NAVIGANT RESEARCH

WHITE PAPER

DC Charging Networks in the United States

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Section 1
EXECUTIVE SUMMARY

1.1 Introduction

A shift is underway in the global plug-in EV market. Automakers are introducing battery EVs (BEVs) with significantly longer ranges than the current generation—200 miles and more—at prices that are much more affordable.

This shift will have important ramifications for the EV charging infrastructure market, which will undergo a significant shift in response to the higher energy capacity vehicles coming to roadways. Public fast charging—from 50 kW up to 350 kW—will play an increasingly larger role in the overall charging market, to meet the charging demands of these vehicles with their much larger battery packs.

1.2 The Coming Wave of Long-Range BEVs

Over the next several years—as automakers rollout BEVs with ranges over 200 miles and as pre-incentive prices reach below $40,000—consumer interest in BEVs is expected to spike. US sales were over 20% higher in 2016 than in 2015, and Navigant Research expects 75% growth in 2017 sales. Navigant Research also anticipates that 2021 BEV sales in the United States will be 500% higher than 2016 levels, reaching around 430,000 sold annually. While lower range BEVs will continue to capture a share of that market, 200+ mile range will likely become the standard expected by most BEV drivers.

1.3 The State of Charging Infrastructure and the Need for Fast Charging

Today, there are two ways to charge an EV, standard or fast. Standard charging is either Level 1 or Level 2 alternating current (AC) charging, which can provide from around 1.6 kW to 7.2 kW of power, and entails significantly less upfront cost than fast charging. Whenever a car is parked for several hours or overnight, Level 1 or Level 2 is a viable option. Charging at home, at the workplace, in parking garages, or other long-term parking situations are all are good options for replenishing a battery over time. AC charging can also fully serve the needs of plug-in hybrids (PHEVs), with their much smaller batteries of 7 kWh-20 kWh.

For BEVs, fast charging is the most appropriate public charging option in and around communities, long distance highway driving, and for shared vehicle fleets. BEVs with batteries of 60 kWh or more will need much higher power than Level 2 for charging while on the go. Direct current (DC) fast chargers from 50 kW can supply the demand for charging in and around communities, evolving to 150 kW chargers over time. DC chargers at 300 kW and higher will let drivers travel long distances in their EVs.

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Navigant Research estimates that there are currently around 1,600 locations with public DC fast chargers in the United States, excluding the proprietary Tesla SuperCharger network; EVgo's network includes 900+ of these public fast chargers. Fast charging stations in the United States are presently concentrated along the East and West Coasts. To meet the demand of the growing long-range BEV population, this number and dispersal needs to increase significantly, expanding beyond the major urban centers on the two coasts. By 2020, the total light duty BEV population in the United States is expected to surpass 1 million; by 2025, it will be over 4.2 million. This represents a significant population to utilize a national DC fast charging network.

Navigant Research's analysis of the need for community-based DC fast charging found that at least 720 additional locations would be needed to create the minimum level of coverage needed for the growing BEV population. Ideally, these stations need to be built out ahead of the growing BEV population, which presents challenges in achieving a timely ROI. Navigant Research expects that this buildout will encourage future BEV sales, and therefore will be of value to automakers as well as the growing number of BEV drivers.

1.4 The Impact of DC Charging Networks

A widespread network of DC fast chargers in and around communities and located where drivers spend 20-30 minutes or more, such as grocery stores and retailers, would have two important effects on the BEV market. First, such a network would provide BEV drivers with a degree of comfort in knowing they can recharge if need be when away from their home charger.

Second, these stations would provide charging accessibility to drivers that are not able to have a dedicated Level 2 home charger. For those living in apartments, condominiums, or a home without a dedicated parking space—as well as those not in an economic position to pay for a Level 2 charger—a widespread network of fast chargers could help open up the BEV market to a new set of customers if they were able to reliably find fast charging near their home and workplace. Navigant Research conducted a survey of US consumers, and found that access to vehicle charging is a key concern for respondents when considering a BEV. As a result, limited or inconvenient access is a potential barrier to adoption. Conversely, building out a fast charging station network that provides a foundation of accessible charging would help create a virtuous circle, where the availability of charging supports greater sales of BEVs, which in turn support the business case for existing and additional DC chargers.

1.5 DC Fast Charging Network Considerations and Opportunities

Building out such a network will require cooperation among the key stakeholders: hardware manufacturers, installers, network operators, site hosts, utilities, automakers, and regulators. Some of the key considerations for developing a network that effectively meets the needs of the market, today and in the future, are:

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- For both drivers and site hosts to get the most out of the stations, stations must be accessible to drivers. This will require some form of interoperability or reimbursable reciprocity across the charging stations to eliminate any inconvenience in charging at multiple locations.
- Such stations will have to be convenient, located in readily accessible parking areas close to multi-unit housing, retail districts, and workplaces, as well as being reliable, safe, and well maintained.
- Site hosts will benefit from support from experienced EV infrastructure companies that can guide them through the process of siting, permitting, installation, network operation, and electricity demand management.
- Site hosts and utilities will need to work closely to ensure adequate electrical power capacity at the site that does not negatively affect the distribution grid, with spare capacity for expected expansion to meet the growing demand from the BEV population.
- Site hosts and utilities will need to create mitigation strategies that anticipate the potential impact of demand charges due to anticipated peak power consumed, so that demand charges do not become a barrier to the business case for public fast charging.
- DC fast charging sites will need to be future-proofed to allow for upgrades in power as DC fast chargers shift from 50 kW to 150 kW or higher.
- Support from utilities and automakers, including financial support and rate structures that minimize the cost of energy, make DC fast charging more attractive to site hosts.

1.6 Future Mobility Models

Finally, as urban mobility moves toward on-demand, automated transportation, EVs are poised to play a critical role in this market transformation. Automated vehicles used in on-demand shared fleets—whether carsharing, ride-hailing, or on-demand mobility services—will need to be electric if these services are to avoid adding to urban pollution and fuel consumption concerns. Fast charging will also maximize vehicle availability and revenue potential for these shared fleets. As public charging stations are built out to accommodate all EV drivers, it will be important to future-proof charging infrastructure to accommodate higher power levels and the advent of automated, electrified fleets.

At the same time, the US utility sector is undergoing its own transformation, with the growth of renewables and distributed energy resources diversifying and complicating the management of the power generation mix. Charging stations will be another asset on the grid that potentially can be used in demand response programs or used to balance the increasing renewable energy portfolios. Stations can be integrated with solar and energy storage directly onsite, or can be managed to work with utilities so that the station's electricity consumption coincides with excess renewables capacity.

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Section 2
THE COMING WAVE OF LONG-RANGE BEVS

2.1 Technology Developments

Declining battery costs have positioned the plug-in EV (PEV) for dramatic market expansion in coming years. The introduction of long-range battery EVs (BEVs) that are competitive with economy brands (after subsidies) marks a threshold likely to move BEVs beyond a niche vehicle option toward eventually becoming a mainstream option for many light duty vehicle consumers. Close to 400,000 preorders of Tesla's Model 3 justifies expectations that the affordable 200+ mile BEV will be transformational. Indeed, Tesla's preorder numbers may indicate a level of pent-up demand for long-range BEVs, and have sent a market signal to other automakers. The coming introduction of multiple long-range BEV competitors to the US market promises a significant shift in the BEV landscape, with a 200-mile range becoming the norm. This shift will have important impacts on charging infrastructure needs.

2.2 EV Market Updates and Outlook

US BEV sales have increased every year since 2011. This trend continued in 2016, with sales around 20% higher than 2015. This growth in 2016 was largely due to the first full year of sales of the Tesla Model X, which was initially deployed in late 2015. Meanwhile, plug-in hybrid EV (PHEV) sales finished 2016 about 50% higher than in 2015, on the strength of a host of PHEVs introduced from luxury brands.

Navigant Research projects that US PEV sales will witness a growth rate increase of close to 50% in 2017 and 2018. This is largely the effect of long-range BEVs to coming to market, as well as continued diversification and expansion of PHEV model lines outside of small car body types.

Based on sales data thus far, the long-range BEV—which until December 2016 was only available from Tesla—has proven highly competitive. An ever-increasing number of 200-mile BEVs are anticipated over the next 10 years, beyond Tesla's and General Motor's (GM's) current offerings. Other OEMs (including Nissan, Ford, the Volkswagen Group, and Hyundai) are close behind GM and Tesla, and Navigant Research anticipates the market for mass-market BEVs will quickly move away from vehicles with ranges below 100 miles.

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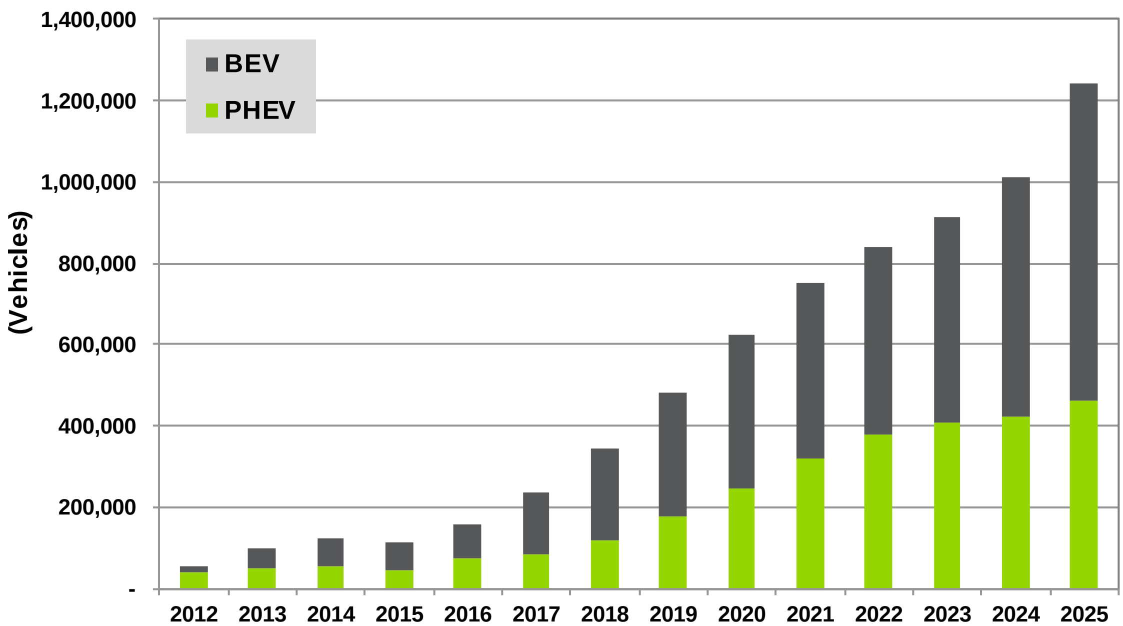
The growing availability of 200-mile BEVs, along with decreasing costs, is anticipated to speed market growth rapidly. Navigant Research projects that US sales are likely to surpass 150,000 in 2017, and by 2021 are likely to surpass 400,000 annually. By 2025—if BEVs continue their current trajectory in terms of range, cost, and availability in multiple vehicle segments—Navigant Research projects that sales will reach almost 800,000 units annually. Navigant Research expects most BEV sales will have ranges over 200 miles by 2025, but niche markets for low-cost/low-range BEVs in the 100-200 ranges will remain among some brands.

Chart 2.1 Plug-in Electric Vehicle Sales, United States: 2012-2025



(Source: Navigant Research)

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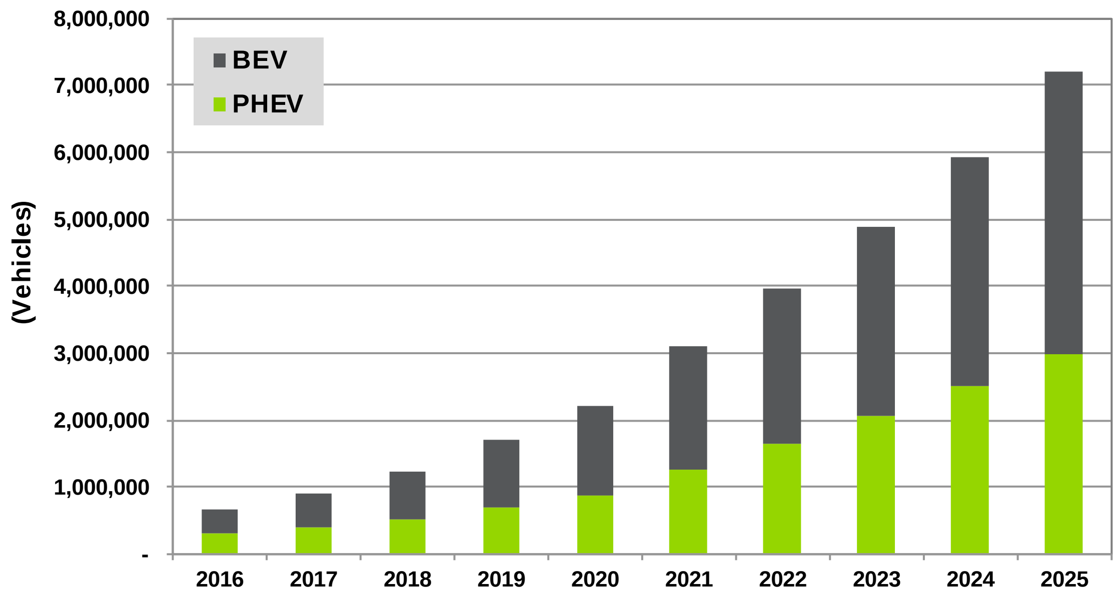
This sales rate will equate to around 4.2 million BEVs on US roads by 2025, while PHEVs would reach a population of around 3 million. This cohort of BEVs will require higher power charging and generate demand for direct current (DC) fast charging.

Chart 2.2 Total BEV and PHEV Population, United States: 2016-2025



(Source: Navigant Research)

The impact on charging demand will not be evenly spread across the United States. In 2025, the largest BEV populations are projected to be along the West and East Coasts, throughout Florida, and in pockets throughout the rest of the country.

By 2025, metropolitan regions with high concentrations of EVs are projected to include greater Los Angeles, which will have 1 in 4 vehicles as an EV. Other leaders will be Seattle, Washington (1 in 9) Portland, Oregon (1 in 11), Kahului, Hawaii (1 in 11), and Boulder, Colorado (1 in 13).

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A map of the top 100 BEV populations in 2025 reveals these higher concentrations of BEVs, and can be used to drive decisions about where to rollout DC fast charging networks. This begins with counties where the BEV population will likely grow the fastest and offer the greatest potential demand for charging, as shown in Figure 2.1.

Figure 2.1 100 Largest BEV Populations, United States: 2025

(Source: Navigant Research)

It is important to note that, while the BEV market will increasingly be led by long-range BEVs moving forward, there will still be segments of the EV driver population that will likely utilize lower power charging. Navigant Research's analysis indicates that around 15% to 27% of the US market may be attained with low-range/low-cost BEVs, and these are likely to utilize workplace charging (at Level 1 or 2) to extend the vehicle's daily range. The PHEV market will also drive demand for lower power charging, at workplaces and potentially for public opportunity charging.

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Section 3

THE STATE OF CHARGING INFRASTRUCTURE AND THE NEED FOR FAST CHARGING

3.1 Charging Infrastructure Needs Changing

The projected landscape for the charging market has shifted significantly over the past year due to the announcements of affordable, long-range BEVs. These BEV drivers will have different charging needs than those for short-range BEV drivers. Long-range BEV drivers are less likely to utilize public Level 2 charging, as they will have little need to top up their battery charge during a typical day. These drivers will likely be unwilling to park at a Level 2 charging spots for an extended time unless it is at their home, the workplace, or a few other sites where long-term parking is the norm—such as airports. However, long-range BEV drivers will be candidates for fast charging, to enable longer trips or facilitate a daily commute without a home charger. Navigant Research anticipates that this shift opens up opportunities for DC fast charging networks.

3.1.1 Where Does Charging Occur?

To understand why charging may change in the future, it is first important to understand where people are charging today. Fundamentally, there are three key factors that influence EV drivers' decisions about where and how to charge:

3.1.1.1 Time

All things being equal, a driver would prefer to have their EV recharged as quickly as possible. Charging time remains a clear drawback for EVs compared to gas cars. Table 3.1 shows how much power can be delivered by each charging type. Using the current 100-mile range Nissan LEAF as an example, at 1.6 kW, a Level 1 charger will take close to 15 hours to provide an 80% charge; a Level 2 charger will take several hours; and a 50 kW DC fast charger provides an 80% charge in just 20 minutes. The Chevrolet Bolt, with its 60 kW battery, would require over 8 hours to recharge on a Level 2 charger, and over an hour on a 50 kW unit.

Table 3.1 Charging Station Types

Type	Power
Level 1	1.6 kW
Level 2	7.2 kW
DC Fast Charging	50 kW
DC Ultrafast Charging	150 kW and above

(Source: Navigant Research)

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3.1.1.2 Convenience

Drivers will prefer to charge in locations where they have ready access and where the charging experience is not disruptive to their schedule. Convenience tends to favor home charging as the first choice, if available. It has also driven interest in charging at work or other locations where vehicles tend to be parked for longer periods of time. If home charging is not a good option, the driver has to make decisions based on upfront costs, charging opportunities, and the intended distance traveled—which is where public DC fast charging becomes an attractive alternative.

3.1.1.3 Cost

Home electricity rates offer the driver inexpensive fueling. For example, at average US electricity prices, it costs $1.00-$1.20 to give a 100-mile Nissan LEAF a full charge. However, the cost of purchasing and installing a Level 2 home charger is a counterfactor. These costs include not only the charger itself, which presently range from $500 to $800 for most 30 amp units, but also the installation costs. These costs vary widely, depending on a number of factors, from around $200 to over $1,000.

3.1.2 How Do Consumers Make Charging Decisions?

It is the nexus of time, cost, and convenience that leads to consumer decisions about where and how to charge. Today, the conventional wisdom is that most charging will occur at home if the driver is able to install a home charger or has a garage where vehicles can reliably be parked for long periods. This offers the benefit of convenience and inexpensive fueling. This is certainly true today: analysis by the Idaho National Laboratory has indicated that that over 80% of charging of PEVs today occurs at the drivers' home.

It is also assumed that the workplace is the second-most likely charging location—since the workplace is where most Americans spend the most time, after the home. Finally, most drivers will utilize other types of charging on a more ad hoc basis—at leisure destinations, shopping centers, or other travel stops.

This conventional wisdom has led to the well-known pyramid of EV charging demand, pictured to the right. However, the pyramid may not apply to the next generation of EV drivers. With long-range BEVs and the shift beyond early adopters to mainstream penetration, the time/convenience/cost nexus shifts. Sections 3.1.3 and 3.1.4 examine how the charging market developed in the first 5 years of EV availability in the United States, and what lessons can be drawn from it.

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3.1.3 Does the Current Charging Infrastructure Match Likely Demand?

The US charging market has grown largely through a combination of government subsidies or incentives and intensive business development efforts by EV charging providers. Leading up to the launch of the Nissan LEAF and Chevrolet Volt, the US Department of Energy (DOE) sought to support the success of these EVs by subsidizing charging infrastructure. This has had a significant influence on the current landscape of EV charging across the United States. As of early 2017, the United States has around 32,000 Level 2 public charging ports according to the DOE's Alternative Fuels Data Center (AFDC). Roughly 8,000 of these were deployed from 2009 to 2013 thanks to the DOE funding program.

3.1.4 Key Lessons Learned

The effectiveness of public Level 2 charging networks serving the EV market has been decidedly mixed. Some of this can be attributed to early market growing pains. EV charging network providers began the rollout of Level 2 public chargers with little real data or insight into where and how much EV drivers would want to charge outside the home or the workplace. There was a significant learning curve for the EV service providers (EVSPs) and for the site hosts, who in general were not familiar with the benefits or costs of hosting a public charging station.

This learning stage frequently has led to challenges for drivers in using stations. There were numerous tales of drivers pulling up to a station only to find it not operational. Access to the stations was not always easy (stations found deep in parking garages or behind buildings), and using the station itself was not always a simple process. Stations have a variety of ways they can be activated: via a credit card, via a network dongle or swipe card specific to each network operator, or via phone. This lack of uniformity stems from some EV charging providers leaving decisions about customer interface and pricing to each site host. This creates confusion for the customer, potentially creates delays in accessing the unit, and occasionally prevents access altogether. This kind of experience is frustrating for a driver and should be avoided in future public charging network deployments, which must be more customer-service oriented. Early adopters of PEVs are more inclined to tolerate these challenges, but the broader consumer population will not. The need for an intuitive interface and a consistent customer experience are discussed further in Section 4, "DC Fast Charging Opportunities."

But the bigger question for the public Level 2 charging market is whether such a network is truly in demand by PEV drivers, and whether there is a solid business case for it. Again, the record here is mixed. Early in the market, many public chargers were free to use, often thanks to having been government subsidizes. This strategy made sense when site hosts wanted to encourage drivers to become accustomed to using public charging networks. However, many public chargers now charge a fee. The evidence to date on utilization is

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that drivers' demand for public Level 2 charging is price sensitive, with little appetite for paying more than a dollar or two for a session, if that.

Looking at the typical upfront cost of a Level 2 alternating current (AC) charger and costs of electricity usage and networking fees or revenue sharing, a station would need to have at least five charging sessions a day at $2.00 a session to provide a timely ROI. Utilization data from the Idaho National Laboratory study suggests that PHEV drivers have an interest in topping up during brief stops to maximize their electric-only driving. Short-range BEV drivers also find some benefit from using public Level 2 charging, but appear unlikely to depend on it for primary fueling.

What do these experiences suggest about how to build infrastructure to meet the needs of the next wave of EV drivers?

3.2 How to Think About Charging Infrastructure Going Forward

Going forward, the needs of EV drivers for charging infrastructure will look quite different than it has in the past 5 years. These changing needs will reward new ways of thinking about charging beyond the traditional pyramid:

- **Home:** Home charging will continue to be a favored option for drivers with the ability to charge at a single-family home. However, Level 1 home charging will be less attractive for long-range BEVs, as it will be untenable to do a significant recharge at Level 1 if the BEV has dropped below 50% charge. These drivers will likely feel the need to purchase a Level 2 charger if they can afford the upfront costs. Since buying and installing a home charger can typically add $700-$1,200 to the purchase of a BEV, there is an opportunity here for a widespread public EV charging network to be utilized instead, if that DC charging is priced competitively.
- **Workplace charging:** Demand for workplace charging from long-range BEV drivers could wane depending on the cost relative to home charging. Since daily driving needs are likely under half of a BEV's total range, drivers likely would only take advantage of workplace charging if it is reasonably priced or offered as a free perk. Level 1 and 2 units will still be the preferred technology at workplaces, given that companies will need to minimize costs of these services and given that drivers will park at these spots a long time. In addition, these lower power chargers will serve the PHEV drivers and drivers of lower cost, lower range BEVs.
- **Public charging:** Public charging with Level 2 units will face declining value for long-range BEV drivers in this new landscape. As discussed, the value to drivers is already limited, with some drivers unwilling to pay a premium for the benefit of gaining a small number of miles in a short-term parking situation, and unwilling to overlook the nuisance of plugging in unless they had planned to stay at a conveniently located charging station for several hours anyway.

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Although the BEV market is moving rapidly toward a 200-mile range minimum, niches for more affordable, shorter range, urban-oriented BEVs like the Honda Clarity EV and Hyundai Ioniq BEV may continue to be offered, and these drivers may still find Level 2 charging sufficient for much of their needs. In addition, PHEV drivers will continue to use Level 2 charging. Both of these driver groups will continue to create demand for public Level 2 charging. However, Navigant Research believes that these drivers will limit their public charging to sites that are free or quite inexpensive—and convenient to their normal driving patterns.

Some retail locations will provide free or low-cost charging as an amenity to attract PEV drivers, who are already an attractive demographic to draw. Level 2 public charging, for the most part, will not be a need to have but rather a nice to have amenity when available in locations close to where people want to go and spend at least an hour. This makes the direct revenue business case for Level 2 public charging difficult for many locations going forward. Public charging for BEVs will, therefore, move to higher power DC fast charging.

- **Multi-Dwelling Units (MDUs):** Finally, for the most part the current EV infrastructure model does not meet the needs of drivers living in apartments or condominiums. In areas where the demographics and driving patterns are a good match for EVs, there is a significant percentage of residents living in MDUs. As MDUs tend to be concentrated in urban areas, the rising rate of urbanization in the United States will likely drive higher levels of residents in MDUs. The United Nations projects that the United States will have 53 urban areas with a population over 1 million by 2030, and that smaller cities will experience significant growth in this period. This market gap could be narrowed by a network of high power DC fast chargers if they are conveniently located, competitively priced, and reliable.

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Section 4

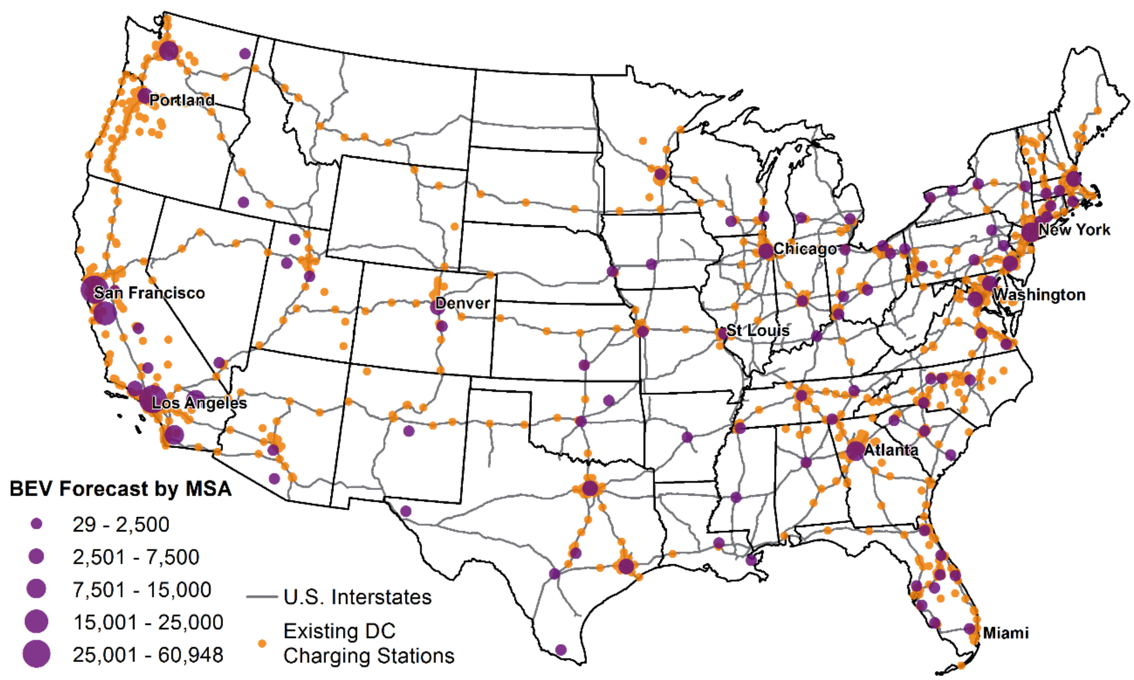
DC FAST CHARGING OPPORTUNITIES

4.1 High Power DC Charging Is the Next Frontier in Charging Infrastructure

Currently, the US DOE's AFDC reports around 3,200 public DC charging points in the United States, excluding the Tesla SuperCharger network. When Tesla is included, that number reaches around 5,700. To meet the expected growing population of BEVs, Navigant Research believes that the DC charging network needs to grow significantly during coming years, with increased emphasis put on public DC fast charging.

Today, DC fast charging stations are heavily concentrated on the West and East Coasts. This is not unexpected, as the extant BEV population is also concentrated in those regions. Figure 4.1 overlays Navigant Research's estimate of the total BEVs in place as of the end of 2016 with the existing network of DC chargers, which shows that the BEV population as of 2016 roughly tracks the DC charging deployments. However, this network of DC chargers will have to grow significantly to meet the demands of the increasing population of long-range BEVs.

Figure 4.1 BEV Population by MSA, with DC Charging Station Availability, United States: 2016



(Sources: Navigant Research, Esri, US Department of Energy Alternative Fuels Data Center, US Federal Highway Administration)

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At present, most DC charging units in the United States are 50 kW units, with some at lower power levels. These chargers are used not only for intercity and interstate driving but also for in-town driving. Analysis by the Idaho National Laboratory on DC fast charger usage in the ChargePoint and Blink networks found that, while DC fast chargers located closer to interstate highway exits tended to be the most highly utilized, fast chargers were just as likely to be used for local travel as for interstate travel. This provides insight into how BEV drivers use an extensive network of fast chargers in and around cities, with fast chargers seen as necessary for daily commuting as well as long distance travel.

As the BEV market changes, DC fast charging stations will likely need to transition to higher power than the current 50 kW standard. While a 50 kW station can charge a Nissan LEAF with a 24 kWh battery to 80% in about 20 minutes, that same 50 kW station would take about 1 hour to recharge a Chevrolet Bolt with a 60 kWh battery up to 80% capacity. DC fast charging stations must move to higher power, at a minimum of 100 kW-150 kW for charging stations serving metropolitan areas. These vehicles will also need to be able to accommodate much faster charging.

Long distance driving will likely see demand for even higher power (on the order of 300 kW or more) in order to provide a recharge time that is considered reasonable for most BEV drivers. If the EV market is to look more like the mainstream vehicle market, customers will need to be able to use EVs for similar longer distance driving as mainstream vehicles. The solution is likely to be the proliferation of ultrafast charging along highways (300 kW or more) and high power fast charging (around 150 kW) in and around high PEV adoption regions.

The push for a long distance DC charging network is already underway, with automakers, charging network companies, and some policymakers (including the US Department of Transportation) currently looking at how to build out such a network. In addition, Volkswagen will be deploying up to $2 billion in infrastructure investment in the United States as part of its settlement for the company’s diesel emissions test manipulation.

4.2 The Need for Community DC Fast Charging

Beyond the need for long distance charging, the market of long-range BEVs will both benefit from and support a broad and expansive network of public DC fast chargers in and around communities. As noted, these chargers will serve a few key purposes:

- They can offer charging services to PEVs of drivers who live in MDUs, opening up the BEV market to a new set of customers across broader socioeconomic segments.
- They can supplement drivers who do not want to or cannot afford to invest in a Level 2 charger at home, but would rather employ Level 1 at home and access fast charging at public sites.
- They can be used by drivers with home Level 2 chargers to support intercity driving.

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The upfront investment for these DC fast charging stations is significant. Today, a 50 kW dual hose charger costs $25,000-$30,000. It is estimated that a 150 kW charger could cost around $50,000-$75,000 and the 300 kW charger around $90,000-$110,000. The siting, installation and balance of system costs add considerably to the upfront investment. These costs vary significantly depending on site specifics, but can easily be two to four times the cost of the charger itself. It will be critical to the long-term revenue potential of a site that sufficient time be invested in determining the most suitable sites for DC fast charging to maximize long-term utilization and to ensure that the site can be upgraded over time to accommodate growth.

While the stations are expected to provide a solid revenue stream once the BEV market has grown and increased utilization supports profitability, the initial deployment of DC fast charging stations is likely to require some financial support from key stakeholders. These may be governments, automakers, or utilities. In addition, operational costs must be managed, particularly demand charges and rate structures. In the near term, some stations on a network may cross-subsidize less utilized stations to support drivers across geographies and use cases. Eventually, once the BEV market grows, and with projected uptakes in fleet travel and eventually in automated vehicle deployments, these stations can reach utilization levels that will provide a positive revenue stream.

4.3 The Requirements of a Successful DC Charging Network

For a network of DC fast chargers to be sustainable and successful, it will require attention to the lessons learned through the current Level 2 public charging networks and an understanding of the different needs of a DC charging network.

EV charging service providers will need to maximize utilization of the stations while managing costs in order to achieve secure an ROI. To do this, DC charging stations will need to be sited optimally, easy to find from the street, easily and safely activated, affordable, and kept in good working order. If drivers pull up to a charger and find it difficult to use, this will inhibit the demand for DC fast chargers and discourage the use of EVs.

So, what must be done? Public stations need to be readily accessible to the majority of EV drivers, and near locations that they frequent for other purposes. Optimal locations are places such as grocery stores and big box retail where people often remain for up to an hour. Stakeholders must ensure that the charger is placed somewhere at the host site where it is relatively easy to find. There needs to be clear and adequate signage so the driver is not confused about where go. The US Department of Transportation’s Alternative Fuel Corridors project will be promoting EV signage on as many as 55 corridors across the United States, but this effort will require continued cooperation among regional stakeholders with authority to establish signage and only covers a portion of the country. It is also important that the charger should not be fenced in or obscured by barriers. A significant number of public chargers cited on the DOE AFDC website indicate that the driver must call ahead or indicate some other restricted access.

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Public stations must also provide a consistent user experience for utilization to increase. This has not been the case with the current Level 2 public charging infrastructure in the United States. While today drivers have an expectation of how to operate any gas station—no matter who runs it—public charging stations can be a new and confusing experience for the driver given the variety of payment and authorization methods.

Because of the multiplicity of networks offering public charging, drivers can struggle to activate the charger itself. Ideally, networks of DC fast chargers would be able to be activated through a single mechanism. If multiple networks are running these chargers, they need to either allow other network cards to activate these chargers or there needs to be a universal access mechanism, such as single app that can be used to locate and activate stations. This adds a challenge for the network operators, as they would be required to cross-bill with and/or reimburse other service providers, similar to an ATM card providing access to any bank machine.

Companies considering adding DC fast charging stations must also consider how to future-proof their investments, given that preferred charging levels will be rising from 50 kW to 150 kW and higher within the next 5-10 years. There is a tradeoff between keeping down the cost of building out a DC fast charging station by avoiding cost in adding power delivery today, versus having to replace the existing equipment in future years. Ideally, today's station operators installing equipment will ensure there is adequate power available to the location when the station transitions from a 50 kW to a 150 kW or higher unit. This requires some level of engagement with utility stakeholders to avoid penalizing future-proofed sites on their capability to draw electricity from the wiring versus what current stations are positioned to discharge. Site hosts should consider the impact of adding more chargers at the location as well, to accommodate the demand from the growing BEV fleet.

EVSPs will need to coordinate with utilities to identify locations where they will not be disrupting the distribution grid as the station grows. More importantly, they will need to evaluate the potential for demand charges—which can be considerable and would devastate a ROI opportunity. Locations that incur significant demand charges due to DC fast charging sessions can become cost prohibitive to operate if these charges are not included in the business planning; in some cases, if the charges are extremely high, the business case becomes untenable.

To successfully address these issues, site hosts will require significant levels of guidance in deploying fast charging. At times, the initial sale of the chargers to a site host has been perceived as the most difficult challenge in the EV infrastructure market. In reality, site hosts require guidance throughout the deployment process. Issues such as site selection, network management, electricity load management, and demand charges likely are not fully understood by many of the sites most likely to host a DC fast charger—e.g., grocery stores and other retail outlets. Entities with experience siting, constructing, and operating

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will provide advantages for hosts and networks alike, and continue to service the stations and the site hosts throughout its operation.

4.4 Stakeholder Cooperation

Addressing the business challenges, expanding the charging networks, and improving the EV customer experience will require cooperation from a number of key stakeholders.

The role of utilities is especially critical. At a minimum, utilities will need to be aware of potential load spikes around DC charging facilities, and will need to work with station hosts and regulators to reduce the impact of demand charges. Demand charges have the potential to disrupt the ROI pathway for DC charging by preventing stations from being revenue positive. For some utilities, this may involve updating or creating rate programs to accommodate the cost and benefits of fast charging loads.

US utilities are beginning to become more engaged in the EV infrastructure market, presenting partnering opportunities for charging network operators. This partnership can help utilities by providing the expertise they lack in charging equipment siting and management, while the utilities focus their strengths in the needed grid infrastructure, maintenance, and power management. If EV charging infrastructure is managed through a network provider, that helps ensure the consistency and ease-of-use needed in a customer-focused charging experience. Customer choice and competition can be enhanced by identifying the instances where partnering makes business sense for both parties versus those where the economics favor either a utility or a charging network.

In several areas, utilities are identifying potential revenue opportunities from EV charging beyond load growth. EV management is being considered as part of a utility's broader distributed energy resource and demand-side management strategy by taking a more active role in grid management and coordinating activities with EV charging network operators. These additional use cases can make EV charging management across all power levels more compelling to explore, although it should be noted that the applications for short dwell-time DC fast charging are not yet clear.

Policymakers and regulators are expected to play a key role in DC charging rollouts. Local regulators will be engaged on a number of fronts, from site permitting to street signage. Policymakers looking to support growth of EVs locally could also have a role to play in providing incentives or other support for public chargers, especially given the significant upfront investment required to deploy DC fast charging stations.

Automakers are another crucial stakeholder partner in this effort. At a minimum, OEMs can continue to partner with network operators to ensure that customers are aware of the DC charging facilities and to help direct them to the use of these chargers, through dealership programs and in-vehicle navigation systems. But automakers are entering a new realm with EVs by participating in infrastructure buildout. OEMs will likely find it beneficial to

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support the rollout of public DC fast charging through collaboration or partnerships with EV charging network providers. This has been done already with some smaller Level 2 and DC charging initiatives. These partnerships can help support both the sale of vehicles and the stations themselves as they seek to become independently financially viable.

In the broader rollout of DC fast charging, OEMs and EV charging networks can collaborate on siting decisions, with the network providing valuable data on utilization. Charging networks can also manage and maintain stations more effectively than an automaker can over the long-term, and would be able to integrate the stations developed by various automaker initiatives to make them easily accessible to more drivers.

These elements of the rollout will benefit from a central network manager with experience engaging with various stakeholders and managing their interactions with site hosts.

4.5 Grid Integration Opportunities

The widespread deployment of BEVs offers some challenges for load management, but also considerable opportunities for absorbing excess capacity and balancing renewable generation assets. In the immediate future, utilities are most likely to be focused on ensuring that the growing fleet of BEVs with batteries at 60 kWh or higher and fast charging capability does not overwhelm local transformers.

However, long-range BEVs also represent an increase in load that could be used to consume renewable electricity generation. While the EV load will remain small relative to overall demand, the potential to manage fast charging could make electricity marginally cheaper and cleaner with reduced upfront cost when compared to other sources. Longer term, there are interesting opportunities for managing and monetizing these vehicles through vehicle grid integration by managing both AC and DC charging.

The concept of vehicle grid integration functions by EVs providing services to the grid by changing the rate they consume power—known as vehicle-to-grid for charge management (V1G)—or by providing power back to the grid—known as vehicle-to-grid power transfer (V2G). V1G is like to occur more frequently with AC charging due to the on-demand nature of minimizing charge time of DC fast charging and the greater frequency of AC charging sessions, especially in residences.

However, encouraging DC fast charging in regions where peak renewable power production outstrips demand (such as in Texas, California, and Hawaii) can be a grid benefit, especially when combined with stationary storage. Site hosts can create multiple revenue streams for stationary storage by using them to absorb excess capacity from wind or solar generation, and then tap into the batteries for fast charging, thus avoiding demand charges. They can also use storage to provide lower power regulation services to the grid throughout the day, which can significantly shorten the payback period

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DC charging may offer an early pathway to exploring the benefits of V2G. An EV with a DC charging port can be used for bidirectional power, since the charge management and AC to DC conversion occurs outside of the vehicle at much higher rates than AC charging. Therefore, initial bidirectional EV charging could be made capable through the DC charging port since that does not require an onboard charger or inverter. In this context, DC chargers can be easier to aggregate load and V2G power from vehicles, whether providing grid services or to power a building as a temporary resource. However, this application is still in early pilot stages so it is not clear how this market will develop.

4.6 The Future is Automated, Shared, and Electric

Shared mobility services will be an increasingly significant part of the transportation system in metropolitan areas. Automakers and technology companies are developing automated driving systems with an eye toward introducing fully automated systems initially through fleets services, especially shared fleets. Navigant Research expects that these shared transportation services will see a much higher percentage of EVs than the general vehicle population. Already, EVs are an early market for shared vehicles with higher levels of autonomy. For example, GM has invested in and partnered with Lyft to use Chevrolet Bolt EVs in its fleet, while Uber is launching test fleets of BEVs from Nissan and BYD and preparing to build out DC fast charging stations.

Future shared automated fleet vehicles are likely to be in near constant use, accruing much higher annual mileage than a typical consumer car does today. This increase in miles traveled will counteract the impact of improved fuel efficiency in the consumer vehicle market coming from federal and state regulations. Using EVs will offset the negative impacts of increased vehicle miles driven.

For the automated fleet operator, EVs offer the potential for recharging without human intervention and fuel cost savings over gasoline vehicles—something that will be especially important with high mileage vehicles. Moreover, maximizing the availability of these vehicles to create revenue requires access to DC fast charging. As urban areas serviced by automated EVs expand over time, it will be necessary to secure charging locations to facilitate opportunistic charging while keeping vehicles available close to where passengers need them. While this mobility transformation will not happen overnight, in addition to servicing individually owned BEVs a community-based DC charging network could support the transition to automated vehicles, providing fast opportunity charging for fleets of automated, shared vehicles.

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Section 5

CONCLUSIONS AND RECOMMENDATIONS

The buildout of a substantial network of public fast charging stations in US communities will create a positive feedback loop in the BEV market. A highly visible and easily accessed DC fast charging network will serve the coming fleet of long-range BEVs and also open the BEV market to drivers without a home charger. The increase in BEV sales will drive greater utilization of the DC charging stations, creating a more attractive business case for deploying DC charging stations. This will likely lead to further expansion of the network of stations, which in turn supports increased BEV sales.

Sustaining this infrastructure investment cycle will require profitable utilization of these DC charging stations. To ensure that stations achieve high utilization levels as the BEV fleet increases, stations must be placed in locations frequented by EV drivers and provide a consistent, convenient customer experience. An appropriately priced, fast charging network available at retail or similar locations that drivers regularly visit would provide consumers with a sense that driving a BEV is not distance limiting, and that charging can be integrated into their regular lifestyle.

Potential site hosts are unlikely to be experienced in the deployment of high power charging stations. They will need guidance on a multitude of issues, from the initial site selection to network management to electricity load management and ongoing maintenance and future upgrades of the stations. An experienced network operator can provide the guidance needed for these site hosts.

The buildout of a successful network will require significant upfront investment and cooperation among stakeholders. EVSPs, utilities, automakers, and government agencies will be the front line for creating a successful, viable network of DC fast chargers. These stakeholders will need to cooperate to ensure that the network is designed to meet the needs of average drivers; that the stations are future-proofed against growing power demands as the stations scale up; that station operators are not burdened by demand charges that eliminate the business case for the stations; and that community-based DC charging can be used to serve fleets of shared automated vehicles as these enter the market.

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Section 6

ACRONYM AND ABBREVIATION LIST

AC .... Alternating Current

AFDC .... Alternative Fuels Data Center

BEV .... Battery Electric Vehicle

DC .... Direct Current

DOE .... Department of Energy (United States)

EV .... Electric Vehicles

EVSP .... Electric Vehicle Service Providers

GM .... General Motors

kW .... Kilowatt

kWh .... Kilowatt-Hour

MDU .... Multi-Dwelling Unit

MSA .... Metropolitan Statistical Area

OEM .... Original Equipment Manufacturer

PEV .... Plug-In Electric Vehicle

PHEV .... Plug-In Hybrid Electric Vehicle

ROI .... Return on Investment

US .... United States

V1G .... Vehicle-to-Grid for Charge Management

V2G .... Vehicle-to-Grid Power Transfer

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Section 7

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Section 8
TABLE OF CHARTS AND FIGURES

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Section 9
SCOPE OF STUDY

This white paper examines the shift toward long-range BEV adoption in the United States from 2016–2025 and the how this shift will create a need for a network of DC fast charging stations to accommodate customer demand and to support the growth of the BEV market. This paper draws upon Navigant Research analysis of the plug-in vehicle market and the EV charging infrastructure market in the United States and globally. The goal is to present an objective analysis of the benefits and challenges (or drivers and barriers) to fast charging infrastructure deployment in the United States.

SOURCES AND METHODOLOGY

Navigant Research's industry analysts utilize a variety of research sources in preparing Research Reports. The key component of Navigant Research's analysis is primary research gained from phone and in-person interviews with industry leaders including executives, engineers, and marketing professionals. Analysts are diligent in ensuring that they speak with representatives from every part of the value chain, including but not limited to technology companies, utilities and other service providers, industry associations, government agencies, and the investment community.

Additional analysis includes secondary research conducted by Navigant Research's analysts and its staff of research assistants. Where applicable, all secondary research sources are appropriately cited within this report.

These primary and secondary research sources, combined with the analyst's industry expertise, are synthesized into the qualitative and quantitative analysis presented in Navigant Research's reports. Great care is taken in making sure that all analysis is well-supported by facts, but where the facts are unknown and assumptions must be made, analysts document their assumptions and are prepared to explain their methodology, both within the body of a report and in direct conversations with clients.

Navigant Research is a market research group whose goal is to present an objective, unbiased view of market opportunities within its coverage areas. Navigant Research is not beholden to any special interests and is thus able to offer clear, actionable advice to help clients succeed in the industry, unfettered by technology hype, political agendas, or emotional factors that are inherent in cleantech markets.

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