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EV Charging Infrastructure Energization: An Overview of Approaches for Simplifying and Accelerating Timelines to Processing EV Charging Load Service Requests

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EXECUTIVE SUMMARY

The United States has seen significant growth in electric vehicle (EV) adoption, leading to increased demand for EV charging infrastructure and electricity. Growth in electricity demand from EV charging, coupled with growth in other sectors like data centers and electrification of other sectors, is impacting electricity infrastructure and load service request processes after two decades of relatively flat electricity demand.[1] While most electric vehicle charging occurs at home, enroute and depot charging for medium- and heavy-duty vehicles, both using high-powered EV charging, are critical to meet electric vehicle operational needs. Over the past decade, EV charging infrastructure site developers, site hosts, and electric distribution utilities have navigated the process to integrate chargers onto the electric grid. Site developers and site hosts have expressed distress that the integration process for high-powered EV charging projects does not meet the needs of the EV market for timeliness or cost. High-powered charging stations typically require a load service request or an agreement with the local utility to connect to the grid. The process of energizing a new high-powered charging site can be complex and time-consuming, often taking up to 2 years. This timeline is the result of current utility energization processes having been designed for construction projects that take longer to build (i.e., buildings). The specific challenges stem from various factors, including compartmentalization in application processes, the integration of EV charging process approvals with other distributed energy resources (DERs), and the need to ensure grid reliability. The energization process needs to evolve to meet the growing demand for high-powered EV charging.

This white paper compiles information gathered through various conversations with key stakeholders, including utilities, utility regulators, EV charging operators, site developers, and authorities having jurisdiction (AHJ) as well as through an extensive literature review. This document identifies the challenges and provides potential solutions to streamline the process of connecting EV charging infrastructure to the power grid in the United States, serving as a starting point for future conversations around these solutions.

The solutions noted in this white paper require collaborative efforts among utilities, regulators, and EV charging infrastructure developers to streamline the grid connection process for EV charging infrastructure. They are broadly organized into four areas:

Increase data access and transparency: Develop automated load service request tools, integrate hosting capacity and load service request analyses, incorporate EV adoption forecasts, and provide transparency on the processing queue.

[1] U.S. Energy Information Administration. 2024. *Total Energy Data for 2000-2023*. Accessed December 19, 2024. https://www.eia.gov/totalenergy/data/browser/index.php?tbl=T07.01#/?f=A&start=200001.

Improve energization processes and timing: Create fast-track options based on prescreening criteria, provide flexibility or phased approvals in the load service request/interconnection process, build internal knowledge within utilities about EV charging technologies, and provide standardized workforce training.

Promote economic efficiency: Right size distribution components to accurately reflect the load requirements of EV charging infrastructure, make proactive investments in grid infrastructure based on EV adoption forecasts and growth projections, and consider energy equity and environmental justice factors such as equitable access to EV charging when planning infrastructure.

Improve grid reliability and resilience: Use load management/power control systems (PCS) at EV charging stations, adopt and implement harmonized standards for communication protocols and information models between the EV charging and grid control infrastructure, and address cybersecurity considerations by implementing robust security measures and standards for EV charging infrastructure—with particular emphasis on clarifying the security requirements for the interface to the grid.

The objective of the solutions proposed in this white paper is to accelerate the timeline and decrease costs associated with connecting EV charging infrastructure to the grid. Electric utilities, utility regulators, EV charging infrastructure developers, and site hosts will first need to understand which solutions are available in their service territory, and if warranted, which combination of solutions would support their specific needs. Through the successful implementations of solutions at scale detailed here, industry will demonstrate a new and innovative ecosystem where timely deployment and energization of EV charging infrastructure with greater grid resiliency and reliability is a reality.

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ACRONYMS

AC	alternating current
BESS	battery energy storage system
BTM	behind-the-meter
DCFC	direct-current fast charging
DER	distributed energy resource
DOE	U.S. Department of Energy
EV	electric vehicle
EVSE	electric vehicle supply equipment
IOU	investor-owned utility
OCPP	Open Charge Point Protocol
PCS	power control system
PKI	public key infrastructure
PUC	public utilities commission
PV	photovoltaics
UL	Underwriters Laboratories
V2G	vehicle-to-grid

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EV Charging Infrastructure Energization: An Overview of Approaches for Simplifying and Accelerating Timelines to Processing EV Charging Load Service Requests

1. INTRODUCTION

As two distinct industries—energy and transportation—learn to interact and understand each other in the continued transportation electrification transition, there is a need for policies, processes, and tools to efficiently manage the connection of electric vehicle (EV) charging infrastructure to the electric grid. Current mechanisms are known barriers for electric vehicle supply equipment (EVSE) deployments, with customers noting that processes are complex and not standardized. The innovative solutions proposed in this paper address these major barriers. While most EVSE today is designed to exclusively transfer power from the electric grid to an EV battery and is permitted to do so through a *load service request*, it is our expectation that both the energy and transportation industries will have to plan proactively for a future where EVSE offers bidirectional power flow functionality (i.e., ability to charge an EV from the grid and supply electricity back into the grid or other devices). This future operating state will require *interconnection agreements* that can be significantly more complex than load service requests. The distributed solar and wind industries have faced a similar barrier with integrating the electricity generated into the electric grid. Simply stated, as load service requests and interconnection requests adapt somewhat separately to the current reality, both processes should be expected to converge into a single process in the future.

The U.S. Department of Energy's (DOE's) "Interconnection Innovation e-Xchange" (i2X™) initiative,[2] led by the Solar Energy Technologies Office and Wind Energy Technologies Office, works with key stakeholders to identify grid interconnection bottlenecks and develop potential solutions to streamline grid connection processes for distributed energy resources (DERs). DOE recently released a draft roadmap for the interconnection of DERs to the distribution and sub-transmission grid.[3] The distribution roadmap, which primarily focuses on storage and generation DER interconnection, includes an overview of the interconnection process tree, describes the current bottlenecks that lead to energization delays, and details potential innovative process solutions to optimize the interconnection process and reduce energization timelines.

In addition, DOE's "EVGrid Assist: Accelerating the Transition" initiative is a cross-office effort to support stakeholders to make actionable progress on transportation electrification goals.[4] A priority activity for EVGrid Assist is reducing energization timelines for EV charging infrastructure.

[2] Office of Energy Efficiency and Renewable Energy. 2024. *i2X: The Interconnection Innovation e-Xchange*. DOE. Accessed Nov. 6, 2024. www.energy.gov/eere/i2x/interconnection-innovation-e-xchange.
[3] Diane Baldwin, Jessica Kerby, Devyn Powell, Robert Margolis, Jarett Zuboy, Karyn Boenker, Eran Schweitzer, and Thomas McDermott. 2024. *Distributed Energy Resource Interconnection Roadmap: Identifying Solutions to Transform Interconnection by 2035*. Draft report. www.energy.gov/sites/default/files/2024-09/Draft%20DER%20Interconnection%20Roadmap%20for%20RFI.pdf.
[4] Office of Energy Efficiency and Renewable Energy. 2024. *EVGrid Assist: Accelerating the Transition*. DOE. Accessed Nov. 6, 2024. www.energy.gov/eere/evgrid-assist-accelerating-transition.

This paper expands on the DOE distribution roadmap and builds on EVGrid Assist to provide an EV-specific resource for site grid connection. This resource provides an overview of the current processes for both load service requests and interconnection agreements for EV charging infrastructure, highlights the current gaps and hurdles that still need to be addressed by key stakeholders, and provides potential solutions that could be implemented to reduce grid connection timelines for energizing high-powered EV charging projects (approximately 100 kW–3 MW in size). The proposed solutions highlighted in this document serve as a starting point for future conversations around these solutions

1.1. Background and Current Electric Vehicle Supply Equipment Connection Process

EV adoption in the United States has shown a year-over-year increase from 2022 to 2023, with the International Energy Agency's *Global EV Outlook 2024* noting approximately 1.4 million new EVs registered in the United States in 2023, a 40% increase from 2022.[5] The necessary EV charging infrastructure to serve these vehicles varies widely and is dependent on the vehicle class, use case, and dwell times. EV owners that lack access to at-home charging are dependent on public charging installations, which can provide a variety of charging options from alternating current (AC) Level 1 to direct-current fast charging (DCFC) ports, with charging capabilities exceeding 350 kW per port. As of December 2024, there are over 200,000 public chargers in the U.S., and a recent analysis by the National Renewable Energy Laboratory estimates the United States will need 1.2 million public chargers by 2030.[6] Unlike at-home charging, high-powered EV charging installations can vary significantly in charging system architecture, number of available charging ports, and total capacity. EV adoption is expected to rise in coming years for not only light-duty vehicles, but also medium- and heavy-duty vehicles as fleets across the United States electrify. Public and fleet charging infrastructure also provides additional complications due to the unfamiliarity of electric utility processes by site developers.

The necessary processes to build and then energize a new high-powered charging site can create significant delays, stalling the rollout of new EV charging infrastructure. To connect to the distribution grid, high-powered EV charging station developers are traditionally required to obtain either a **load service request** or an **interconnection** agreement. Load service requests are agreements between the station developer and the utility (investor-owned utility [IOU], publicly owned utility [public power], or cooperative utility [co-op]) to authorize access to the grid for unidirectional power delivery to charge EVs from the grid. The simplest architecture for an EV charging installation utilizes a load service request for the nameplate rating (i.e., the sum of rated capacity of the chargers on the site). An interconnection agreement is between a station developer and utility to authorize access to the grid for bidirectional power delivery. Regardless of the connection type, according to the Interstate Renewable Energy Council, DCFC installation energization timelines can take upwards of 2 years depending on many factors (e.g., resource availability, design and engineering, utility easement, permitting and zoning, impact studies).[7]

Figure 1 illustrates a high-level flow chart of the EV charging infrastructure energization process, with 11 steps, as well as the four responsible parties—applicant, authorities having jurisdiction (AHJ), utilities, and landowner—that need to collaborate for the process to be successful.

[5] International Energy Agency. 2024. *Global EV Outlook 2024: Moving towards increased affordability*. iea.blob.core.windows.net/assets/a9e3544b-0b12-4e15-b407-65f5c8ce1b5f/GlobalEVOutlook2024.pdf.

[6] NREL. 2023.*The 2030 National Charging Network: Estimating U.S. Light-Duty Demand for Electric Vehicle Charging Infrastructure.* https://www.nrel.gov/docs/fy23osti/85654.pdf

[7] Interstate Renewable Energy Council (IREC). 2022. *Paving the Way: Emerging Best Practices for Electric Vehicle Charger Interconnection*. www.irecusa.org/resources/paving-the-way-emerging-best-practices-for-electric-vehicle-charger-interconnection/.

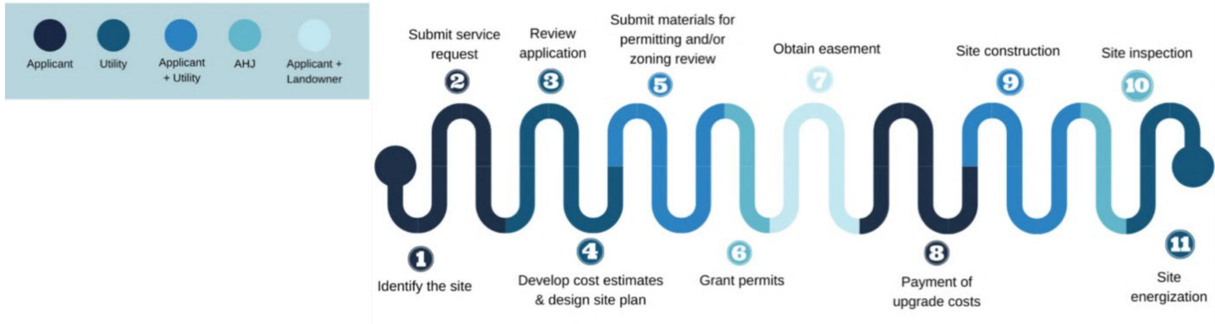

Figure 1. Path to connecting EV chargers to the grid.[8]

The type of utility service connection can be further complicated by additional assets and services that are included with the proposed charging installation, such as the integration of DERs (e.g., photovoltaics [PV], battery energy storage) and other grid services (e.g., vehicle-to-grid [V2G], grid-responsive load management, reactive power delivery). Furthermore, there are approximately 3,000 utilities (IOUs, cooperatives, and public power) serving customers in the United States, with many having unique application processes and requirements.[9] The gaps and solutions discussed in this paper span across multiple stakeholders and procedural stages in the energization process, including increasing data access and transparency, procedural necessities and timing, economic efficiency, and maintaining grid resiliency and reliability.

2. CHALLENGE/NEED: INCREASING DATA ACCESS AND TRANSPARENCY

Like other DERs connecting to the system, EV load service and interconnection requests are important processes to ensure that the power system can accommodate the new resources and devices at the requested point of connection without impacting system reliability. Understanding the available capacity at different points on the electricity system is key to accommodating EV charging infrastructure. Capacity is loosely defined as how the electric grid can accept and power the EV project without any detrimental effects, including things like overloading lines or transformers, causing voltage stability issues, or disrupting protection schemes on that system.[10] This capacity must be evaluated whether the EV deployment is simply charging, providing bidirectional charging services, or coupled with an energy storage system. Capacity information can help developers and customers understand where the grid can easily accommodate the EV charging infrastructure, where it may prompt an upgrade to the distribution system (feeder, substation, or other components), and whether there is any advantage to co-locating other DERs like PV or energy storage at that location. Access to data needed to assess the interaction of an EV project on the system and a transparent evaluation process are necessary to help accelerate developers and fleet deployments through either a load service request or an interconnection request.

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[8] Interstate Renewable Energy Council. 2022. *Paving the Way*.

[9] U.S. Energy Information Administration. 2024. *Electric Power Annual*. Released Oct. 17, 2024. www.eia.gov/electricity/annual/.

[10] Frank Tuffner. 2023. *Grid Capacity – What is it, what determines it, does one number work, and how does it relate to electric vehicles?* Richland, WA: Pacific Northwest National Laboratory. PNNL-SA-192631. doi.org/10.2172/2221804.

To improve data access and transparency for the planning of EV charging infrastructure energization locations, the following solutions are proposed (more detail in the individual subsections that follow):

- Proactively establish and maintain load service request tools that perform repeated studies for integration of large electric loads.
- Integrate hosting capacity and load service request analyses and queues with distribution upgrade workflows and general rate cases.
- Incorporate EV adoption forecasts for each service territory, as well as supplementary information about the expected charging load profiles and utilization.
- Provide transparency about the state of the processing queue for both load service requests and interconnection applications.

The successful implementation of these solutions requires coordination between electric distribution utilities, state utility regulators, and technology developers, as well as support from federal, state, and local officials.

2.1. Solution: Proactively Establish and Maintain Load Service Request Tools to Perform Repeated Studies for Integration of Large Electric Loads

One motivation for the i2X program has been to accelerate the integration process of distributed energy generation and storage by improving the interconnection process. One solution discussed in both DOE's *Transmission Interconnection Roadmap*[11] and *Distributed Energy Resource Interconnection Roadmap* is the development of standardized tools and analysis approaches to automatically evaluate the interconnection capabilities of the electric grid. Prioritizing a similar standardization of automated tools and approaches on the load service request side can benefit the deployment of large EV charging sites by helping to streamline and expedite the service request process.

An automated load service request tool would perform an initial evaluation of a specific load deployment on the feeder, as well as potentially show alternative locations that could accommodate that load size. Depending on the deployment, this automated evaluation could serve a twofold purpose. The first would be providing an initial screen for the utility engineer, automatically providing some initial information to them, as well as informing the submitter (developer/customer) of any potential constraints. The second purpose would help inform the developer if the large load (EV charging project) can be accommodated by the existing planned location, but also if there are suitable locations nearby that may not require infrastructure changes. This initial analysis would still be subject to engineer review and more detailed analysis, but the initial screening would improve the site selection and reduce the number of completely infeasible load service requests.

The power system analysis associated with a load service request can often involve feeder information and customer load profiles that the utility may have concerns over releasing publicly. To help protect this information, many utilities limit access to the information to their internal network. Furthermore, much of the analysis is currently manually evaluated. Automation exists but is limited in deployment.

[11] Will Gorman, Joseph Rand, Julia Matevosyan, and Fredrich Kahrl. 2024. *Transmission Interconnection Roadmap: Transforming Bulk Transmission Interconnection by 2035*. Washington, D.C.: DOE. DOE/EE-2838. www.energy.gov/sites/default/files/2024-04/i2X%20Transmission%20Interconnection%20Roadmap_1.pdf.

To promote a standardized approach to the analysis, as well as help protect the potentially sensitive data, one potential solution is to have the automated analysis run on utility-owned/utility-hosted or trusted platform servers. In addition to both the utility engineers and the developers using a common approach/software, it would also help protect sensitive data. Automated analysis would allow the utility to keep sensitive data enclaved by running it on locally hosted or private cloud systems. This would provide only the relevant load service request results to the interested party while keeping sensitive utility information properly protected, alleviating the concerns by some utilities about sharing too much data about their system.

Additional cost would likely be associated with deploying an automated system, including the development of the application, the workforce training, and the integration into the existing utility processes. Furthermore, there are going to be costs associated with maintaining the server and licenses needed to do the analysis. However, the automated tool can preserve the planning engineers' time for processing the detailed analysis of more feasible sites, as well as providing an initial set of information on what restrictions may exist at the site. Furthermore, widespread automated load service requests would promote standardizing the utility data for input into such a tool. This may not only benefit the load service request analysis, but potentially help standardize the interconnection analysis and other utility functions. A unified input dataset also benefits an integrated generation and load capacity analysis, discussed in the next subsection.

2.2. Solution: Integrate Hosting Capacity and Load Service Request Analyses and Queues

For many utilities, generation connections go into the interconnection queue, and load connections go into a separate load service request queue, often managed by different engineering teams and groups within the organization. However, these two queues may benefit from one another and coincidental projects. Large EV charging depots often explore the option of using energy storage to mitigate local grid restrictions, which would not be captured by the independent processes; energy storage would end up in the separate interconnection request queue, and the offset it provides to reduce the EV demand (on the load service request) may not be captured. Hosting capacity and load service request analysis and queues should be combined into a single analysis process to analyze hybrid load and generator deployments, whether coincidental (e.g., nearby PV deployed by one developer/customer and an EV charging depot deployed by a separate developer/customer) or deliberate (the same developer/customer deploying PV generation to offset the additional demand of the EV charging depot). A capacity-constrained feeder may be able to accommodate a larger load if a PV array were being placed nearby, especially with advanced grid service capabilities such as a volt/var ability (provide voltage support and regulation at that point). Performing the hosting capacity analysis and load service request analysis individually (and independently—not aware of the other) would not necessarily allow this synergy to be recognized and leveraged. For deployments such as a medium-duty EV charging depot being built with on-site energy storage, this holistic capacity analysis would help capture the combined operation that may require lower capacity on the feeder or provide grid services to enable nearby projects. Integrated analysis would also help capture the benefits of any V2G services, such as a commercial fleet discharging to offset demand at a nearby public fast charging station, in a single analysis platform.

Combining the interconnection analysis and load service request into a unified feeder capacity analysis also provides the ability to leverage changing characteristics of the feeder with time, which can help accommodate other approaches of integrating devices such a flexible interconnection or flexible service requests (see the i2X webinar on flexible interconnections[12]). This flexibility may be as simple as staging charging station installation times so that some of the stations come online quickly, but others may be preset with "make-ready" infrastructure. This could be "future-proof" installations with electrical panel capacity added and conduits laid in advance such that expanded wiring and additional chargers could be more easily built and commissioned in a couple years when vehicle demand materializes. Such proactive approaches help the developer and site owner avoid costs associated with digging up a parking lot each time a new bank of chargers is brough online, or when higher-power chargers become available. The incremental deployment leveraged by a flexible interconnection or load service request may be due to a pending feeder upgrade or local generation interconnection that alleviates some of the constraints on the feeder but may also be due to supply chain logistics for the stations or the business case for the selected site (e.g., slow replacement of existing vehicle fleet).

The combination of both the load service request and interconnection requests into a single analysis will be more complex. If the automated tools suggested in the prior solution and in the overall DOE interconnection roadmaps are developed, they would provide the basis for a combined tool to evaluate both. The timing of projects, especially for flexible interconnection and load service request deployments, may require additional thought to coordinate the deployments, such as breaking requests down into monthly or quarterly groups of projects. The exact breakdown would need to be examined and may vary by feeder or utility; the groups may be defined by a set time period, a set aggregation of load and generation in the combined queue, or perhaps a simple customer count.

2.3. Solution: Incorporate EV Adoption Forecasts, Charging Load Profiles, and Utilization into Distribution Planning

For larger load service requests, especially for a service-oriented or large public charging EV project, EV adoption forecasts are useful for updating projections of feeder capacity and potential future load service requests. Additional supplemental information, such as how the EVs plan to be charged at that site (e.g., en route charging or overnight charging, weekday vs. weekend differences) should also be considered for creating the load profile useful for feeder capacity evaluations. With a standardized and trusted EV adoption forecast, the utilities can better plan (and make better cases to regulatory bodies) how to upgrade their system in advance of the increased demand. A standard repository or resource for those forecasts (both within a single utility and across the nation), as well as a common format, would ensure all projects work from the same assumption. Individual locational forecasts and load shapes would vary, but the approach to produce the forecast would be based on a common assumption set to prevent the utility from using adoption Forecast A and the developer from using Forecast B with completely different expectations. This would also provide the local utility with some expectations of load growth associated with EV deployment and adoption. This updated load growth information can be fed into the integrated interconnection and load service request process of Section 3.2, helping both the utility and developers/customers evaluate where upgrades (and delayed deployment) may occur on the system.

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[12] U.S. Department of Energy. 2024. *i2X Distributed Energy Resource (DER) Flexible Interconnection Strategies and Approaches – UPDATE.* Aug. 16, 2024. YouTube, 1:31:03. youtu.be/ta_E_dVS-hg.

2.4. Solution: Provide Transparency About the State of the Processing Queue for Both Load Service Requests and Interconnection Applications

Much like the interconnection queue transparency discussed in DOE's *Transmission Interconnection Roadmap* and *Distributed Energy Resource Interconnection Roadmap*, the load service request queue can equally benefit from transparency. This is not only transparency of the process (knowing what analysis occurs at each step, how it is accomplished, and what acceptance criteria look like), but also where a particular request is in the approval and evaluation process. This transparency helps developers understand the status of the project and anticipate where additional input may be needed. It also helps hold the utility accountable toward reasonable evaluation periods, particularly if there are regulations from a governing agency like a public utilities commission (PUC) on the maximum time such a request can take.

A transparent load service request queue can also help those looking to deploy EV infrastructure to understand what else may be coming to that particular feeder or location. Such information is likely to be generic, such as "5-MW load in the queue to energize at this location," rather than a specific charging provider's request, to help maintain potential business-sensitive matters or inadvertently revealing competitors' plans. At some point in the process, pending load service requests should be incorporated into the automated hosting capacity and load service analysis models mentioned earlier in the document.

2.5. Summary of Recommendations

Data access and transparency recommendations can help ensure utilities and developers/customers are working from a common understanding toward EV infrastructure deployments. Much of this data access and process transparency is oriented toward the actual analysis to evaluate the load service requests, whether that is providing the utility's power system data to interested parties to perform the analysis themselves, or more likely through an automated system that accepts submissions in a common format. Either of these analysis approaches should incorporate both interconnection and load service request information to allow synergistic deployments of EV infrastructure and energy storage being deployed, as well as leverage potential V2G capabilities. The full "load and generation" insight can also inform implementation of flexible interconnection and load service requests, where additional generation being deployed on a power system may enable more EV charging to be accommodated while waiting for a utility infrastructure upgrade. The overall process should be outlined clearly so any applicants know what each step entails. Applicants should also be able to gain insight into where projects are in the evaluation queue.

3. CHALLENGE/NEED: IMPROVING ENERGIZATION PROCESSES AND TIMING

The current load service request process and timelines were designed for large construction projects like commercial buildings. However, EV charging infrastructure projects have much shorter construction timelines, and many distribution utilities lack the tools, capabilities, and resources to process and approve EV charging energization requests to meet the pace of site development, leading to delays and higher costs. The sheer quantity of individual and shared tasks by the customer, the authority having jurisdiction, and utility provide more opportunities for complications, leading to further delays. The timely deployment of EV charging infrastructure requires new approaches and added flexibility in the load service request process to accelerate energization timelines.

The Alliance for Transportation Electrification recently published an EV charging energization brief through their Interconnection Task Force, which included an example of a major IOU EV charging energization timeline that details these complexities.[13] Figure 2 shows a general EV customer/IOU "journey map" representative of the process in the service territories of Pacific Gas & Electric, Southern California Edison, and San Diego Gas & Electric. Whereas Figure 1 illustrates a high-level flow chart of the EV charging infrastructure energization process, Figure 2 illustrates the intricacies and roles of the customer/site developer of the charging station (in green) and the servicing utility (in blue) or both (blue and green) from initial application to final EV charging infrastructure energization. The map details a complex and lengthy process with almost 15 different processes, introducing numerous opportunities for delays.

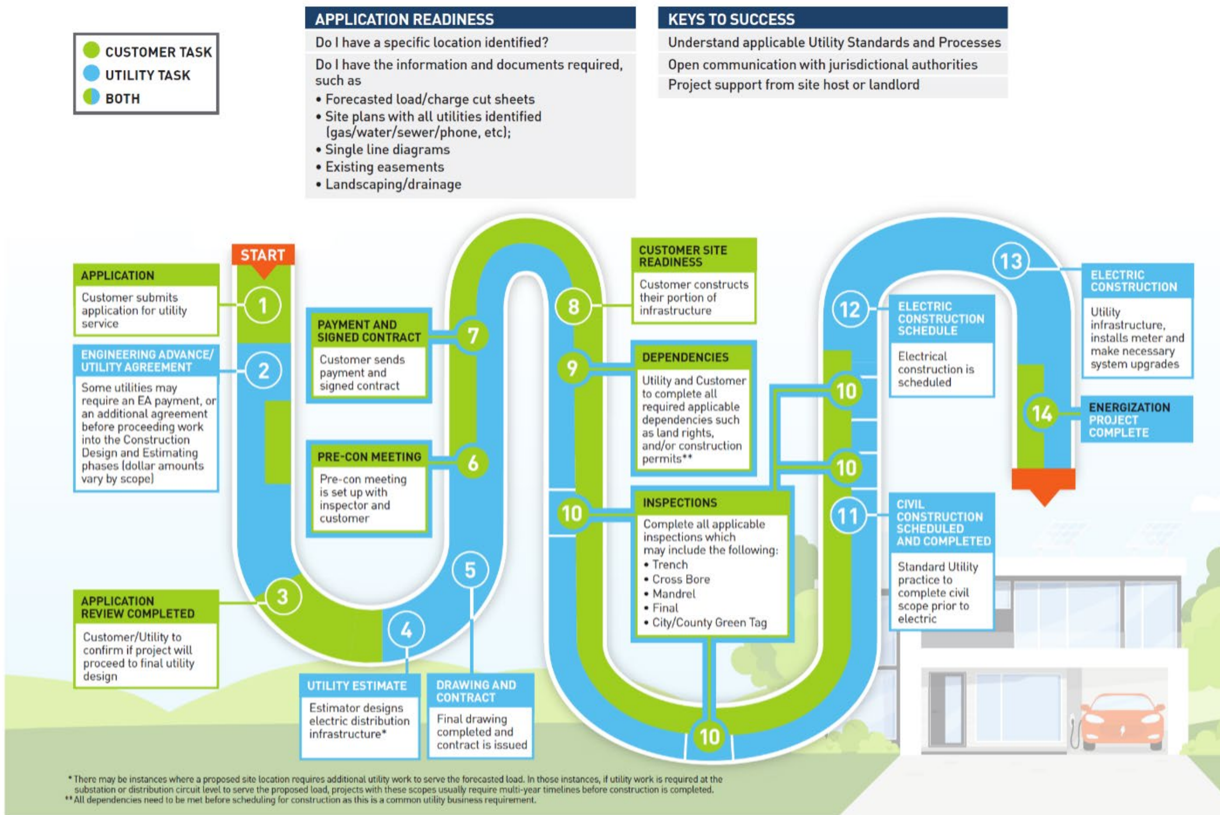

Figure 2. General EV customer/IOU journey map.[13]

[13] Alliance for Transportation Electrification. 2023. *Energizing EV Charging Stations: Issue Brief 1*. evtransportationalliance.org/wp-content/uploads/2023/04/FINAL-ATE-Interconnection-Brief-1.pdf.

Due to federal, state, and local tax incentives and decarbonization goals, as well as corporate commitments for fleet electrification (e.g., PepsiCo[14]), the demand to site and build EVSE projects quickly is expected to increase. Furthermore, *The 2030 National Charging Network* report from the National Renewable Energy Laboratory notes a need for 182,000 publicly accessible fast chargers to meet anticipated EV adoption.[15] Distribution utilities nationwide could implement similar tools and procedures to efficiently process energization applications to avoid queue backlogs and long delays in connecting new or upgraded public and private EV charging infrastructure projects. The following solutions, described in more detail in this section, can help accelerate the processing of both load service requests and interconnection applications for EV charging infrastructure projects:

- Create new or expand existing fast-track options based on prescreening criteria.
- Provide flexibility in the load service request/interconnection process to adapt to the utility available capacity while also meeting the customer's needs.
- Build internal knowledge base for EVs and EV charging infrastructure.
- Enact regulatory actions to coordinate with utilities on timely integration and energization of EV charging infrastructure.
- Provide standardized workforce training and support.

The successful implementation of these solutions requires coordination and collaboration between many stakeholders, including but not limited to electric distribution utilities; EVSE site developers; federal, state, and local energy and education officials; and both private and public educational institutions.

3.1. Solution: Create New or Expand Existing Fast-Track Options Based on Prescreening Criteria

There is an opportunity for utilities to streamline and accelerate the load service request/interconnection process for EV charging projects by providing fast-track application programs, which may eliminate additional delays to EV infrastructure build-out. Similar efforts for DER interconnection have been effective at reducing application process timing and accelerating DER deployment. Southern California Edison, for example, has a fast-track interconnection process (Figure 3) that is estimated to shorten energization timelines from years to months.[16] Though interconnection processes vary across utilities, the primary components of the interconnection process presented in Figure 3 are representative of most utilities.

Figure 3. Southern California Edison interconnection agreement process with fast-track review.

[14] PepsiCo. 2024. *Fleet decarbonization*. https://www.pepsico.com/our-impact/esg-topics-a-z/fleet-decarbonization.
[15] Eric Wood, Brennan Borlaug, Matthew Moniot, Dong-Yeon Lee, Yanbo Ge, Fan Yang, and Zhaocai Liu. 2023. *The 2030 National Charging Network: Estimating U.S. Light-Duty Demand for Electric Vehicle Charging Infrastructure*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5400-85654. www.nrel.gov/docs/fy23osti/85654.pdf.
[16] Southern California Edison. 2021. *SCE's Generator Interconnection Processes*. Sept. 2021. edisonintl.sharepoint.com/:p:/t/Public/Misc/EfhyKTr-pEdPt7fblJ4Uyb4BoIZQqPliVwVFbfjLk6Hcjg?rtime=kFXNqfC_3Eg.

In the case of EV charging infrastructure, fast-track program eligibility is structured where an offering utility determines each case based upon the EV charging project type or use case, the size of the EV charging project, voltage of the line, and the location and type of line at the point of common coupling.[17] The customer proposing the EV charging project must first meet the codes, standards, and certification requirements provided by the servicing utility, as well as pass an initial set of review screenings that determine whether the installation can be done safely and reliably.

For the fast-track process to be successful, utilities will need to be transparent in their requirements and include clear communication channels with applicants as a main component of the fast-track process. Utilities may require EV charging developers to select the appropriate equipment on the customer side of the meter (e.g., EVSE) and grid connection equipment on the utility side of the meter (e.g., transformers) from an approved product list or a list of minimum requirements developed by the servicing utility. Providing an approved product list or a list of minimum requirements (e.g., product must be Underwriters Laboratories [UL] listed) will simplify equipment procurement for developers to satisfy necessary safety and reliability requirements and accelerate an application through the fast-track process. The utility may also provide an initial engineering screening for an EV charging project applying for service. If the proposed EV charging project application satisfies the equipment and safety requirements and passes an initial engineering screening, the application can move forward past system impact and feasibility studies to a service agreement.

Providing a transparent fast-track option for both EV charging load service requests and interconnection would allow site developers to design and prepare future EV charging projects with relevant requirements in mind to expedite the energization process. This would also reduce the amount of processing effort on the utility side, reducing the total workload, which is currently stretching utility staff thin due to the spike in new service applications. Further, establishing equipment standards pertaining to grid hardware and software can aid in managing the demand for grid components and providing signals for manufacturers' capacity planning and product development.

3.2. Solution: Create Flexibility in the Load Service Request/Interconnection Process

The direct path to improving energization processes and timelines is to add flexibility into the load service request process. There are a multitude of approaches, tools, and process changes available today to create flexibility and streamline the load service request process that will lead to faster EV charging project energization. There is no one-size-fits-all solution, and electric utilities will need to assess available solutions for their specific needs, with some utilities potentially using multiple solutions.

Historically, utilities have undertaken a project-by-project approach to studying the impact of new loads to the electric grid. Clustering or group engineering studies, where appropriate, can optimize the load service and/or interconnection queues. Though setting up a framework for locational cluster/group studies requires time and resources, the outcome is a more efficient use of utility resources, which are currently spread thin.

[17] Minnesota Municipal Interconnection Process (M-MIP). 2022. *Interconnection Process: Fast Track Process*. https://assets.noviams.com/novi-file-uploads/mmua/GR_files/M-MIP-149d9844.pdf

Traditionally, load service request and interconnection agreements are fixed to the total nameplate rating of all the EV chargers at a charging site. Nameplate rating (also known as nameplate capacity, rated capacity, nominal capacity, installed capacity, maximum effect, or gross capacity) is the maximum output from the end use device, such as an EV charger, under ideal conditions. One approach, flexible load service request or flexible interconnection, can improve and accelerate the processing of load service requests and interconnection of EV charging projects. The flexible interconnection or load service request approach requires an agreement between the servicing utility and site host in which the servicing utility provides load below the nameplate rating of the system being energized over a certain period. EV charging site developers incorporate tools like load management software into their project design to ensure the site does not draw the full nameplate capacity from the grid when there is limited available distribution capacity and to mitigate additional stress on the grid. Pacific Gas and Electric is already demonstrating this approach, recently introducing a flexible service agreement pilot called Flex Connect. Flex Connect aims to provide customers seeking energization in a capacity-constrained area with a dynamic connection agreement allowing for operation at a limited capacity with the use of a local energy management system.[18] Through a Flex Connect agreement, participating customers could also receive their full requested capacity a majority of the time, and only be throttled during specific hours of high demand.

Furthermore, EV charging project developers will need to plan for how the limited electric capacity will impact the use of the EVSE and build into their project design complementary technologies like an on-site battery energy storage system (BESS). Flexible load service requests or flexible interconnection allow for the build-out of desired EV charging infrastructure and connect to the distribution grid at a lower total capacity than the nameplate rating of the system, with an agreement to serve load below a set point until additional capacity is available. This allows for both site developers and utilities to accelerate the timeline from application to energization by eliminating the need to wait for infrastructure upgrades to be completed.

Behind-the-meter (BTM) assets, such as co-located PV, wind, and/or BESS, as well as the utilization of site/facility energy management systems, allow for site developers to optimize the maximum allowable power demand from the grid. The challenge for site developers is that utilities assume demand factors—the degree to which the proposed load coincides with other peak load drivers—up to 100% of nameplate capability for sizing calculations.[19] The addition of BTM assets enable EV charging installations to provide grid demand flexibility and grid resiliency, making flexible load service requests and interconnection more viable today.

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[18] San Diego Gas and Electric Company, Southern California Edison, and Pacific Gas and Electric Company. 2024. *Vehicle-Grid Integration Forum Workshop Report*. docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M532/K262/532262533.PDF.

[19] Cody Davis and Lisa Schwartz. 2024. *Sizing Electric Service Panels and Utility Infrastructure for Residential Electrification and Distributed Energy Resources Adoption*. Berkeley, CA: Lawrence Berkeley National Laboratory. Technical brief. live-lbl-eta-publications.pantheonsite.io/sites/default/files/electric_service_sizing_technical_brief_2024072_kj-ls.pdf.

The addition of a BESS to an EV charging project for the purpose of filling the gap in nameplate capacity adds another layer of intricacy to the energization process that EV site developers need to understand. For one project, the site host will need to submit two applications to the servicing utility, as current BESS projects go through the interconnection process, and EV charging infrastructure projects go through the load service request process. Due to this separation in utility processes, the efficiency created by co-locating EVSE and BESS may be lost. It is crucial that the nameplate rating for the EV chargers and the BESS not be taken into consideration separately, but as one, so that both the EV charger and BESS are optimized for flexible and scheduled loads.

Flexible load service and interconnection approaches combined with tools like load management software and co-locating DERs like BESS allow for both site developers and utilities to accelerate the timeline from application to energization by eliminating the need to wait for infrastructure upgrades to be completed. Flexible interconnection can keep projects alive that may have otherwise collapsed due to the substantial additional cost that would have been incurred due to necessary utility upgrades.

3.3. Solution: Build Internal Knowledge Base for EVs and EV Charging Infrastructure

Just as each electric utility knows their customers and territory, it is also important that each utility build an internal knowledge base for how and when EVs and EV chargers will impact their respective electric grids. EVs and EV charging technology are changing quickly, and utilities will need to evolve with the changing needs to better service their customers. For the near term and for those utilities that have resources, the creation of a utility team dedicated to EVs and EV charging supports two functions for the utility, one internal and the other external. Internally, the resources support other utility staff through knowledge sharing from both the policy/strategy side and the technical side. Externally, the utility has a go-to team that can engage and build a relationship with the customer segment that is often technology-forward. At a minimum, the creation of a load service request/interconnection ombudsperson and/or independent support engineer dedicated to EV charging is essential for near-term EV charging project success. For those utilities that are resource constrained and unable to dedicate a human resource to EVs and EV charging, utility industry groups like the American Public Power Association, National Rural Electric Cooperative Association, and Edison Electric Institute provide their members with training and support. In the long term, as utilities understand and become comfortable with EV charging loads, the internal EV utility team role will shift and change as needed to meet the needs of the utility’s customers.

3.4. Solution: Regulatory Support to Coordinate with Utilities on Timely Integration and Energization of EV Charging Infrastructure

In the case of regulated utilities, reducing timelines and costs to energize EV charging infrastructure can be influenced by regulatory bodies like PUCs and state legislatures. PUCs regulate utilities to ensure they provide reasonable and efficient services to customers, while also maintaining reasonable electricity rates. PUCs typically have authority to introduce rulemaking to impact day-to-day operations for utilities in their state, including modifications to energization process requirements and setting maximum timelines for processing service request applications. State legislatures may introduce and enact state laws and policies that directly impact utilities and the PUC.

Utility regulators like the California Public Utility Commission (CPUC) are already taking actions to proactively address energization timelines to meet the greater EV demand and California's clean energy transition. Through CPUC Order 24-01-018, California's three large IOUs are required to expedite the process for new and upgraded electrical services, with the potential to reduce grid connection timelines by up to 49% compared to current operations.[20] Similar actions by other state PUCs would motivate utilities to take proactive measures to optimize and accelerate energization processes and timelines.

Some states have enacted bills to ensure utilities in the state modify energization processes to provide greater transparency and reduce energization timelines. In early 2024, the Colorado state legislature passed Bill 218, which requires the utilities in the state to provide transparent deadlines for energization, establish programs to allow new customers to utilize flexible interconnection, and develop rightsizing and future-proofing grid investments to prepare for an ever-growing electrification ecosystem.[21] Similar measures in other jurisdictions might enhance utility service to customers by providing greater transparency and streamline energization processes.

3.5. Solution: Workforce Training and Support

A workforce that is trained and knowledgeable is critical for timely energization of EV charging projects. A greater number of trained utility staff with experience processing energization requests for EV charging may provide greater support to customers submitting EV load service requests and interconnection applications. Improving the processes for EV charging load service request and interconnection agreements are possible through instituting standardized workforce training for both utility staff and EV charging site developers, as well as development of EV-specific project support programs that provide guidance and assistance through the energization process. Currently, utility staffers and site developers involved in the deployment of EV charging infrastructure have a different understanding of the state-of-the-art EV charging technologies available or may not be aware of the additional system benefits provided by behind-the-meter DERs with smart charge management. For example, as of 2023, all commercially available EV charger systems that meet National Electric Vehicle Infrastructure Formula Program requirements include communication standards necessary to perform smart charge management and plug and charge.[22]

Greater integration of DERs with EV charging infrastructure present another learning curve for both site developers and utility staff processing load service request and interconnection applications. With BTM storage and energy management load control software, a site developer may request an interconnection agreement for an EV charging installation that includes BTM assets to reduce peak grid demand and interconnect at a lower total grid capacity, mitigating grid upgrades. Utilities traditionally take a conservative approach to site capacity and nameplate rating, adding on-site DER assets like BESS to the total nameplate rating of the site. Utility engineers will require training to see the BESS as a BTM asset to smooth the charging load and reduce the nameplate rating of the system, instead of identifying a BESS as additional load. Clearly, this training will also require awareness of BESS, energy management, and smart charge management systems, as well as the requirements for reliability and performance to obviate utility upgrades and processing delays.

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[20] California Public Utilities Commission. 2024. *CPUC Sets New Statewide Energization Timelines and Targets for Timely Grid Connections*. Sept. 12, 2024. www.cpuc.ca.gov/news-and-updates/all-news/cpuc-sets-new-statewide-energization-timelines-and-targets-for-timely-grid-connections.

[21] Colorado General Assembly. 2024. *Modernize Energy Distribution Systems*. SB24-218. 74th General Assembly, 2024 Regular Session. Effective May 22, 2024. leg.colorado.gov/bills/sb24-218.

[22] Federal Highway Administration. 2023. *National Electric Vehicle Infrastructure Standards and Requirements*. *Code of Federal Regulations* 23 CFR Part 680. www.federalregister.gov/documents/2023/02/28/2023-03500/national-electric-vehicle-infrastructure-standards-and-requirements.

Some utilities have accelerated approval processes and offer fleet electrification planning services by collaboratively working with fleets and public charging developers to design, develop, and energize their charging installation projects. This allows the utility to develop a relationship with this new customer segment and increase information flow between the two. Two examples of current utility programs supporting EV charging infrastructure deployment include National Grid's Fleet Advisory Services Program and Commercial and Fleet EV Charging Programs and Exelon's EVsmart program. Through National Grid's programs, fleet customers are provided with an assessment that identifies fleet vehicles ready for electrification and provides a roadmap for when the fleets' vehicles will electrify and incentives to install EV charging infrastructure on both the utility side and customer side of the electric meter. The customer is responsible for the selection, purchase, and installation of the EVSE.[23] Through Exelon's EVsmart program, the utility works with the fleet owner or site developer to review the service application prior to submission to ensure the existing service will meet the customer's needs, assists with development of the initial design of the utility equipment, and develops an optimized timeline for the project based on the available/requested capacity. Figure 4 illustrates an example roadmap for the energization process through Exelon's EVsmart program, including the customer responsibilities (blue) and Exelon responsibilities (purple).[24]

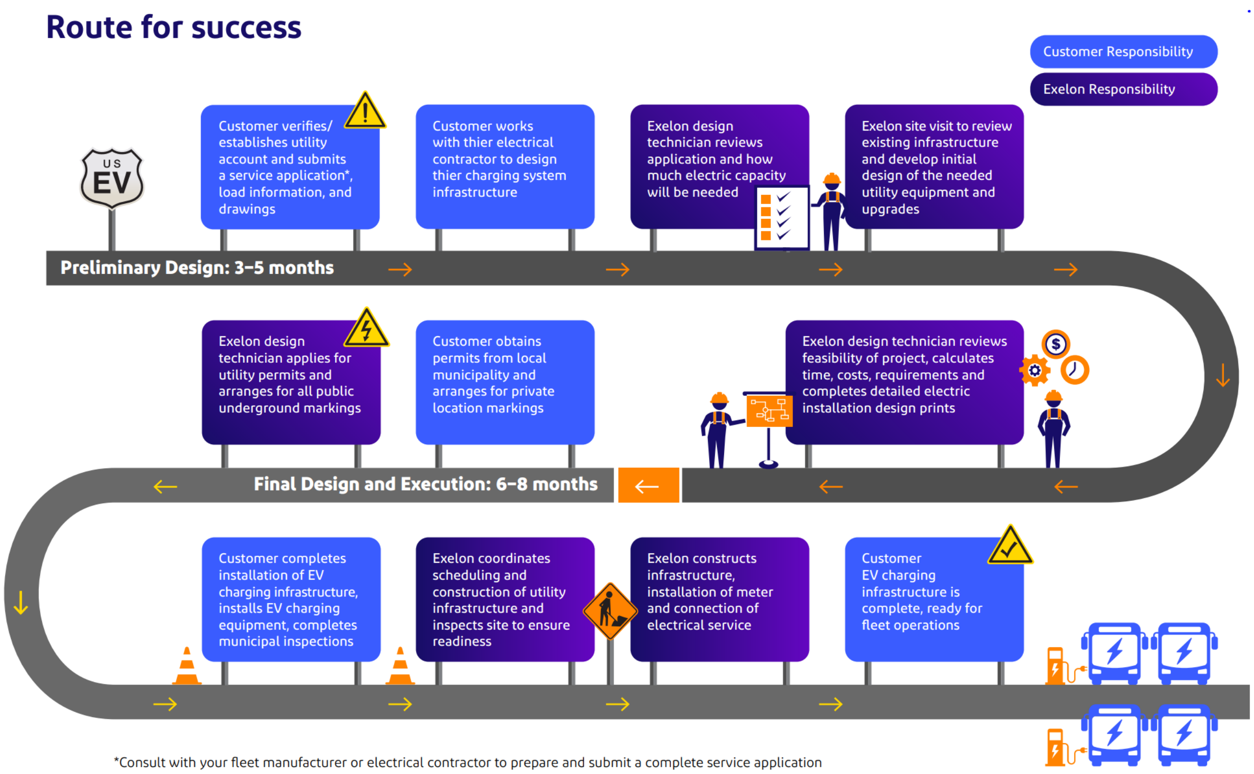

Figure 4. Exelon's EVsmart "route for success."

[23] National Grid. 2024. *Commercial and Fleet EV Charging Programs*. Accessed Nov. 7, 2024. www.nationalgridus.com/Upstate-NY-Business/Energy-Alternatives/Commercial-and-Fleet-EV-Charging-Programs.

[24] Exelon. 2022. *Your Roadmap to Drive: Vehicle Electrification*. azure-na-assets.contentstack.com/v3/assets/blt71bfe6e8a1c2d265/blt6321e31d946c50d4/65735560971ffe000ddddcb5/EXL_EVprogram_Roadmap.pdf.

3.6. Summary of Recommendations

Improving load service request processes and fostering a broader understanding of EVs and vehicle-grid integration among both EV charging site developers and utility staff will support the accelerated deployment and energization of EV charging infrastructure. Though utility load service request processes have been in place for many decades, utilities and industry at large need to assess the process from the perspective of a rapidly growing transportation electrification segment. Based on the needs of the utility territory, a utility may choose one or a combination of the proposed solutions.

4. CHALLENGE/NEED: PROMOTING ECONOMIC EFFICIENCY IN PLANNING

Streamlining the overall load service request process to aid EV infrastructure deployment should also aim to improve the overall economic efficiency on the planning portion of the process. The economic efficiency may come from direct savings from reducing evaluation timelines and workforce requirements (with initial screens being automated and reserving specialized staff for the more detailed evaluations) but may also reveal additional value to justify proactive upgrades to areas of known growth or to promote growth in an underdeveloped area with additional capacity. Furthermore, there may be opportunities to leverage the ability of an EV charging load request to be approved in phases to accommodate existing upgrades (which would allow the developer/customer to start collecting revenue on the site faster than waiting for a full upgrade). This would also enable the utility to being collecting electricity revenue to help provide funding for upgrades to the system. The utility may also leverage load management and control options for those deployments to accommodate site-specific grid constraints, again leading to a faster time to operation (for some of the assets) and at least partial revenue generation.

Exploring the interplay between the load service request approaches described above and proactive utility investments in grid infrastructure upgrades can promote greater economic efficiency in the deployment of EVs. Due to long-standing regulatory approval and utility planning and maintenance practices, most utilities wait until load service requests or interconnection requests trigger an upgrade on the system. However, emerging industry trends and general growth information may point to prudent and reasonable upgrades that can occur before the load service requests due to their large size and associated planning, approval, and commissioning requirements (e.g., substations and feeder upgrades). In addition, proactive upgrades smaller in size can quickly promote adoption in areas that require simpler utility interventions (e.g., reconductoring service or smaller transformers at the secondary distribution level) that could be implemented but for the absence of a regulatory pathway to approve and recover reasonably anticipated costs. Such an evaluation could also enable upgrades in infrastructure in underserved or economically disadvantaged areas, helping spur adoption in that location. The following solutions are recommended to promote economic efficiency (with more detail provided in the subsections that follow):

- Right size distribution components.
- Make proactive investments.
- Incorporate EV load forecasts into grid planning and investment decisions.
- Factor in energy and environmental justice.

The successful implementation of these solutions requires coordination between electric utilities and state utility regulators and support from federal, state, and local officials.

4.1. Solution: Rightsizing Distribution Components

The first element in promoting economic efficiency for the load service request and infrastructure upgrade process is to ensure electrical components are rightsized. Utilities should work with developers and regulators to establish criteria to reasonably quantify attributes and requirements of proactively deployed assets (e.g., undergrounding a feeder in an area where this may not have any resilience or reliability benefits), as well as the conditions where proactively deploying equipment can efficiently enable future upgrades. An example could be upgrading a feeder from a 4.16-kV system to a higher 12.47-kV or 13.2-kV system that could accommodate future growth or upgrades more easily. The feeder may not be at capacity yet, but if it is in an area of potential large growth (e.g., industrial park with lots of shipping depots), proactively upgrading the feeder voltage when there are fewer customers on the line may be easier and more cost-effective than performing the upgrade when at capacity. Rightsizing can also be as simple as matching distribution transformers to the net load of an EV deployment or reflecting the usage patterns of the devices (e.g., how many EVs actually charge at once vs. the nameplate rating of all chargers), where energy storage or BTM load management may be in place to prevent exceeding a designated capacity. This case would often require smaller ratings on equipment and may even defer an infrastructure upgrade entirely—beyond some potential metering and protection equipment to enforce local limits. Autonomous control of local power limits may also decouple the load service request process from supply chain timelines for transformers because an existing, lower-capacity transformer could be used rather than replacing it with a larger transformer that has a longer manufacturing lead time.

4.2. Solution: Proactive Investments

Proactively planning for the large investments with long lead times needed to support EV charging infrastructure projects is the primary driver of economically efficient outcomes for utility investors and their regulators and customers that share the goal of reliable and affordable power. Proactive investments will enable EV load to connect in a timelier manner and improve the service quality of the distribution network. Utility planners must overcome uncertainties associated with proactive investments, with potential main uncertainties being their size, timing, and location (all in relation to load growth and how or when the investment will be utilized). Scenario modeling for proactive investment based on state, regional, and corporate net-zero policies supported with site-specific analysis helps bound uncertainty. Proactive investments must first account for non-wire alternatives including charge management, V2G, and DERs in the context of rate designs, including time-of-use pricing. Proactive investments may have a higher upfront cost for ratepayers but allow more selective equipment purchasing or relaxed time frames than an emergency upgrade of the system, which can lead to lower rates for ratepayers over time. Proactive investments and planning frameworks need to ensure that individual utilities not only expand the system in a cost-effective and timely manner, but also ensure that neighboring and regional utilities leverage and share information and techniques across service territories to account for the mobility of transportation loads.

4.3. Solution: Tie Grid Investments to EV Forecasts

The accuracy of long-term demand forecasts is a key driver of economically efficient EV deployment and day-to-day management of load service requests. Very similar to proactive investments and rightsizing distribution components, the quality and reliability of forecasts may suggest divergent investment decisions—for example, whether a single, larger upgrade to a system is favorable to several incremental upgrades. The result may be a higher initial or upfront cost but greater economic efficiency over a longer time period by allowing more EV customers' load service requests to be filled faster and/or capitalizing on the cost of installation. For example, if a feeder upgrade already requires refitting a substation or trenching for an underground portion, forecasted growth (and EV adoption) may make it reasonable to do a bulk upgrade rather than several incremental upgrades.

4.4. Solution: Factor in Energy Equity and Environmental Justice

Load service and interconnection requests for EV installations can occur on all different locations and economic categories of feeders and are handled through the same process in all cases. However, areas of the power system that are traditionally underserved may be more capacity-constrained than others. For EV integration, this may mean nearly every interconnection or load service request may trigger a larger feeder upgrade.

Underserved communities often have power reliability issues, with more frequent interruptions or longer restoration times. Aging infrastructure that has not been prioritized for replacement due to a lack of growth in that area often is the cause of the decreased reliability—the aging components often require more significant repairs after an outage.[25] While many federal funding sources require a consideration of energy equity and environmental justice metrics to help promote investments in such areas (for a specific project, like EV integration), the utility may have secondary benefits to the upgrade to help promote the economic efficiency. Upgrades to enable more customers may also improve overall resilience and capabilities of that section of the grid through the replacement of deteriorating or poorly performing equipment, reducing maintenance and outage costs and promoting the overall economic efficiency of the utility's system and operations.

4.5. Summary of Recommendations

Economic efficiency helps not only enable efficient operations of EV deployments, but also justify any upgrades and costs associated with their integration into the grid. The efficiency may come from enabling existing capacity in traditionally underserved areas or areas with neglected infrastructure. The economic efficiency can also take forms like sizing the equipment for the actual need or a forecasted need inclusive of EV charging load, but also leveraging non-wire alternative solutions and nascent technologies like V2G and other DERs. Proactive investments in these capabilities lead to quicker deployments of EV charging infrastructure, but also enable improved service for the customers. Furthermore, load service or interconnection requests may benefit from consolidating upgrades or meeting multiple objectives (e.g., one large, proactive upgrade as opposed to many smaller replacement upgrades), which should be leveraged to improve the overall economic efficiency.

[25] Scott C Ganz, Chenghao Duan, and Chuanyi Ji. 2023. *Socioeconomic vulnerability and differential impact of severe weather-induced power outages*. *PNAS Nexus* 2 (10): pgad295. doi.org/10.1093/pnasnexus/pgad295.

5. CHALLENGE/NEED: IMPROVING GRID RELIABILITY AND RESILIENCE

Uncertainty about the impact of EV charging load on the reliability of the distribution network is often a key technical hurdle in processing new load service requests. Greater interactivity between distribution management systems and EV loads could alleviate some of these uncertainties because EV loads can rapidly respond to grid congestion constraints and associated curtailment/deferment signals, providing a service called managed EV charging. Grid operators are justifiably cautious about active load management capabilities when performing preapproval analysis because the U.S. grid is objectively reliable and continuing to improve. Reliability indicators for traditional grid control components in the bulk energy system are monitored by regulators, and tactical measures to improve reliability are codified in national standards. Reliability metrics can be generally classified into two categories: (1) resource adequacy, which is the probability of unserved load due to insufficient generation, and (2) performance metrics, which measure the frequency and duration of distribution system service outages. Resource adequacy planning metrics are needed to determine generation margins, while performance metrics reflect the reliability of all the grid components required to transfer electric power to end users. Resource adequacy standards in the United States typically consider the probability of insufficient generation to be 0.02%. In the last decade, the annual average duration of electricity interruptions has remained consistently around 2 hours (excluding major weather events), which translates to approximately 0.02% as well.[26]

If EV charging systems are to be trusted as grid components to provide load management services—and in turn help alleviate uncertainty in processing a new load service request—then work is needed to demonstrate that grid-responsive EV charging is a reliable capability. User surveys note that current charging system reliability is close to 81%.[27] Reliability of the charging infrastructure is continually improving, aided in part by the requirements in 23 CFR 680 (National Electric Vehicle Infrastructure Program), which sets a reliability target of 97% uptime. We can expect by induction that managed EV charging systems will eventually reach the 97% uptime target. This target number is still two orders of magnitude less reliable than the current electric grid. It is in the context of this disparity in reliability that we consider what should be done to foster tighter coupling between the electric grid and the charging network without significant detriment to the reliability of the integrated system. Three reliability-enhancing architectural choices discussed in the following subsections highlight emerging concepts that require coordination between grid operators and charging station operators to build bilateral trust in capacity, control, and communications, thereby making it easier to process load service requests.

5.1. Solution: Load Management/Power Control Systems to Specify Nameplate Rating

An effective near-term approach—especially for capacity-constrained sites—is to delegate management of EV charging load to a load management or power control system (PCS) that operates at the point of coupling between a charging station (with multiple charging dispensers) and the grid. This device works similarly to a traditional facility/building energy management system or microgrid control system, providing the utility with a single functional entity at the grid edge that purports the peak rating of the loads behind it. With such a system in place, efforts could then be made to define the performance and reliability requirements for the load management system from the grid's point of view, thereby giving the utility verifiable confidence in the configured load capacity of the PCS.

[26] North American Electric Reliability Corporation. 2024. *Reliability Assessments*. Accessed Nov. 7, 2024. www.nerc.com/pa/RAPA/ra/Pages/default.aspx.

[27] J.D. Power. 2024. *Public EV Charging Sees Consistent Progress for Two Consecutive Quarters, J.D. Power Finds*. Press release, Aug. 14, 2024. www.jdpower.com/business/press-releases/2024-us-electric-vehicle-experience-evx-public-charging-study.

This design offers two benefits when processing load service requests. The first benefit is confidence that deployed load will never exceed the approved capacity, allowing a system planner to safely use the PCS load rating as though it were the nameplate rating (as identified in the National Electric Code 750.30) in capacity planning and transformer sizing. This reduces the inflationary stacking of safety margins to address worst-case load scenarios when processing a load service request. Many charge station operators already implement a PCS—sometimes backed with grid-tied battery storage—to mitigate peak load and associated demand charges, but until recently, there has been a lack of standardized technology certification to define the functional safety requirements and interoperability required from a PCS to ensure stable grid load under a variety of operating conditions, including failures in software, communication, and varying user demands. In other words, the PCS must meet the reliability expectations of the electric grid.

UL 3141 is an upcoming test standard for PCS that aims to meet this need and defines some core functional safety requirements. One of the key elements of reliability it addresses is that networked or software-managed PCS must continue to function autonomously even if network connections and back-end equipment fail. Offline operation of the PCS is critical to ensuring reliability by decoupling cloud infrastructure from the safety-critical capabilities provided by the PCS. Moving forward from the current specifications for a PCS, researchers are evaluating a more abstract notion of a PCS as a "virtual transformer," a term that is intended to specify requirements for high-reliability software controls that provide guaranteed nameplate rating, power factor remediation, and phase balancing functions that are traditionally provided by transformers meeting the IEEE C57 series of standards.

The second benefit of a high-reliability PCS is that it provides a definite data boundary between customer data and utility data to an evaluator considering load service requests or implementing phased approvals as discussed in Section 4.2. A clearly established data boundary helps define the roles for the various agents involved in operating the load management service, including customers, utilities, and intermediaries. Specifically, when using a UL 3141-qualified PCS as the data boundary, the utility operator specifies performance, security, and interface standards for the PCS-grid connection, enabling implementers to innovate on the control and communications behind the PCS. To assist an evaluator in determining requirements for the PCS, we can map the security profile for the PCS to the current version of the smart grid system logical reference model described in NISTIR 7628.[28] In the cybersecurity logical reference model from NISTIR 7628 shown in Figure 5, we see that the PCS security profile aligns with Actors 5 and 7—the customer energy management system and associated grid gateway, respectively. The security and reliability posture for the PCS-grid connection in a distribution system management setting would map to logical interfaces U32, U42, and U88 in Figure 5. Similarly, requirements for interfaces between PCS and other grid edge systems such as advanced metering infrastructure can be referenced to logical interfaces U106, U41, U60, U47, U50, U24, and U25. These interfaces often have established policies and technical standards, thereby simplifying cybersecurity compliance and privacy protection considerations that may be a factor in processing some load service requests.

[28] National Institute of Standards and Technology. 2014. *Guidelines for Smart Grid Cybersecurity, Volume 1 - Smart Grid Cybersecurity Strategy, Architecture, and High-Level Requirements*. NISTIR 7628 Revision 1. csrc.nist.gov/pubs/ir/7628/r1/final.

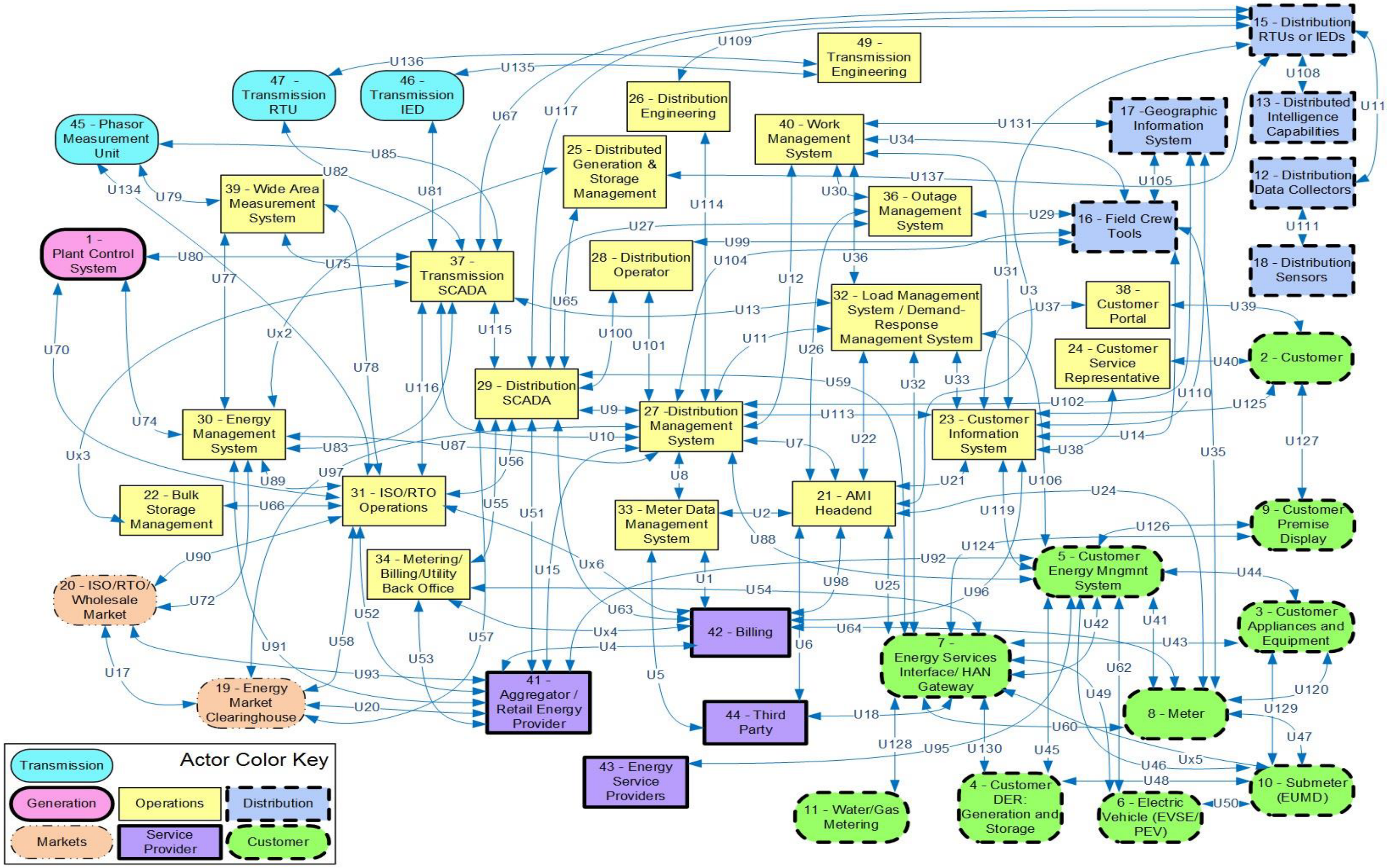

Figure 5. Cybersecurity logical reference model from NISTIR 7628.

5.2. Solution: Adopt and Implement Harmonized Standards to Manage EV Charging Load Across All EV-Grid Communication Pathways

As with operating the electric grid, semantic clarity (explicit documentation of dependencies, actions, and attributes) of the capabilities and behavior of a grid edge resource is an important factor in processing a load service request. In the case of traditional loads, grid operators are familiar with transformer capacity and ampacity requirements for commercial and residential customers, and the processes for a load service request are well established. Even with well-characterized traditional loads, the use of advanced load metering and better feeder-level measurements from digital substations have improved a grid operator's visibility of load dynamics at the edge of the grid. These data can drive improved visibility and allow for refinements in loading estimates such that additional loads could be connected to the grid. At the same time, as grid-responsive load curtailment and demand response capabilities have become more standardized, concepts such as coordinated dynamic hosting capacity now offer a range of non-wire alternatives to capacity planners.

EV charging is a unique grid edge resource because charging loads (for actively charging EVs) can be controlled and scheduled more predictably than stochastic renewable energy resources such as PV, wind, or thermostatically controlled loads. Utilizing the control flexibility awarded by managed EV charging could defray incremental distribution system upgrade costs by 30%.[29] This is an attractive prospect to meet the projected EV load growth but requires interoperability of communication protocols, information models, and semantics used to interconnect the grid infrastructure with the EV charging infrastructure. Furthermore, to fully leverage charging flexibility, communication standards must consider a diversity of charging modes over multiple data pathways, as illustrated in Figure 6.

[29] Office of Policy. 2024. *New Multi-State Analysis Helps Guide Grid Planning for Electric Vehicle Charging Infrastructure*. DOE, March 20, 2024. www.energy.gov/policy/articles/new-multi-state-analysis-helps-guide-grid-planning-electric-vehicle-charging.

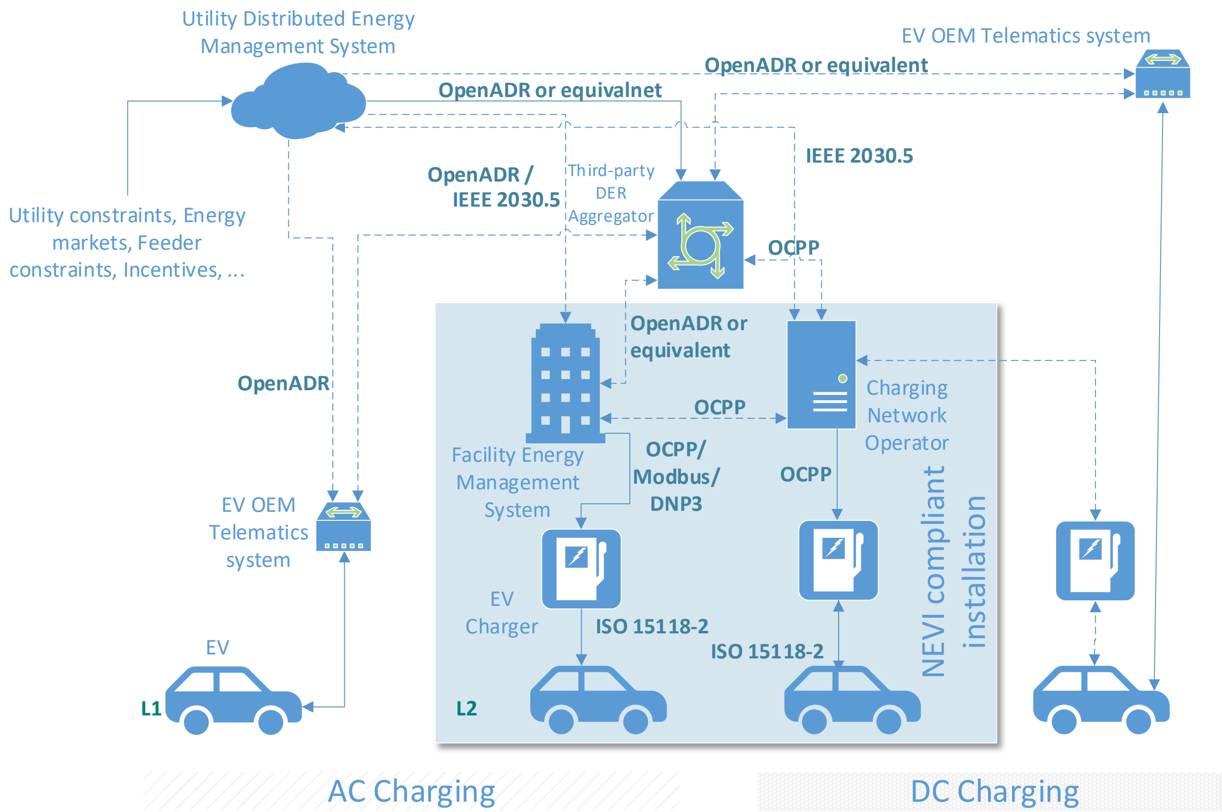

Figure 6. A schematic showing multiple communication pathways and a select set of associated communication protocols.

For generators, the IEEE 1547-2018 standard and the UL 1741 testing requirement have been instrumental in helping grid operators process interconnection requests for distributed generators by requiring semantic consistency and well-defined grid stabilizing functions across a range of distributed generator technologies.

Consider the case of processing a load service request for a DCFC station (see Table 1 and Figure 6 for an outline of communication protocols and a map of where they are applicable). A DCFC station incorporates elements of traditional load and a distributed generator. Unmanaged EV charging is a stochastic load subject to the ergodicity of charger utilization—based on when drivers need to charge their vehicles. Higher-resolution measurements from the EV charging infrastructure would help grid operators refine their load models, but the models generated must be based in trusted data to be useful. EVs and DCFC chargers can report signed measurements of their charging load over the ISO 15118-2 protocol used to communicate between the EV and DCFC's respective charge controllers. These signed measurements can be propagated to the grid over the Open Charge Point Protocol (OCPP) charger-to-network infrastructure protocol and then recast into the variety of existing grid edge communication protocols such as ANSI C12.22 or IEEE 2030.5, allowing a grid operator to verify the provenance of the data when building a model.

Using insights from the models generated from the trusted data sources, a grid operator can transmit signals to charging EVs to modulate their charging current. These signals can be communicated to the charge controller in an EV either through the EV charger or through the EV's telematics interface. In a typical implementation, a grid operator could induce EVs to curtail load in response to a grid requirement. This capability would also fit within the expected capability of a traditional grid-responsive load (typically mediated through OpenADR), except that EVs are able to modulate their power in seconds rather than hours, allowing them to coordinate with facility energy management systems to avoid peaks and mitigate congestion.

Some DCFC stations are equipped with common supervisory control and data acquisition interfaces such as Modbus and DNP3 to facilitate integration with existing transformer controllers of feeder control systems. Moving beyond traditional load control, modern EVs communicating over ISO 15118-2 and OCPP 2.0.X back-end interfaces have load scheduling and forecasting capabilities. These protocols have been designed to communicate grid constraints and tariff schedules to an EV prior to initiating a charge session. The protocols allow the EV-EVSE pair to coordinate with the grid to generate a charging profile that satisfies the user's needs while abiding the grid's incentives and constraints. Unifying the EV-EVSE charging profile according to a load service constraint is akin to a distributed generator responding to a locational marginal price and subject to an interconnection agreement. Some pilot studies have also successfully demonstrated watt-hertz responsiveness using the same communication infrastructure. Some DCFC power converters are also able to implement grid codes. These enhanced services have the potential to provide valuable stability enhancements to the grid. However, for these systems to integrate with analysis and planning tools used for load service requests, it is critical that these functions and capabilities be well defined and reliable. Multiple standardization efforts are beginning to emerge to support this goal. A functional model of grid-coupled DCFCs has been developed as part of the IEEE 2030.13 standard, enabling automated impact assessment and planning. Improved mapping to DER capabilities has been facilitated through DCFC representations using IEEE 2030.5. Work is ongoing to broker operational signaling from DER management systems or advanced distribution management systems using an OpenFMB broker. A more thorough treatment of the maturity grid relevant of EV charging protocols has been published by the New York State Energy Research and Development Authority.[30]

This section focuses on direct-current charging modes in Figure 6 because load service requests for DCFCs are significantly larger than most AC charging requests. It is expected that large clusters of Level 2 AC public charging at workplaces and multifamily dwellings with load ratings comparable to DCFC stations may become more prevalent. All the standards discussed in this section are relevant to AC charging, including ISO 15118-2 and OCPP. However, current onboard AC chargers may not be able to implement grid codes such as voltage regulation, ride through, and droop response. AC charging is expected to deliver the bulk of the energy needed for electric mobility, which is why several standardization efforts are currently in progress to define interconnection requirements for AC onboard chargers with the goal to assist grid operators in utilizing EVs as a grid resource and to reduce the uncertainties and risks to consider when processing a load service request.[31]

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[30] New York State Energy Research and Development Authority. 2022. *Managed Charging for Electric Vehicles*. White paper, 22-09. www.nyserda.ny.gov/-/media/Project/Nyserda/Files/Publications/Research/Transportation/22-09-Electric-Vehicle-Managed-Charging-White-Paper.pdf.

[31] Hank McGlynn. 2024. *Hybrid-EV Committee Publishes SAE J3072 on Interconnection Requirements for Onboard, Grid Support Inverter Systems*. SAE Blog, June 19, 2024. www.sae.org/blog/j3072-gp-hank-mcglynn.

Table 1. Communication and Control Signaling Commonly Used for Vehicle-Grid Interaction.

Communication Links (NIST 7628 Interface Number)	Common Protocols	Relevance to Load Requests
EV charging management system and load aggregator to the grid (U92, U95, U18)	OpenADR 2.0, IEEE 2030.5, custom APIs	Aggregate DER model, interfaces for dynamic prices, flexibility assessment
EV charging station to point of coupling with the grid (U88, U32, U106, U25, U60)	IEEE 2030.5, IEEE 2030.13, DNP3, ANSI C12.22, Modbus	Load measurements/verification, supervisory control and data acquisition interfaces, fast-acting load response, grid support functions
EV charger to charging management system (U95, U18, U119)	OCPP 2.0.X, OCPP 1.6, vehicle telematics	Communicating real-time grid constraints and incentives
EV to EV charger (U62, U49, U44)	ISO 15118-2, ISO 15118-20, legacy low-level protocols	Load scheduling, granular incentive response feedback
Note: The list is not exhaustive and does not include some legacy implementations.		

5.3. Cybersecurity Considerations for EV Load Service Requests

Historically, distribution utilities have had minimal cybersecurity compliance requirements from regulators, but this is changing with distribution systems playing a more active role in the bulk energy system such as by providing underfrequency load shed, undervoltage load shed, and other critical stability functions. These new capabilities, coupled with an increase in served load resulting from the growing need for electric mobility, would require some distribution control systems to meet the NERC CIP-003-7 requirement among other requirements placed by the transmission and sub-transmission service providers.[32] Though the CIP-003-7 requirements are intended for the bulk energy system, distribution utilities may need to take the risk management components in the requirements into account within the load service request process.

Managed EV charging with closed-loop communications to the grid will likely be considered a critical function to distribution system operators requiring careful consideration of all security management controls when processing an EV charging load service request. While the specific security policies may vary between utility companies, we aim to capture the unique considerations related to EV charging in this section.

[32] North American Electric Reliability Corporation. 2014. *CIP-003-7 — Cyber Security — Security Management Controls*. www.nerc.com/pa/stand/prjct2014xxcrtclinfraprtctnvr5rvns/cip-003-7_clean.pdf.

In prior efforts to model cybersecurity dependencies at a logical level between interacting grid agents described in NISTIR 7628,[33] EV charging (shown as Agent 5 in Figure 5) was considered a subsystem of a customer-owned and customer-operated load management system—with minimal interaction with distribution control systems. As noted in the previous sections, this paradigm is changing, with multiple pathways connecting EV charging software infrastructure with the distribution and bulk energy systems, as illustrated in Figure 6. Cybersecurity risk frameworks, such as the NIST Risk Management Framework,[34] recommend assessing risk at a functional level—in other words, determining a capability such as "communicating with a charging station to set a load profile" and then assigning a risk threshold for the capability. This risk-based approach penalizes using multiple interfaces and pathways that have mutually independent risk probability to achieve the same function. When processing a load service request, to reduce risk, it may be appropriate to define a function or capability and then to streamline or reduce the number of possible pathways or implementation options to achieve it.

Another consideration is the number of external entities that must be admitted into the risk profile when considering the addition of a new EV charging load. Each row in Table 1 is likely to be provided by a different vendor, which generates a multitude of dependencies crossing data ownership boundaries. Figure 7 illustrates the many entities and data boundaries that are likely to be involved in a managed charging program that provides bulk energy resources in addition to congestion management and non-wire alternatives for distribution systems. From a cybersecurity perspective, each domain (shown as a shaded box) is likely to have agency in implementing internal security management controls but will have to coordinate their security posture with the distribution system, which must be established prior to authorizing a load request. The trade-off of this consideration may be that all relationships with third-party data entities are periodically evaluated, updated, and pruned to minimize risk at the cost of losing the ability to manage some quantum of EV load.

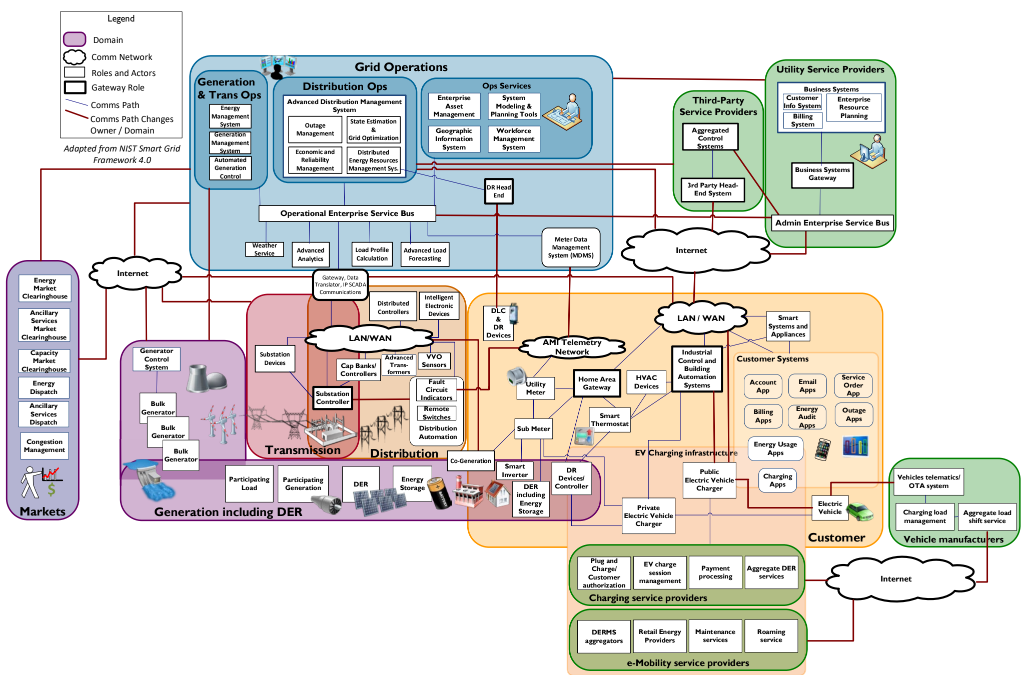

Figure 7. Data pathways and ownership boundaries for EV charging and grid operations.

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[33] National Institute of Standards and Technology. 2014. *Guidelines for Smart Grid Cybersecurity*. https://nvlpubs.nist.gov/nistpubs/ir/2014/NIST.IR.7628r1.pdf

[34] National Institute of Standards and Technology. 2018. SP 800-37 Rev. 2 *Risk Management Framework for Information Systems and Organizations* https://csrc.nist.gov/pubs/sp/800/37/r2/final

Lastly, we consider some specific cybersecurity technologies that are being introduced to the EV charging infrastructure that will likely have a positive impact on grid integration and consequently alleviate some of the security risks to be considered when processing a load service request. EVs connecting to EV chargers using the ISO 15118-2 protocol have the option to bilaterally exchange cryptographic keys to encrypt and sign data. The OCPP standard for chargers to back-end communication also supports secure communications—typically through Transport Layer Security—over the internet and other public networks. In contrast, control and operations networks used for grid operations are often air-gapped or firewalled from public networks and commonly utilize shared symmetric keys to secure information when needed.

Aligning the overarching security risk posture between utilities and charging infrastructure providers is essential toward promoting mutual trust among the parties involved in the connection and management of new loads. For example, because public EV charging requires coordination between multiple entities such as payment processors and roaming service providers, the infrastructure is evolving to use public key infrastructure (PKI) along with the use of digital certificates (X.509) traceable to a trusted certificate authority allowing the multiple interacting entities to verify each other's identity and message integrity instead of implicitly trusting self-assertions (as is the case with shared symmetric keys). Incorporating a shared root certificate authority or sub-certificate authorities between the utility and EV charging infrastructure and the associated asymmetric encryption would enable the distribution system operator to execute end-to-end encryption with the EV charging load site and verify signed messages from a specific EV or EV charger. There are nascent efforts, such as through the Electric Vehicle Public Key Infrastructure Consortium,[35] to develop these shared certificate authorities. This capability would be valuable to verify real-time load and to obtain accurate capability specifications from a charger or charging station. Implementing PKI with shared certificate authorities between the distribution system and the EV charging infrastructure would speed up the qualification of new charging service vendors while reducing the risk of on-path or identity attacks.

5.4. Summary of Recommendations

Interactivity between distribution management and EV loads will improve grid reliability and resilience. Grid operators should develop systems that interact with EV loads to alleviate uncertainties in processing new load service requests. EV charging systems should be able to respond to grid congestion to enhance load management. Using PCS at the point of coupling between EV chargers and the grid ensures that the load does not exceed bilaterally established limits, reducing the need for inflated safety margins. PCS should meet functional safety and reliability expectations to build grid confidence. UL 3141 is an upcoming standard to address this need. EV charging loads can be predictable and controllable, unlike other distributed resources (e.g., wind or solar). To realize the potential of EV loads for grid management, communication standards across various EV-grid interactions must be harmonized. Interoperability of communication pathways, such as between the EV telematics system, EVSE and utility systems, is crucial for successful load management. As EV charging becomes more integrated into grid operations, cybersecurity must be a priority. Managed EV charging will likely be considered a critical grid function as EV loads continue to expand, necessitating compliance with NERC CIP requirements and other regulatory standards. Standardized cryptographic protections, such as PKI for communication between EVs and the grid, will help maintain security and trust.

[35] SAE Industry Technologies Consortia. 2024. *About EVPKI.* Accessed Nov. 7, 2024. www.sae-itc.com/programs/evpki.

6. CONCLUSIONS

The rapid growth of the EV market necessitates a corresponding expansion of high-powered EV charging infrastructure. Connecting these stations to the grid presents a complex challenge with a lengthy and often cumbersome energization process, leading to uncertain processing queues and slow EV charger deployment. To address this challenge, this white paper recommends series of proposed solutions that can be implemented through a multi-stakeholder approach to enhance data access, improve data and grid transparency, streamline processes, promote economically efficient planning, and ensure grid reliability. These solutions, summarized below, provide a starting point to improve energization timelines:

- **Data transparency and standardized tools:** Utilities and developers will mutually benefit from developing automated load service request tools and readily available data on grid capacity, EV adoption forecasts, and project queues. This transparency can inform decision-making regarding site selection and resource allocation.
- **Process optimization and flexibility:** Utilities should create fast-track application programs for eligible projects and introduce flexibility into both the load service request and interconnection processes. For instance, flexible load service requests would allow developers to build charging infrastructure at full capacity while initially drawing power below the maximum limit until the point of connection can accommodate the full load.
- **Knowledge-building and workforce training:** Given the evolving nature of EV charging technologies, expedited energization requires continuous learning and knowledge sharing within utilities and among stakeholders. Utilities alongside automotive and charging manufacturers, installers, and standards development organizations should develop standardized training programs and the internal knowledge base for technical requirements, safety protocols, and emerging technologies, such as managed charging and behind-the-meter DER integration.
- **Proactive infrastructure investments:** Utilities' efforts toward proactive planning and investment in grid infrastructure are essential to accommodate anticipated load growth from EV adoption. With this forward-thinking approach, complemented by the recommendations above and guided by reliable forecasts, utilities and their regulators can ensure the grid can accommodate demand and prevent bottlenecks in EV charging deployment and maximize affordability.
- **Reliable and secure grid integration:** In support of charging station operators connecting new loads with utilities, equipment manufacturers and charging network providers should use appropriate load management systems to regulate EV charging loads and ensure grid reliability. Additionally, the implementation of robust cybersecurity measures, such as standardized communication protocols, secure data exchange, and PKI infrastructure, is crucial to safeguarding the integrated EV charging and electric grid system from cyberthreats.

As described in the DOE's shared vision of vehicle-grid integration:

> *"By 2030, millions of electric vehicles, charging at home and work, at charging depots and along the route, are integrated with the electricity system in a way that supports affordable and reliable charging for drivers and enables a reliable, resilient, affordable, and decarbonized electric grid for all electricity customers."*[36]

[36] U.S. Department of Energy. 2024. *The Future of Vehicle Grid Integration: Harnessing the Flexibility of EV Charging*. DOE/EE-2820. www.energy.gov/sites/default/files/2024-07/future-of-vehicle-grid-integration.pdf.

By embracing and building upon the proposed solutions, utilities can streamline the connection process, developers can deploy charging stations more efficiently, and policymakers and other stakeholders can create an environment conducive to EV accelerated adoption.

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