomes such as more employees charging at home at night rather than during the day when the grid may be more constrained. Or it could involve more daytime charging when surplus solar energy is available. In addition, workplace rates for Level 2 charging could encourage more turnover so employees do not park their vehicles all day for a few hours of sufficient charge, in order to allow other employees to take advantage of a single charging site. Workplaces could also install more Level 1 charging for all-day "slow" charging with less strain on the grid.

The California Public Utilities Commission could ensure that rates are flexible and tailored for different solutions and use cases. As an example, a fleet of electric vehicles through Lyft or Uber or at public transit agencies might warrant options for rates that are different for private vehicle owners, in order to reflect the different charging needs and resources that fleets can provide compared to single-vehicle owners. With rate options for fleets, the charging station operator would need to be able to communicate optimal pricing with the fleet operators, in order to notify them when to send their electric vehicles for charging to use surplus or inexpensive electricity. While single-vehicle owners may need charging on-demand at any time, a fleet owner of buses, for example, could potentially charge at night for most of its needs.

California policy makers could consider other incentives beyond rates to influence charging behavior to optimize the grid. For example, the state could consider using low carbon fuel standard (LCFS) credits or greenhouse gas reduction funds under the cap-and-trade program to give commercial customers a rebate when they do not charge during times that exceed the available capacity of the grid, assuming usage times can be verified easily. As discussed above, the effort could potentially involve third parties to help aggregate and monetize the credits for users. Industry leaders and state policy makers could educate charging station operators about how to manage usage to avoid high demand charges. Industry leaders and state policy makers could also educate operators on the value of low carbon fuel standard credit options to partially offset high demand charge costs.

The California Air Resources Board could maintain and strengthen the low carbon fuel standard (LCFS) program to ensure continued credits are available for charging. The program is subject to regulatory changes, per statutory authority under AB 32 (Nuñez, 2006) and SB 32 (Pavley, 2016). The agency could ensure that the program continues to provide credits for charging and explore additional ways the funds can encourage optimal charging, as discussed above.

CHALLENGE: High demand charges can discourage deployment of electric vehicle charging infrastructure

As discussed, utilities apply demand charges to large and many medium commercial and industrial customers to recover costs associated with grid component wear-and-tear and transmission, which are usually predicated on the maximum capacity needed at any given facility. Some electric vehicle charging can have high but infrequent demand and inconsistent and low energy utilization, particularly at smaller-load commercial sites that are often adversely impacted by demand charges (such as the aforementioned San Diego fast charger with demand charges responsible for over 90% of the electricity costs during summer months). Larger commercial sites with significantly more load and energy utilization typically can absorb or mask spikes in usage from fast-chargers or spread the associated demand charges over many kilowatt-hours. At the same time, utility leaders may be concerned that alleviating demand charges could lead to distribution grid assets that ratepayers would no longer cover sufficiently with the loss of revenue, while some load management companies may fear that removing demand charges could lead to higher electricity prices to cover the infrastructure costs of serving new fast charger stations in areas with previously low electricity demand. Ultimately, the demand charge issue for DC fast charging may be a short-lived problem for sites where overall utilization is expected to increase, but less so for chargers in remote locations that are sited simply to complete a long-distance network.

SOLUTION: Explore options to replace demand charges in certain locations and scenarios with more grid-efficient rates that recover costs associated with electric vehicle charging

The California Public Utilities Commission could direct utilities to develop new electric vehicle charging rates that institute alternatives for demand charges with proper cost recovery and strong price signals on timing, such as enhanced time-of-use, demand response or vehicle-grid integration rates. Utilities and policy makers may want to differentiate commercial rates for bulk-charging uses versus single-vehicle charging and for location-specific charging, if such differentiation can bring specific grid benefits, such as relieving strain in specific areas of the distribution grid or encouraging greater fleet participation in bulk charging. As discussed, Southern California Edison has proposed suspending demand charges for commercial electricity charging for five years in their recent proposal, to be replaced in part by volumetric and more granular time-of-use rates. In addition, San Diego Gas & Electric began piloting a vehicle-grid integration rate with day-ahead, real-time pricing to encourage daytime charging during certain times of the year to match solar surplus production conditions ("filling up the belly of the duck curve," which refers to a chart showing future daily surpluses of solar energy during the middle of the day).

"High demand charges can be three times the cost of gasoline, so they can be a significant disincentive to install charging. They may not be as big a deal when someone adds a DC fast charger at a Walmart, which is a big user, but adding it to a smaller facility could be a big deal."

- Tyson Eckerle
Governor's Office of Business and Economic Development (GO-Biz)

The California Public Utilities Commission and utilities could adopt "conjunctive" or network billing for electric vehicle charging service providers. Conjunctive billing (discussed previously) in this context would allow the service provider to pay one electricity bill for all its various charging sites, with the utility billing for these various metered sites as if they were together at one physical location. This structure would allow the individual sites to avoid high demand charges, given the overall high usage when combining the sites together. The structure would not eliminate demand charges but would change the cost recovery mechanism for utilities. Because some locations in the network might be in a grid-constrained area that generate a higher cost, while other charging might be in lower-impacted or cost locations, the collective bill would still need to recover costs in aggregate for all the charging operations, possibly requiring customized billing situations.

Utilities and electric vehicle service providers, with state policy makers' encouragement, could educate site hosts and operators on technology solutions to avoid high demand charges. Some energy storage solutions and facility energy management systems could offset or reduce these demand charges, as could pricing that encourages charging at optimal times. Energy storage, such as on-site batteries, can help owners avoid spikes in demand by drawing down electricity over a longer period of time and at a lower rate. The energy storage assets can also dispatch electricity during the time of fast charge to avoid the spike and associated costs. Energy management systems can proportionally control charging load to ensure a facility never goes over a specified loading condition. This feature allows the facility to control its demand charge exposure and contain unplanned-for costs. Some utilities also offer "concierge service" for fleets and workplaces to educate them about how to manage their bill, as well as the technology options for doing so, and state policy leaders could partner with utilities for more of these services related to electric vehicle charging.

The California Public Utilities Commission and Energy Commission could encourage the inclusion of energy storage assets, particularly for fast-charging sites, in order to reduce the costs and need for capacity upgrades and encourage the use of vehicle-grid integration and battery "second-life" applications. Fast chargers in particular, specifically the planned ultra-fast combined-charging standard 350 kW (far exceeding the current 50 kW CHAdeMO and SAE Combo public chargers or Tesla 120 kW Superchargers), require significant amounts of power capacity. They may entail steep costs for distribution and service upgrades, depending on the location. The California Energy Commission, through its Electric Program Investment Charge (EPIC) program, could expand and commercialize its funding for research and deployment to assist regulators with determining how to manage on-site demand long term, including through energy storage deployment when the additional revenue or savings would offset the capital costs. Likewise, the California Public Utilities Commission could encourage utilities to leverage the energy storage inherent in electric vehicle batteries through smart charging, "vehicle-to-grid," and battery second-life programs. These programs could also help lower the costs of meeting the state's 50 percent renewables portfolio standard and energy storage procurement mandate.

State policy makers and/or industry leaders could develop an easily understandable metric like "e-gallon equivalent" (EGE) and post it widely on all charging infrastructure. Industry leaders could consider integrating this information for the consumer in a smart phone app along with public charging locations, although the information may be difficult to gather due to time-based rates and different on-board charger speeds in various vehicle models. State policy makers could also mandate transparent pricing at all charging locations. Policy makers could implement this goal through the California Department of Food and Agriculture's Division of Measurement Standards (DMS), which could propose amendments to the National Institute of Standards and Technology (NIST) Handbook 44 (which ensures "uniformity of weights and measures" for the country).[81]

Industry leaders and state policy makers could educate consumers and dealers on attractive rate options. Utilities are currently limited in knowing whom to educate because they lack access to information on where the electric vehicles are owned. As a result, the state and utilities could develop creative opt-ins, such as through Southern California Edison and Pacific Gas & Electric's relationship with electric vehicle dealers to educate new buyers about rates, the Clean Vehicle Rebate Project that generates a list of new electric vehicle buyers/leases, and proposals to limit eligibility for charger rebates and incentives to customers who 'opt in' to time-of-use rates. Ultimately, dealers are the likely key point of contact with consumers and could be encouraged to report and communicate with utilities on purchases and rate options. Utilities could also require customers to sign up for optimal rates in order to qualify for rebates and other incentives.

Next Steps

Solving California's shortage of electric vehicle charging infrastructure will require multiple stakeholders and solutions, such as those described in this report. Policy makers could identify the most promising solutions and topics on electric vehicle infrastructure and launch further discussion among experts and stakeholders, fund additional research, and chart implementation on priority solutions. Policy makers could also identify options for rate design and associated technology costs to boost electric vehicle infrastructure deployment. They could develop a comprehensive "tariff playbook" for California regulators and utilities, as well as for out-of-state public utilities commissions, to encourage nationwide deployment of charging infrastructure to help California drivers. With sustained attention to address the shortage of charging stations, California could provide a powerful example for other states by adopting smart policies and commercial electricity rates to meet the challenge of developing a twenty-first century transportation system.

"If drivers don't realize fuel cost savings, a mainstream EV market may not materialize."

- Max Baumhefner
Natural Resources Defense Council

Participant Bios

Convening #1 (June 2016)

Max Baumhefner
Natural Resources Defense Council

Max Baumhefner is an attorney in the Clean Vehicles and Fuels, Energy & Transportation program. He works to make our nation's cars, trucks, and buses zero emission vehicles. He focuses on electrifying the transportation sector in a manner that also accelerates the transition to a smarter, more affordable electric grid powered by renewable resources. He holds a bachelor's degree in history from Pomona College and a JD from the University of California, Berkeley. He is based in San Francisco.

Josh Boone
California Plug-In Electric Vehicle Collaborative

Josh is deputy executive director of the California Plug-In Electric Vehicle Collaborative. He is responsible for advising and assisting the Executive Director and Chairman in development and implementation of the PEV Collaborative strategic plan, goals and policies to accelerate plug-in electric vehicle sales in California. In addition, he oversees day-to-day operational direction across all programs, including leadership and guidance to staff. He maintains strong relationships with Collaborative members, leads business development activities and management of the workplan. Josh holds MS and BS degrees from the University of California, Davis, and has authored several scientific publications. Josh drives electric!

Frank Breust
BMW Group

Frank Breust is heading the government and external affairs office of the BMW Group in Sacramento, California since July 2013. In this function he coordinates corporate positioning with all relevant stakeholders in the fields of environmental, mobility and sustainability policies. Prior to this, Mr. Breust was responsible for coordinating the political communication of the BMW Group in Munich with regard to human resources related issues as well as sustainability engagements. Mr. Breust also steered social sustainability topics in the HR strategy. Before joining the BMW Group, Mr. Breust was an officer of the German Air Force and served as an air traffic controller and in the German Military Intelligence Service for twelve years. Frank Breust was born and grew up in Oldenburg, Germany and holds a Diploma in Business and Economics Education and a Master of Business Administration (MBA) degree.

Jana Corey
Pacific Gas and Electric Company

Jana Corey is the Director of PG&E's Electrification and Alternative Fuels Department, part of the company's Customer Care organization. Ms. Corey's team is responsible for promoting electric vehicle adoption and exploring other electrification opportunities as well as alternative fuels for medium and heavy duty applications, with the express objective to support California climate and environmental policy goals. Prior to her current position, Ms. Corey served as Director of Energy Efficiency Strategy and Director for PG&E's SmartMeter™ Advanced Metering Infrastructure project, now the largest deployment of smart metering technology in North America. Ms. Corey has previous experience in PG&E's corporate strategic planning, regulatory relations, and field operations groups. Ms. Corey has a BS and MS in Electrical Engineering from UCLA, and an MBA from the Stanford Graduate School of Business.

Wade Crowfoot
Office of California Governor Edmund G. Brown, Jr. (formerly)

Wade Crowfoot served as Deputy Cabinet Secretary and Senior Advisor to Governor Brown. He joined the Brown administration in May 2011. Wade's portfolio included transportation, infrastructure, military and veterans issues. Recently, he led an effort to expand zero-emission vehicles in California and build international partnerships with China and other countries to fight climate change. Also, as the Governor's Military Advisor, Wade worked to strengthen California's support for federal military bases located in the state. Prior to joining Governor Brown's Administration, Wade served as Regional Director for the Environmental Defense Fund (EDF). In that role, he helped to lead EDF's 40 western regional staff and worked with leaders throughout California to implement key climate, water and oceans policy. Wade has also served as senior environmental advisor to San Francisco Mayor Gavin Newsom. Wade holds a bachelor's degree from the University of Wisconsin-Madison and a Master's Degree in Public Policy from the London School of Economics, where he graduated with honors.

Joshua M. Cunningham
California Air Resources Board

Joshua Cunningham is the Branch Chief of the Advanced Clean Cars Branch within the Air Resources Board. This branch develops and implements the Advanced Clean Cars regulations, which includes the Low Emission Vehicle (LEV) III greenhouse gas and criteria emission fleet standards, and the Zero Emission Vehicle (ZEV) regulation. Joshua has been with the Air Resources Board for over seven years contributing to a number of advanced vehicle and emission reduction programs. He spent his first few years working on the ZEV regulation update focusing on technology feasibility and environmental benefits. Complementing this regulatory experience, Joshua helped launch the Plug-in Electric Vehicle Collaborative, addressing market barriers to the emerging ZEV sales. Most recently, Joshua managed the Transportation Planning Section, leading the development and use of the ARB Vision scenario planning tool.

Mark Duvall
Electric Power Research Institute (EPRI)

Mark Duvall is Director of Energy Utilization at the Electric Power Research Institute (EPRI), an independent, non-profit center for public interest energy and environmental collaborative research. He is responsible for EPRI's research and development program for electric transportation, including electric, plug-in hybrid, vehicle programs and related advanced infrastructure, and non-road transportation electrification. Prior to joining EPRI, Duvall held the position of Principal Development Engineer at the Hybrid Electric Vehicle Center of the University of California, Davis. He has worked in the field of advanced transportation since 1990 and has led the development of several prototype advanced vehicles. He received his bachelor's degree in 1990 and his master's degree in 1994, both in mechanical engineering, from the University of California, Davis and a doctorate in mechanical engineering in 1998 from Purdue University.

Tyson Eckerle
Governor's Office of Business and Economic Development (Go Biz)

Tyson Eckerle was recently appointed to be the Zero Emission Vehicle Infrastructure Project Manager for the Governor's Office of Business and Economic Development (Go Biz). In this role, he focuses on streamlining the permitting process for hydrogen and plug-in stations so that these critical stations can be deployed as quickly as possible. Prior to joining Go Biz, Tyson served as Executive Director of Energy Independence Now (EIN), a non-profit focused on developing policies and projects necessary to decrease petroleum use in the transportation sector. Tyson holds a B.A. in Biology from the University of California, Davis and a Master of Environmental Science and Management (MESM) from the Bren School of Environmental Science and Management from the University of California, Santa Barbara. In his spare time, he likes to hang out with his dog, young sons, and wife, not necessarily in that order.

Jamie Hall
General Motors

Jamie Hall is a manager on the public policy team at General Motors, where he focuses on policies and programs to support commercialization of GM's advanced vehicle portfolio. He works closely with GM technical teams, policymakers, and industry stakeholders on policy considerations affecting the development and deployment of electric, fuel cell, and other advanced technology vehicles. Jamie has more than ten years of environmental and energy policy experience in the public, private, and nonprofit sectors. He received degrees from Princeton University and the Goldman School of Public Policy at UC Berkeley.

Andrew Hoskinson
Center for Sustainable Energy (CSE)

Andrew Hoskinson is Senior Project Manager for Electric Vehicle Initiatives at the Center for Sustainable Energy (CSE), where he leads a team of professionals developing and delivering EV infrastructure market development projects. Andy is currently overseeing the CEC-funded implementation of regional PEV readiness plan initiatives in San Diego and the San Joaquin Valley. Implementation initiatives include educating potential workplace and multi-unit dwelling infrastructure site hosts on installation processes and streamline local government EV infrastructure installation permitting and inspection policies, among other activities. Prior to joining CSE, Andrew spent six years managing EV infrastructure installations for NRG EVgo and ECOtality and 10 years in land use planning in the public and private sectors. Andrew earned an MBA from San Diego State University, and a B.A. in Urban Studies and Planning from the University of California at San Diego.

Joel Levin
Plug In America

Joel Levin is executive director of Plug In America, a leading voice for the transition to plug-in vehicles. Joel is an advocate for low-carbon technologies and a frequent speaker and writer on topics relating to electric vehicles, clean energy, water policy and climate policy in California and throughout North America. Prior to joining Plug In America, he served as vice president for business development at the Climate Action Reserve, the state-chartered nonprofit that runs North America's largest carbon offset registry.

Tony Markel
National Renewable Energy Laboratory

Tony Markel is a Senior Engineer and has worked on systems analysis of advanced vehicles for the past 19 years at the National Renewable Energy Laboratory in Golden, Colorado. Tony is currently focused on Electric

Vehicle Grid Integration technology development in support of the US Department of Energy. He earned a B.S. in Mechanical Engineering from Oakland University in 1995 and a M.S. in Mechanical Engineering from the University of Colorado. Tony's expertise spans advanced vehicle technologies including hybrid electric, fuel cell, plug-in hybrid, and electric vehicles and was instrumental in the development of the ADVISOR™ software tool for vehicle systems simulation. He leads a team researching grid integration challenges facing plug-in vehicles with a mission to highlight opportunities for electrified transportation to reduce our nation's petroleum consumption and enable a smart, renewable, future electricity grid.

Fred Minassian
South Coast Air Quality Management District (SCAQMD)

Fred is the Assistant Deputy Executive Officer in the Technology Advancement Office (TAO). He has B.S. and M.S. degrees in Chemical Engineering from the Engineering Academy of Denmark, and the California State University, Northridge, respectively. Before joining the SCAQMD, he has worked in the private sector for four years, including three years on research and development projects at the Atlantic Richfield Company. Fred joined the South Coast AQMD in May 1987. He has worked at the Source Testing and Engineering divisions before joining the Technology Advancement Office in 1994, where at its Technology Demonstration section he has managed projects in the areas of on-road emissions, development of low-NOx heavy-duty engines, and development of electric and hybrid electric vehicles. As Assistant Deputy Executive Officer since December 2014, Fred is overseeing both the Technology Demonstration and the Technology Implementation programs of the agency.

Patricia Monahan
Energy Foundation

Patricia Monahan is the Transportation Program Director at the Energy Foundation (EF), whose mission is to promote the transition to a sustainable energy future. The Transportation Program works to reduce energy use and carbon pollution through policies that improve vehicle efficiency and promote clean fuels. Patricia makes grants that promote innovative state and federal policies to speed commercialization of clean transportation technologies and fuels. Patricia worked for 10 years at the Union of Concerned Scientists (UCS), where she was the Director of the California office and Deputy Director for Clean Vehicles. Patricia spent eight years as a scientist working on air pollution and toxics issues at the U.S. Environmental Protection Agency in Washington DC and San Francisco. She also worked for several years as an energy analyst at Lawrence Berkeley Laboratory, where her research encompassed industrial energy use and efficiency, projections of energy use and pollution, and international strategies for reducing global warming pollution. Ms. Monahan has a bachelor's degree in environmental science from the University of California at Berkeley and a master's degree in energy analysis and policy from the University of Wisconsin at Madison.

Marvin D. Moon
Los Angeles Dept. of Water and Power (LADWP)

Marvin D. Moon is the Director of the Power Engineering Division at the Los Angeles Dept. of Water and Power (LADWP). Mr. Moon is responsible for the design and management of all projects related to the Power System infrastructure of the Los Angeles Department of Water and Power (LADWP). This includes projects for generation, substations, transmission, renewable projects, smart grid, and the distribution system. He is also LADWP's Electric Vehicle Program supporting sponsor.

Tim Olson
California Energy Commission

Tim Olson has held several management and policy positions at the California Energy Commission and previously served as a policy advisor to Commissioners James Boyd and Carla Peterman on transportation, climate change, energy research and development and international affairs topics. He also served as manager of the Emerging Fuels and Technology and Transportation Energy Offices. He represents the Energy Commission as a member of several technical advisory committees and presents information in several forums, including U.S. Congress. He currently leads the Energy Commission's strategic planning for emerging fuels and technologies to develop alternative fuel growth scenarios, facilitate private investment in California projects, and conduct technology merit reviews. This work is included as part of the annual Integrated Energy Policy Report to the Governor and Legislature and investment plans for the annual $100 million Alternative and Renewable Fuels and Vehicle Technology Fund. Mr. Olson received a bachelor's degree in Environmental Studies/Biology from UC Santa Barbara and serves as an appointed member of the Sacramento Metropolitan Air Quality Management District Hearing Board.

Colleen Quinn
ChargePoint

Colleen Quinn is Vice President, Government Relations and Public Policy with ChargePoint. She has served in the highest level government and political appointed positions, as well as a senior corporate officer and senior non-profit management and advocacy roles. Colleen is a member of the ChargePoint Executive Staff responsible for all legislative, regulatory and government market activity. She is on various EV Industry boards and EV Stakeholder groups including: Executive Committee of the CA Plug In Electric Vehicle Collaborative, Electric Drive Transportation Association, Vice Chair of the NEMA EVSE Committee, Massachusetts Zero Emission Vehicle Commission and the

Maryland Electric Vehicle Infrastructure Council. Colleen received her BA degree from the University of California at Berkeley and a JD from the University of California, Hastings College of Law and was a distinguished fellow with the CORO Foundation.

Cliff Rechtschaffen
Office of the Governor (formerly)

Clifford Rechtschaffen was a senior advisor in the Office of California Governor Jerry Brown, working on climate, energy and environmental issues. In 2011, he served as Acting Director of the California Department of Conservation. From 2007 to 2010 he was a special assistant attorney general on climate and energy issues for Attorney General Jerry Brown. He currently is on leave from Golden Gate University School of Law, where he taught environmental law and directed the environmental law program from 1993 to 2007. Prior to becoming a professor at Golden Gate, he worked in the Environment Section of the California Attorney General's Office from 1986 to 1993. He is a graduate of Princeton University and Yale Law School.

Stacey Reineccius
Powertree Services

Mr. Reineccius is a lifelong entrepreneur bringing decades of successful innovation experience from telecommunications, video, multi-family solar, EV charging and energy storage to bear. Having designed, developed, manufactured and marketed dozens of products globally, he has been awarded multiple patents in energy storage and EV Charging systems technology. Mr. Reineccius is Founder, Chairman and CEO of Powertree Services. He is also Founder and former Chairman of Stem, Inc.

Dr. Nancy E. Ryan
Energy and Environmental Economics (E3)

Dr. Nancy E. Ryan is an economist with over two decades of experience in energy and environmental policy. A partner at Energy and Environmental Economics (E3), she leads projects in the areas of electric transportation, GHG mitigation, strategy and policy for clients in the public and private sectors. Prior to joining E3, Dr. Ryan held several high-level appointed positions at the California Public Utilities Commission including Deputy Executive Director for Policy and External Relations (2011-2013), Commissioner (2010-2011), and Chief of Staff to President Michael R. Peevey (2007-2009). Dr. Ryan's career path has also included positions in advocacy and academia. For many years she taught applied economics at UC Berkeley's Richard and Rhoda Goldman School of Public Policy. Dr. Ryan received her Ph.D. in Economics from the University of California at Berkeley and a BA in Economics from Yale University.

Janea Scott
California Energy Commission

Janea A. Scott is one of five Commissioners on the California Energy Commission. Ms. Scott was appointed by Governor Edmund G. Brown Jr. in February 2013 to serve as the Commission's public member. She is the lead Commissioner on transportation and western regional planning, and last year Ms. Scott led the 2014 Integrated Energy Policy Report Update. Ms. Scott serves as the chair of the California Plug-In Electric Vehicle Collaborative, a public/private organization focused on accelerating the adoption of PEVs to meet California's economic, energy and environmental goals. Prior to joining the Energy Commission, Ms. Scott worked at the U.S. Department of the Interior in the Office of the Secretary as the Deputy Counselor for Renewable Energy and at Environmental Defense Fund in both the New York and Los Angeles offices as a senior attorney in the climate and air program. Ms. Scott earned her J.D. from the University of Colorado Boulder Law School and her M.S. and B.S. in Earth Systems from Stanford University.

Mark Triplett
Green Charge Networks (GCN)

As Chief Operating Officer at Green Charge Networks (GCN), Mark Triplett oversees sales, marketing, and operations of the largest behind-the-meter commercial energy storage developer in the United States. GCN has over 43MWh of distributed energy storage in operation or in construction that it owns and operates sharing energy savings with its host customers. Mark brings more than 20 years of utility, smart grid, distributed energy resource, and enterprise software experience. Prior to GCN he led the 'Demand Response Management Systems' product line worldwide for Alstom Grid, a global leader in utility infrastructure and control room hardware and software. Mark is a graduate of The United States Military Academy at West Point and received his Master's Degree in Business Administration from San Diego National University.

Eileen Wenger Tutt
California Electric Transportation Coalition (CalETC)

Eileen Tutt joined the California Electric Transportation Coalition (CalETC) in 2010 as Executive Director. CalETC has also informed the California policy landscape with robust analytics that prove the benefits of transportation electrification to California's economy, environment, consumers and electricity grid. Prior to becoming the Executive Director of the California Electric Transportation Coalition, Eileen served as Deputy Secretary for the California Environmental Protection Agency (Cal/EPA). Prior to her time at Cal/EPA, Eileen worked for the California Air Resources Board, an agency within Cal/EPA. In her ten years at the Air Resources Board, Eileen helped develop regulations and programs that have placed the State of

California at the forefront of environmental protection. A long-time supporter of electric transportation, Eileen has logged over 250,000 all electric miles. Active in civic duties, Eileen serves as a trustee for the Climate Action Reserve, on the External Advisory Committee for the Sustainable Transportation Center at UC Davis, and as a Board member for the Yolo County SPCA. Eileen is married with two children and received her bachelor's degree in Mathematics with a minor in Statistics.

Convening #2 (Nov 2016)

Repeat participants are listed without reprinting their bios.

Tom Ashley
Greenlots

Alberto Ayala
California Air Resources Board

Alberto Ayala was appointed as Deputy Executive Officer of the California Air Resources Board at the end of 2012. In this capacity, Alberto is responsible for the Board's ambient monitoring and laboratories and mobile source control and operations programs. Alberto became a member of CARB's Research staff in 2000 and has since held various management assignments in programs such as Carl Moyer Incentives, AB 32 early actions, mobile refrigerant rules, diesel retrofits, and car, truck, and bus emissions research. Prior to CARB, Alberto was a member of the engineering faculty at West Virginia University, where he now holds an adjunct appointment, and was an ordnance system design engineer for Teledyne Ryan Aeronautical. He holds B.S., M.S., and Ph.D. degrees in Mechanical Engineering from the University of California, Davis.

Marcus Alexander
Electric Power Research Institute (EPRI)

James P. Avery
San Diego Gas & Electric (formerly)

James P. Avery was the chief development officer for San Diego Gas & Electric. He was responsible for new strategic initiatives, including clean transportation, advanced technology programs and the expansion of local generation resources and services. He is the Chairman of the California Transmission Planning Group and a Director of CleanTech San Diego. He is a senior member of the Association of Energy Engineers, National Society of Professional Engineers, Institute of Electrical and Electronics Engineers and American Mensa. Avery is a graduate of the Executive Management Program at Dartmouth College and holds a Bachelor of Engineering degree from Manhattan College.

Max Baumhefner
Natural Resources Defense Council

Josh Boone
California Plug-In Electric Vehicle Collaborative

Eric Borden
TURN

Eric Borden joined TURN as an Energy Policy Analyst in February of 2015. He prepares testimony, conducts analyses, and represents TURN in various proceedings at the California Public Utilities Commission (CPUC) related to electric vehicle charging infrastructure, distributed energy resources, and rate cases. Prior to joining TURN, Eric was a consultant for major utilities an inter-governmental energy agency, and an energy services company. He is the author of academic publications on renewable integration and energy storage topics and was awarded a German Chancellor Fellowship by the Alexander von Humboldt Foundation, which facilitated a research project in Germany. Eric holds a Masters in Public Affairs with a concentration in natural resources and the environment from the University of Texas at Austin, and a Bachelor's degree in finance and entrepreneurship from Washington University in St. Louis.

Bill Boyce
Sacramento Municipal Utility District (SMUD)

Bill Boyce has led SMUD's Electric Transportation Program for the last 16 years. He has a broad technical background that includes aerospace, environmental, mechanical, and mining engineering along with his electric utility experience. Prior to working at SMUD, Bill spent 15 years working in the liquid rocket industry. He currently serves on the Board of Directors for the California Electric Transportation Coalition and is active in many industry initiatives including the U.S. DOE EV Everywhere Utility Working Group, Electric Drive Technology Association and the Electric Power Research Institute.

Jana Corey
Pacific Gas and Electric Company

Tyson Eckerle
Governor's Office of Business and Economic Development (Go Biz)

Jamie Hall
General Motors

Steve Jones
ITM Power

Steve joined ITM in 2005 as a research technologist and has progressed through to his current role as Managing Director for ITM Power Inc. based in Anaheim, California. Steve has held positions in R&D, product, systems and business development roles and as such has an excellent understanding of the technical and commercial aspects of the business. Steve holds a board position within the California Hydrogen Business Council and is vice chair of the Hydrogen Energy Storage sub group. Steve holds a BSc and MPhil in Materials Science from Birmingham University, a MBA from Sheffield University and is a chartered manager.

Marvin D. Moon
Los Angeles Dept. of Water and Power (LADWP)

Terry O'Day
EVgo

Terry is vice president at EVgo, responsible for product strategy and market development. Prior to joining EVgo, Terry was Executive Director of Environment Now foundation, a strategic, entrepreneurial, activist leader in California. Terry began his career with Edison International, where he contributed to founding four businesses in energy, security services, and electric vehicle charging. He went on to cofound EV Rental Cars, which was the first rental company in the United States to offer only environmental vehicles, such as hybrid, natural gas, and electric cars to the general public. He holds an MBA from The UCLA Anderson School of Management and completed the Coro Public Affairs Fellows Program in Los Angeles. He earned a BA with honors in Public Policy at Stanford University, with a thesis addressing public finance and demand management of electricity. Terry was first elected as Councilmember for the City of Santa Monica in November 2010. He has served two years as Mayor Pro Tempore and currently serves as a Councilmember.

Tim Olson
California Energy Commission

David Peterso
ChargePoint

As Director of Utility Solutions, David works with electric utilities to develop programs that accelerate EV market adoption. He also leads business development and sales for ChargePoint's fleet products and services. David joined ChargePoint from Nissan where he led EV market development and charging infrastructure strategy. Prior to Nissan, David was an analyst at ING Bank Shanghai working on Benelux-China joint ventures, as well as a project finance consultant to government and private clients across Asia and the Middle East for real estate and energy projects. He holds a bachelor's degree from UC Berkeley, and a master's degree from the UCLA Luskin School of Public Affairs where he focused on new value creation at the intersection of mobility and energy.

Stacey Reineccius
Powertree Services

Laura Renger
Southern California Edison

Laura Renger is the Principal Manager of Air & Climate for Southern California Edison's Regulatory Affairs organization. Laura leads a team responsible for the utility's regulatory and legislative policy concerning air quality, climate change and transportation electrification. Prior to this position, Laura was a Senior Attorney in the SCE Law Department, primarily focusing on air quality, climate, and transmission project licensing. Laura is the immediate past Chair of the Environmental Section of the Los Angeles County Bar Association and the current Treasurer of Neighborhood Legal Services of Los Angeles. Laura lives in an all-electric vehicle household in Long Beach, California.

Dr. Nancy E. Ryan
Energy and Environmental Economics (E3)

Katherine Stainken
Plug In America

Katherine is focused on promoting policies and programs that will transform the transportation sector and encourage more EVs on the road. Prior to her work at Plug In America, Katherine was a Director of Government Affairs at the Solar Energy Industries Association (SEIA), focused on policies to promote solar on the federal level as well as southeast and northeast regions, along with regulatory work at the DOE, EPA, CFTC, OMB, FHFA and other federal agencies. Katherine was also the lead staff on the Clean Power Plan and chief liaison to the solar heating and cooling and EH&S groups at SEIA. She received her Masters from American University in Global Environmental Policy and Bachelors from Boston College. When she's not promoting EVs, you can find her on the water rowing at the Port of Sacramento.

John Tillman
Nissan

Mark Triplett
Green Charge Networks (GCN)

Sarah Van Cleve
Tesla

Sarah manages Tesla's energy policy for the Western US, collaborating with regulators and legislators on energy policies affecting the development of distributed energy resources, primarily energy storage and electric vehicles. She leads Tesla's policy activities on various electricity industry issues including integrated resource planning, resource procurement, electricity market design, and rate design. Prior to working at Tesla, Sarah managed energy storage policy at Southern California Edison where she helped guide the utility's groundbreaking procurement of 264 megawatts of energy storage. Sarah started her career as a financial analyst in electricity and emissions markets working in operations, trading, and market design. She holds a B.A. in Economics from UCLA.

Eileen Wenger Tutt
California Electric Transportation Coalition (CalETC)

Endnotes

1 California Assembly Bill 32 (Nuñez, Chapter 488, Statutes of 2006). Available at: http://www.leginfo.ca.gov/pub/05-06/bill/asm/ab_0001-0050/ab_32_bill_20060927_chaptered.html (accessed August 30, 2016).

2 California Senate Bill 32 (Pavley, Chapter 249, Statutes of 2016). Available at: https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201520160SB32 (accessed August 30, 2016).

3 California Senate Bill 350 (De Leon, Chapter 547, Statutes of 2015). Available at: http://www.leginfo.ca.gov/pub/15-16/bill/sen/sb_0301-0350/sb_350_bill_20151007_chaptered.pdf (accessed August 30, 2016).

4 "California Greenhouse Gas Emission Inventory - 2017 Edition," California Air Resources Board webpage. Available at: https://www.arb.ca.gov/cc/inventory/data/data.htm (accessed June 14, 2017).

5 Executive Order B-16-2012, March 23, 2012, Governor Edmund G. Brown, Jr. Available at: https://www.gov.ca.gov/news.php?id=17472 (accessed May 12, 2017). ZEVs include battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs), and fuel cell electric vehicles (FCEVs). "Tracking Progress – Zero-Emission Vehicles and Infrastructure," California Energy Commission, updated October 13, 2016, p.1. Available at: http://www.energy.ca.gov/renewables/tracking_progress/documents/electric_vehicle.pdf (accessed January 9, 2017).

6 California Senate Bill 1275 (De Leon, Chapter 530, Statutes of 2014). Available at: http://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201320140SB1275 (accessed April 19, 2017).

7 California PEV Collaborative, "Detailed Monthly Sales Chart**,"** June 2017. Available at: http://www.pevcollaborative.org/sites/all/themes/pev/files/5_may_2017_Dashboard_PEV_Sales.pdf (accessed June 2, 2017).

8 "2015 Zero Emission Vehicle Credits," California Air Resources Board webpage. Available at: https://www.arb.ca.gov/msprog/zevprog/zevcredits/2015zevcredits.htm (accessed January 11, 2017).

9 *See* 13 CCR § 1962 et seq.

10 "Alternative Fuels Data Center – Hybrid and Plug-In Electric Vehicles," U.S. Department of Energy webpage. Available at: http://www.afdc.energy.gov/vehicles/electric.html (accessed January 11, 2017).

11 Id.

12 "Clean Vehicle Rebate Project (CVRP)," Center for Sustainable Energy. Available at: https://cleanvehiclerebate.org/eng (accessed May 12, 2017). *See* "2016 ZEV Action Plan – An updated roadmap toward 1.5 million zero-emission vehicles on California roadways by 2025," Governor's Interagency Working Group on Zero-emission Vehicles, October 2016, p. 7. Available at: https://www.gov.ca.gov/docs/2016_ZEV_Action_Plan.pdf (accessed January 11, 2017). *See also* "Clean Air Vehicle Rebate Project," California Air Resources Board webpage. Available at: https://www.arb.ca.gov/msprog/aqip/cvrp.htm (accessed January 11, 2017).

13 "CVRP Rebate Statistics," Cleanvehiclerebate.org webpage. Available at: https://cleanvehiclerebate.org/eng/rebate-statistics (accessed January 11, 2017).

14 "Federal Laws and Incentives for Electricity," U.S. Department of Energy webpage. Available at: http://www.afdc.energy.gov/fuels/laws/ELEC/US (accessed January 11, 2017).

15 "Eligible Vehicle List – Single Occupant," California Air Resources Board webpage. Available at: https://www.arb.ca.gov/msprog/carpool/carpool.htm (accessed January 11, 2017).

16 Max Baumhefner, Roland Hwang and Pierre Bull, "Driving Out Pollution: How Utilities Can Accelerate the Market for Electric Vehicles," Natural Resources Defense Council, June 2016, p. 4 (citing Center for Sustainable Energy, California Plug-in Electric Vehicle Owner Dashboard). Available at: https://www.nrdc.org/sites/default/files/driving-out-pollution-report.pdf (accessed January 9, 2017).

17 "California Statewide Plug-in Electric Vehicle Infrastructure Assessment," National Renewable Energy Laboratory, May 2014, p. 28. Available at: http://www.nrel.gov/docs/fy15osti/60729.pdf (accessed January 11, 2017).

18 Id.

19 "Alternative Fuels Data Center – Developing Infrastructure to Charge Plug-In Electric Vehicles," U.S. Department of Energy webpage. Available at: http://www.afdc.energy.gov/fuels/electricity_infrastructure.html (accessed January 11, 2017).

20 "Chevy Bolt Charging User Guide," Chevrolet webpage. Available at: http://www.chevyevlife.com/bolt-ev-charging-guide/ (accessed May 12, 2017). *See also* "Alternative Fuels Data Center – Developing Infrastructure to Charge Plug-In Electric Vehicles."

21 David Herron, "Tesla joins 150 kW CCS Forces, CHAdeMO's Days are Numbered in EV Fast Charging," Longtailpipe.com, April 18, 2016. Available at: https://longtailpipe.com/2016/04/18/tesla-joins-150-kw-ccs-forces-chademos-days-are-numbered-in-ev-fast-charging/ (accessed January 11, 2017).

22 Jo Borrás, "Nissan and BMW to Double EVgo Fast Charging Network," Gas2.org, January 27, 2017. Available at: http://gas2.org/2017/01/27/nissan-and-bmw-to-double-evgo-fast-charging-network/ (accessed January 27, 2017).

23 "CHAdeMO Announces 150kW Protocol," CHAdeMO Association webpage. Available at: http://www.chademo.com/chademo-announces-150kw-protocol/ (accessed January 11, 2017).

24 "BMW Group, Daimler AG, Ford Motor Company and Volkswagen Group with Audi and Porsche Plan a Joint Venture for Ultra-Fast, High-Power Charging Along Major Highways in Europe," Ford webpage. Available at: https://media.ford.com/content/fordmedia/fna/us/en/news/2016/11/29/bmw-daimler-ford-volkswagen-audi-porsche-plan-ultra-fast-charging-major-europe-highways.html (accessed January 11, 2017).

25 Kelly Pleskot, "Elon Musk Hints at Tesla Supercharger V3 with Well Over 350 kW," Motortrend.com, December 27, 2016. Available at: http://www.motortrend.com/news/elon-musk-hints-tesla-supercharger-v3-well-350-kw/ (accessed January 11, 2017).

26 "December 2016 Plug-in Vehicle Sales," ElectricCarsReport.com webpage. Available at: http://electriccarsreport.com/2017/01/december-2016-plug-vehicle-sales/ (accessed January 11, 2017). *See also* "Monthly Plug-In Sales Scorecard," InsideEVs.com webpage. Available at: http://insideevs.com/monthly-plug-in-sales-scorecard/ (accessed January 11, 2017).

27 Mark Kane, "BYD, Nissan and Tesla Lead Worldwide EV Sales in First Four Months of 2016," InsideEVs.com, June 2016. Available at: http://insideevs.com/byd-nissan-tesla-leads-plug-electric-car-sales-first-four-months-2016/ (accessed January 11, 2017).

28 Bart Demandt, "European sales 2016 Q1-Q3 EV and PHEV segments," Carsalesbase.com, December 6, 2016. Available at: http://carsalesbase.com/european-sales-2016-q1-q3-ev-phev-segments/ (accessed January 11, 2017).

29 Mark Kane.

30 *See* "Monthly Plug-In Sales Scorecard." *See also* California Clean Vehicle Rebate Project webpage. Available at: https://cleanvehiclerebate.org/eng/eligible-vehicles (accessed January 11, 2017).

31 Stephen Edelstein, "2017 Mitsubishi Outlander Plug-In Hybrid: U.S. Debut," Greencarreports.com, March 24, 2016. Available at http://www.greencarreports.com/news/1103051_2017-mitsubishi-outlander-plug-in-hybrid-u-s-version-finally-unveiled (accessed January 11, 2017).

32 "Ioniq," HyundaiUSA.com webpage. Available at: https://www.hyundaiusa.com/ioniq/ (accessed January 11, 2017).

33 Jeff Cobb, "2018 Nissan Leaf Could Get Battery Options Up to 60 kWh," Hybridcars.com, June 22, 2016. Available at: http://www.hybridcars.com/2018-nissan-leaf-could-get-battery-options-up-to-60-kwh/ (accessed January 11, 2017).

34 Brad Berman, "Toyota Plans a Long-Range EV for 2020," Plugincars.com, November 07, 2016. Available at http://www.plugincars.com/toyota-plans-long-range-ev-2020-132356.html (accessed January 11, 2017).

35 Based on the number of deposits by customers. *See* Katie Fehrenbacher, "Tesla's Model 3 Reservations Rise to Almost 400,000," Fortune, April 15, 2016. Available at: http://fortune.com/2016/04/15/tesla-model-3-reservations-400000/ (accessed January 11, 2017).

36 Steven Overly, "At CES 2017, Faraday Future Showed the Car that Could Make or Break It," Washington Post,

January 4, 2017. Available at: https://www.washingtonpost.com/news/innovations/wp/2017/01/04/at-ces-2017-faraday-future-showed-the-car-that-could-make-or-break-it/ (accessed January 11, 2017). *See also* James Ayre, "Lucid Motors Officially Unveils the Air," Cleantechnica.com, December 15, 2016. Available at: https://cleantechnica.com/2016/12/15/lucid-motors-officially-unveils-air-20-pictures/ (accessed January 11, 2017).

37 "Alternative Fuels Data Center – Developing Infrastructure to Charge Plug-In Electric Vehicles."

38 "Taking Charge: Establishing California Leadership in the Plug-In Electric Vehicle Marketplace," California Electric Plug-In Vehicle Collaborative, December 2010, p. 26. Available at: http://www.pevcollaborative.org/sites/all/themes/pev/files/docs/Taking_Charge_final2.pdf (accessed January 11, 2017).

39 See Nikki Gordon-Bloomfield, "Renault-Nissan CEO Rejects Battery Swapping, Leaving Better Place Stranded," Plugincars.com, May 06, 2013. Available at: http://www.plugincars.com/renault-nissan-ceo-rejects-battery-swapping-127151.html (accessed January 11, 2017). See also Kirsten Korosec, "Tesla's Battery Swap Program is Pretty Much Dead," Fortune, June 10, 2015. Available at: http://fortune.com/2015/06/10/teslas-battery-swap-is-dead/ (accessed January 11, 2017).

40 Max Baumhefner, Roland Hwang and Pierre Bull, p. 4.

41 Id.

42 Id at 5.

43 *See* "California Tops a Quarter Million Electric Vehicles Sold," PEVcollaborative.org webpage. Available at: http://pevcollaborative.org/sites/all/themes/pev/files/161110_PEVC_PEV_250KSales_Milestone_Release%5B4%5D.pdf (accessed January 11, 2017). *See also* "Tracking Progress – Zero-Emission Vehicles and Infrastructure," California Energy Commission, October 2016, pp. 1-2. Available at: http://www.energy.ca.gov/renewables/tracking_progress/documents/electric_vehicle.pdf (accessed January 11, 2017).

44 "CVRP Rebate Statistics."

45 *See* "Monthly Plug-In Sales Scorecard."

46 "Alternative Fueling Station Counts by State," U.S. Department of Energy webpage. Available at: http://www.afdc.energy.gov/fuels/stations_counts.html (accessed January 11, 2017).

47 "Tracking Progress – Zero-Emission Vehicles and Infrastructure," pp. 5-7.

48 *See* Borrás. *See also* John Voelcker, "California Utilities Submit $1 Billion of Electric-Car Projects to Regulators," Greencarreports.com, January 24, 2017. Available at: http://www.greencarreports.com/news/1108500_california-utilities-submit-1-billion-of-electric-car-projects-to-regulators (accessed January 27, 2017).

49 "Tracking Progress – Zero-Emission Vehicles and Infrastructure," pp. 3-5.

50 "Notice of Proposed Award – Alternative and Renewable Fuel and Vehicle Technology Program: Grant Solicitation GFO-15-601 DC Fast Chargers for California's North-South Corridors," California Energy Commission, February 16, 2016. Available at: http://www.energy.ca.gov/contracts/GFO-15-601_NOPA.pdf (accessed January 11, 2017).

51 "California Capital Access Program (CalCAP) – Electric Vehicle Charging Station (EVCS) Financing Program," Office of the State Treasurer webpage. Available at: http://www.treasurer.ca.gov/cpcfa/calcap/evcs/ (accessed May 12, 2017).

52 *See* "Alternative Fuels Data Center: California Laws and Incentives for Electricity," U.S. Department of Energy webpage. Available at: http://www.afdc.energy.gov/fuels/laws/ELEC/CA (accessed January 11, 2017).

53 "California Air Resources Board's Guidance to Volkswagen on First 30 Month Electric Vehicle Infrastructure Investment Plan of the 2.0 Liter Diesel Engine Partial Consent Decree Settlement," Volkswagen Settlement: California Zero Emission Vehicle Investment Commitment, California Air Resources Board, February 2017, p. 4. Available at: https://www.arb.ca.gov/msprog/vw_info/vsi/vw-zevinvest/documents/carb_guidance_021017.pdf (accessed April 25, 2017). *See also* "Tracking Progress - Zero-Emission Vehicles and Infrastructure."

54 Southern California Edison news releases, “SCE Receives CPUC Approval for ‘Charge Ready’ Pilot Program; Will Install As Many As 1,500 Electric Vehicle Charging Stations in Southland,” January 14, 2016. Available at: http://newsroom.edison.com/releases/sce-receives-cpuc-approval-for-charge-ready-pilot-program;-will-install-as-many-as-1-500-electric-vehicle-charging-stations-in-southland (accessed February 13, 2017). *See also* San Diego Gas & Electric news releases, “SDG&E to Install Thousands of Electric Vehicle Charging Stations,” January 28, 2016. Available at: http://www.sdge.com/newsroom/press-releases/2016-01-28/sdge-install-thousands-electric-vehicle-charging-stations (accessed February 13, 2017).

55 California Public Utilities Commission, Decision D1612065, issued December 21, 2016. Available at: http://docs.cpuc.ca.gov/SearchRes.aspx?DocFormat=ALL&DocID=171539218 (accessed February 13, 2017).

56 *See* Senate Bill 350 (de León, 2015) Clean Energy and Pollution Reduction Act of 2015.

57 “Transportation Electrification Activities Pursuant to Senate Bill 350,” California Public Utilities Commission webpage. Available at: http://www.cpuc.ca.gov/sb350te/ (accessed May 2, 2017).

58 UCLA Luskin Center for Innovation, “Financial Viability of Non Residential Charging Stations,” August 2012. Available at: http://luskin.ucla.edu/sites/default/files/Non-Residential%20Charging%20Stations.pdf (accessed January 9, 2017).

59 “Fact #910: February 1, 2016 Study Shows Average Cost of Electric Vehicle Charger Installations,” U.S. Department of Energy, February 2016. Available at: https://energy.gov/eere/vehicles/fact-910-february-1-2016-study-shows-average-cost-electric-vehicle-charger (accessed February 13, 2017).

60 By comparison, residential installations (not the subject of this report) had the lowest average installation cost, with a mean of $1,354, though individual installation costs ranged from just a few hundred dollars to as much as $8,000.

61 Data provided by Marvin Moon, Los Angeles Department of Water & Power.

62 “Charge Ready Pilot Program Quarterly Report for Fourth Quarter 2016,” Southern California Edison, March 1, 2017, at p. A-27. Available at: http://www.edison.com/home/our-perspective/charge-ready-a-plan-for-california.html (accessed March 3, 2017). A site has an average of 16 ports.

63 *See* John Clint, Billy Gamboa, Brandon Henzie, and Akane Karasawa (Alternative Energy Systems Consulting, Incorporated), “Considerations for Corridor Direct Current Fast Charging Infrastructure in California,” California Energy Commission. Available at: http://www.energy.ca.gov/2015publications/CEC-600-2015-015/CEC-600-2015-015.pdf (accessed March 3, 2017).

64 Data provided by Brian Fauble, Energy Commission Specialist I in the Zero-Emission Vehicle and Infrastructure Office at the California Energy Commission.

65 UCLA Luskin Center for Innovation, “Financial Viability of Non-Residential Charging Stations,” August 2012, pp. 2-3. Available at: http://luskin.ucla.edu/sites/default/files/Non-Residential%20Charging%20Stations.pdf (accessed January 9, 2017).

66 The UCLA study also found that workplaces with “Level 1” (110-volt) chargers potentially exhibited positive net present value (NPV), although all modeled scenarios reflecting attributes of a grocery store, shopping mall, and workplace (presumably with non-Level 1 chargers) generated negative NPV. The workplace scenario with Level 1 chargers, assuming 8 hours of charger utilization and zero fixed-fee, generated the least negative NPV. Although Level 1 chargers showed a lower breakeven electricity sale markup, which may point to a higher potential of profitability, customers may be less willing to pay for Level 1 chargers due to the slow rate of charge. UCLA Luskin Center for Innovation at 6.

67 In sum, the study found that the two key determinants of the profitability of an electric vehicle charger are 1) utilization (a function of turnover and parking duration) and 2) the price consumers are charged, which is dependent on willingness to pay. Id at 29.

68 Garrett Fitzgerald and Chris Nelder, “EVgo Fleet and Tariff Analysis,” April 2017, Rocky Mountain Institute, p. 1. Available at: https://www.rmi.org/wp-content/uploads/2017/04/eLab_EVgo_Fleet_and_Tariff_Analysis_2017.pdf (accessed May 8, 2017).

69 Rule 2202 – On-Road Motor Vehicle Mitigation Options, South Coast Air Quality Management District, Adopted December 8, 1995. Available at: http://www.aqmd.gov/docs/default-source/rule-book/reg-xxii/rule-2202.pdf?sfvrsn=7 (accessed April 25, 2017).

70 *See* "Electricity as a Transportation Fuel," California Air Resources Board, Staff Discussion Paper, November 23, 2016, p. 8. Available at: https://www.arb.ca.gov/fuels/lcfs/lcfs_meetings/12022016discussionpaper_electricity.pdf (accessed May 12, 2017).

71 For more information on AB 1452, please see: https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201720180AB1452 (accessed April 25, 2017).

72 Adam Langton and Noel Crisostomo, "Vehicle-Grid Integration: A Vision for Zero-Emission Transportation Interconnected throughout California's Electricity System," California Public Utilities Commission, October 2013, p. 15. Available at: http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M080/K775/80775679.pdf (accessed May 9, 2017).

73 For more information on "Nissan No Charge to Charge," please visit: https://www.evgo.com/special-offers/nissan-no-charge-charge/ (accessed May 2, 2017).

74 Senate Bill 350 (De Leon), Chapter 547, Statutes of 2015.

75 "California Vehicle-Grid integration (VGi) Roadmap: Enabling Vehicle-Based Grid Services," California Independent System Operator, February 2014, p. 3. Available at: http://www.caiso.com/documents/vehicle-gridintegrationroadmap.pdf (accessed May 9, 2017).

76 Max Baumhefner, Roland Hwang and Pierre Bull, p. 16.

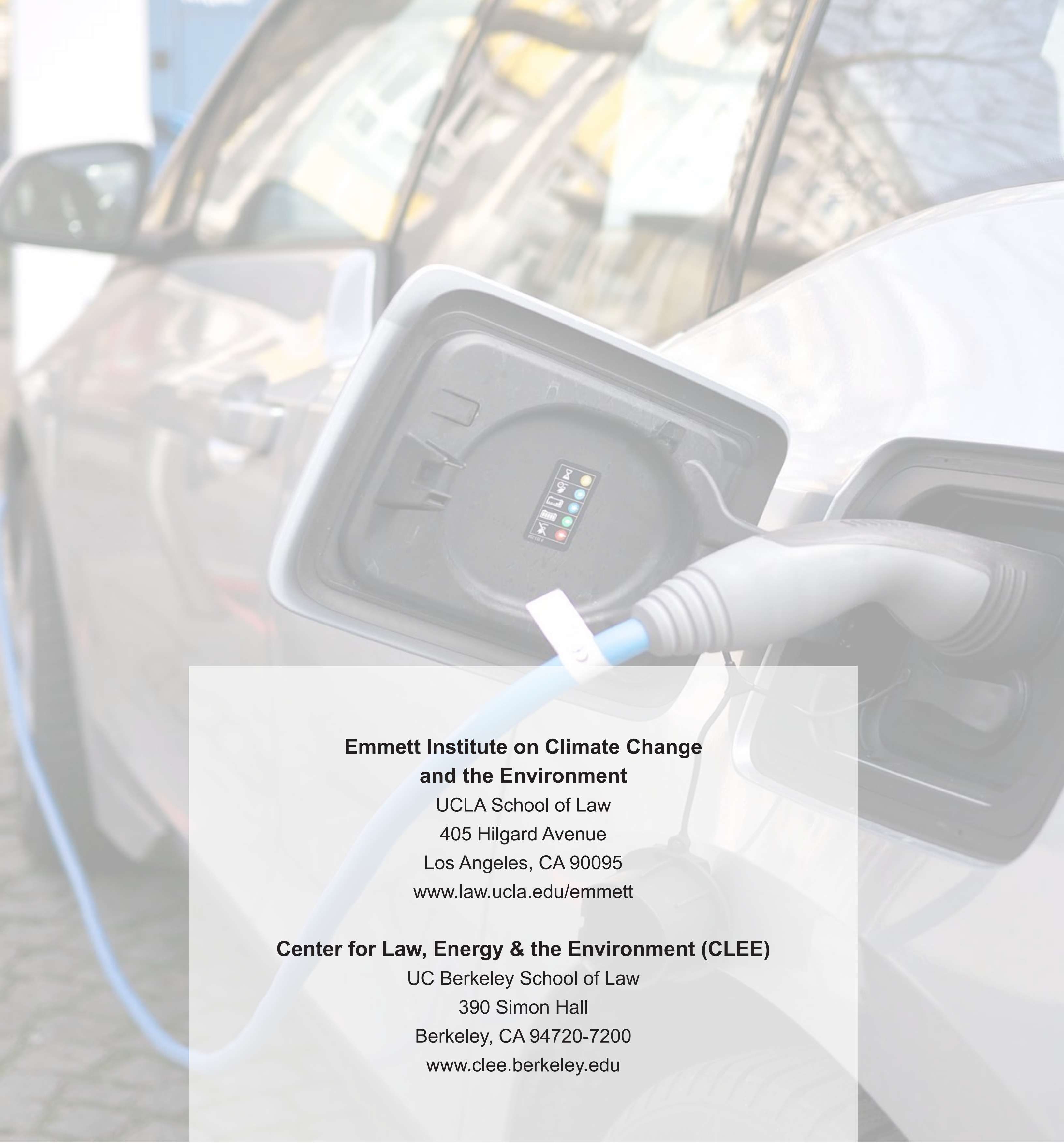
77 Id. at 10.

78 San Diego Gas & Electric proposed a "Commercial Grid Integration Rate" comprised of three components: a monthly demand charge, an hourly base rate, and "dynamic adders." The Grid Integration Rate is based on cost-causation principles to send price signals to minimize incremental system and local capacity needs. Prepared Direct Testimony of Cynthia Fang on Behalf of San Diego Gas & Electric Company, Chapter 5, Jan. 20, 2017, A1701020 – Commercial Grid Integration Rate. Available at: https://www.sdge.com/sites/default/files/regulatory/Direct%20Testimony%20Chapter%205%20-%20Rate%20Design.pdf (accessed February 13, 2017).

79 Pacific Gas & Electric offered its electric vehicle commercial rates in its 2017 general rate case as part of its application for transportation electrification. Pacific Gas & Electric proposed to change the seasons and time-of-use periods for electric vehicle rate schedules, including a peak, partial-peak, and off-peak for both winter and summer seasons. The proposal would expand the part-peak periods. Proposed electric vehicle rates would range from $0.15 winter off-peak to $0.37 summer peak. Pacific Gas & Electric Company's (U 39 E) Electric Vehicle Infrastructure and Education Senate Bill 350 Transportation Electrification Program Application, Jan. 20, 2017. Available at: http://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M172/K518/172518496.PDF (accessed February 13, 2017).

80 Southern California Edison proposed three new, optional commercial rate schedules, which will use up-to-date, time-of-use periods as more accurate price signals of system grid conditions. The new rate classes will make use of new, more granular time-of-use periods beyond the existing peak and off-peak rate schedules. Southern California Edison proposed a winter super-off-peak 8:00am to 4:00pm, summer off-peak 4:00pm-9:00pm. The new electric vehicle rates would be composed of fixed charges, energy rates, and demand charges. The rates would have a five-year introductory period where Southern California Edison would not access demand charges, instead using primarily volumetric energy charges. Southern California Edison would phase in demand charges over the following five-year period, before implementing a stable demand charge at year ten. Southern California Edison, A1701021 - Optional Commercial Rate Schedules, Southern California Edison Company (U 338 E) for Approval of its Transportation Electrification Proposals, Jan. 20, 2017, at 4. Available at: http://www3.sce.com/sscc/law/dis/dbattach5e.nsf/0/4D320467F986C8FA882580AE007EF90E/$FILE/A1701XXX%20-%20SCE%20TE%20Application%201-20-17.pdf (accessed February 13, 2017).

81 To view the current edition of Handbook 44, please visit: https://www.nist.gov/sites/default/files/documents/2016/11/10/hb44-2017-web_final.pdf (accessed April 25, 2017).



Emmett Institute on Climate Change and the Environment
UCLA School of Law
405 Hilgard Avenue
Los Angeles, CA 90095
www.law.ucla.edu/emmett

Center for Law, Energy & the Environment (CLEE)
UC Berkeley School of Law
390 Simon Hall
Berkeley, CA 94720-7200
www.clee.berkeley.edu

Bank of America

BerkeleyLaw
UNIVERSITY OF CALIFORNIA
Center for Law, Energy & the Environment

THE EMMETT INSTITUTE
ON CLIMATE CHANGE AND THE ENVIRONMENT
UCLA | SCHOOL OF LAW