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# Priming the United States Grid for High-Powered Electric Vehicle Charging

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**Summary**

High-power electric vehicle (EV) charging stations can help reach emission reduction goals in the United States (U.S.) and Europe as the EV adoption increases. However, the energy demand associated with high-power charging stations is raising questions in the U.S. about the impacts to electric utilities, energy management, and grid stability. Energy solutions such as energy storage, managed charging, and controlling distributed grid assets are important considerations in the U.S. With a comprehensive approach, the industry can lay a foundation that prepares the market for EV adoption and adequate energy delivery for charging station infrastructure while minimizing grid impact.

*Keywords: charging, deployment, energy storage, EV (electric vehicle), load management, utility*

## 1. A Call to Action: Reduce Greenhouse Gas Emissions

According to the Intergovernmental Panel on Climate Change (IPCC) 2014 report [1], transportation accounts for 14% of greenhouse gas (GHG) emissions across the globe. To reduce emissions, the IPCC calls for innovation in environmentally sound mobility infrastructure while escalating human systems resilience and decreasing adverse impacts on natural systems. The transportation sector accounts for 26% of GHG emissions in the U.S. Within this sector, 61% of the emissions come from light-duty vehicles (LDV), like passenger vehicles and pickup trucks, and 23% come from medium-duty vehicles (MDV) and heavy-duty vehicles (HDV)[2]. To reduce GHG, twenty states plus Washington DC have GHG emissions targets [3] and several are exploring clean vehicle technologies to help reach their GHG reduction goals.

### 1.1. GHG Reduction and Electric Vehicle Innovation

Towards GHG reduction, the electric vehicle (EV) industry is preparing for the next generation of EVs that have larger battery capacity and are capable of charging at much higher rates than the current vehicles. This ultra-charge innovation is already underway in Europe through a joint venture of automakers formed in 2016. With deployment starting in 2017, this alliance will form a network where each station will feature the new high-powered charging infrastructure, in addition to today's typical levels of AC and DC charging ports. These stations will deliver up to 350 kW, which is twice the capacity of currently available maximum charging capacity (145kW) [4].

In the U.S., as EV adoption trends up, the topics of grid readiness and power delivery become important. This paper discusses the EV adoption trends in the U.S., as well as predicted energy demand and energy solutions, such as energy storage and managed charging, which help mitigate grid impact. Finally, this paper discusses how industry stakeholders can best support EV adoption, high-power charging, and grid management.

# 2. High-Power Electric Vehicles

As EVs of all sizes (LDV, MDV, and HDV) become more cost effective, fleets and individuals will accelerate adoption, and high-power charging will become pervasive. Two scenarios drive high-power charging configurations: a large quantity of lower power charging in a single location and growing numbers of high-power chargers in a single location. Both scenarios will significantly affect the grid. In the first scenario, organizations will transition their fleets to EVs and add multiple chargers at the same site, creating high-power demand. For example, if a fleet installs 6-20 chargers and uses their full capacity concurrently, then the cumulative demand would reach 300 kW to 1000 kW at that location. Black & Veatch sees fleet applications like transit depot sites that *start* at 2.5MW with a trend towards 10MW or more. Likewise, fleets of high-utilization LDV will require facilities with as much as 20MW of charging capacity.

In the second scenario, deployment of 150 kW – 400 kW charging systems will occur by 2018-2020. U.S. EV service providers like ChargePoint and EVgo are installing pilot versions in response to requests from vehicle manufacturers such as Porsche [5], Audi, Ford, Hyundai, and General Motors [6]. Other applications include transit buses, shared vehicle fleets like Uber [7] and eventually, aircraft. When high-power chargers become widely available, they will create significant point loads of up to half a MW—individually or cumulatively. When consumers operate multiple large-scale chargers at the same site, the resultant large load places an unbalanced, asymmetric demand on utility distribution networks, which triggers equipment upgrades.

## 2.1 Light-Duty Vehicles: Sales and Energy Demand

As battery technology improves, more compelling EV models become available with a longer range and lower cost even before and incentives. For example, the 2016 GM Chevy Bolt is the first long-range, moderately priced all-electric car available in the U.S. It boasts a 238-mile range, at a base price of $35,000. In 2017 and 2018, Tesla, Nissan and Hyundai will also offer long-range EVs in the $30,000 to $40,000 range [8][9]. Low mileage, earlier generation models such as 2012-2104 Nissan Leafs are available for well under $10,000.

EVs are becoming a key part of the LDV market more quickly than expected. Michael Liebreich of Bloomberg New Energy Finance (BNEF) estimates that "by 2020 there will be over 120 different models of EV across the spectrum" [10]. Volkswagen AG estimates that by 2025, 25% of its sales will be EVs, and Toyota Motor Corp believes they will not sell any fossil fuel vehicles by 2050 [11]. The early adopter market is becoming the mainstream market.

According to BNEF, the cost of unsubsidized LDV EVs will equal that of conventional cars by 2022, leading to global plug-type LDV sales that are 35% electric by 2040. Similarly, one of the world's biggest oil producers, Total SA, stated that EVs could be 15 to 30% of new car sales by 2030. If these forecasts occur, then EVs will draw 1,900 TWh of electricity by 2040, which is equal to 10% of global electricity production in 2015 [12].

The energy implications of EV adoption forecasts are staggering. In 2014, the U.S. had over 240 million LDVs (Table 1) [13], and the total energy consumed across LDV was equivalent to 4,300 TWh of electricity usage [14]. To put this in perspective, this is greater than total U.S. electricity usage across all sectors in 2015 (3,759 TWh) [15]. As Table 1 shows, electrifying the 10, 50 and 100% of the existing LDV fleet will have a significant effect on the electric grid, and the impact will increase with MDV and HDV electrification. At 100% electrification of 2014 LDV, the U.S. would use 926.6 TWh per year, which is about 25% of the total U.S. electricity consumption in 2015.

**Table 1 Annual Electricity Demand with 10%, 50%, and 100% Vehicle Electrification**

| | Number of vehicles (millions) | Energy used (Tbtu) | Equivalent Electricity (TWh) | Electrify 10% of Vehicles: Electricity Usage (TWh) | Electrify 50% of Vehicles: Electricity Usage (TWh) | Electrify 100% of Vehicles: Electricity Usage (TWh) |
|---|---|---|---|---|---|---|
| **Total LDVs** | 240.2 | 14,630 | 4,300 | 92.7 | 463.3 | 926.6 |
| ***LDV – sedan*** | *187.6* | *10,300* | *3,030* | *72.4* | *361.8* | *723.7* |
| ***LDV – pickups*** | *52.6* | *4,330* | *1,270* | *20.3* | *101.5* | *202.9* |
| **MDV & HDV** | 10.9 | 5,460 | 1,600 | 45.0 | 225.0 | 450.0 |
| **TOTAL:** | **251.1** | **20,090** | **5,900** | **137.7** | **688.3** | **1376.6** |

## 2.2 Medium and Heavy Duty Vehicles: Sales and Energy Demand

MDV and HDV in the U.S. travel over 270 billion miles per year, using 38.5 billion gallons of fuel with consumption as low as 4 miles per gallon (mpg) for transit applications and a category average of 7 mpg [16]. Fuel economy of conventional drivetrains will increase to 10 mpg by 2040 [17], however, they will lag behind the predicted 40% efficiency gains of electric drivetrains [18]. Today's MDV and HDVs represent over 22% [19] of the energy consumed for transportation, and they are the basis of logistics, transit, municipal and commercial fleet applications.

Fleet operators must consider the range of costs before embracing new technology. Electric MDVs and HDVs generally have a higher upfront purchase price than conventional versions, but Black & Veatch observes that fuel costs are generally lower than conventional vehicles and EVs can reduce maintenance costs 10-80%, depending on vehicle type. Technology availability, price and performance are advancing the total cost of ownership—some vehicle types are now comparable to or lower for an EV than a conventional vehicle (e.g., transit buses). Soon the cost of not electrifying fleets will outweigh today's cost of investment. Businesses that do not electrify will be at a competitive disadvantage, municipal fleets that do not transition will lose the benefits of EV, and utilities will lose revenue streams.

Pilot programs in California, New York, Chicago and Kansas are crucial to establish the viability of MDV and HDV electrification, loads, and charging infrastructure requirements in applications like garbage trucks, ports, drayage vehicles, mail trucks and logistics. For example, in May 2017, the California Energy Commission (CEC) announced US$36 million for clean transportation – US$24 million of which was to three entities "to conduct field demonstrations of medium- and heavy-duty vehicles and cargo handling equipment that have zero or near-zero emissions" [20].

Similar to LDV, electrified MDV and HDV will impact total electricity consumption. In 2014, the U.S. had over 10.9 million MDV and HDV (refer to Table 1) [21], and their total fuel consumption was equivalent to 1,600 TWh of electricity [22]. This is a little less than half the total U.S. electricity usage in all sectors for 2015 (which was 3,759 TWh) [23]. Electrifying 100% of MDV and HDV would use 450 TWh per year (equivalent to 12% of the total U.S. electricity consumption in 2015).

Table 1 demonstrates that the total combined annual electricity usage of LDV, MDV and HDV for 10% electrification is 137.7 TWh, 688.3 TWh for 50% electrification, and 1,377 TWh for 100% electrification (4%, 18% and 37% of total U.S. electricity consumption in 2015, respectively). EVs will undoubtedly increase total electricity usage, but if the industry manages charging as a flexible load on the grid, then additional electric generation or transmission capacity may be unnecessary (see Section 3.1.4, Managed EV Charging).

## 2.3 Range Assurance

EV customer adoption hinges on range assurance, but better range assurance creates a larger impact on the grid. Since the launch of the first EVs in 2000 and 2010—such as the Nissan Leaf, BMW i3, Chevy Spark, and Honda Fit—the early adopter customer base accepted that EVs were a convenience car for regular routes, with an average of 40-50 miles per day maximum. The cars had attractive features, were economical, required low maintenance, and charged easily with a level 2 charger. However, these applications had limited interest for most customers and fleets because they were not appropriate for long-range driving.

The next-generation EVs will reach a broader market. The success of the Tesla Supercharger DC Fast Charging (DCFC) network highlighted customer desire for longer-range EVs and quick charging outside of the home. At the same time, the industry noted a segment of EV owners who could not charge at home, like people without garages, multi-unit dwelling residents, and renters. By 2020, the industry expects EV ranges of more than 100 miles to nearly 350 miles. [24]. The variety of EVs is expanding too; LDVs are evolving to full sized sedans and SUVs/trucks [25]. Small vans, delivery vans and transit buses are already available, and pickup trucks and long-haul tractors are not far behind. Higher kW capacity vehicles, longer distances across all applications, and a more complete charging network will decrease range anxiety significantly, particularly in urban areas; these dynamics support expanded adoption. Demand will hit a tipping point if EV costs at all sizes reach parity with conventional vehicles.

## 2.4 Corridor Travel

Corridors connect urban areas and provide public charging options for EV owners without home or work charging. Corridors also provide low-income EV charging and enable rural EV travel. The CEC has invested nearly $220 million for charging along California corridors, at the workplace, and at multi-unit dwellings across the state (through projects *PON-13-606* [26], *GFO-15-601* [27], and *CEC-GFO-16-603* [28]). Other states are following California’s lead, including Colorado, Utah, Nevada and Texas. EV adoption and demand on the grid will increase along with the challenges of supplying high-power to areas not adequately served, such as suburban commercial and residential areas.

## 2.5 High-Density Charging / High-Utilization Vehicles

City transportation systems must move more passengers and goods, and level 2 chargers can meet charging needs when duty cycles permit longer charge times. Even so, if the vehicles charge simultaneously, then the power demand density increases. High-utilization vehicles like car shares, taxi and autonomous fleets need to charge quickly because idle service vehicles equate profit losses. Corridor-charging hubs may have a few dozen or more high-power charging stations to sustain charging volume. Depots, multi-modal freight centers, and distribution centers will have charging requirements in the 5MW, 10MW or more with 100+ chargers simultaneously operating at high-power levels.

## 2.6 Municipal Fleets & Specialty Vehicles

As demonstrated by the 114,000 Municipal Fleet Request for Information (RFI) led by Los Angeles, San Francisco, Seattle and Portland [29], cities want to adopt EVs for a variety of applications. They may use Level

2 charging and high-power charging to meet these fleet's typical hours of operation and duty cycles. The commitment of these large fleets will drive adoption.

Specialty fleets can leverage advances in traction electrification (i.e., taking AC power from the grid and converting it to DC voltage for use by traction motors) to forward their specific missions, like utility service trucks with power export capabilities, ambulances with long standby times, and any application that traditionally requires a mobile generator. With or without plug-in hybrid drivetrains, the unique charging requirements of specialty vehicles may far exceed typical vehicle charging, necessitating high-power infrastructure to support their auxiliary applications.

# 3 Grid Management to Ensure Adequate Power Delivery

When deploying high-power EV charging, there are a number of challenges and opportunities associated with managing the electric grid as EV penetration increases. Utilities are required to provide reliable electric power to their customers, and EVs could affect this mission in both positive and negative ways. As documented by Black & Veatch and the Smart Electric Power Alliance [30], it is critical to anticipate the number of EV adopters, the location and timing of adoption, and the need for additional charging infrastructure, to ensure the grid is prepared and the utility can maintain reliability. In addition, technology integrators will be critical to deploy EVs and charging infrastructure in a way that supports, rather than stresses, the grid.

Currently, EVs represent a very small proportion of the electric load served by utility companies in the U.S. and most other countries, but as this proportion rises, unmanaged EV growth has the potential to:

- Overload transformers on electric distribution circuits in areas of high adoption
- Alter the utility's overall load profile, impacting the timing of generation dispatch
- Drive unexpected changes in retail electric sales
- Stretch the utility companies' existing resources for grid planning and operations

However, EVs also have the potential to:

- Increase utility revenues
- Help balance grid demand and supply and integrate variable generation resources like wind and solar
- Provide ancillary grid services in wholesale electricity markets
- Drive new grid and charging infrastructure from which utilities could earn a return

To address these challenges and take advantage of these opportunities, electric utilities will need to engage proactively throughout the lifecycle of planning, installing, and operating high-power EV charging infrastructure.

## 3.1 Distributed Energy Resources (DER)

An important trend that electric utilities are seeing today is the unprecedented growth in customer-owned and controlled DER technologies, which include EVs and distributed generation, energy efficiency, demand response (DR) and energy storage. Black & Veatch's Strategic Directions: Smart City/Smart Utility Report (2017) found that many electric utility leaders are concerned about lack of control over customer-owned DERs and maintaining grid stability. However, utilities also see opportunities for new utility business models and for DERs to provide locational value on the distribution grid [31].

Each DER technology has differing attributes, costs and benefits. EVs are the most versatile—and unpredictable—when compared to other DERs like rooftop solar or energy storage. Utilities will need to manage DERs as a portfolio to take advantage of synergies and manage compounding factors. With appropriate planning and investment, other DER technologies can help to integrate high-power EV charging into the grid.

### 3.1.1 Renewable Energy (On and Offsite) and Other Distributed Generation

Policy support, efficiency gains, and rapid cost declines have driven solar photovoltaics (PV) growth. The total installed cost has declined 80% since 2009 [32]. Solar PV receives policy support largely because it reduces GHG emissions. Customers invest in distributed solar PV to reduce electric bills and environmental impacts, decrease dependence on the grid, and support new technologies. In some cases, solar PV can power EV charging infrastructure at a lower cost than grid power, although this depends on utility tariff structures. Additionally, solar PV output correlates well with EV workplace or mid-day charging activities, so that the solar energy can be consumed on-site instead of exported to the grid or curtailed.

Increasingly customers are investing in off-site renewables through direct power purchase agreements, community/shared solar and renewable energy credits, which can all be cost-effective means to supply high-power EV charging load [33]. The potential for long-term energy cost savings and stability, as well as personal and corporate sustainability goals, drives this dynamic. In addition to renewable energy technologies, other types of distributed generation powered by conventional fuels are growing, including microturbines, fuel cells, and combined heat and power systems. The industry can integrate these technologies with EV charging.

### 3.1.2 Demand Response (DR) and Energy Efficiency

Energy efficiency includes energy-saving products like LED lightbulbs that reduce customer electric bills and permanently decrease overall utility load. DR modifies customer loads at specific times based on signals from the utility. For example, smart thermostats receive utility requests via Wi-Fi to reduce air conditioner operations when overall utility demand peaks on hot days. This automation saves money and reduces the need for expensive “peaking” generation units. Increasingly, utilities are geographically targeting energy efficiency and DR programs to reduce load on specific distribution circuits as they approach maximum capacity. Efficiency and DR can be managed in conjunction with EV charging to minimize non-EV load overall and adjust other flexible loads as EV demand rises and falls. Additionally, commercial microgrids and home energy networks can contribute to the pool of grid balancing resources. This creates synergy between electricity supply and demand behind-the-meter at the local distribution level and at the regional transmission level.

### 3.1.3 Energy Storage

The electric grid instantaneously balances supply and demand. However, energy storage, which can act as both a generation source and a load source, allows greater flexibility in grid operations, while empowering customers to better manage their personal energy use. As shown in Figure 1, energy storage can provide a variety of grid services [34]. This diagram shows that behind-the-meter storage can provide a larger suite of services to the grid than transmission or distribution-level storage, as long as utilities can aggregate and effectively control fleets of small, distributed storage devices (although there is debate about which storage size is most cost-effective). Energy storage also allows customers to reduce their peak demand on the grid, shift their energy consumption to times of lower cost, and maximize self-consumption of on-site distributed generation like solar PV. Combined, EV chargers and stationary storage make the magnitude and timing of EV demand more flexible. This reduces the cost of charging and allows on-site distributed generation output to be stored for use by EV chargers as needed.

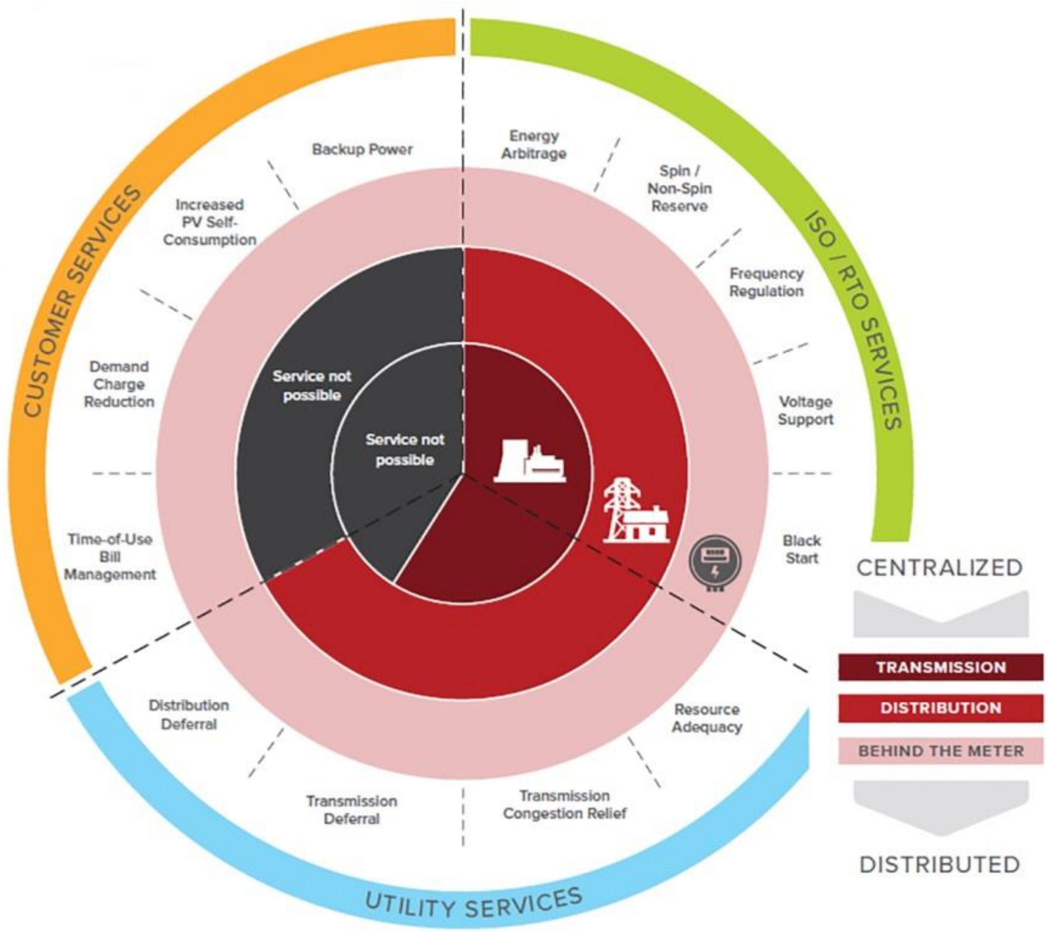


**Figure 1: Battery Storage Suite of Grid Services**

### 3.1.4 Managed EV Charging

As EV adoption grows, EV charging will constitute a substantial portion of utility load. With proper control, EV chargers can act as a flexible load that can be quickly shed to reduce demand or enabled to consume energy [35]. Pacific Gas & Electric (PG&E) and BMW completed a study in California demonstrating that a fleet of 100 EVs can effectively respond to DR signals from the utility, meaning that EV charging can be a valuable form of demand response [36]. In addition, the implementation of vehicle-to-grid (V2G) technology in the future will allow EVs to act as a generation source by discharging stored electricity back to the grid.

Unmanaged EV charging can lead to distribution-level grid impacts, like transformer overloads, and to transmission-level impacts on the utility load profile—both of which can result in localized outages and lead to increased capital and operational spending at utilities. Black & Veatch's recent study for the Sacramento Municipal Utility District in California revealed that concentrated EV charging at the wrong time could cost tens of millions of dollars in transformer replacements alone [37]. However, these impacts diminish if the utility or third party EV aggregator spreads the charging load evenly throughout the day or shifts charging to times of excess solar generation. Managed EV charging could enable EVs to provide ancillary services in wholesale electricity markets, creating another financial opportunity. EV owners would receive a portion of these new revenue streams as compensation for allowing these charging adjustments. When designed well, managed EV charging allows utilities and grid operators to capture grid benefits by harnessing the latent capabilities of EVs, which are often parked over 95% of the time [38].

## 3.2 Integration with Regional Power Systems

It is expected that EVs will be the most pervasive and widespread DER on the grid. In the near (1-3 years) and mid-term (3-10 years), traditional power generation will be vital to maintain grid reliability. With EV adoption escalation, traditional utility-scale generation will help balance the portfolio of DER assets for several years to come--providing ramping, reactive power and voltage support, frequency regulation, spinning reserves, and other services during operation [39]. As EVs become integrated, utilities can supplement traditional power generation with energy storage, managed charging, and coordinated control of distributed grid assets to meet EV charging needs; this can also help optimize use of conventional generation.

### 3.2.1 Grid Technical Challenges

New charging locations may require distribution upgrades to handle the increased load. There is no standard to determine who is responsible for upgrade costs, which could be assumed by the charging station developer/owner, the electric utility (who would pass the costs onto the ratepayers), or some combination of the two. In the western U.S., utilities received pre-authorization to proactively upgrade the system and earn a regulated return for areas that needed upgrades to accommodate the best variable renewable energy (VRE) resources (which could be emulated for EV infrastructure) [40]. One or all of these scenarios could occur as EV adoption increases.

A second challenge relates to integrating energy storage, managed charging, and DER asset controls with existing power, transmission and distribution resources. These charging networks can create greater grid flexibility if utilities and stakeholders can develop an advanced charging environment. A third challenge is system coordination. Stakeholders must consider the technical challenges of high-power EV charging and DER grid impacts simultaneously. Experts at the National Renewable Energy Laboratory (NREL) see three main events that will characterize the 20-year grid-planning horizon [41]:

- The rise of low-carbon, centralized generation
- Rapid growth of DER
- Interactivity of the grid and demand

NREL expects that each region and state in the U.S. will experience all three events to some degree [42]. The technical challenges that arise will need to be coordinated with larger, longer-term efforts of grid modernization, increased amounts of centralized VRE, the growth of other DERs, and increased interaction between the transmission and distribution system, as well as between the utilities and their customers. As EV charging systems expand, stakeholder coordination and proactive planning will also be critical. EV charging station locations can support the varied interests of the many stakeholders, but only through discussions, data, and analysis to allow the decision-makers to balance the need for rapid expansion of EV charging infrastructure with intelligent location selection for that infrastructure.

### 3.2.2 Utility Approaches to Charging Infrastructure Deployment and Integration

Utilities are studying EV charging ownership, rate impacts, charging engineering and site preparation to support integration of these behind-the-meter assets. Combined, the three California investor-owned utilities, Southern California Electric (SCE), PG&E, and San Diego Gas and Electric (SDG&E) have proposed two-phase pilots totaling more than US$1 billion of investment over the next 5 years [43]. The first phases of these pilots will:

- Leverage pricing signals that reflect grid conditions to provide pricing incentives to charge during periods of low demand. SDG&E will own and operate all of the charging stations in their program, which allows site hosts to select their preferred hardware and billing options.
- Focus on "Make Ready" infrastructure, where SCE will provide infrastructure up to the charging station. Site hosts select from a number of approved hardware choices.
- Test full PG&E ownership along with third party ownership of the infrastructure and the charging stations in their service territory.
- MDV/HDV (Phase 2 Priority) focuses on high-power charging in transit, corridors and ports.

By design, each of the California investor-owned utility (IOU) programs requires that charging stations are DR-capable so that resources can be controlled remotely in times of high grid demand. Following a balanced approach that leverages utility and private investment, all stakeholders can benefit from these programs and lessons learned. As the California IOU pilots begin to ramp up, dozens of utilities across the country are exploring options or already filed with their Commissions. Eight other U.S. utilities have pilot EV infrastructure investment programs that total well over US$60 million in investment if they all are completed [44].

# 4 Conclusions

As EVs of all sizes become more cost effective with longer ranges, fleets and individuals will accelerate adoption, and demand for high-power charging will become pervasive. This surge of innovative technology will help cities build sustainable transportation and slash GHGs. This transformation is not without its challenges. Electrifying all of the LDVs, MDVs and HDVs from 2014 will require 1,377 TWh per year—this is equal to 37% of total U.S. electricity consumption in 2015. Each industry stakeholder can positively influence the pace of EV adoption, the deployment of charging infrastructure, energy management, and the provision of grid power. To ensure grid-readiness, Policymakers and Regulators, OEMs, Utilities and Technology Integrators must contribute to the positive momentum.

## 4.1 Policymakers and Regulators

Policymakers at all levels—federal, state and local—are essential to encourage and facilitate EV adoption. New policies and regulations that benefit all stakeholders can foster early market progress and address desired mid-term and long-term outcomes for a sustainable market. Successful policy frameworks are emerging through worldwide study and information sharing. Utility regulators must prioritize approaches to help shoulder the upfront capital costs to support EV loads where the grid infrastructure is deficient. Beyond provisions for grid supply, policymakers can create programs that address capital costs associated with deploying high-power charging. These programs, strategies and rates can recover capital costs over time through increased load while leveraging the diversity and flexibility of vehicle charging on a system-wide basis. Properly developed frameworks will pay dividends to all stakeholders through focused efforts to:

- Encourage win-win investment strategies that leverage public and private funding for infrastructure.
- Develop inventive programs that directly drive behavior and adoption, such as targeted rebates and incentives on vehicles and charging infrastructure.
- Support electric utilities as they develop effective rate structures and communications protocols for EV charging that keep pace with changing technologies and shifting system load profiles.
- Develop and deliver education and outreach programs to government, commercial and consumer audiences to increase awareness of EVs in all vehicle segments and their many benefits.

## 4.2 Vehicle OEMs

Vehicle OEMs will need to continue to focus on developing vehicles that are compelling, meet customer needs, incorporate the latest technologies, are energy efficient, and take advantage the full spectrum of charging power levels. With these bases covered, OEMs can participate with other stakeholders to mitigate adoption challenges. Specifically, OEMs need to:

- Communicate high-power charging requirements to customers and fleets so they can plan for facility upgrades, and promote early engagement with their host utilities.
- Collaborate with utilities, industry and communities to build awareness as vehicle programs and applications are addressable with electrification.
- Find ways to share data with all stakeholders to inform planning, operations and grid value of an electrified fleet.

## 4.3 Utilities

The growth of EVs carries both risks and opportunities for electric utilities, so utilities must evolve by adopting best practices and technologies for grid planning and operations, as well as exploring new business models and rates/programs. Utilities will need to:

- Incorporate EVs into every aspect of the utility enterprise—e.g., load forecasting, generation resource planning, transmission/distribution planning, market designs, real-time distribution operations.
- Proactively engage with customers, technology integrators, and regulators to develop tariffs and incentive programs that support EV adoption while keeping costs low and maintaining a reliable grid.
- Create technical/market mechanisms for managed EV charging to become a versatile grid asset.
- Be prepared to make significant investments in distribution grid hardware, in communications networks and operational technologies/software, and in staff hiring/retraining to facilitate EV growth.
- Begin investigating new potential revenue streams related to EV infrastructure that expand the market and serve the customer; e.g., owning/financing customer charging stations in underserved areas, or aggregating EV charging loads and bidding them into wholesale electricity markets.

## 4.4 Technology Integrators

Technology Integrators like Black & Veatch help unify planning and deployment across stakeholders and systems. Detailing stakeholder goals and conducting roadmap planning and scenario/sensitivity analysis will help balance competing interests and create a vision for the future. Decision-makers will be able to establish stakeholder rules of participation so that the high-power EV charging network can account for site-specific approaches to building the new infrastructure, while keeping the larger program goals in mind. Black & Veatch has participated in successful infrastructure integration in 48 states and has observed that technology integrators need to:

- Conduct data collection and analysis as EV charging stations become operational to help utilities understand system status and set rates that incentivize consumer behavior that supports system operation.
- Revise the planning and operations parameters and analyses as EVs accelerate to assist growth.
- Support new tools and approaches to integrate DERs into the grid effectively.
- Work with utilities on siting / interconnection and engineering high-power utility service, including medium voltage.
- Develop and deploy energy solutions in areas where sufficient power does not exist.

- Keep pace with emerging technologies to support stakeholders through product development cycles, due diligence and first-of-their-kind deployments that scale can into nationwide solutions.
- Understand stakeholder point-of-view and coordinate efforts with utility, hardware OEMs, vehicle OEMS, and charging network owners.

With much to gain, stakeholders need to evaluate tools, approaches and mechanisms collectively that fortify the grid to support the substantial energy demands associated with EV adoption and high-power charging. The actions of regulators and legislators will be critical—they can either facilitate EV adoption and new revenue for the utilities or their actions can create barriers that stunt EV market growth. Markets with policymaker support will allow utilities, charging infrastructure developers, cities, technology integrators and the auto OEMs to establish operation, policy and technology platforms that expand EV adoption and prepare the U.S. grid for high-power charging.

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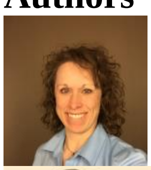
# Authors



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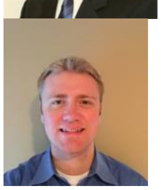

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