EV Charging Infrastructure Deployment Strategies to Maximize the Net Benefits of Transportation Electrification

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Introduction

Since 2017, CLEAResult has supported electric vehicle (EV) adoption through various program models—from outreach and education, to incentive programs targeting vehicles and managed charging. Our work on these programs spans numerous states, coast-to-coast. Most of what this whitepaper focuses on is based on our experience in Arizona and California, where our programs have deployed EV charging infrastructure (EVCI) to public, workplace, and multifamily sites.

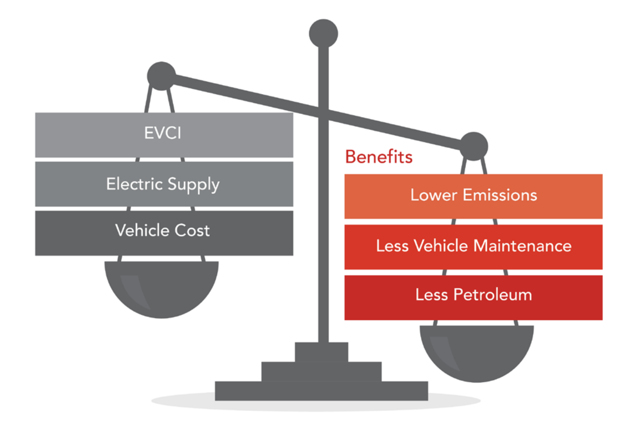
This whitepaper is motivated by the need for a strategic approach to transportation electrification (TE) that incorporates key considerations related to grid integration needs in order to maximize benefits of this major market transformation. It begins by introducing a framework for why this is important and how it can be accomplished. It then presents specific insights from program delivery that are useful to developing a program strategy.

Framework

The value of an integrated approach

Many in the energy industry naturally recognize the need for considering the grid impacts of EV charging. Still, we believe that stating our rationale in a somewhat rigorous fashion will help us judge whether the approaches we later pursue are consistent with our framework. If they are not, they should be revised. The first tenet of an integrated approach is to ensure safety and reliability—really a core focus of the industry. While we are not suggesting this is easy, there's a lot of evidence from the past 50 years to indicate that established planning and development practices can accommodate the scale of load increase that can be expected for TE over the next 20 years[1]. But the big question is: at what cost? That's where we'll direct the majority of our focus.

Figure 1. Community Costs & Benefits of Transportation Electrification



The comparison of costs and benefits for TE may put a boundary for analysis around ratepayers, but given the cross-sector impacts of the transition drawing a boundary around a community or society is more appropriate. The balance displayed in the figure above is an example of this community boundary. Within that, EVs are generally found to have benefits such as emission reductions, vehicle maintenance cost savings, and petroleum fuel cost savings that are greater than the costs of EVCI, increased electricity supply, and the incremental vehicle purchase price. So, from an economic perspective, this justifies our encouragement of EV adoption.

[1]US DRIVE (2019), Summary Report on EVs at Scale and the U.S. Electric Power System

Other benefits like safety are also important to consider but are more difficult to quantify and often omitted from analyses. Within the boundaries of our analysis, many of the costs and benefits are largely outside of the control of program designers and implementers like CLEAResult and others operating in the utility space. But EVCI and electricity supply most certainly are not. That is where our industry has the most influence, and by shifting costs lower we do our part to help ensure that the net benefits of the transition to electrified transportation are maximized.

And shift we can. An ever-growing body of research shows that there are a wide range of potential costs associated with these electric supply and EVCI investments. A recent study from Szinai et al (2020) suggested that annual electricity supply costs in CA for the year 2030 with an aggressive 5 million EV penetration could be as little as nine to as much as 20 percent higher than the no EV scenario, depending on how the charging load is managed.[2] At the scale of the State of California, that difference represents many billions of ratepayer dollars annually.

Likewise, there are many studies of EVCI costs that indicate a wide range of other potential costs. The 2019 summary report from the Rocky Mountain Institute does an excellent job illustrating the vast range–truly massive differences in cost-per-port based on type of port, site characteristics, and a wide array of "soft" costs.[3] So vast is the range, that when most people in the industry are asked about it, they sigh and say, "Well it depends…" Well, in part it depends on the programs deployed by our industry, so let's see what we can do about it, shall we?

How to take an integrated approach

The figure on the right illustrates the step-by-step process for incorporating charging infrastructure in electric system planning. First, we need to understand the current state of things. In some places CLEAResult conducts business, an increasing amount of that information is being made publicly available via capacity maps.[4] Regulatory actions in multiple states are examining how to expand this type of data access while addressing confidentiality and security concerns. The example in Box 1 of the figure is from New York state. It was selected not because it's necessarily the most robust of those maps, but because it nicely illustrates how variable charging capacity can be within a very limited area–in this case, Ithaca. Other clients we work with have this information organized in a non-public GIS system, as I'm sure is the case for many readers. But regardless of how it is stored, access to that existing system data is essential to establish a foundation for strategic planning and delivery.

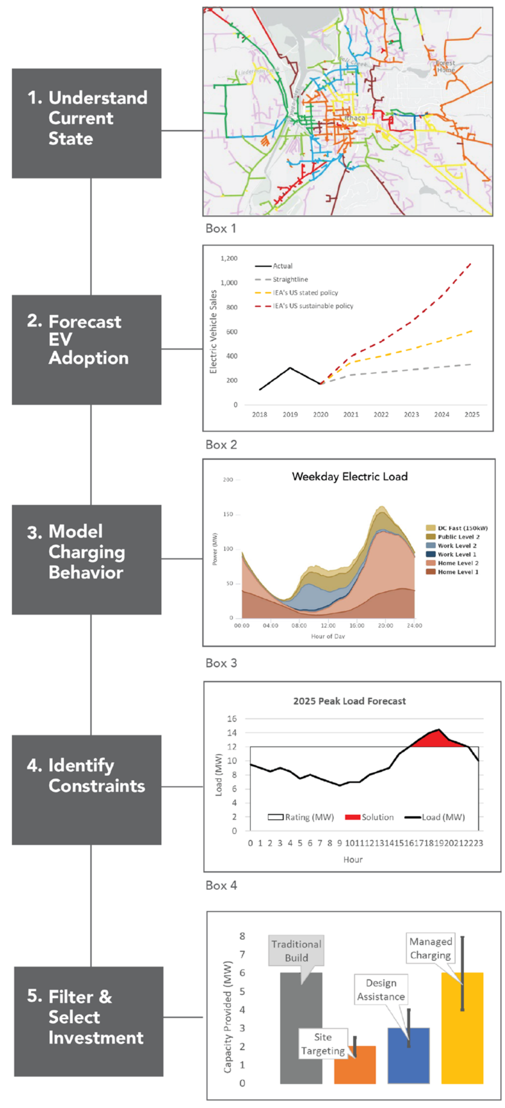


Figure 2.

[2] J.K. Szinai et al. (2020), Reduced grid operating costs and renewable energy curtailment with electric vehicle charge management, Energy Policy
[3]Nelder and Rogers (2019), Reducing EV Charging Infrastructure Costs, Rocky Mountain Institute.
[4]Examples include: PG&E's Integration Capacity Analysis map, https://www.pge.com/en_US/for-our-business-partners/distribution-resource-planning/distribution-resource-planning-data-portal.page and NYSEG/RGE's Hosting Capacity map, https://www.arcgis.com/apps/webappviewer/index.html?id=84de299296d649808f5a149e16f2d87c

From that foundation, we can begin to examine forecasts of EV adoption. Such forecasts can be done with varying degrees of rigor, but you can almost guarantee that the result will be the type of upward sloping arc indicated in Box 2 of Figure 2. on the previous page, with multiple potential scenarios playing out in a future that becomes increasingly uncertain the further out you wish to look.

After choosing a potential EV adoption scenario, we can layer on charging behavior. NREL continues to advance the capabilities of the EVI Pro model. Since it's freely available, it's a hard option to beat. When modeling charging behavior with EVI Pro—or a similar model—one can adjust various levers regarding how and where people charge and see the impact that has on the overall charging load.[5]

Next, selecting the scale of the analysis, whether it's a feeder, substation, or the overall system, we can combine the charging load with other load forecasts to come up with the total load. Then we can see what problems arise. The most common issues are periods when assets are overloaded or there's an increasing demand for very expensive peak generation.

Finally, we can decide how do address those issues. If you take anything away from this white paper, we'd hope it's an understanding that there are some high impact strategies that can be incorporated in the design and delivery of programs that will mitigate those issues, in addition to traditional 'poles and wires' solutions. Each such strategy has some quantifiable potential and some degree of uncertainty associated with that potential. To include those strategies in your planning, it's best to start assessing those options early.

That process sounds pretty straightforward—but of course, it is not. Many assumptions must be made along the way to developing a charging integration strategy, and deciding what assumptions to make prompts some very tough questions, such as:

- What is the EV adoption trajectory and how much will favorable policies and programs accelerate it?
- Where on the grid is it happening and how much can we direct so it is accommodated within available capacity?
- When are people charging and how can that charging be shifted to off-peak times?

Unfortunately, there is no simple answer we can provide as to what assumptions to make. Your assumptions will be very specific to your context. But the remainder of this white paper presents some examples from our work that illustrate the range that we believe is worth considering.

[5] EVI-Pro Lite, https://afdc.energy.gov/evi-pro-lite

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EV Charging White Paper

Insights from Program Delivery

The insights collected here are selections from our past several years of program delivery and highlights from some recent noteworthy research. Taken together, these can help inform EVCI deployment strategies that will be useful for managing costs of grid integration of EV charging.

Adoption forecasts

An EV adoption forecast is needed to target an appropriate scale of EVCI deployment. One can invest a lot in a custom EV adoption forecast for a given territory, and if you have the resources to do so that's great–the more econometric analysis we can derive insight from, the better. At the outset of any one of our programs, we will do a basic analysis, at least, where we're leveraging some of the many projections that have already been done.

We start with EV adoption to date, which of course varies considerably by state and territory. Figure 3 illustrates the vast difference in adoption between states, and even within states we find large differences. When we consider the range of forecasts that have been made, using more local forecasts when available or national level forecasts like those of the International Energy Agency[6], Bloomberg New Energy Finance[7], or Deloitte[8], we find predictions in the range of eight to 30 percent EV share by 2030, equating to a fourfold or fifteenfold increase from today. Applying those growth factors to the baseline activity of the territory in question enables us to produce a range of possible adoption scenarios.

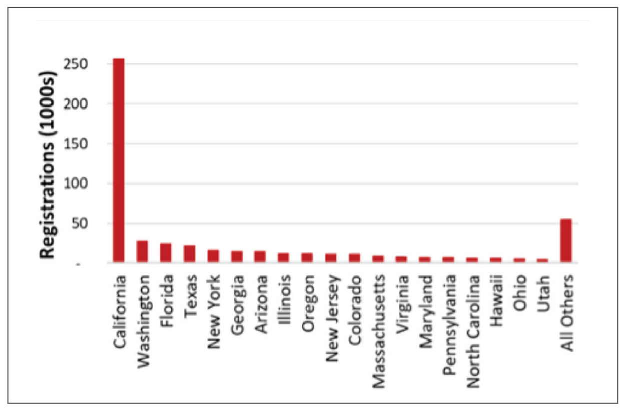

Figure 3. Variation in State-Level EV Adoption (source: National Renewable Energy Laboratory (2020), Electric Vehicle Registrations by State.)

Here we've done so specifically using the IEA's forecast. The graph in Figure 4 shows the growth in the cumulative stock of EVs for the US as a whole. In the context of EVCI program planning, one particularly appealing feature of the IEA forecast is that it's explicit in saying that this growth depends on the policies we choose. With policies that, to date, at the national level, are not particularly aggressive, we'll see moderate growth, represented by the yellow line. Or, if we choose to adopt more pro-transportation electrification policies, we can set ourselves on the higher, red trajectory.

Of course, once that range is established, one still needs to select some point values within it. One way to do that is using this rubric created by the National Association of State Energy Officials (NASEO), a summary of which is shown in the table on the following page.

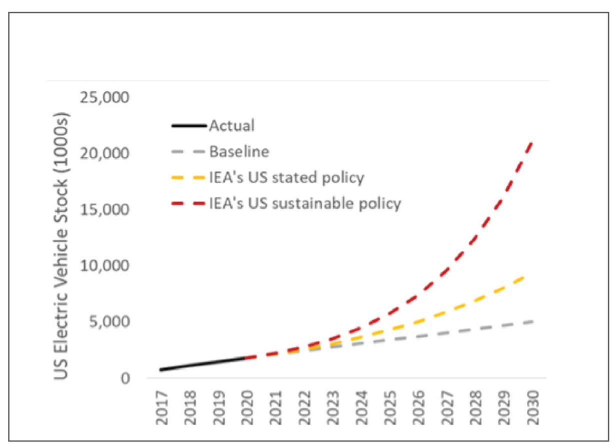

Figure 4. Electric Vehicle Stock Forecast

[6] IEA (2020), Global EV Outlook 2020.
[7] BNEF (2020), Electric Vehicle Outlook 2020.
[8] Deloitte (2020), Electric vehicles - Setting a course for 2030

This is a system wherein one evaluates a suite of existing or contemplated TE policies. A score is tabulated for each policy, some with a simple binary determination while others, such as purchase incentives, have a range based on how aggressive the support for EVs is. Once all areas are scored, you then apply the effectiveness weighting to each, and aggregate to get a total score between 1 and 100. After tabulating that score, one can use that to pick a point estimate within the range of low to high adoption scenarios. For example, if we tabulate a score of 50 out of 100 for a mix of policies and programs, we can then put the corresponding scenario right in the middle of the red and yellow lines. Of course, in practice we often find that some goal or policy target number of vehicles has already been established, and that more directly defines where we center the adoption forecast.

Policy or Program Type	Effectiveness Weighting
Purchase incentive	30
Deployment target	20
EVSE installation assistance	10
EVSE operation support	10
Marketing & communication	9
Transportation climate policy	5
Other policies & programs	16

Table 1. NASEO's relative effectiveness of approaches to enabling EV adoption. (source: NASEO and Cadmus (2018), PEV Policy Evaluation Rubric: A Methodology for Evaluating the Impact of State and Local Policies on Plug-in Electric Vehicle Adoption)

Locating Adoption

That approach to EV adoption forecasting gives us a starting place. As we then begin implementing programs, we immediately start generating a much richer data set and understanding of what's happening in the territory, as well as where exactly it's happening. This enables both planning of specific actions to address system constraints as well as refinement of the overall program strategy.

In shared, public charging programs, projects often produce quite concentrated, high-power demands. One single project could determine whether a feeder or substation will need to be upgraded. For this type of program, the program pipeline, from outreach to installation, provides a crucial view into the near-term integration challenge. We are able to use that pipeline to forecast distribution infrastructure needs for the one to two years that the pipeline represents, as illustrated in Figure 5.

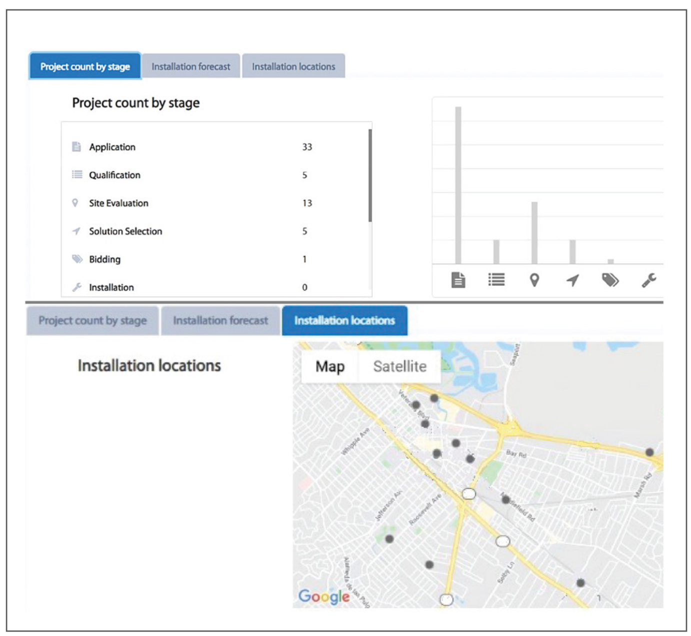

Figure 5. Forecasting shared charging pipeline and locations

On the residential charging side, the projects and load additions are smaller and more distributed—one 7 kW charger here, another perhaps the next block over, and so forth. This distributed nature lends itself to developing and sharing a different type of information to the distribution planning team. Here, we can use the characteristics of EV adopters to date and combine that with household-level demographic data to assess which areas are likely to see the greatest share of our EV adoption forecast over the next three to five years. An example of this for a very high penetration EV area is shown in Figure 6. This type of program data-driven forecast can't tell us for certain that any particular customer will add EV charging load, but it can tell us with a reasonably high degree of confidence that this neighborhood, served by a particular feeder or substation, is likely to be first impacted by the growth in EV charging.

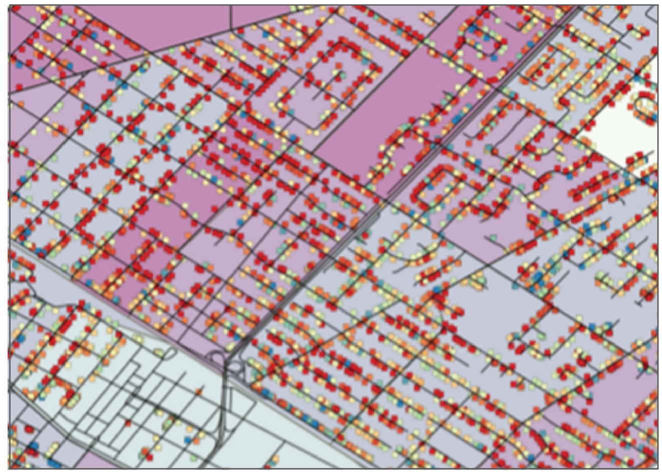

Figure 6. Residential EV adoption propensity forecast

Again, such refinements of the forecast become much easier to perform when you have active program data flowing in. Data generation is an important (though admittedly difficult to quantify) value of deploying programs sooner than later.

Utlizing existing capacity

To illustrate how much charging can be accommodated within existing infrastructure, we will share here two examples from actual projects that help illustrate what is possible. Like all projects, each is a bit of a story, which we will share in brief to explain how we arrived at the solution.

The first example, depicted in Figure 5(A), shows the importance of thoughtful site design. In this example, we were consulting with a client and one of their business customers on the layout of a new charging installation that included both Level 2 (L2) charging for customers of the business, as well as DC fast charging (DCFC) for the medium duty trucks operated by the business. The initial idea on the table was to add a new utility service, S2 in the figure, next to the existing service S1. The new service would provide power to the DCFC and with a new step-down transformer would also serve the L2s located on the other side of the building. That seemed like a fine plan initially.

Then we gathered data on the site, and we identified the opportunity to connect the L2s to an existing

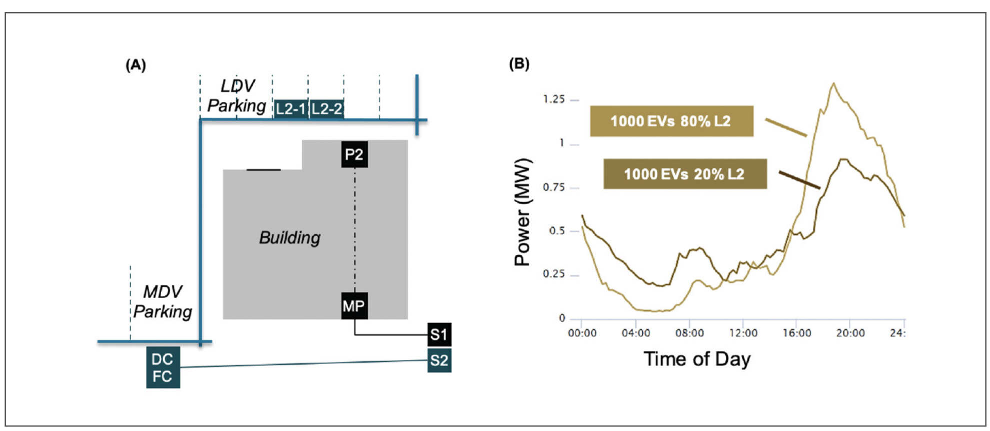

Figure 7. Optimizing site layouts (A) and load comparison of Level 1 dominant versus Level 2 dominant charging in multifamily (B)

240V supply on an underutilized panel—P2 in Figure 7—near where they would be installed. Using robust cost estimating tools, we were able to determine that avoiding a step-down transformer and a whole lot of conduit and cable would save this project roughly $25,000, or roughly 30 percent of total costs. That's a big bite out of the cost of the project. And, reflecting back to the cost-benefit framework introduced at the beginning of this paper, it's also a meaningful contribution to driving greater net benefits from TE.

Our second example of using existing capacity is provided by the class of solutions that we've been proposing to the multifamily segment. In this segment, a common scenario is that a customer applies to the program with an initial idea of what charging services they need. For example, they now have some tenants who purchased EVs and are asking to have chargers installed, so they apply to have several L2 chargers put in. We find it to be best practice to consider what the customer has requested and also offer them some solutions that they may not have considered, solutions that would mean both better grid integration and better service for their future charging needs. In other words, we provide analysis to help them scope a 'best fit' solution for their growing EV charging needs.

In this example, we have the flexibility to recommend and incentivize Level 1 (L1) charging as well. So, considering how long the vehicles are parked at the multifamily site – typically 12-14 hours overnight – and the daily charge requirements, it's pretty easy to determine that on an average day a level one charger would suffice. Yes, there will be those days where a faster charger is needed, but we can accommodate that need with fewer, shared L2 chargers. In this example, our recommendation provides a 4-to-1 ratio of L1-to-L2 chargers. With this type of solution, the site supports more charging access in total, at a much lower cost within existing capacity.

To demonstrate the importance of such a strategy, Figure 7(B) uses EVI Pro to compare the predicted maximum charging load if 20 percent of home charging were done on L2 (as opposed to 80 percent) with the remainder done on L1. It's the same amount of energy, just more spread out and therefore putting less strain on the larger system, from the site, to distribution infrastructure, and on up to generation.

Load Management

That mixed model of L1 and L2 is a great solution for multifamily, which faces some of the greatest barriers to EVCI deployment. But we don't pretend L1 charging is the solution for every site. Fortunately, there are other solutions for managing that peak demand, both at a site level and system level.

At a site level, we are regularly recommending EVSE that incorporate automated load management (ALM) capabilities. This is suitable both for limiting the site infrastructure requirement as well as for managing peak demand. With ALM, we share power between two or more networked charging stations. The example in Figure 8 depicts two networked charging stations, at two different snapshots in time.

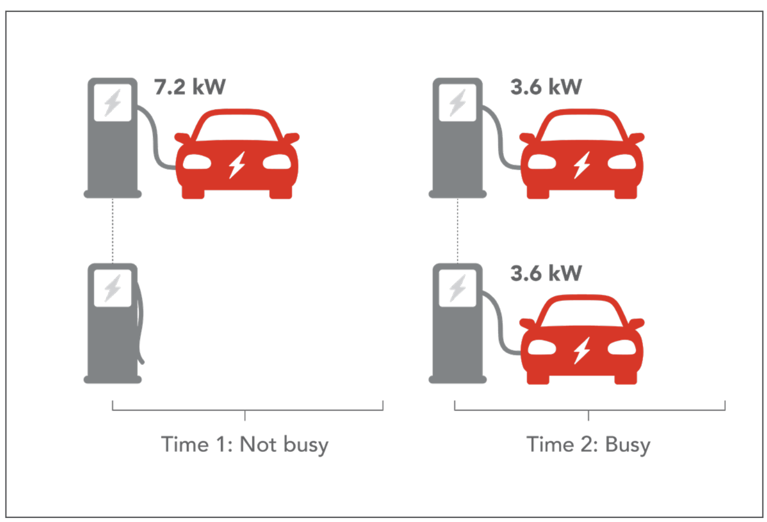

Figure 8. Illustration of atomated load management

When one vehicle is connected, it receives the full 7.2 kW. When two vehicles are connected, they share that power. There are various ways to implement this, but the basic idea is the same. This approach reduces site-level peak demand by 50 percent or more. The tradeoff is that during times of high utilization vehicles are charged more slowly, so it's most appropriate for workplace and multifamily sites. The ability to schedule departure times and prioritize charging in the network management software can also mitigate concerns about slower charging, particularly for fleet charging.

Figure 9. Hours of residential charging flexibility

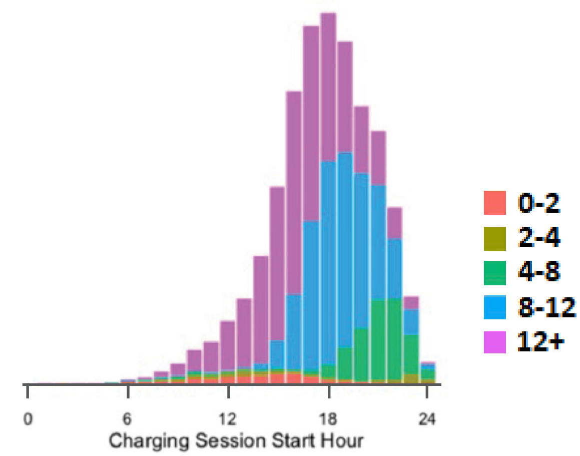

Figure reproduced from Szinai et al (2020)

At a system level, the potential for managed charging has been clearly illustrated by many studies and increasingly so by real world pilots. The potential certainly varies by site type. Referencing again the recent study by Szinai et al, the vast majority of load flexibility is found in residential charging. This is due to a couple of key factors: 1) 80 percent of charging or more is done at home, and 2) vehicles have the longest dwell times there. The graph reproduced in Figure 9 shows the amount of flexible charge time vehicles have, depending on when they plug in. The purple shows vehicles with more than 12 hours of charge time and blue with more than 8 hours. Given that vehicles will require less than 2 hours of level 2 charging on a typical day, that gives a lot of flexibility for shifting the load off peak and ideally to times when there's a lot of renewable energy generation. Again, in this study that strategy is shown to reduce the incremental system cost associated with a large EV penetration by over 50 percent.[9]

EVSE hardware & software cost

Our final insight from program delivery pertains to the cost of the actual EVSE hardware and software. Through program startups, we have now hosted multiple RFQs for potential EVSE hardware and network software providers. Based on the responses received, it's very clear that there is a great deal of qualified hardware and software, and an almost equally great diversity in the fee structures of those providers. In the interest of providing program customers the features they

[9] J.K. Szinai et al. (2020), Reduced grid operating costs and renewable energy curtailment with electric vehicle charge management, Energy Policy

Table 2. Results from the analysis of EVSE software and hardware fees (24 total EVSE packages)

Average Cost					
	Responses	Hardware	+ Network	+ Site Fees	+ User Fees
Dual-port pole mounted	14	$2,695	$3,193	$3,458	$3,996
Single-port pole mounted	10	$3,563	$4,387	$4,571	$6,386
Standard Deviation of Cost					
	Responses	Hardware	+ Network	+ Site Fees	+ User Fees
Dual-port pole mounted	14	$351	$591	$662	$1,400
		13%	19%	19%	35%
Single-port pole mounted	10	$678	$1,681	$1,740	$3,141
		19%	38%	38%	49%

require at a reasonable cost, we performed a thorough evaluation of the options. We had to take a very careful look at features and fee structures to ensure we were comparing apples to apples. Specifically, we broke down the cost into all the hardware and software and other site and user fees for each submitted hardware and software combination.

The basic methodology was to make sure each combination met the minimum requirements—UL listed, OpenADR capable and so forth—and then take each of the fee components and normalize it to a two-year operating period and a cost per charge port. We assessed operating fees by developing and applying a standard per-port utilization model.

What we found was very interesting. Table 2 shows the results for the most common L2 categories, dual and single port models rated for 32 or 40 Amps. We had 24 qualified hardware and software combinations in these categories. In the average cost portion of the table, you see the base fee for each type of hardware, followed by another $500-$800 for network software, along with some modest site fees. Lastly, there is another sizeable step up in cost when you factor in the access or transaction fees that we estimated for the first two years of utilization.

The result that was most surprising was the divergent rather than convergent cost trend. The second portion of the table illustrates that best. We had hypothesized that the fees among vendors would converge as they got more inclusive, meaning a vendor with high hardware fees might have low usage fees and vice versa. But what we see is that the spread, here measured by standard deviation of the costs, actually increases the more comprehensively we consider costs, rather than decreasing.

So, the lesson there is that if one cares about operating costs, it's critical to take a careful look at those fees. With this analysis and some follow-on price commitments with discounts from MSRPs that we secured from the providers, we can offer customers greater certainty about their costs. We also help them plan their operating model, so they know what user fees they'll need to charge to cover those costs or even make a small return on their investment over the long haul if they choose.

Conclusion

If you combine the forward-looking forecast approaches with these site design, load management, and EVSE cost management approaches, you have a lot of power to plan programs that will deploy EVCI in a manner that is both safe and reliable with a lower price tag. Bottom line, the benefits to TE easily outweigh the costs. When utilities take an active role in EVCI deployment, it helps inform grid planning and control costs to increase the net benefits of transportation electrification. ■