REDUCING EV CHARGING INFRASTRUCTURE COSTS

BY CHRIS NELDER AND EMILY ROGERS

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ACKNOWLEDGMENTS

This work was funded by Energy Foundation. The authors gratefully thank the anonymous study participants who made this work possible.

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SUGGESTED CITATION

Chris Nelder and Emily Rogers, *Reducing EV Charging Infrastructure Costs,* Rocky Mountain Institute, 2019, **https://rmi.org/ev-charging-costs**.

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As utilities and private sector charging networks begin to move beyond the early pilot stage and start building charging infrastructure for electric vehicles (EVs) at scale, it is increasingly important for both utility buyers and utility regulators to understand what charging infrastructure components cost. This is particularly true where utilities own, operate, and recover the cost of EV charging infrastructure through the general rate base, to ensure that ratepayer dollars are invested wisely and in the public interest. Federal, state, and local municipalities, transit agencies, fleet operators, and businesses that want to install workplace chargers also need to understand the wide ranges of these costs and the trade-offs involved in reducing costs.

However, because of wide variability in the cost of nearly every element of charging infrastructure, as well as vendor concerns around protecting proprietary information and competitive advantage, it has been difficult to identify and compare these costs across various vendors and installations.

To address this need, we probed the industry for recent cost data, summarized in this study, which we drew from numerous sources, including literature, publicly available information on utility procurements, and two dozen original interviews that we conducted under nondisclosure agreements with utilities, hardware providers, software providers, operators of charging networks, transit agencies, states, laboratories, contractors, and consultancies. The data are summarized in the table below.

EXHIBIT 1

Cost ranges for charging infrastructure components.

COST ELEMENT	LOWEST COST	HIGHEST COST
Level 2 residential charger	$380 (2.9 kW)	$689 (7.7 kW)
Level 2 commercial charger	$2,500 (7.7 kW)	$4,900 (16.8 kW); outlier: $7,210 (14.4 kW)
DCFC (50 kW)	$20,000	$35,800
DCFC (150 kW)	$75,600	$100,000
DCFC (350 kW)	$128,000	$150,000
Transformer (150–300 kVA)	$35,000	$53,000
Transformer (500–750 kVA)	$44,000	$69,600
Transformer (1,000+ kVA)	$66,000	$173,000
Data contracts	$84/year/charger	$240/year/charger
Network contracts	$200/year/charger	$250/year/charger
Credit card reader	$325	$1,000
Cable cost	$1,500	$3,500

Note: DCFC denotes direct-current fast chargers.

We also sought to understand where the best opportunities may be to reduce the total cost of deploying EV charging infrastructure. (In this study, we do not address Level 1 charging, which requires no additional infrastructure, or operational costs such as utility bills, which we addressed in previous papers.[i])

What we discovered is that the cost of EV chargers is following a progression that is very similar to that seen in the solar sector over the past decade: The cost of hardware components that are (or could be) manufactured at scale is already declining along a typical "experience curve" (see Exhibit 3) for a new technology, as manufacturers gradually find ways to squeeze cost out of their processes. Software systems are a relatively small part of total infrastructure cost and do not present a significant cost reduction opportunity.

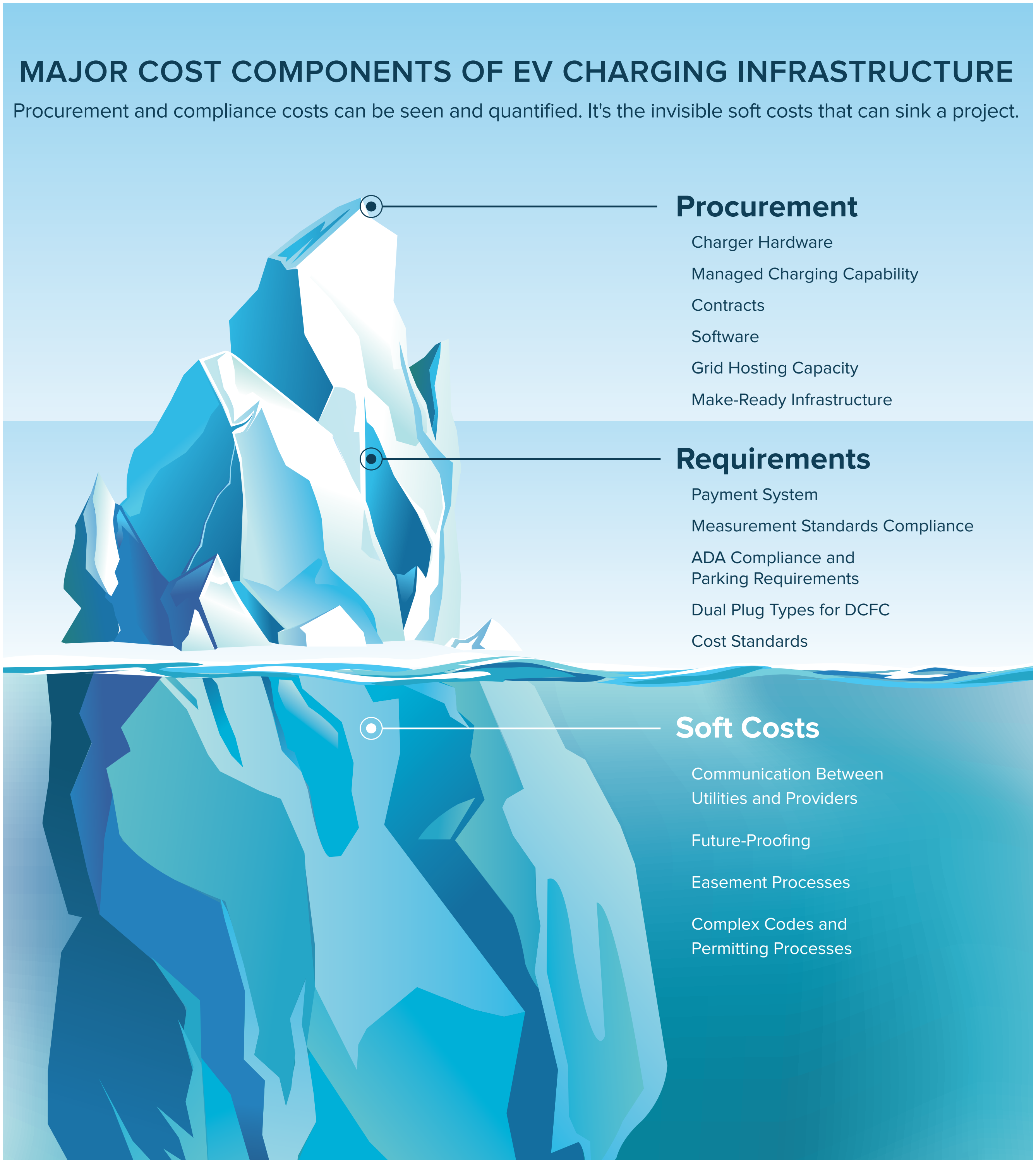
[i] For our previous studies on how utility tariffs affect the cost of operating DCFC networks, see the September 2019 *DCFC Rate Design Study* (https://rmi.org/insight/dcfc-rate-design-study) and March 2017 *EVgo Fleet and Tariff Analysis* (https://www.rmi.org/wp-content/uploads/2017/04/eLab_EVgo_Fleet_and_Tariff_Analysis_2017.pdf).

To our surprise, we found that the greatest opportunity for cost reduction lies in "soft costs": process costs, marketing costs, opportunity costs, the cost of delays in permitting, and so on (see Exhibit 2). These costs are poorly understood, very hard to quantify, and almost entirely undocumented in the literature. We strongly suspect that soft costs are a big part of the reasons why charger installation costs in the United States are three to five times the cost of the charger itself, a much higher ratio than that seen in Europe (even after allowing for some charging hardware in Europe having higher costs). Indeed, soft costs were frequently cited as more significant cost drivers than charging station hardware in the United States.

The primary aim of this study is to arm all stakeholders with a comprehensive study of the costs involved in deploying charging infrastructure, to ensure greater program success and a more rapid transition to transportation electrification. Ultimately, we believe our study makes a compelling case for why much more extensive exploration of soft costs in EV charging infrastructure in the United States is needed.

EXHIBIT 2

Major cost components of EV charging infrastructure.



1 THE COST CONUNDRUM

THE COST CONUNDRUM

As utilities begin to move beyond the early pilot stage and start building or supporting the development of charging infrastructure for electric vehicles (EVs) at scale, it is increasingly important for utility regulators and utility procurement agents to understand what components should and do cost, to ensure that ratepayer dollars are invested wisely and in the public interest. This is particularly true where utilities own, operate, and recover the cost of nonresidential EV charging infrastructure through the general rate base. Federal, state, and local municipalities, transit agencies, fleet operators, and businesses that want to install workplace chargers also need to understand the wide ranges of these costs and the trade-offs involved in reducing costs.

Utility regulators have been vocal in their requests for current and comprehensive data about the costs of charging infrastructure. However, because of wide variability in the cost of nearly every element of charging infrastructure, as well as vendors' desire to protect proprietary business practices to maintain their competitive advantage, it has been difficult to identify and compare these costs across various vendors and installations. That is the need that this report attempts to address. (Most of this report focuses on nonresidential installations designed for light-duty vehicles, although much of the Level 2 data and recommendations are applicable to residential installations. Our general process-oriented recommendations apply equally to the medium- and heavy-duty sectors.)

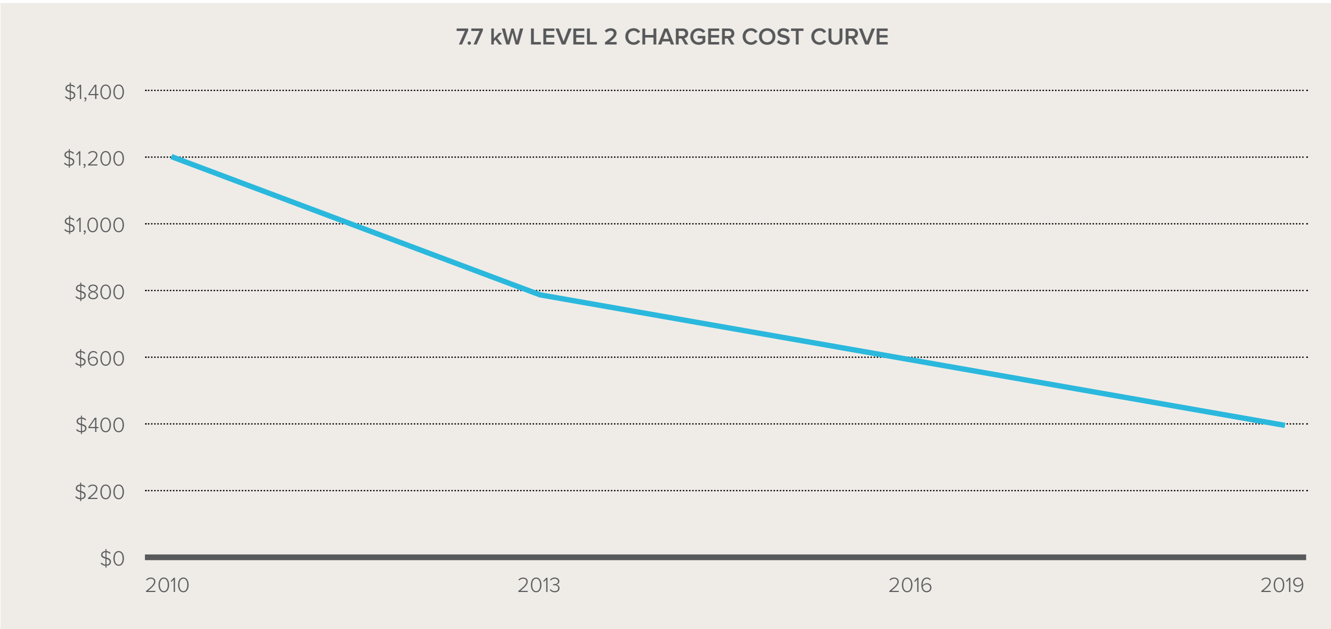
As Exhibit 3 shows, the costs of non-networked charging station hardware are falling at typical rates for technologies that are just starting down their "experience curves," as manufacturers learn how to refine their production processes.

It is likely that the cost of charging station hardware will continue to decline without any special intervention or regulatory guidance; as the EV charging industry matures, demand for charging infrastructure increases, and manufacturers scale up production.[ii] Even so, we offer some suggestions that can accelerate cost reduction.

[ii] Offsetting the natural decline of hardware costs as measured on a per-kW basis is a counter-trend toward larger and more powerful charging stations. So the apparent, absolute cost of procurement may not decline, or could even increase, even as hardware is getting cheaper at a component level.

EXHIBIT 3

Experience curve for Level 2 charger over nine years.



Source: C. Botsford

Unlike the trends in hardware costs, soft costs for nonresidential charging stations—such as the costs of acquiring sites, meeting local building codes, and participating in extended processes for obtaining utility interconnections, easements, and local building permits—are not so easily reduced. A surprising finding of this study was that these soft costs were frequently cited as more significant cost drivers than charging station hardware. Soft costs were also identified as some of the most problematic and unpredictable costs that developers of charging networks encounter, and they are often the reason why a candidate site for a charging station is rejected or abandoned, even after significant expenses have been incurred in its development. Worse, when a site under development must be abandoned, the normal expenses incurred for activities like securing a site lease, designing an installation, and building it can be compounded by additional costs such as late fees and penalties.

As a 2015 study for the US Department of Energy on nonresidential charging stations put it, "Installation costs, however, are highly variable and there is no consensus among industry stakeholders about the direction of future installation costs."[1] Although our study offers more up-to-date information about an industry that is evolving and expanding rapidly, we would say that statement still holds true. Without more investigation into and transparency about soft costs, and ways to avoid or reduce them, the direction of installation costs will remain unclear.

DATA COLLECTION PROCESS

To obtain the data for this study, we conducted interviews under nondisclosure agreements, with the assurance that all data would be anonymized and reported in aggregate fashion. We conducted 24 interviews with a variety of organizations, including utilities, hardware providers, software providers, operators of charging networks (known colloquially as electric vehicle supply providers or EVSPs), transit agencies, states, laboratories, contractors, and consultancies. These interviews were helpful in assigning values and magnitudes to component costs and opportunities, even when quantitative data were challenging to obtain or compare. We supplemented this information with additional research on publicly disclosed project budgets, data published in the literature, and component costs listed publicly on vendor websites.

CHALLENGES IN DATA ACQUISITION AND COMPARISON

A few factors made it challenging to obtain and compare data in this cost study.

First, given the relative nascence of the EV charging market, vendors are reluctant to disclose component costs, as doing so could reduce their competitive advantage. Accordingly, some of the sources we interviewed for this study were hesitant to share full-cost data or to share it at the component level. Even in the publicly available data from utility procurements, many components of chargers and their installations were aggregated, obscuring costs at the component level.

Second, because chargers come in such a wide variety of configurations, it can be challenging to compare their costs. For example, we found a range of $380 to $4,900 for Level 2 chargers, which reflects differences such as residential or commercial installations, different power ratings (2.88–19.2 kW), different levels of weatherproofing, different numbers of ports, different payment systems, different communications systems, and different types of cable management systems. Without being able to distinguish the costs of individual components of each of these chargers because of the way they are manufactured or procured, or to obtain cost data from multiple vendors for a specific configuration of charger, comparing charger costs is challenging.

Third, installation costs were often calculated and reported on a per-site basis. Because utilities and installers calculate installation costs such as trenching based on a specific site and number of chargers, it was challenging to convert these costs to something that would enable a comparison on a per-charger or per-kW-of-capacity basis. For example, if a project's total trenching cost is summed and reported across several sites, each with different numbers of chargers and unique distances to the electrical power source, it would be incorrect to calculate an average trenching cost per site or per charger.

Finally, soft costs are hard to rationalize and compare because they vary widely among projects. For example, delays in obtaining utility easements and grid interconnections can add weeks, months, or more than a year to a project schedule. The cost of complying with certain requirements, like Americans with Disabilities Act (ADA) accessibility, can be negligible in one location and extremely expensive in another. And opportunity costs are not formally defined. Accordingly, rather than attempt to rigorously quantify soft costs in this study, we identify some major areas of concern that legislators, regulators, elected officials, and municipal agency staff can address.

2 PROCUREMENT

PROCUREMENT

Most major procurements of charging infrastructure, whether by a utility or a private company, include some common components:

- Hardware and software
- Network access contracts and/or cellular data contracts
- Maintenance contracts

The costs reported for these elements vary by utility, manufacturer, or provider, and it is not always possible to discern why costs vary as they do, particularly in this relatively early stage of the market.

Hardware costs primarily consist of chargers,[iii] plus "make-ready" hardware such as distribution feeders, transformers, meters, and the service drop (see diagram below). To the extent they were willing to do so, we asked the experts we interviewed to share the costs of these components and to suggest where there may be opportunities to reduce their costs.

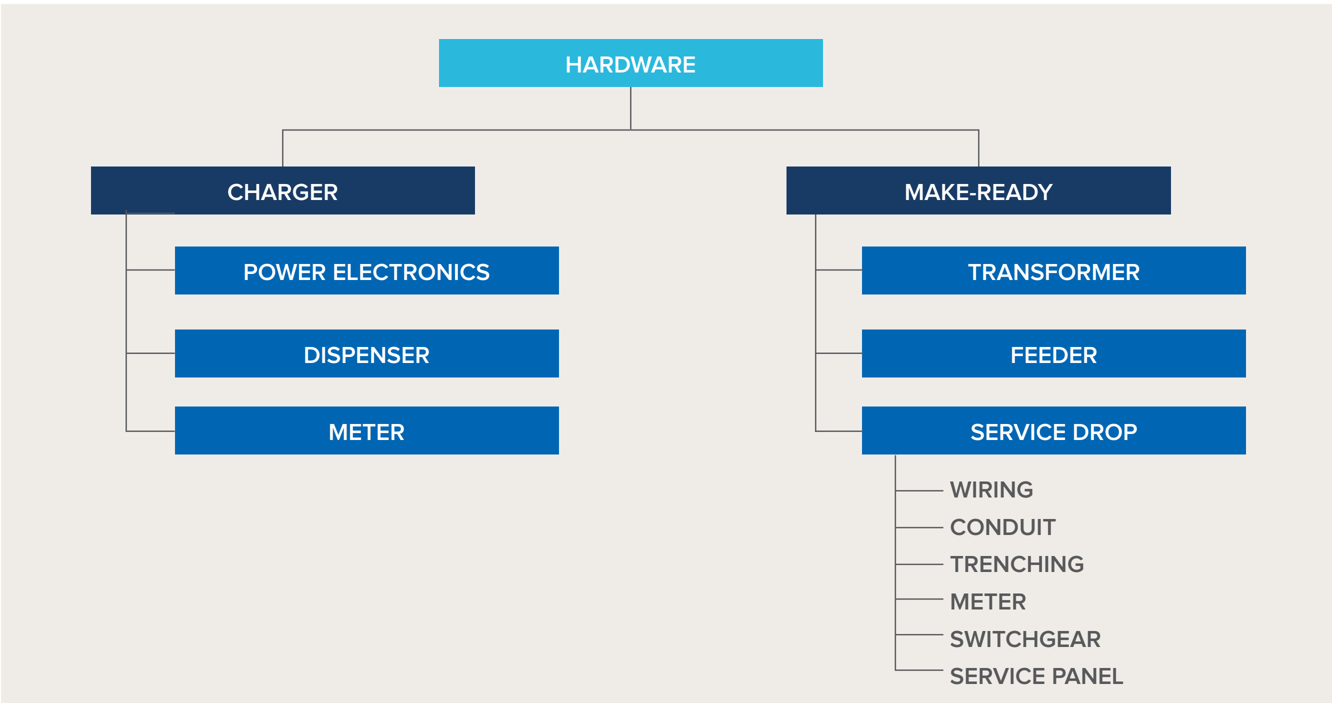
We found that the three biggest drivers of procurement costs are:

- The power rating of the chargers or the total power requirements of a site with multiple chargers
- The existing grid power capacity at the site
- The location of the chargers within the site (excluding chargers at single-family homes)

[iii] Throughout this report, we use "chargers" in a generic sense to mean charging stations (sometimes also referred to as EVSE [electric vehicle supply equipment]) that are entirely self-contained units. However, modern high-speed kiosk-style charging stations are more likely to have a "dispenser" located next to a parking space that holds the charging cable, whereas other key components—such as an AC to DC converter, voltage regulation equipment, switchgear, power cabinets, and (optionally) battery storage—are typically located elsewhere on the site.

EXHIBIT 4

Major elements of charging infrastructure hardware.



Communications and network access contracts, maintenance contracts, and software management systems all contributed lesser shares of total project costs than these three drivers.

As a share of total project costs, the elements of a charging site (charging hardware, management software, and maintenance and communications contracts) are typically 10%–30% of the total. The rest of the project costs are in utility grid hardware and the various aspects of installation, including soft costs. In one proposed budget for a California corridor project, of the $129,000 allocated to "materials and miscellaneous," 11.6% was for conduit, 22.5% was for feeder wire, and 17.8% was for trenching. The remaining 48% of the budget was spread across various breakers, additional wiring, electrical panels, nuts and bolts, permits and drawings, and other smaller construction and installation line items.

CHARGER HARDWARE

For both Level 2 and direct-current fast chargers (DCFC), cost correlates with power rating: the higher the charger's rating, the higher the cost (although the relationship between power and cost is not linear). This is especially true for DCFC, where higher-power chargers must be equipped with liquid-cooled cables so they can deliver more power without overheating and still be light enough for a person to lift and use them.

A number of configuration characteristics can also add significant costs to a charger's final price tag:

- Whether a charger is "smart" or "dumb"
- The number and types of communications systems (Wi-Fi, Ethernet, cellular)
- The number and length of charging cables on a dispenser
- The need for cable retractors and cable management systems

- The type of electricity meter
- The type of authentication and payment system
- Whether a charger is wall-mounted or has a pedestal or pad
- The degree of weatherproofing and durability

Level 2 chargers designed for residential applications are typically much cheaper (often less than $500) than nonresidential chargers because they are typically wall-mounted in a weatherproof location such as a garage. Commercial Level 2 chargers and DCFC designed for use by the public and exposed to the elements are usually weatherized and installed on a pad or pedestal, all of which add cost to the chargers.

The range of costs for Level 2 chargers and DCFC are shown in Exhibit 5 and Exhibit 6, respectively.

EXHIBIT 5

Range of Level 2 charger costs.

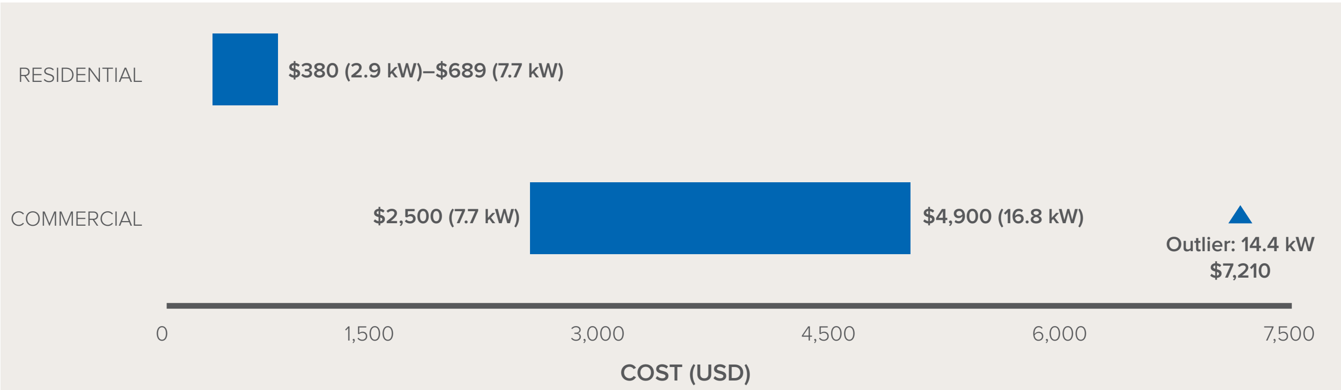
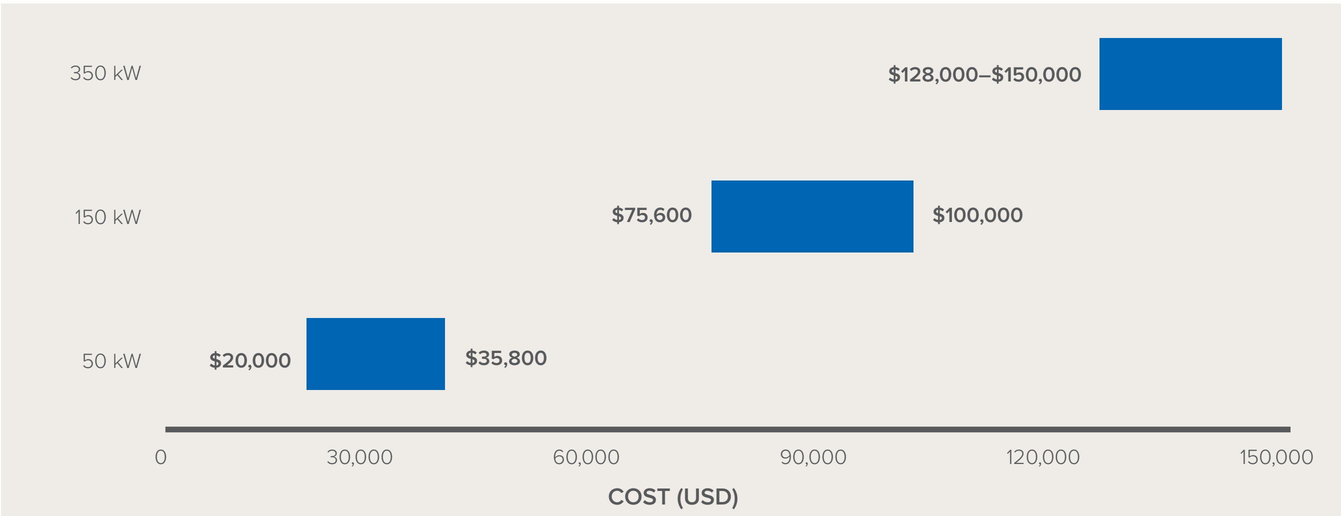


EXHIBIT 6

Range of DC fast charger costs.



The difference in cost between residential and commercial Level 2 chargers is also evident when comparing them on a per-kW basis, as shown in Exhibit 7. The higher costs for commercial Level 2 chargers reflect the additional costs of such features as weatherproofing, mounting style, durability, and networking and communications. Commercial Level 2 chargers and DCFC have comparable costs per kW, despite their very different power ratings.

EXHIBIT 7

Charging station hardware cost ranges per kW.

CHARGER TYPE	KW RATING	MINIMUM COST/KW	MAXIMUM COST/KW
Level 2: Residential	2.9	$131	
	5.8	$87	$98
	7.7	$52	$90
Level 2: Commercial	7.2	$444	$542
	7.7	$326	$391
	9.6	$396	$448
	14.4	$501	
	16.8	$292	
DCFC	50	$400	$716
	150	$504	$667
	350	$366	$429

lowest cost highest cost

MANAGED CHARGING CAPABILITY

To respond to grid conditions and reduce the total cost of vehicle-grid integration, it is important to enable "managed charging": deliberately charging during the low-demand hours on a utility grid, when providing power is inexpensive, and avoiding charging during the peak demand hours, when providing power is expensive. In addition to responding to grid conditions, managed charging also enables greater integration of variable renewable generation on a power grid, by matching the flexible load of EVs to hours when solar and wind generation is abundant.[2]

One way to enable managed charging is by using "smart" chargers that are networked so they can perform two-way communications with the utility or another entity that manages the chargers remotely. The entity managing the charging can turn the chargers on or off, or adjust the rate of charging up or down, to respond to grid conditions. A "dumb" charger is typically not networked and simply delivers as much power as the vehicle will allow. Smart chargers typically support billing, connectivity with control apps, and other customer services. More advanced smart chargers are compliant with the ISO 15118 specification and support the Open Automated Demand Response (OpenADR) standard so they can deliver grid services. (We discuss standards in more detail below.)

The most common type of managed charging is responding to a utility's time-of-use tariff, which helps drivers minimize the cost of recharging by charging when electricity costs are low and avoiding charging when they are high. Another form of managed charging is turning down the rate of charging or turning the charger off entirely when grid conditions are constrained, or when directed by a demand response signal from the utility.[iv] Although the additional technology required to make a Level 2 charger smart typically costs less than $50; some smart chargers can cost as much as $500 more than a non-networked equivalent. The cost premiums for smart chargers can be highly variable, and they will likely fall as manufacturers achieve economies of scale. But because managed charging will play a critical role in demand management, especially as EV adoption increases, simply procuring non-networked chargers without also enabling another method of managed charging is not necessarily the best way to save money on charging infrastructure.

Although the various methods of managing charging are still very much in the testing and evaluation phases, smart chargers are becoming standard in some areas. For example, the UK's Department for Transport recently instituted a requirement that all government-funded residential chargers must be smart chargers by 2025.[3]

Two new laws in California aim to encourage managed charging (which they call vehicle-grid integration), although they do not specify any particular management method, and they forbid requiring any specific technology to implement it. AB 1100 expresses the intent of the legislature to maximize the benefits and minimize the costs of vehicle-grid integration,[4] and requires that any investments in transportation electrification do not foreclose the electric vehicle-grid integration potential of those investments. SB 676 additionally requires the California Public Utilities Commission to establish strategies and quantifiable metrics to maximize vehicle-grid integration and to consider the potential for vehicle-grid integration while executing its responsibilities.[5] It also requires publicly owned electric utilities (with some restrictions) and Community Choice Aggregations to develop integrated resource plans incorporating vehicle-grid integration strategies. Smart chargers are one way to fulfill these new requirements in California.

Although using smart chargers is becoming the preferred approach to managed charging in some areas, there is not yet broad agreement in the industry about which methods of managing charging will become dominant, and which ones will result in the lowest total system-wide cost. Some believe that controlling the vehicle through its telematics will be preferable to controlling the charger. Others advocate using dumb chargers controlled by a centralized smart controller, noting that the real cost premium in using smart chargers lies in the operating costs for their networked communications, and not in the capital cost of the charger hardware. It is also unclear who is the most desirable entity to manage charging: the driver, the charging station owner, a charging management entity controlling multiple chargers or vehicles, or the utility. But until a dominant paradigm for managing charging emerges, procuring smart chargers seems sensible, if they are procured at a reasonable cost and there is a reasonable expectation that the cost of communications contracts will fall over time.

[iv] For a comprehensive guide to managed charging, see the May 2019 publication, *A Comprehensive Guide to Electric Vehicle Managed Charging*, from the Smart Electric Power Alliance (https://sepapower.org/resource/a-comprehensive-guide-to-electric-vehicle-managed-charging).

CONTRACTS

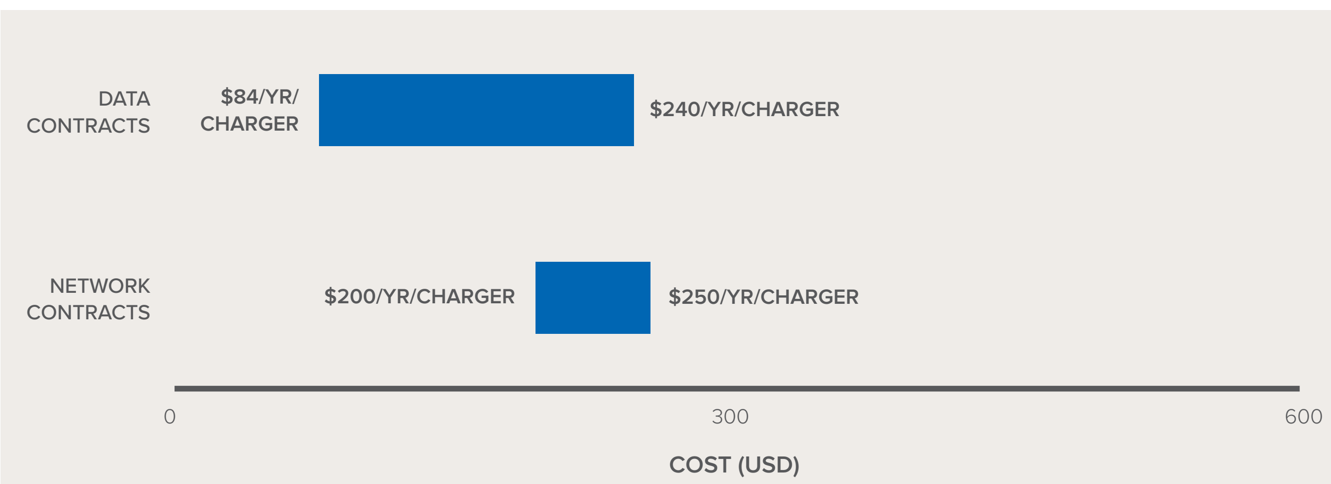
In addition to hardware and installation costs, EVSPs usually procure network, data, and maintenance contracts. These can vary in length of time and level of service. In general, shorter contracts provide more opportunities to renegotiate, which can be especially beneficial with data contracts, where costs are expected to decline over the coming years. Where possible, it may be ideal to procure and negotiate these contracts independently of the rest of the procurement, so that equipment operators have greater flexibility to select the best offer periodically, rather than buying it once as part of a turnkey package for the lifetime of the chargers. Network access contracts should also ensure interoperability and adhere to open standards, as we discuss later in this report.

Larger EVSPs and utility procurements may realize cost savings by negotiating discounted contracts across their entire service territory. For example, rather than spend $20 per month on a data plan for individual chargers, the operator of a network of sites could negotiate a lower cost for data services across their entire network, on the order of $7 per charger per month. The use of other communication systems (such as a Wi-Fi or Ethernet connection), or of technology that enables the sharing of a single cellular connection across multiple chargers, can also reduce communication costs.

As shown in Exhibit 8, the cost of data and network contracts can vary quite widely, although the reasons for the variance were not always clear from the available data. For example, network contracts also include data transfer across a cellular network, making it difficult to distinguish them from data-only contracts.

EXHIBIT 8

Range of contract costs.



Maintenance contracts are based on site-specific parameters that are so variable that characterizing costs on a per-unit or even a per-site basis is problematic. We saw costs ranging from $575 per charger per year, to $8,500–$15,000 per site per year, to $8,000 per charger over an unspecified time frame.

SOFTWARE

We found that the software required to operate chargers is typically included or integrated with a hardware purchase. There did not seem to be significant cost or savings opportunities associated with purchasing software, although there are several options for how to procure and integrate a software package.

Although there may be a potential savings opportunity in procuring hardware and software separately to obtain the best price for each one, doing so may also incur an additional integration cost to ensure that the hardware and software are compatible and that the combination serves the EVSP's needs. However, integration costs can be avoided by purchasing chargers and software platforms that are compliant with open standard communication protocols (e.g., Open Charge Point Protocol [OCPP]). This approach would also be cost-optimal from the perspective of a utility, for which software integration can be a significant expense.

Some charging system providers require EVSPs and site hosts to rent their proprietary management software through expensive software-as-a-service contracts. Before committing to such a contract, purchasers should carefully evaluate whether the proposed solution is cost-effective and should consider alternate solutions that comply with open standards and are agnostic to any particular hardware or software provider.

GRID HOSTING CAPACITY

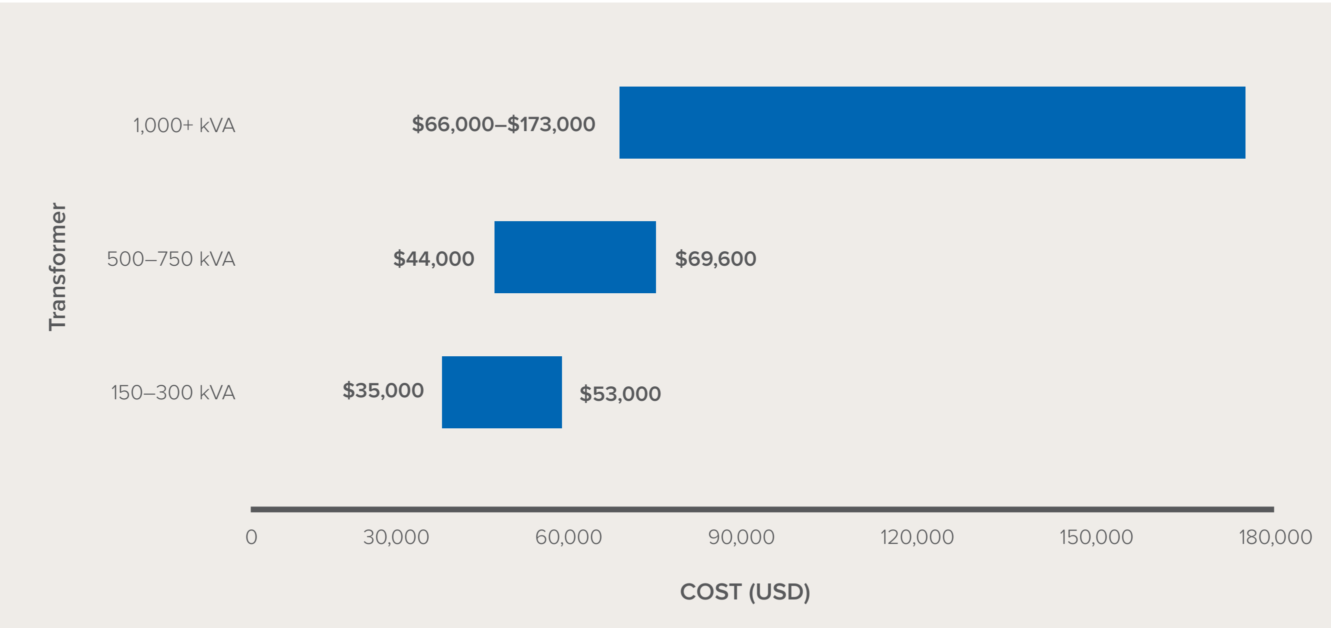
On most utility grids, hosting capacity—the available grid power capacity at a site—is often sufficient to host a 50 kW DCFC, or the equivalent load of several Level 2 chargers operating simultaneously. At higher levels of power demand, the likelihood that a site will require upgraded power grid capacity increases. Where required, that usually means upgrading a distribution transformer. For sites with power demand in the range of 1 MW or higher, it may also be necessary to upgrade the distribution grid feeder supplying the transformer.

Although some utilities, particularly in the Midwest, may have ample hosting capacity at potential charging sites, coastal utilities are more likely to have to bring in additional power supply to serve a new charging site. With even a small transformer costing about $15,000, plus another $8,000 in labor costs, bringing additional power to a site can add significantly to the project's total cost, as Exhibit 9 shows. The National Renewable Energy Laboratory's (NREL's) 2019 Distribution System Upgrade Unit Cost Database details other components that may be required in line extension or grid upgrades, as well as their associated costs.[6] Because there is wide variation in existing capacity and upgrade needs at each site, the current site infrastructure must be understood before the costs of upgrades can be calculated.

Where grid upgrades are needed, some utilities will share in the cost of the upgrade under a line extension policy. In other cases, the cost of grid upgrades must be borne entirely by the EVSP. These costs can be significant, even for lower-powered Level 2 sites. For example, under Southern California Edison's Charge Ready Pilot Program, the utility-side infrastructure alone in Q2 2019 cost $2,452,656 for 75 sites, or $32,702 per site.[7] For higher-powered sites and remote sites, utility-side infrastructure costs can be upwards of $1 million per site. This wide variance in costs underscores the importance of assessing the specific requirements for a given site and the problem of identifying any generally applicable cost metric for grid upgrades.

EXHIBIT 9

Range of grid upgrade costs.



Therefore, it is important that an EVSP considering a prospective site have clear guidance on the cost of power provisioning to the site before it makes a final investment decision. But in many cases, our expert interviewees said they were unable to get clear and correct information on the existing grid hosting capacity at the site in a timely manner. Some utilities do not have that information available and need to send a technician to the site to physically inspect the infrastructure and determine the available capacity. Where utilities have that information, they still may not have an efficient process for accessing it and getting it to the EVSP. This lack of critical information about grid hosting capacity, and delays or inaccuracies in obtaining it, adds to project delays and total program costs for EVSPs. In some cases, our expert interviewees said they had to abandon a site after significant costs had been sunk in its development because the actual cost of power provisioning, once it had been accurately determined, was deemed to be too high.

MAKE-READY INFRASTRUCTURE

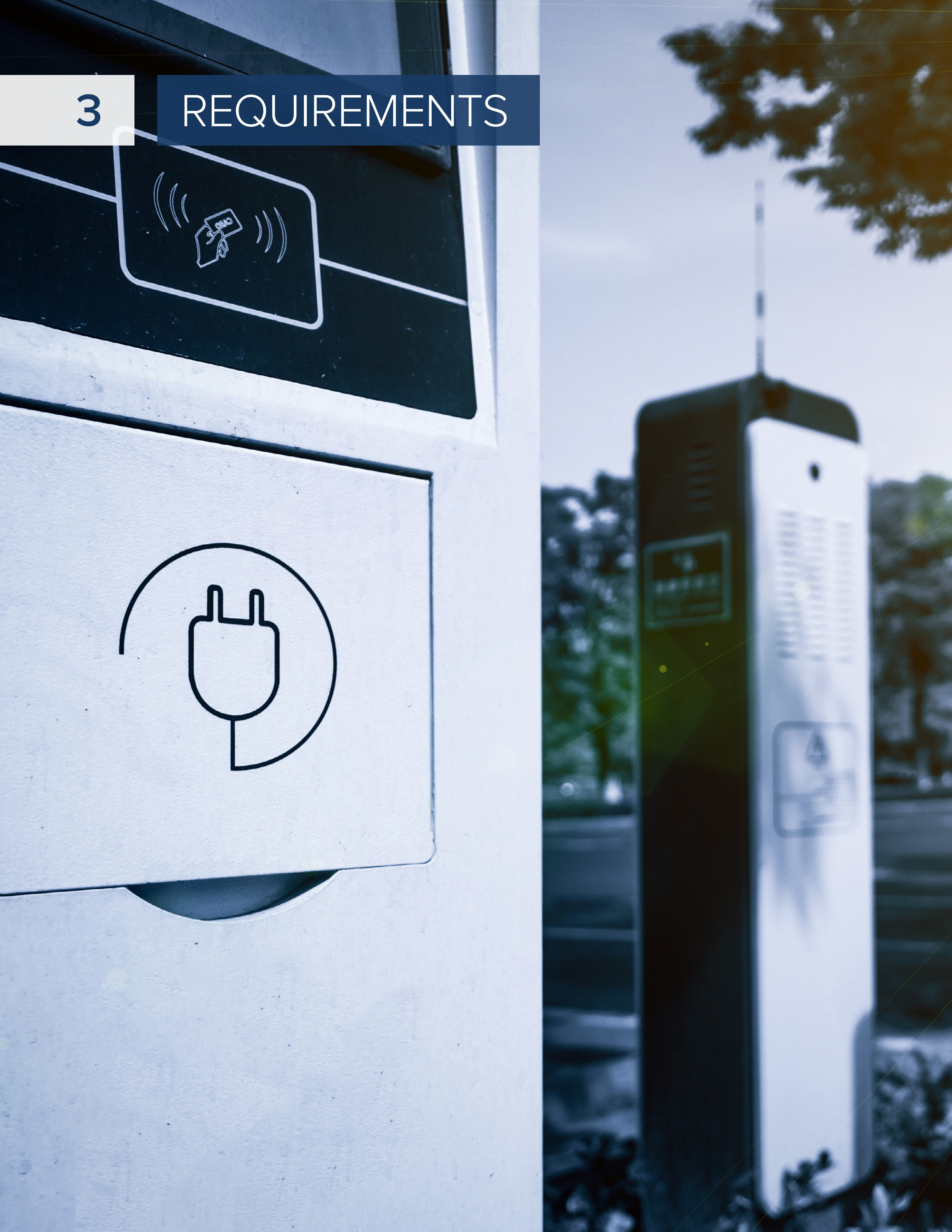
Between the utility-side infrastructure and the actual chargers, there is additional infrastructure colloquially known as "make-ready."[8] Although there is no formal definition of make-ready, it broadly refers to all necessary electrical infrastructure between the utility grid interconnection and the chargers, including step-down transformers, electric service panels, conduit, conductors (wire), switchgear and power conditioning units (for DCFC), mounting pads or brackets, and other such elements.

As with so much of the data we gathered for this study, quantifying the range of make-ready costs in a useful way is challenging because of the wide variance in the requirements of each site. For a simple wall-mounted residential installation of a Level 2 charger, the make-ready often consists of no more than a breaker in the service panel, some conduit and wire, and an outlet, and costs less than $1,000. But for public or workplace

Level 2 chargers, which are usually mounted on a concrete pad in a weatherproof installation, the costs can be much higher. For example, under Southern California Edison's Charge Ready Pilot Program, the customer-side infrastructure alone in Q2 2019 cost $7,586,387 for 75 sites, or $101,152 per site.[9]

Make-ready costs are typically a large percentage of the capital costs of an installation, at about 30%–40%. However, they are largely quite fixed. The opportunities for cost reductions are more in the domain of soft costs than they are in hardware costs.

3 REQUIREMENTS



REQUIREMENTS

Beyond the costs of the requisite components of a charger installation, the specifications, codes, and other regulatory requirements can add to the complexity and cost of an installation, and can even detract from the customer experience of using a charger. Revisiting, standardizing, and harmonizing these rules can significantly reduce the costs of deploying charging stations.

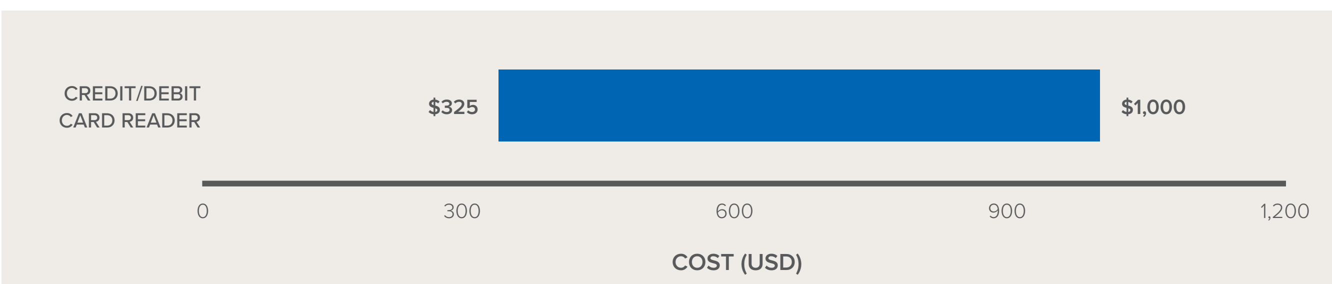
PAYMENT SYSTEM

A heavily debated topic is California's requirement—which is being considered elsewhere—for all public charging stations to have physical credit/debit card readers. These card readers are intended to provide a universal payment system across chargers of all networks. Although some robust commercial credit card readers can cost as much as $1,000, other models are available starting at $325 (see Exhibit 10). Credit card readers may have additional associated costs because they present another potential point of failure for a charger, and thus increase the probability or frequency that a charger will stop working and need to be serviced. There is also the maintenance cost of cleaning the readers, and credit card processing fees or contracts with payment clearinghouses. However, the cost of alternate payment systems, like radio-frequency identification (RFID) readers for contactless payment, is hard to determine because it is often built into the charging station hardware, and those components typically are not designated as optional.

The intention of this report is not to discuss the merits of having physical credit card readers on a public charging station; it is simply to note that they do add capital and operational costs. Whether those costs will fall over time as manufacturers are able to realize economies of scale is unclear.

EXHIBIT 10

Range of credit/debit card reader costs.



MEASUREMENT STANDARDS COMPLIANCE

Currently, the regulation of EV charging equipment to ensure that it conforms to measurement specifications is not enforceable. The National Institute of Standards and Technology (NIST) *Handbook 44—Specifications, Tolerances, and Other Technical Requirements for Weighing and Measuring Devices* was adopted as a national code in 2015 with a "Tentative Code" designation. Now, the California Air Resources Board is considering new regulations that will remove the tentative status in order to permit enforcement of the code.[10] The new regulation will enable the California Department of Food and Agriculture to begin formal oversight of EV charging equipment "used commercially for the sale of electricity as a motor vehicle fuel," using standardized units of measure such as megajoules or kilowatt-hours so that customers can compare value on a consistent, statewide basis. This new requirement will likely add some cost for manufacturers of EV charging equipment, who will pass that cost along to their customers. When California proceeds with the requirement, we would expect other states and/or NIST to lift the code's tentative status as well. This additional compliance cost is likely unavoidable, and we have no recommendations for its avoidance or reduction.

ADA COMPLIANCE AND PARKING REQUIREMENTS

A necessary yet complex, inconsistent, and expensive set of requirements has to do with ADA requirements for public chargers and their parking spaces. In its current state, ADA compliance is federally required, but locally regulated, meaning there is not a single set of standards that govern how to make a site compliant.

In many cases, this lack of standardization can drive up project costs. EVSPs indicated that without an in-depth understanding of local requirements, they may not get their initial design plans approved, forcing them to spend additional project time and cost revising their site plans. One proposed method to decrease costs associated with ADA compliance is to create an educational offering that details common missteps and compliant case studies to help designers create a compliant design in their initial drafts. Some of this study's interviewees stated that this basic education is currently lacking, so there is great potential for addressing undue ADA compliance-related costs.

However, even with increased education about ADA-compliant design, EVSPs will have to balance ADA compliance with other construction costs. For example, the least expensive way to make a charging station ADA compliant is typically by locating it near other accessible parking spaces, tying the parking spaces for charging into the existing ADA parking spaces and path of travel to the nearby buildings. However, with accessible parking spaces typically located at the front of a building, if the electrical power source were located at the rear of the building, locating a station near the existing ADA parking spaces might entail increased trenching cost. In such a situation, site designers must balance the cost of trenching to the electrical power source with the cost of constructing new ADA features.

Part of the difficulty with ADA compliance owes to the fact that ADA requirements were originally developed for Level 2 chargers and are not yet fully cognizant of the differing aspects of a DCFC installation. A broad revision of ADA requirements could reduce the complexities and costs of compliance.

Beyond ADA compliance, state or local building and planning rules also can inhibit the deployment of charging stations through general minimum requirements for parking spaces. In some instances, developers said that they had to eliminate a potential site from consideration because they would have had to create new parking spaces for the charging stations, but it was impractical to do so given the physical arrangement of the site.

California's 2019 law, AB 1100, helps alleviate this requirement by allowing a parking space served by a charging station, or designated for a future charging station, to count as at least one standard parking space for the purpose of meeting minimum parking requirements established by a local jurisdiction. It would also allow an accessible parking space served by a charging station, or intended for a future charging station, as well as its access aisle to count as at least two standard parking spaces for the purpose of complying with local minimum parking requirements.[11]

DUAL PLUG TYPES FOR DCFC

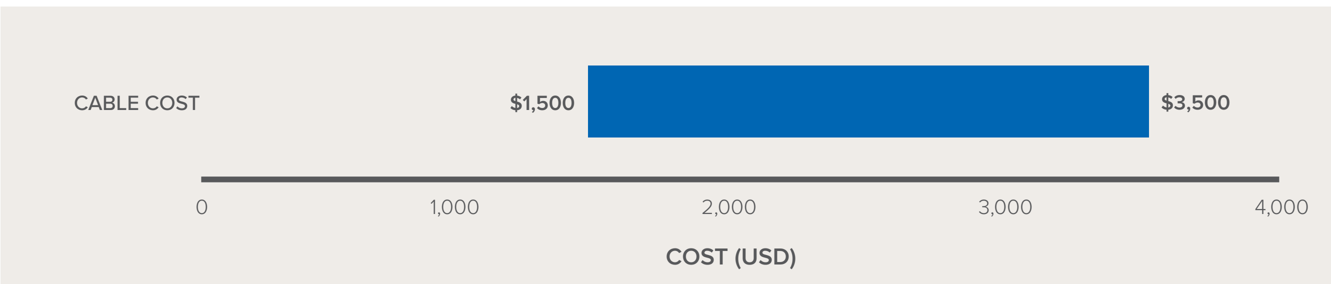
Another common cost driver is the requirement that public DCFC sites be able to support both Combined Charging System (CCS) and CHAdeMO charging standards to get public funding. This has prompted some EVSPs to deploy DCFC equipped with both port types.

With cables costing about $1,500–$3,500 (see Exhibit 11), equipping DCFC with two different cables constitutes about 5%–10% of the cost of the charger. Should auto manufacturers shift to using only CCS plugs on their vehicles, this requirement could become obsolete. (Note that Tesla has its own type of plug and typically does not have to support other standards because it does not receive any public funding for its charging stations.)

Reducing cable length could also save hundreds of dollars per charge. If auto manufacturers standardized the location of the socket on the vehicle, shorter cables could be used to reach all vehicles. With current vehicle designs, multiple, longer cables are often needed to ensure that a charger can be used with all vehicles.

EXHIBIT 11

Range of cable costs for dual plug chargers.



OPEN STANDARDS

Open standards, such as the OCPP, OpenADR, Open Charge Point Interface (OCPI), and Open InterCharge Protocol, ensure equipment interoperability and promote open and competitive markets for charging infrastructure. Compliance with open standards does not appear to contribute meaningfully to the cost of new projects, but it does offer savings opportunities. When chargers from multiple vendors are compliant with these standards, they can be more easily accessed and controlled as a single network, which unlocks further potential savings from managing charging to take advantage of the low-cost hours in a utility tariff. Compliance with open standards also ensures that network providers will continue to compete to provide service over the life of the chargers. In the long term, supporting open standards can eliminate some system integration costs as well, because the hardware and software systems are natively interoperable. Furthermore, when all chargers are compliant with open communications protocols, customers can select the lowest-cost combination of network services and hardware, and reduce the overall project cost. For a helpful review of the relevant standards, see the “Electric Vehicle Charging Interoperability” brief from MJ Bradley & Associates.[12]

4 SOFT COSTS

SOFT COSTS

In addition to the procurement costs required in all projects, as well as the costs related to meeting local specifications and requirements, there are soft costs: process costs, marketing costs, opportunity costs, negotiating with property owners, and so on. In building charging infrastructure, soft costs often consist of delays—for example, delays in obtaining utility interconnections, utility easements, and building permits. Such delays can add weeks, months, or more than a year to a project schedule, with wildly varying cost implications for a project. Worse, because EVSPs often have to evaluate multiple potential locations before selecting one, these costs can multiply.

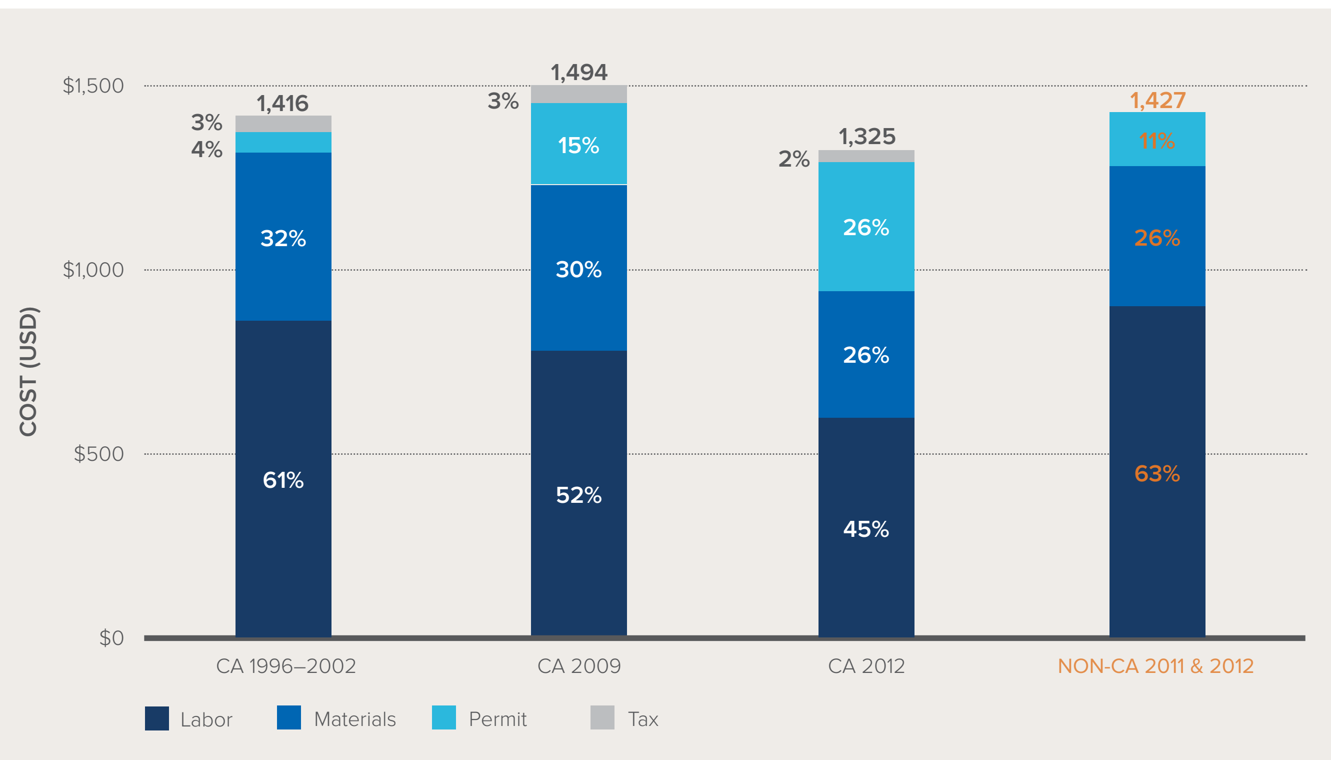
Soft costs can add significantly to a project budget, particularly for public DCFC sites or other large, complex installations, and are borne indirectly by the operators.

The experts we interviewed frequently cited soft costs as some of the largest and most unpredictable costs that developers of charging networks encounter, saying they are often the reason why a candidate site for a charging station is rejected or abandoned, even after significant costs have been incurred.

Although many soft cost elements are normally associated with higher-powered DCFC installations, an early Electric Power Research Institute (EPRI) study on EVSE installation costs found that as overall residential installation costs in California fell from 1996 through 2012, costs associated with permitting grew, both in absolute terms and as a percentage of total installation costs, as shown in Exhibit 12. This increase was attributed to financially strapped cities raising permit fees to cover the cost of services in California.

EXHIBIT 12

Median residential installation costs by category 1996–2012.



Source: EPRI, *Electric Vehicle Supply Equipment Installed Cost Analysis*, 2013

For those who followed the progression of the solar industry over the past decade, the issue of soft costs will be familiar. The US Department of Energy's Solar Energy Technologies Office has a dedicated subprogram aimed at reducing solar's soft costs,[13] noting, "The soft or 'plug-in' costs of solar account for as much as 64% of the total cost of a new solar system. These barriers are often the result of a lack of information needed to do a job or make a decision. These information gaps can slow market growth or prevent market access." The Electricity Markets and Policy Group at Lawrence Berkeley National Laboratory (LBNL) produces *Tracking the Sun*, annual reports that have traced the progression of the various costs of solar installations, including soft costs, for over a decade.[14] And NREL and Rocky Mountain Institute (RMI) offered a roadmap for reducing solar soft costs in 2013.[15] That body of research ultimately led to measures such as California's AB 2188, which created streamlined permitting processes for solar projects across the state.[16]

The parallels between the soft costs of EV infrastructure and the soft costs of solar are worth exploring in much greater depth. The 2013 edition of the LBNL report, *Tracking the Sun VI*,[17,18] made particular note of the role that soft costs played in making US solar installations much more expensive than equivalent installations in Germany. Chances are very good that there are similar reasons why charger installation costs in the United States are three to five times the cost of the charger itself, a much higher ratio than that seen in Europe, according to our expert interviewees.

Our study found extensive parallels between the soft costs of solar and the soft costs of EV charging infrastructure. The US Department of Energy grouped soft costs into five categories:

- Customer acquisition
- Financing and contracting
- Permitting, inspection, and interconnection
- Installation and performance
- Operations and maintenance

Customer acquisition is quite different for EV charging infrastructure, in that—apart from utility programs aimed at the residential market—charging infrastructure "customers" are primarily a handful of large companies like EVgo or Electrify America that are deploying networks of charging stations. These larger companies must in turn go through their own acquisition process to identify willing site hosts. Currently, most utilities are not yet focused on courting smaller customers, although they could reduce residential customer acquisition costs if they were. Aside from differences in customer acquisition and ADA compliance, the rest of the soft cost categories for solar are essentially the same for EV charging infrastructure.

Although this study can only begin to identify some of the salient ways in which soft costs add to the total cost of deploying charging infrastructure, and point to ways they could be minimized or avoided, there is clearly a need for an in-depth effort to study and reduce the soft costs of EV charging infrastructure.

COMMUNICATION BETWEEN UTILITIES AND PROVIDERS

One issue that charging network operators cited most often was poor communication with utilities, which led to costly delays and forced operators to rework their plans. Most of these issues centered either on understanding the available capacity to add new loads to a distribution network at a prospective site—evaluating multiple prospective sites before the EVSP can select one—or on the process of obtaining a utility interconnection.

When evaluating the grid hosting capacity at a prospective site, EVSPs may encounter wide variance in how much information utilities make available. This is a critical question because high-speed public charging sites can demand a significant amount of power. For example, a bank of six 150 kW DCFC can require nearly a megawatt of power supply—equivalent to that of a high-rise office building. Some utilities have detailed hosting capacity maps at the ready and can give an expedient answer about available capacity at

a site, or at least suggest locations that are known to have sufficient available capacity. Other utilities are not as forthcoming or proactive and may take weeks to determine how much hosting capacity there is at a site. They may not have hosting capacity maps available, and they may need to send a technician out to the site to evaluate the capacity in person. In some cases, EVSPs may decide to invest in exploring multiple potential sites just to improve the odds that one will be successful, which adds to their total costs of doing business. In the worst cases, EVSPs may find that simply locating a site with sufficient grid capacity can take months.

The process of applying for utility interconnections is also highly variable and unpredictable, and can entail lengthy delays. Although some utilities will alert EVSPs proactively when there will be a delay in interconnection, others will not, exposing EVSPs to the risk of discovering a delay once the project is already under way and potentially putting their investment at risk. If EVSPs were able to get advance notice that a utility interconnection application might be delayed, or were able to estimate the risk of discovering that grid capacity at the site is insufficient and the cost of requisite grid upgrades, it would help them reduce losses and be more efficient in their capital planning, and thus reduce their overall costs. Furthermore, increased communication around the interconnection process can help providers understand and address the nuances of the process in each utility territory. This is particularly true when battery storage is integrated with a DCFC installation, a relatively recent technique for which there is no real standardization and which increases the complexity of an interconnection process.

Some utilities may be willing and able to expand hosting capacity at a given site as part of an existing line extension investment policy, whereas others may require the EVSP to pay for expensive grid upgrades.

There are a few key ways in which utilities can help reduce costs by communicating more clearly with EVSPs. First, if utilities have records on the hosting capacity of their distribution networks, they can tell EVSPs where on their systems there is ample capacity. This makes the siting process far simpler for EVSPs, enabling them to proceed through it quickly.

The second is to ensure that EVSPs have a single point of contact within the utility for each project. These individuals can help keep EVSPs informed of any potential delays, and more broadly, can track project progress, ensuring adequate communication among all necessary parties. Furthermore, they can look for opportunities to coordinate the power provisioning needs of multiple parties, potentially avoiding the need for retrenching to a single site by enabling more integrated planning and installation among providers.

In addition to needing increased communication from municipal and investor-owned utilities, EVSPs would benefit from more transparency from utility co-ops. Not all co-ops are required to disclose rate structures to nonmembers. In some cases, EVSPs are required to pay membership fees (as much as $5,000) simply to discover the details of the utility tariffs their equipment will operate under. In such an instance, if the EVSP determines that the utility rate structure does not afford them an opportunity to operate a profitable charging station, the membership fees they paid will become sunk costs with no benefit.

FUTURE-PROOFING

At sites where increased charging needs can be anticipated in the future, utilities and site owners may decide to front-load investment and install excess capacity in the make-ready elements when installing the first set of chargers. This helps "future-proof" the site by minimizing the effort and cost required to upgrade the number of chargers or power rating of existing chargers later on. Future-proofing requires balancing the extra cost incurred today against the savings that it can offer in the future. From our interviews in this study, it became clear that existing future-proofing practices can lack clarity, structure, and consistency. Although the degree of future-proofing can be heavily dependent on project budget and who the equipment owner is, there are a few best practices and suggestions that can reduce lifetime costs at a site.

One suggestion is that regulators could allow utilities to rate base extra grid hosting capacity or make-ready capacity at a site if the EVSP can demonstrate that more chargers will be needed to meet demand in the near future. This flexibility would need to be limited and monitored to protect utilities from building make-ready capacity that is never used because an EVSP later decided that it did not need additional stations.

Another money-saving practice that many utilities and EVSPs use is to oversize the transformer and lay additional conduit to support expansion, where the marginal cost of doing so is not prohibitive. This enables more efficient future expansion of a site by

avoiding the need to purchase a new transformer or retrench the site to lay additional conduit. In one California project proposal, trenching and conduit contributed around 18% of total project cost. Even if future-proofing mitigates the cost of future trenching and conduit by only 50%, it could still deliver savings on the order of 10% of the total project cost.

Regardless of the methods, sharing current future-proofing practices and informal policies could help customers take advantage of the savings associated with future-proofing.

EASEMENT PROCESSES

Although easements are not always required, depending on equipment ownership and local policy, variation and complexity in the easement process can drive project delays and additional cost. In one California pilot project report, the utility described a change in easement policy midway through the project (from a blanket easement over the entire property to an easement covering only the charging station infrastructure locations). Because the customers required additional time for legal review, the easement process took longer than anticipated. On average, the process took 59 business days, with some customers taking up to 234 business days, causing construction delays.

COMPLEX CODES AND PERMITTING PROCESSES

Because building codes and permits vary by local jurisdictions, the process of design and approval can be lengthy and complicated. If a single EVSP wanted to install 20 chargers in 10 different jurisdictions, it would have to go through 10 unique permitting processes, and potentially modify its designs 10 different ways to ensure that they complied with local regulations.

Even if all 20 chargers were located within one jurisdiction, its permitting process may be complex enough to force multiple design iterations and create delays in obtaining permits. For example, in California, many zoning reviews require a public hearing, which can introduce a waiting period of several weeks. Typical California building reviews take three to four weeks but can be extended to take six to eight weeks. Nationwide, an average of 1.86 design revisions are required before a design gets approved. In California, that number is even higher, at 2.41 revisions.

To reduce this complexity and streamline the permitting process, the city of Fresno, California, has revisited its permitting process repeatedly, creating progressively more detailed checklists to guide applicants through the permitting process. The city is currently working on a seven-page checklist that will clarify and simplify the requirements to obtain a permit. Other cities would be well-advised to follow suit.

California has also undertaken a statewide effort to streamline the permitting process for EV charging stations in the form of AB 1236 (Statutes of 2015, Chapter 598).[19] It was enacted to speed the permitting process for applicants, give cities and counties better information, and establish best practices for permitting and communication requirements. In response to AB 1236, the state's Governor's Office of Business and Economic Development has created a permitting guidebook providing detailed information on the optimal permitting process and the current restrictions and requirements, as well as a tool to track which local jurisdictions are "permit ready" and have streamlined permitting processes.[20]

Ideally, a similar tool with national coverage could streamline permitting costs across the industry. Even better, if it were possible to establish a single national set of standards governing the permitting process, it could substantially reduce associated complexity and delays nationwide. However, even statewide harmonization around a single set of rules and codes would be a vast improvement over the current balkanized landscape of hundreds of local jurisdictions. If local jurisdictions maintain their unique processes, they should strive to become "permit ready" jurisdictions, per the guidance in the California handbook (or equivalent), where feasible.

5 OPPORTUNITIES FOR COST REDUCTION

OPPORTUNITIES FOR COST REDUCTION

Based on our survey of industry experts, we have identified the following significant opportunities to reduce charging infrastructure costs.

We highlight these avenues for cost reduction because we suspect they are the largest opportunities that regulators and buyers can address, but there are undoubtedly many others. This is not a comprehensive list of all possible ways that charging infrastructure costs could be reduced. Also, as noted previously, this study addresses only those costs incurred in deploying charging infrastructure. It does not contemplate Level 1 charging, which requires no investment in additional infrastructure, or operational costs such as utility bills, which we have addressed in previous papers.[v] How the cost of deploying charging infrastructure compares to the cost of operating it—particularly where utility tariffs are unfavorable—and how both capital and operational expenses affect the profitability of owning and operating a charging network are areas for further study and are beyond the scope of the present study.

PROCURE IN LARGER VOLUMES

Volume discounts are common in nearly every industry, and EV charging infrastructure is no exception. At this early stage of the industry's maturation, most projects—especially ones that are procured by utilities—are pilot-scale projects. But, almost by definition, pilot projects are the most expensive projects.

Although pilot projects are a sensible way to test the viability of new sites and new business models in a new industry, once sites and business models have proven to be successful, they should be scaled up to accelerate manufacturers' ability to move along the experience curve and reduce the long-term cost of hardware procurement.

Some operators of large charging networks and repeat customers already obtain modest discounts (on the order of single-digit to low double-digit percentage discounts) from their vendors, but those discounts are not generally disclosed, nor are they necessarily awarded based on an established discounting schedule or even directly linked to current order volumes.

Several of our interviewees who purchase equipment indicated that they view the relative youth of EV charging manufacturing as a risk factor, and they worry that if they rely too heavily on a single manufacturer, they will expose themselves to the possibility that all of the machines in their networks could malfunction in the same way or at the same time. They also expressed concerns that the production capacity of a single manufacturer could be inadequate to fulfill a larger order and expose them to delays in delivering on the order. As a result, purchasers have tended to issue smaller requests for proposals (RFPs) and procure smaller orders of charging stations from a variety of vendors to spread the risk. (The Australian government requires at least two vendors for a given solicitation whenever they are buying chargers, as a way of avoiding corruption.) But doing so forecloses on the opportunity to reduce per-unit costs by procuring in larger quantities from a single vendor.

Some of our expert interviewees indicated that they would expect vendors to offer more significant volume discounts when their unit volumes are considerably larger—on the order of hundreds of thousands of units. It will likely be some years before the industry matures enough to need such volume. But going beyond pilot projects and procuring charging station hardware in larger orders will lead to cost reductions across the industry. To the maximum extent possible, it would be advisable for buyers to seek larger procurements where they have a reasonable expectation of being

[v] For our previous studies on how utility tariffs affect the cost of operating DCFC networks, see the September 2019 *DCFC Rate Design Study* (https://rmi.org/insight/dcfc-rate-design-study) and March 2017 *EVgo Fleet and Tariff Analysis* (https://rmi.org/wp-content/uploads/2017/04/eLab_EVgo_Fleet_and_Tariff_Analysis_2017.pdf).

able to deploy the equipment within a year or two, if the cost of warehousing the equipment until it is needed is not prohibitive.

COORDINATE AND CONSOLIDATE CHARGING SITES

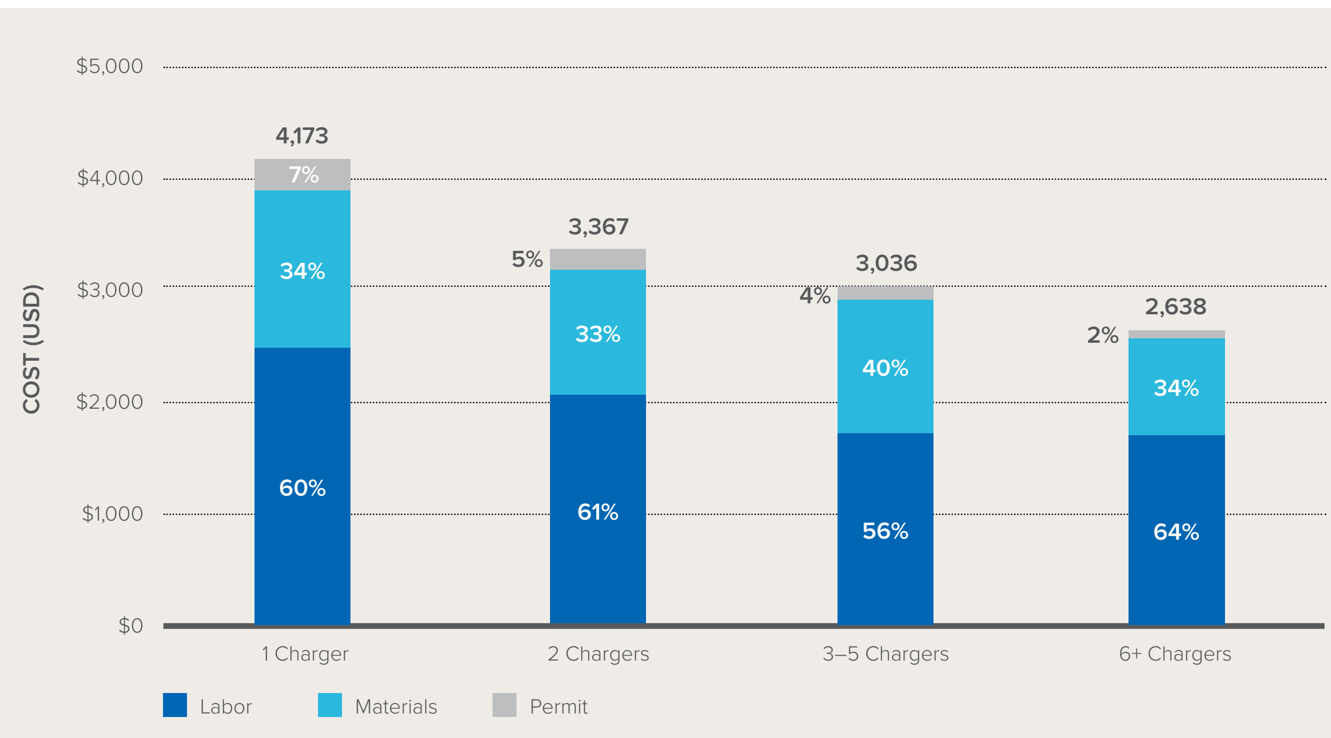
Where it is practical to do so, grouping more chargers at a single site instead of dispersing them across multiple sites can significantly reduce costs in two ways:

- Spreading the fixed costs such as site preparation and utility interconnection across more chargers
- Reducing the number of sites that maintenance personnel must visit

The cost savings from these measures is demonstrated in Exhibit 13 and Exhibit 14, which show how the installation costs per port and per charger for commercial Level 2 chargers fall as more chargers are located at a single site. Note that this data is taken from a 2013 EPRI report, and we would expect the costs for materials to be somewhat lower in today's more mature market.

EXHIBIT 13

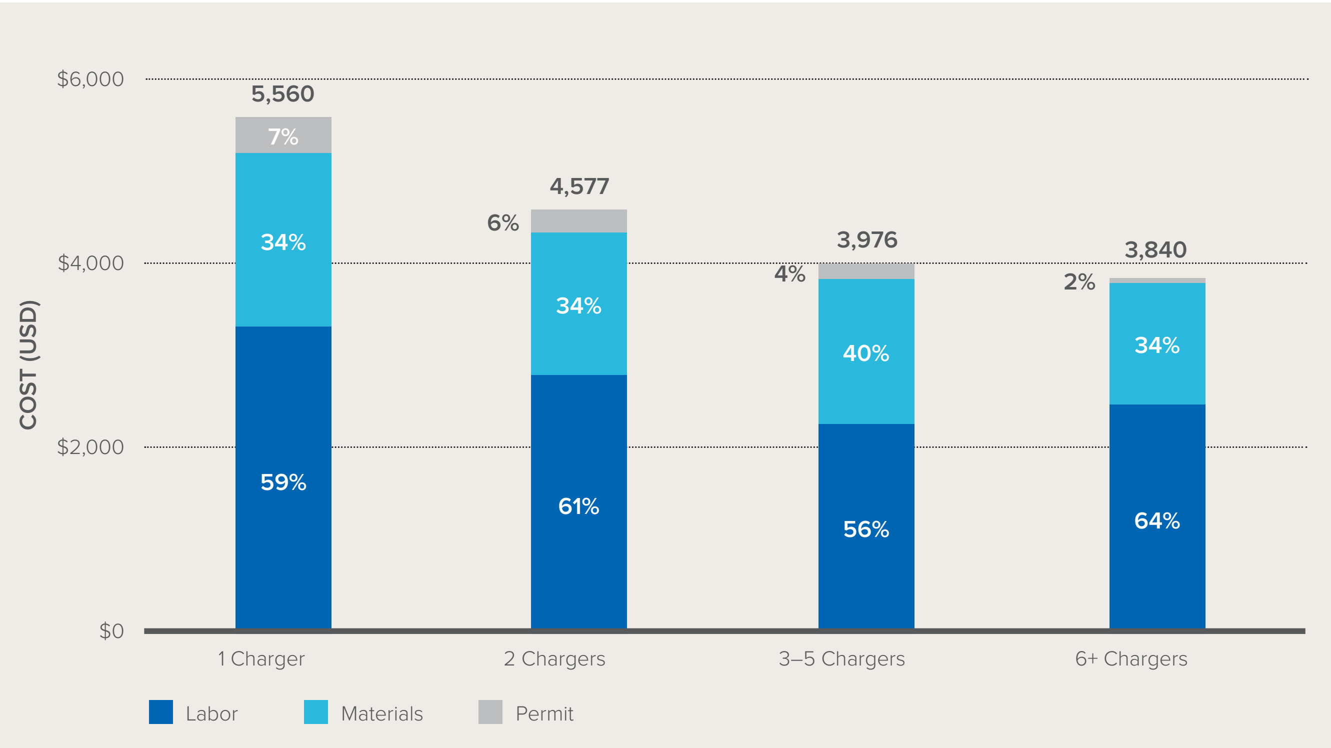
Average commercial Level 2 installation costs per charge port by cost category, by number of chargers per site.



Source: EPRI, *Electric Vehicle Supply Equipment Installed Cost Analysis*, 2013

EXHIBIT 14

Average commercial Level 2 installation costs per charging station by cost category, by number of chargers per site.



Source: *Electric Vehicle Supply Equipment Installed Cost Analysis*, EPRI, 2013

Significant cost savings can also be realized by powering multiple charger ports with as much shared infrastructure as possible:

- At sites owned by a single operator, it may be possible to reduce costs by installing larger switchgear panels and power conversion modules to support more ports. A 200 kW charging station with four ports can be cheaper to buy and install than four self-contained 50 kW charging stations. However, this cost savings can be nullified by higher costs for DC cabling if the dispensers are far from the power cabinets. Also, some EVSPs may elect to install separate charging stations rather than a single station that shares power across multiple dispensers, to ensure a particular rate of charge for each customer.
- At sites where chargers might be owned by more than one charging station operator, the owners should look for opportunities to make shared investments in site hosting capacity analyses, obtaining utility easements, and upgrading the capacity of the electricity grid at the site, such as distribution system feeders, distribution transformers, service drops, trenching, conduit, and conductors. For example, charging infrastructure built for transit vehicles may be shared with other government vehicles, or sites can be codeveloped as public–private partnerships with mixed vehicle uses, and so on.

The value of coordination and consolidation is particularly significant in sites that are located in remote areas far from high-capacity feeders, and in city centers where any sort of construction is complex and expensive. In extreme cases, the cost of power provisioning alone can approach $1 million, so being able to spread that cost across more plugs is a real benefit.

CHOOSE SITES CAREFULLY AND CONSIDER CONDUIT RUNS

Anecdotal evidence from some of the experts we interviewed indicates that site selection is often a significant operational expense, and one that is not reflected in the data on mere construction and installation costs. On average, these experts said that for a public DCFC site, they had to evaluate 2.5 to 3 potential locations before selecting one to pursue to completion. Those evaluations typically include some effort to explore utility interconnection options, develop engineering plans, identify permitting requirements, and perform other work, which all adds up to significant program overhead. Accordingly, the soft costs related to site selection should not be overlooked.

Even once a site is selected, it is important to choose the location of chargers within the site carefully and to be aware of the distance between the chargers and the nearest utility interconnection point, because trenching to lay conduit is consistently one of the largest costs for a public or outdoor charging site. This can entail balancing customer convenience against total project costs. Although it is important to install chargers where they will be most utilized and to site chargers where they will be highly visible to passing traffic, the cost of doing so can be significant. For example, the cost of trenching (about $200 per linear foot) and laying conduit can add thousands of dollars to project costs for a decision as seemingly trivial as siting chargers on one side of a building lot instead of the other.

Consequently, it can pay to think creatively about alternate ways to deliver power to the chargers. If the preferred site for the chargers is a long run from the utility service, would it be possible to locate the chargers closer to the utility lines? If utility service is on one side of a large building and the chargers are on the opposite side, would it be possible to run the conduit through the building instead of trenching? If the conduit run would have to take a complex or circuitous route to avoid obstacles, would it be possible to move the chargers to a place with a shorter and simpler conduit path?

PLAN FOR THE FUTURE

EVSPs should future-proof their sites as much as possible by installing more infrastructure capacity than is needed by the initial set of dispensers, with the expectation of installing more chargers or upgrading to higher-powered chargers in the future. Cutting through pavement, opening a trench, and laying conduit and conductors is one of the most expensive parts of an installation, and it is worth the extra effort to avoid doing it twice if possible.

For example, most of the major charging networks are moving to chargers that can support 150 kW or higher power output levels, and the luxury EV segment is likewise beginning to produce vehicles that can take 150 kW rates of charge. So if one or more EVSPs can anticipate that a given site might, in the future, need to be able to accommodate as many as six vehicles charging at once, it would be wise and cost-effective to build the initial site with 1 MW of grid capacity, conduit, and stub-out infrastructure, even if the site will have only one 50 kW charger for vehicles that can only charge at rates up to 50 kW initially.

However, future-proofing a site by installing more grid and make-ready capacity can also incur unexpected utility costs, such as minimum demand charges or minimum bills, so those issues should be explored with the utility before a decision is made to build excess capacity.

UNBUNDLE PROCUREMENTS

Because the market for charging infrastructure is young, and inexperienced buyers are often embarking on their first pilot project purchases, they typically rely on the knowledge of vendors to provide all the components that a project needs. As a result, the first RFP contracts are typically awarded for a turnkey package procured from a single vendor. This helps to reduce the risk of a buyer not procuring all the necessary elements, particularly for a complex procurement such as a transit bus fleet, or procuring elements that are not compatible. But it also tends to increase costs because the vendor is essentially bundling in some cost for their system integration services.

As the market matures, charging infrastructure buyers and fleet operators gain experience, EV fleets mature, and procurements scale up beyond pilot projects, buyers could structure their RFPs to seek the best mix of charger, networking services, make-ready equipment, and service contracts on a competitive basis from multiple vendors.

INSTALL CHARGING INFRASTRUCTURE DURING CONSTRUCTION

The cheapest way to install charging infrastructure is to build it as part of a new building or parking facility, or during a major facility upgrade. Installing charging infrastructure as part of a construction project can eliminate much of the iterative design costs and soft costs, as well as reduce costly retrofit trenching through existing concrete or asphalt parking lots. Some states and communities already require charging infrastructure to be installed with new buildings and parking facilities, or as part of major facility upgrades.

PROCURE SHORTER DATA PLANS

The cost of cellular data plans and network access contracts is not a significant share of initial costs, but over the life of a charger, they can be a large share of total ownership costs.

Although the cost of a data plan might be roughly the same for a Level 2 or a DCFC charger—in the range of $20 per month per charger, or $240 per year—over 10 years the cost of the data plan alone could be equal to the cost of the Level 2 charger, but only about 2% of the cost of a $100,000 DCFC charger.

Several of the experts we interviewed expect the cost of cellular data plans and network access plans to fall over time, as the cellular industry and network operator industry become more competitive. Therefore, it seems prudent to avoid signing long-term contracts at current prices, and instead seek short-term contracts with the expectation of shopping for cheaper contracts in the future.

USE STANDARD RFPS

While the opportunity to cut costs through standardized procurement is hard to quantify, there is no doubt that bespoke configurations of charging equipment are expensive, and that if procurements could be done in a more standardized way, costs could be reduced.

It would be impractical to impose any such requirements on private sector EVSPs, but if utility buyers could converge on standardized RFPs (which would include requirements that the charging equipment support open standards and interoperability through shared and standardized protocols such as OCPP and OCPI), it would be easier for vendors to produce equipment in volume, realize efficiencies of scale, and offer steeper discounts for larger orders.

Standard RFPs could also enable other cost-saving measures, such as standardized site engineering, standardized make-ready approaches, and standardized and interoperable components.

OFFER FOCUSED UTILITY SUPPORT

As mentioned earlier, our expert interviewees from EVSPs all said that more support from the host utilities could sharply reduce wasted effort and expense, and thereby help reduce soft costs. They said that the best approach is to have a utility support representative acting as a single point of contact for each charging site project, and that where they have such support, projects proceed more smoothly and with fewer revisions and delays.

The utility representative can help in a variety of ways:

- Locating requisite information about grid hosting capacity at the proposed site and identifying any needed grid upgrades early on, before significant investment has been made in designing and permitting the site.

- Providing guidance on the process of filing a utility interconnection application, along with all requisite documentation, and then shepherding the applications to completion in an expedited manner to avoid costly project delays.

- Identifying any other EVSP projects that are planned or in-process and that are on the same utility feeder or distribution transformer, or located near the same site, which could be paired or leveraged with the new site to reduce costs. For example, the utility could identify opportunities for multiple projects to share in the cost of a single trenching job and conduit run, or share in the cost of upgrading a transformer that will supply multiple sites.

- Coordinating any needed utility work with the rest of the site preparation, to avoid delays in commissioning the site.

- For utility co-ops, simply making information about grid hosting capacity available to prospective site builders without requiring them to join the co-op first could significantly reduce costs.

Improving utility support to reduce costs could also take the form of better process. For example, a utility could accept a lower cost deposit to help an EVSP evaluate three sites, then help the EVSP select the best candidate. Only after the final site selection is done would the EVSP submit a regular service request and deposit to initiate the full utility interconnection application process.

A more agile process could also help reduce the risk of encountering other showstopper issues that doom or add costs to projects after utility distribution planning work has commenced. These issues are beyond the scope of this work, but they can include any number of hurdles such as discovering that an easement cannot be secured, that amenities at the site are deemed to be inadequate, that 24/7 access cannot be guaranteed, or that landlord/tenant consent cannot be secured. Being able to address these issues before full utility planning work has been completed could reduce costs.

EXPEDITE PERMITTING

One of the nearly universal complaints we heard from EVSPs was about a lack of clear guidance in meeting the requirements for obtaining a building permit and slow processes for getting approval. By deliberately trying to meet the needs of charging site builders, municipal building and planning departments can help reduce soft costs.

The best practice our expert interviewees recommended was for building departments to offer online checklists identifying the requisite documentation, and an online method for applying for a permit. This could save a significant amount of time that site planning and building staff have to spend inefficiently and redundantly searching for information about requirements and process. Additionally, civil staff can help reduce the cost of project delays by reprioritizing requests and providing faster responses to EVSP questions and review requests.

But a caveat is in order here: although it is important to streamline and expedite permitting, it is also important to ensure that every site is properly evaluated by the utility. The impact on the grid and the local community of a handful of Level 2 chargers is different from that of a bank of 150 kW DCFC chargers, which is an order of magnitude different from that of a 20–40 MW truck charging depot. Utilities need to have visibility on all loads coming onto their grids because even a small cluster of 19.2 kW Level 2 chargers can force distribution system upgrades. So although streamlining permitting processes is advised, it is also advised to ensure that essential load data about each new charger is conveyed to the utilities.

CONSIDER WIRED COMMUNICATIONS

There are numerous ways that charging stations communicate with a back-end network, to do such things as processing charging transactions and monitoring the performance of charging stations. For public charging stations, these communications are typically done via the cellular network using relatively expensive (e.g., $20/month) data plans, in which the charging network operator may be embedding as much as $15/month of fees to access their network, over and above what the cellular provider charges for the actual data transfer.

Wi-Fi connections can be free (using an existing Wi-Fi connection at a site) or provided through an inexpensive plan from an internet service provider. For stations that are owned by the property owner, Wi-Fi can be an economical way to support required communications. But in some commercial applications, Wi-Fi signals are not reliable enough, so most commercial EVSPs providing public charging service do not use Wi-Fi. For example, about half of the garages where charging stations were installed have unreliable Wi-Fi connections, making it challenging to piggyback onto existing networks for a large number of installations.

Another alternative is to use a wired Ethernet connection to the internet. This is probably the most reliable communication method, and one of the least expensive to maintain. However, some commercial operators (such as transit fleets) consider the risk of physically hacking into the network too great, and so they opt for cellular data network connections instead, where authentication and security are built into each connection.

Most chargers come equipped with the option of all three of these communications capabilities. The hardware vendors we interviewed did not believe that there was a particularly significant cost reduction opportunity in reducing the number of communication systems built into each charger. However, a charging station operator, particularly one that owns the hardware and sites and has control over when and how its charging stations are used, may find long-term operational costs can be reduced by using a wired Ethernet connection, particularly if they are confident that they can maintain network security.

COMMUNICATE AND STANDARDIZE ADA COMPLIANCE REQUIREMENTS

Another way that municipal building departments can help reduce charging infrastructure costs is by clearly communicating the requirements for ADA compliance before the site owner begins engineering work. Horror stories abound about unnecessary costs related to ADA compliance:

- Sites that were originally deemed to be ADA compliant, then were repowered with larger chargers, and forced to demolish the original pads and bollards and rebuild them because the upgraded chargers made the sites noncompliant
- Sites where the given ADA requirements were incomplete, vague, or incorrect, and site owners were forced to re-engineer and rebuild to meet different requirements in order to obtain a final sign-off on the project
- Sites where it was not practical to meet the given ADA requirements because charging station equipment was not available that could conform to them, or because the physical site was not oriented in a way that made compliance possible

Furthermore, the California requirement that a site with up to four charging stations only needs one ADA-compliant space, but a site with five to twenty-

five charging stations needs two compliant spaces (one of which must be reserved for handicapped users), is in direct conflict with potential savings associated with larger charging sites. We heard that because of this regulation, EVSPs would cap sites at four chargers. (And, as noted previously, California's 2019 law, AB 1100, is aimed at helping to alleviate the impact of this requirement.[21])

Although we are not advocating for fewer ADA-compliant spots, it is important to note the ways in which ADA compliance can contribute to higher costs. Essentially, this ADA compliance requirement is working against the cost savings opportunity of building more charging stations per site, to spread the site's significant fixed costs across a larger number of ports.

Ultimately, the balkanized landscape of state ADA requirements probably needs to be replaced with a common federal standard that EVSPs can build to, reliably, nationwide. But in the absence of such a common standard, state and municipal officials can help reduce costs by simply offering clearer information and better guidance to EVSPs.

PROMOTE MANAGED CHARGING

As mentioned earlier, two new laws in California—AB 1100[22] and SB 676[23]—require the state utility commission and utilities serving the state to use managed charging to maximize the benefits and minimize the costs of vehicle-grid integration. Although procuring smart chargers can help enable managed charging, there are other important elements that may round out a robust approach to realizing the benefits of vehicle-grid integration. These additional elements include:

- Offering time-varying utility tariffs that encourage charging in low-cost hours
- Using software platforms and aggregators to control charging
- Offering wholesale market structures that create opportunities to deliver value to the grid through managed charging
- Using battery storage systems colocated and integrated with DCFC chargers to perform grid power price arbitrage, avoid demand charges, and deliver grid power regulation services

These are not ostensibly elements of a charging infrastructure procurement or installation, and as such, they are beyond the scope of this study. At the same time, a smart charger without a time-varying tariff to manage against cannot deliver much value.

However, to the extent that supporting managed charging requires the procurement of some of these elements, it is important to note that their cost can be outweighed by the benefits of managed charging. Investing in managed charging support can ultimately reduce the costs that are passed on to customers, or generate net benefits through thoughtful and deliberate vehicle-grid integration. Therefore, the value of managed charging should be considered along with the cost of enabling investments, particularly where those investments are made by utilities and recovered through the general rate base.

If managed charging were done at a system-wide scale, it would be possible to realize significant additional system-level benefits that would not be contemplated in a typical small procurement of charging infrastructure. To manage charging at such a scale, it may be best (or even necessary) to procure the software management system separately from the hardware it manages, instead of buying them bundled together. In turn, this would require that the hardware be compliant with open standards such as OCPP, so that it can be controlled by a nonproprietary charging management software platform. This underscores the value of taking a long-term view of building charging infrastructure, particularly for utility regulators and state legislators.

For a deeper discussion on the value of managed charging and appropriate utility tariffs to enable it, see our previous reports, *DCFC Rate Design Study* (2019; **https://rmi.org/insight/dcfc-rate-design-study**), *From Gas to Grid* (2017; **https://rmi.org/insight/from_gas_to_grid**), and *Electric Vehicles as Distributed Energy Resources* (2016; **https://rmi.org/insight/electric-vehicles-distributed-energy-resources**).

6 RECOMMENDATIONS FOR FURTHER STUDY

RECOMMENDATIONS FOR FURTHER STUDY

Although we were able to obtain accurate and reasonably current data on the costs of charging infrastructure components, it became quite clear over the course of this study that the greatest risk to project budgets, and the greatest opportunity for cost reductions, lies in soft costs.

According to the US Department of Energy Solar Energy Technologies Office, the soft or “plug-in” costs of solar account for as much as 64% of the total cost of a new solar system. Although we were not able to obtain sufficient data within the scope of our study to make a precise determination of the magnitude of the soft costs of EV charging infrastructure, we believe the evidence we have gathered for this study suggests that they could have a similar share of total project costs as they do for solar projects. And we believe our study makes a compelling case for why much more extensive exploration of soft costs in EV charging infrastructure in the United States is needed—an exploration well beyond the scope of our study.

Just as it took the combined and sustained efforts over several years of the US Department of Energy, multiple US national laboratories, and nongovernmental organizations, including RMI, to discover and present comprehensive findings on soft costs and how they can be reduced for solar projects, we believe it will take a similar level of effort to really understand the soft costs of EV charging infrastructure and how they can be reduced. We strongly advise that such an effort be undertaken with all due haste.

Once that information is gathered, the efforts of a wide variety of actors, including regulatory agencies, civic officials, the staff of local building and planning departments, utilities, and private sector charging network operators will be needed to implement their recommendations. This will likely require the vigorous support of legislators and regulators.

More broadly, the total cost of operating public charging infrastructure needs further study. As we detailed in our previous reports, inappropriate utility tariffs can make the business case for owning public chargers challenging and inhibit their deployment. Even small incremental costs, like a $20/month networking fee for a nonresidential Level 2 charger, can eliminate the cost advantage of owning an EV over a conventional petroleum-powered vehicle when those costs are passed along to drivers.[24] This is particularly relevant to drivers who must use public chargers because they don’t have a place at home to charge up overnight. If transportation electrification is to proceed at a pace commensurate with meeting the challenge of climate change, we must ensure that recharging an EV at a public charger is no more expensive than refueling a conventional vehicle. Getting there will require particular attention to the cost of every element involved in charging infrastructure and squeezing out costs wherever possible.

ENDNOTES

ENDNOTES

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