ESIG
ENERGY SYSTEMS
INTEGRATION GROUP

ESIG REPORT

Charging Ahead

GRID PLANNING FOR VEHICLE ELECTRIFICATION

EXECUTIVE SUMMARY

Transportation electrification is accelerating and will affect all facets of the power system, but the effects will be most pronounced for distribution systems where vehicle charging could quickly overwhelm grid edge equipment. Public charging sites and vehicle fleet depots can be planned, permitted, and constructed much more quickly than other loads such as commercial sites or industrial facilities. Utilities therefore have much less time to upgrade distribution system infrastructure for electric vehicle (EV) integration compared with new loads historically.

Faced with this rapid change, planning practices need to evolve to keep pace. Decisions today will strongly affect the preparedness of the grid for vehicle electrification. This has implications for customers' EV adoption, vehicle manufacturers' ability to sell new cars, and public policies intended to reduce emissions and encourage EV growth. The distribution planner's job is not an easy one. Planners must grapple with the possibility of either over-building the system for load that may not materialize or under-building and potentially leaving the system with insufficient infrastructure to meet EV charging demand.

Depending on the approach chosen, the distribution system can be a bottleneck for vehicle electrification, hamstringing EV adoption, or it can support more sustainable transportation thanks to thoughtful planning. Despite incomplete information about the timing, magnitude, and location of EV charging behavior, there

See the full report, Charging Ahead: Grid Planning for Vehicle Electrification.

are opportunities to lay a grid planning foundation today that will support the evolution of the grid and enable widespread vehicle electrification.

The Energy Systems Integration Group (ESIG) convened the Grid Planning for Vehicle Electrification Task Force to discuss the challenges throughout the grid planning process from multiple perspectives, identify gaps in distribution system planning for vehicle electrification, discuss ways to address these gaps, and articulate promising practices and next steps. The task force included grid planners from across the globe, vehicle and charge station manufacturers, charging network operators and aggregators, regulators and state offices, researchers, and consultants active in the intersection of EVs and grid planning.

The task force report, *Charging Ahead: Grid Planning for Vehicle Electrification*, walks through four high-level steps in grid planning and suggests good, better, and best practices associated with the planning attributes that lead to effective grid planning for vehicle electrification. It also discusses the areas where improvements are needed, gaps in our collective knowledge, and the role of various stakeholders. The four steps are to: (1) improve forecasting, (2) embrace smart charging, (3) incorporate future-ready equipment, and (4) promote proactive upgrades and processes to support an electrified future.

Priority Actions to Take Today

Improve Forecasting

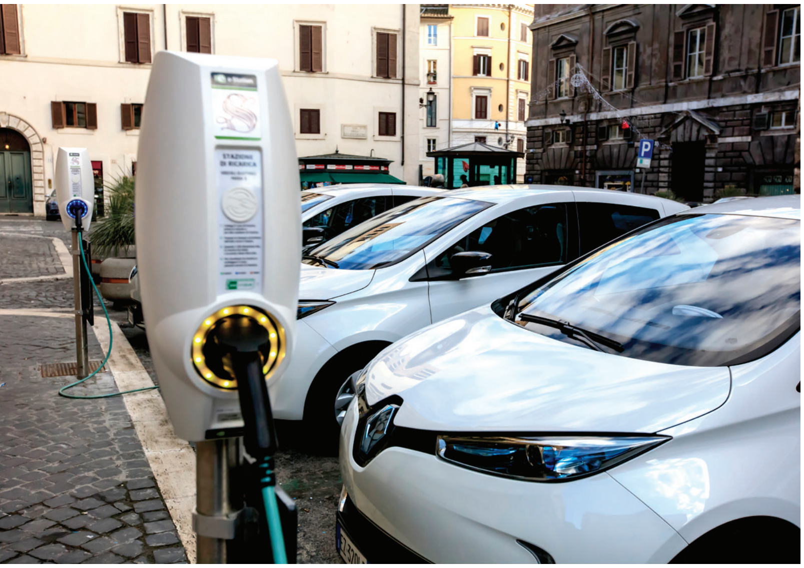
Forecasting vehicle impact can be improved by enhancing adoption and behavior models to consider multiple vehicle end uses, new vehicle technologies, and additional data sources. First, forecasting adoption at a granular level can be achieved through likelihood models informed by costs, policies, and customer preferences, as well as through new sources of data, such as fleet electrification surveys. These adoption models can include locational components and characterize the types of vehicles that will connect to the grid, including the technology that underpins the vehicle (the battery technology, size, and charger). Second, forecasting charging behavior and how the vehicle is used (e.g., school bus vs. city bus) will inform impacts of EVs both temporally and locationally.

Targeted smart charging, operating limits, and strategically located storage can help with immediate load growth, and these remain useful as more solutions are implemented over time.

These two key elements—the location and timing of charging—are intertwined, elastic, and changing as EV adoption increases and vehicle technologies progress. Even with the best models and data, forecasts will not capture everything. In time, we will learn how technological, regulatory, and social-human factors will impact EV charging. Embracing the uncertainty around EV adoption and charging patterns through scenario planning helps planners think in broad strokes rather than narrow solutions. Scenario planning can help identify the suitability of the power system—generation resources through distribution equipment—to support a range of futures, not just the adoption timeline and charging behavior that grid planners hope will manifest.

Embrace Smart Charging

Smart charging programs hold great promise for utilizing grid infrastructure efficiently, aligning charging with infrastructure capabilities and the lowest-cost electricity. Smart charging options using rate designs, automation, or demand response programs can align charging with



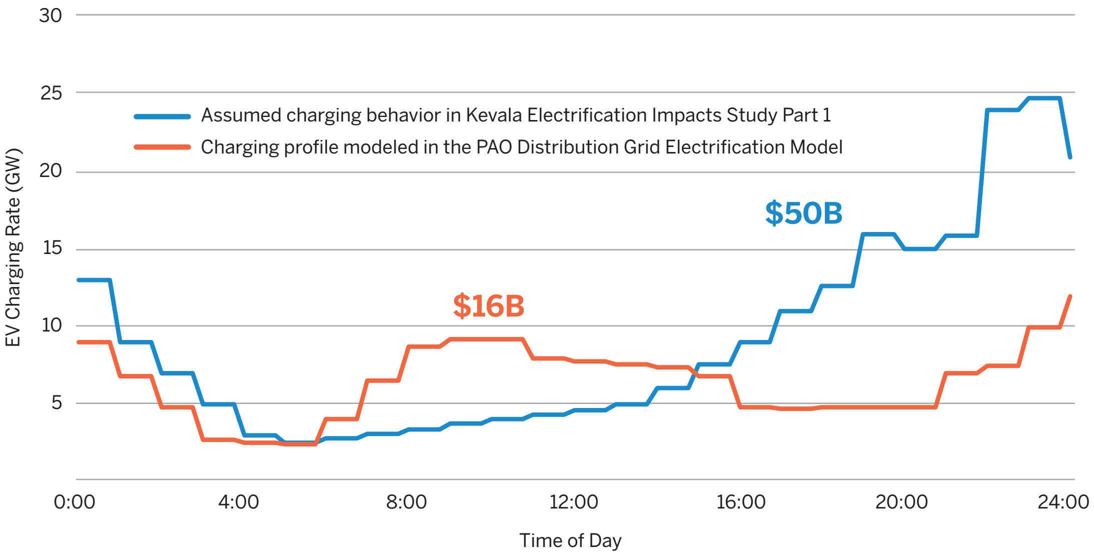
more affordable energy and reduce total infrastructure needs at every level of the grid from the premise to the bulk system. Targeted smart charging, operating limits, and strategically located storage can help with immediate load growth and remain useful as more solutions are implemented over time.

Studies recently completed in California highlight the impact of smart charging on estimates of distribution upgrades that will be needed as vehicles electrify (Figure ES-1). One study found that unmanaged EV charging, coupled with some electrification of other loads, could lead to $50 billion in distribution upgrades in California alone (Kevala, 2023). Another study, which used different assumptions on charging behavior, found that distribution upgrade costs could be $16 billion (roughly $800 per metered user) (PAO, 2023). While these studies assessed different levels of electrification, they underscore the wide range of potential costs being contemplated. With smart charging increasing the utilization factor of grid infrastructure, new EV loads may be able to justify grid upgrades by spreading the costs across a larger volume of electricity sales, thereby potentially decreasing rates for everyone, not just EV owners.

Smart charging strategies vary from simple tools (such as predefined time-of-use rates and demand charges) to sophisticated control measures (like dynamic operating envelopes) that can address varying grid needs. The overarching goal of each strategy is to align charging within grid infrastructure limits, help integrate clean energy, and reduce the costs of charging. As such, the costs of sophisticated smart charging solutions, including participation incentive costs, can be evaluated against

FIGURE ES-1

Differences in EV Charging Assumptions and Costs of Distribution Upgrades in Two Recent Studies

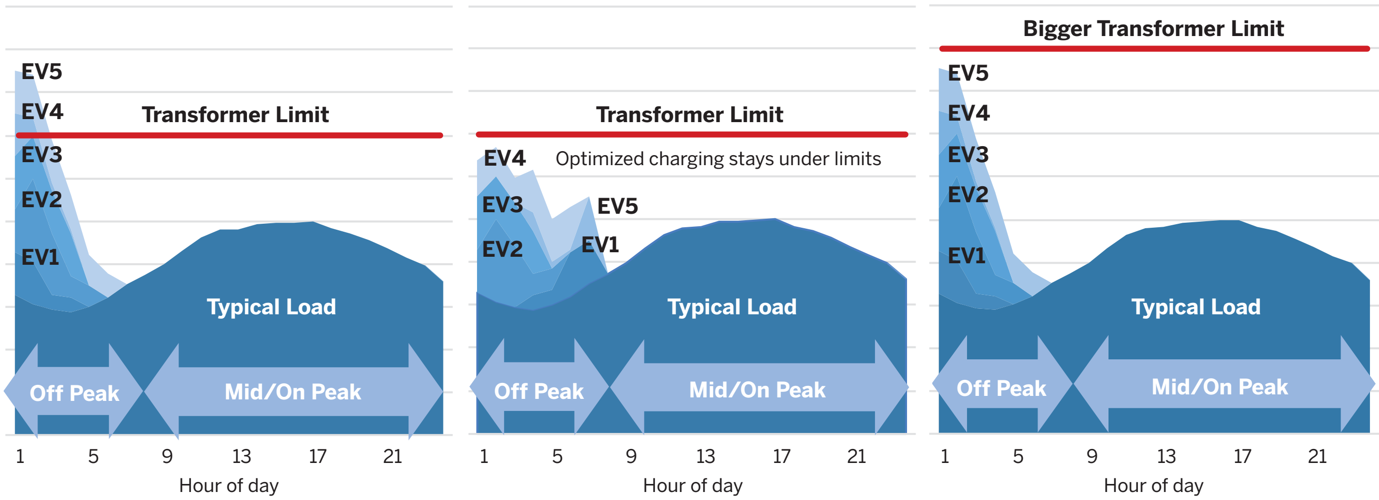


Differences in charging assumptions can have a large impact on the cost of distribution upgrades. Smart charging can adjust the charging profile.

Source. Energy Systems Integration Group. Data from Kevala (2023) and the California Public Utilities Commission's Public Advocates Office (2023).

FIGURE ES-2

Optimized Charging Aligned with Time-of-Use Rates



Time-of-use (TOU) rates with load optimization can simultaneously address bulk system and distribution constraints. If we only focus on bulk system needs with rate designs, EV charging may all start at the beginning of the off-peak period and overwhelm the distribution equipment (left). We can instead stagger charging and get the bulk system benefits of TOU without overwhelming the distribution system (middle). However, simply upgrading the distribution transformer may be more cost-effective and requires less of customers (right). The industry is learning more about the best mix of solutions to enable charging.

Source: Energy Systems Integration Group.

the cost of traditional upgrades, such as the installation of larger equipment. Multiple smart charging strategies could be used to simultaneously address multiple grid constraints, as is shown in Figure ES-2.

Incorporate Future-Ready Equipment

The optimal grid plan will likely be some combination of smart charging paired with infrastructure upgrades. More subtle strategies can enable electrification over time, including using future-ready equipment designed to support future load growth from EVs and other sources. Distribution utilities can strategically plan for the future by upgrading equipment when it is slated to be replaced or first commissioned, thus making better use of the labor and maintenance costs associated with grid equipment with the goal of limiting the long-term cost associated with grid upgrades for higher levels of electrification.

Planning for EVs requires a holistic analysis of the assumptions that drive grid planning decisions. Many of those assumptions are embedded in equipment design standards, which are assessed infrequently, and leading

Distribution utilities can strategically plan for future load growth from EVs and other sources by upgrading equipment when it is slated to be replaced or first commissioned.

utilities are re-evaluating these design standards because of vehicle electrification. Unfortunately, there is no consensus on optimal designs today as engineers balance uncertain equipment loading levels (driven in part by the diversity of charging behavior) and equipment rating methodologies that are also undergoing innovation thanks to new equipment-ageing methodologies.

Promote Proactive Upgrades

Future-ready grid upgrades that take place over decades may not be sufficient to meet all projected EV charging needs, and specific locations within a region may need upgrades before the existing equipment has reached the end of its expected lifespan. Widespread just-in-time upgrades of distribution equipment to support the level of electrification projected would likely be both costly

The risks of over-building and under-building the distribution system have asymmetric impacts. The impact of over-building includes increased costs, while under-building leads to stunted interest in electric vehicles and falling short of public policy.

and infeasible for utility construction crews. Distribution utilities can be proactive but should do so intelligently by working with multiple stakeholders and using improved, granular forecasts that may help to avoid over-building the system and creating stranded assets. The risks of over-building and under-building the distribution system have asymmetric impacts. The impact of over-building includes increased costs, while under-building leads to stunted interest in electric vehicles and falling short of public policy. By analyzing forecasts, working with a multi-stakeholder group, and considering these asymmetric impacts, distribution planners can prioritize areas for targeted upgrades.

Proactive upgrades could include larger equipment, new equipment, or non-wires alternatives, such as batteries or behind-the-meter generation. These upgrades can be strategically implemented based on improved forecasting techniques and identified by a multi-stakeholder group, to help ensure a targeted and efficient response to changing needs. Regulatory and policy efforts may be needed to support proactive upgrades because these upgrades may not be "used and useful" when they are first implemented.

Diversifying Planning Processes

Different processes can be used to identify different types of grid solutions. While much of distribution system planning has traditionally been handled by utilities, the role of state legislators, regulators, and other state officials will continue to grow as multiple power grid objectives compete for priority. Similarly, retail rate designers, vehicle manufacturers, and charge station operators will need to work with grid planners to design solutions that balance the cost of new infrastructure with customer charging flexibility. And the need to ensure equity in designing the grid that supports an electrified future is best accomplished through a broad range of stakeholder input.

Given the scale and layers of considerations that go into grid planning for vehicle electrification, three types of planning processes can be helpful to facilitate EV grid

Design of a grid that supports an electrified future can draw from multiple planning processes working together by supplementing existing processes with new approaches.

TABLE ES-1
Multiple Processes Provide a Holistic Approach to Grid Planning for EVs

Existing Processes
While today's grid planning processes vary across the country, they generally include: • Annual system reviews • Regularly updated grid plans with a medium- to long-term planning horizon • Isolated evaluation of interconnection requests
Customer-Collaborative Processes
A customer-collaborative process between planners and customers allows for open communication about: • Multiple options for interconnection • Multiple locational alternatives
Proactive, Multi-Stakeholder Processes
Given the volume and multiple use cases of EVs, proactive processes can be well suited to: • Ensure access to EV charging for underserved communities and determine where local, traffic-related pollution may be mitigated through vehicle electrification • Facilitate regional networks • Provide clear roadmaps for electrification planning progression

Multiple planning processes can be used together to effectively plan the grid for vehicle electrification. This approach supplements existing processes with customer-collaborative processes and proactive, multi-stakeholder processes.

Source: Energy Systems Integration Group.

integration. Table ES-1 describes the role for existing processes, customer-collaborative processes, and proactive multi-stakeholder processes in enabling vehicle electrification.

As air conditioning loads transformed customer demand in the 1960s/1970s, grid planners innovated by pairing large grid build-outs with demand response. Thanks to their lead, we do not need major technological innovation to meet EV demand. We know how to meet large demand growth; we have done it before. We do, however, need to quickly understand the magnitude of change that will be required and take action. Because of the multi-billion-dollar scale of these grid planning decisions, coordinated and holistic planning is needed to design grid architecture that effectively balances uncertainty around EV adoption (and when and where vehicles will charge), which can lead to an overly cautious investment approach, with ensuring the grid is adequately prepared for EVs. Grid planning for vehicle electrification is an opportunity to further integrate the energy systems that power our lives while establishing a platform for a wholly sustainable future.

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Charging Ahead: Grid Planning for Vehicle Electrification, by the Energy Systems Integration Group's Grid Planning for Vehicle Electrification Task Force, is available at https://www.esig.energy/grid-planning-for-vehicle-electrification.

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